Energi Myndigheden

Klivaløkshagi wind farm, Sandoy, Faroe Islands

Assessment of turbine size

Assignment no.: **52109455** Document no.: **KVT/2021/R149/BB** Version: **J02** Date: **2022-03-15**

KJELLER VINDTEKNIKK
Part of Norconsult

Client: Energi Myndigheden
Client's Contact Person: Kári Mannbjørn Mortensen
Consultant: Norconsult, Tærudgata 16, NO-2004 Lillestrøm
Assignment Manager: Lars Tallhaug

Version	Date	Description	Prepared by	Checked by	Approved by
J02	2022-03-15	Updated with new production tables for both no HWO and HWO for all turbine types	Elektra Kleusberg	Øyvind Byrkjedal	Lars Tallhaug
J01	2022-01-27	Final	Brian Riget Broe and Ove Undheim	Øyvind Byrkjedal	Lars Tallhaug
C01	2021-12-22	Draft	Brian Riget Broe	Ove Undheim	Lars Tallhaug

Summary

This report presents the results of a wind and energy production assessments of the planned Klivaløkshagi wind farm located the western part of Sandoy, Faroe Islands. The planned wind farm consists of 5-7 turbines, depending on the installed capacity of each turbine type. The site is characterized by grassland, bare rock, small lakes, and the sea. The terrain in the area is mountainous with the elevations at the planned turbine locations varying from 168 m to 277 m above sea level (ASL). Overview maps of each layout type are found in Figure 4 - Figure 9 inclusive the wind resources for the six hub heights. The main results are summarized in Table 1-1.

The report was updated to include both production calculations when using the high wind operation (HWO)/storm control power curves as well as calculations without the power curve adjustment. HWO allows turbines to operate at higher wind speeds than normal with a reduced power output. No new calculations of noise, shadow flicker, extreme winds or fatigue loads were made compared to the original report (J01).

Table 1-1. Wind farm information and main results for the Klivaløkshagi wind farm.

Klivaløkshagi												
Wind turbine type	Enercon E-82 E4 3.0 MW		Vestas V105 3.6 MW		Enercon E-115 EP3 E4 4.26 MW		Enercon E-115 EP3 E4 4.26 MW		Vestas V117 4.2 MW		Vestas V117 4.2 MW	
Number of turbines	7		6		5		5		5		5	
Installed capacity	21.0 MW		21.6 MW		21.3 MW		21.3 MW		21.0 MW		21.0 MW	
Hub height	78.3 m		72.5 m		77.0 m		92.0 m		91.5 m		96.5 m	
Tip height	119.3 m		123.0 m		134.5 m		149.5 m		150.0 m		155.0 m	
Mean wind speed at hub height	10.1 m/s		10.0 m/s		10.4 m/s		10.5 m/s		10.5 m/s		10.5 m/s	
Operation	No HWO	HWO	No HWO	HWO	No HWO	HWO	No HWO	HWO	No HWO	HWO	No HWO	HWO
Estimated total production losses including icing losses [%]	15.8	14.6	15.8	14.9	13.4	12.3	13.4	12.3	12.6	12.2	12.7	12.2
Expected net annual energy production [GWh/y]	**73**	**75**	**85**	**87**	**89**	**92**	**90**	**93**	**91**	**92**	**91**	**93**
Full load hours [h]	3474	3580	3948	4012	4182	4308	4224	4359	4338	4402	4350	4416

The full load hours are found by dividing the Net AEP in Table 1-1 with the installed power.

Noise calculations for the hearing range and for low frequency have been carried out in accordance with the requirements from the Danish authorities for 8 locations. The noise levels at the 8 locations will be below the noise demands. All 8 locations will experience low frequency noise levels well below the demand of 20 dB(A).

Shadow flicker has been calculated for outdoors at the 8 locations. The results are, for all locations, below the requirements of 10 h/year.

Different turbine types have been analyzed to assess the suitability of different turbine classifications, hub heights and rotor diameters in the wind climate of the Faroe Islands.

Extreme wind evaluation shows that only the layouts Enercon E-82 IA and Vestas V105 IA have calculated extreme wind speed level below class I limit of 50 m/s for all turbines. The remaining IA layouts have small exceedances for 1-2 turbines, while a significant exceedance is found for all turbines for the layout Enercon E-82 IIA (class II limit is 42.5 m/s).

Preliminary load calculations show fatigue loads just at the limits of the IEC IA and IB design. The only turbine type, which has fatigue life blow 20 years, is the E-82 IEC IIA turbine. The fatigue life of the turbines is found to have negligible impact from the rotor diameter. Regardless of turbine types, special attention is needed to ensure a turbine classification suitable for the site resulting in the required expected fatigue life of the turbines, especially for the shaft which has fatigue life just at the order 20 years for all IEC I turbines. With the small margins, it is also important that the layout is designed for the turbine type with sufficient distance between turbines.

Contents

1 Data Analysis

1.1 Input data

A summary of the input wind data used for the analysis is presented in Table 1-1.

Table 1-1. Summary of the wind data used in the current analysis.

	Type	Name	Data period	Coordinates (UTM zone 29)	
				Longitude	Latitude
On site measurements	Met mast, 85.1 m above ground level (AGL)	Klivaløkshagi	2019-09-05 – 2021-08-31	612564	6858449
Reference long-term data	9 km x 9 km, Hourly model data	KVTMeso (NSF09 ERA5)	2000-09-01 - 2021-08-31		

The met mast has been operational from 2019-09-05 until present. The data has been analysed until 2021-08-31. The data period given in Table 1-1 has been chosen to match the concurrent period of long-term data and the measured data, in order to have as long analysed period as possible. The measured data cover 2 full years except for 5 days. Even though, 5 days are missing in the chosen data period to have 2 full years, it is found sufficient to cover all seasonal changes.

1.2 Data inspection and filtering

The mast measurement data have been through inspection, manual and automatic filtering, and ice filtering which are in-house procedures of Kjeller Vindteknikk. The resultant data availabilities of the relevant sensors of the met mast are shown in Table 1-2 for the chosen data period. The corresponding monthly values for the main top sensor, anemometer B, are presented in Appendix C.

1.2.1 Further remarks on the data analysis

- The met mast has been installed and operated by Kjeller Vindteknikk. Documentation of the mast is found in [1].
- The Anemometer B is chosen since it has the highest data availability in comparison to the other top sensor, Anemometer A. The concurrent data from Anemometer B and Anemometer A are consistent and show minor shadow effects due to the lightning rod.
- The data availability was low in January and February 2020 (13.2 % and 43.2 %, respectively). However, the two years data period is found to be representative for the site, since the technical availability for the analysed period is 92.7 % with a final availability of 89.4 % when faulty data are removed. These availabilities are found to be acceptable for further analysis but may affect the quality of the analysis. The site is in a marine and relatively cold climate with high wind speeds, which affects the measurement system, so periods of missing data are expected.
- The time offset in the data logger program is provided in the data files. An additional check of the time synchronization with the long-term reference data has been made and has confirmed the UTC setting.
- Information of the offset of the wind direction sensors has been provided. However, comparison with long-term reference data has resulted in a correction of -8° applied to the measured data.

- The boom lengths are known and the wind speed sensors used for wind shear calculation are affected by mast shadow in similar manners.

Table 1-2. Percentages of missing and removed data for the wind speed sensors of Klivaløkshagi met mast. The total data coverage presented is the value if there is no replacement of missing or removed data. The green row represents the main wind speed sensor.

Sensor names (types)	Sensor height (m AGL)	Technical data coverage [%]	Removed data due to icing + fault (%)	Total data coverage (%)
Anemometer A, Thies First Class Adv.	85.1	92.7	8.7	84.0
Anemometer B, Thies First Class Adv.	85.1	92.7	3.3	89.4
Anemometer C, Thies First Class Adv.	76.0	92.7	11.8	80.8
Anemometer D, Thies First Class Adv. II	56.8	92.7	21.7	71.0
Anemometer E, Thies First Class Adv.	37.0	92.7	7.7	85.0
Sonic A, Gill Wind master Pro	80.1	75.0	0.7	74.3

1.3 Calculation of long-term wind statistics

The long-term correction of the measurement data has been performed using the KH method [2] and the U&N method [3]. Table 1-3 shows the measured and the long-term corrected mean wind speeds (LTC wsp) at the measurement height. The long-term correction has been made with data from the KVT Meso suite as shown in Table 1-3. The KVT Meso dataset is in resolution 9 km x 9 km and is generally regarded as a representative dataset for long term corrections (see also Appendix A).

Table 1-3. The long-term correction results to be used further in the wind resource assessment.

Sensor used	Measured mean wind speed	Measurement period used	Main sensor height	Reference data	Hourly correlation	Long-term corrected wind speed at the meas. height
-	[m/s]	-	[m AGL]		-	[m/s]
Anemometer B, filtered	9.97	2019-09-05 – 2021-08-31	85.1	KVTMeso (NSF09 ERA5)	0.86	10.21

1.3.1 Long term wind speed and direction distributions

The estimated long-term wind speed and direction distributions for the results shown in Table 1-3 are presented in Figure 1.

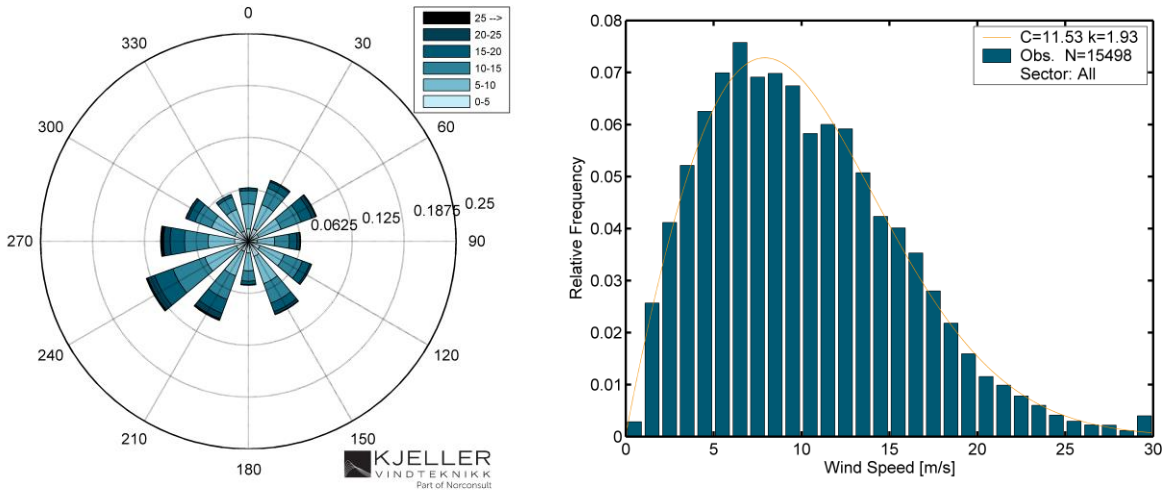


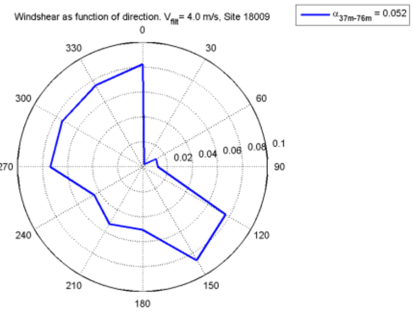
Figure 1. Long term wind rose and Weibull distribution at the site (85.1 m AGL) with KVT Meso as reference data.

1.3.2 Wind shear

Table 1-4 shows the calculated wind shear for the met mast Klivaløkshagi. The wind shear is low but is in line with experience in similar terrain.

Table 1-4. Calculated measured wind shear exponent, α [-]. The mean wind shear is the frequency weighted mean of all sectors (excluding tower shadow sector).

Sensors used	A3 and A5 (filtered data only; not replaced)
levels used	76.0 – 37.0 m
Sectors excluded	Sector 2 and 3 [015º - 075º]
Weighted mean wind shear α[-]	0.07



1.3.3 Long term wind conditions at the hub height

Klivaløkshagi mast is located in an area with mainly grassland, a few water bodies, and the open sea close by. Thus, it is not necessary to take any displacement height into account for this site.

The long-term wind speed extrapolated to hub height is presented in Table 1-5 using the shear value in Table 1-4.

Table 1-5. Long-term corrected mean wind speed at the hub height of 78.0 m AGL, with used wind shear value.

Source measurement height	Long-term corrected mean wind speed at hub height (HH) AGL using measured wind shear					
	HH 72.5 m	HH 77.0 m	HH 78.3 m	HH 91.5 m	HH 92.0 m	HH 96.5 m
[m AGL]	[m/s]					
85.1	10.12	10.15	10.16	10.25	10.25	10.28

1.3.4 Ambient turbulence intensity

The average turbulence intensity (TI) above 5 m/s for the mast is 8.5 % for hub heights at 72.5 m, 77.0 m, 78.0 m, 91.5 m, and 92.0 m AGL, see Figure 2 to the left for 72.5 m AGL. The average TI above 5 m/s for the mast is 8.4 % at 96.5 m AGL, see Figure 2 to the right. The highest values of TI are from the southwestern sectors from which directions the wind from the sea meet steep slopes. This may explain the high turbulence observed in the southwestern sectors.

The TI as function of wind speed for hub heights of 72.5 m (left) and 96.5 m (right) is seen below in Figure 3. The 90th percentile of the TI as function of wind speed is shown with a yellow line in the plots in Figure 3 and show that the TI is mainly below the IEC requirements for TI in subclass C (magenta line).

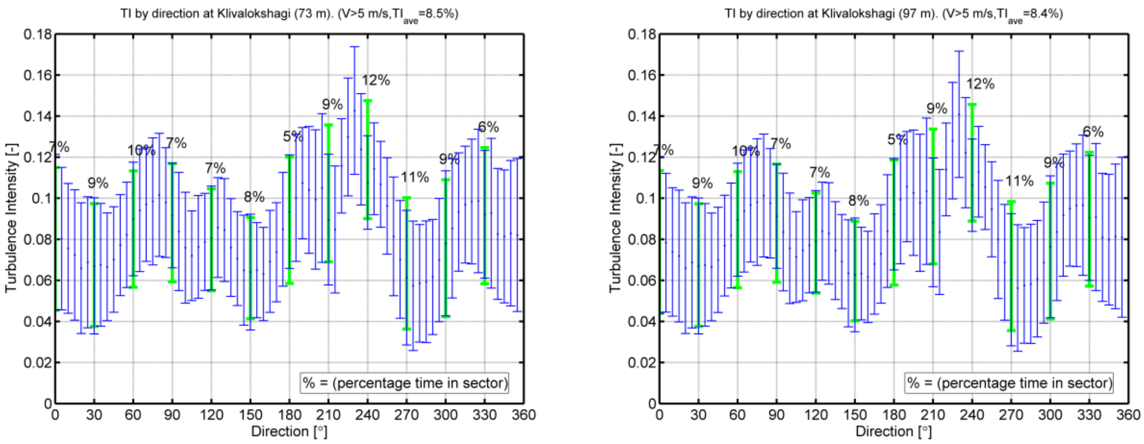


Figure 2. Ambient turbulence intensity as a function of the wind direction. The middle dots mark the mean TI. The upper and lower whiskers mark the mean value plus/minus one standard deviation, respectively. The values presented in the figure show the occurrence frequency of each wind direction sector.

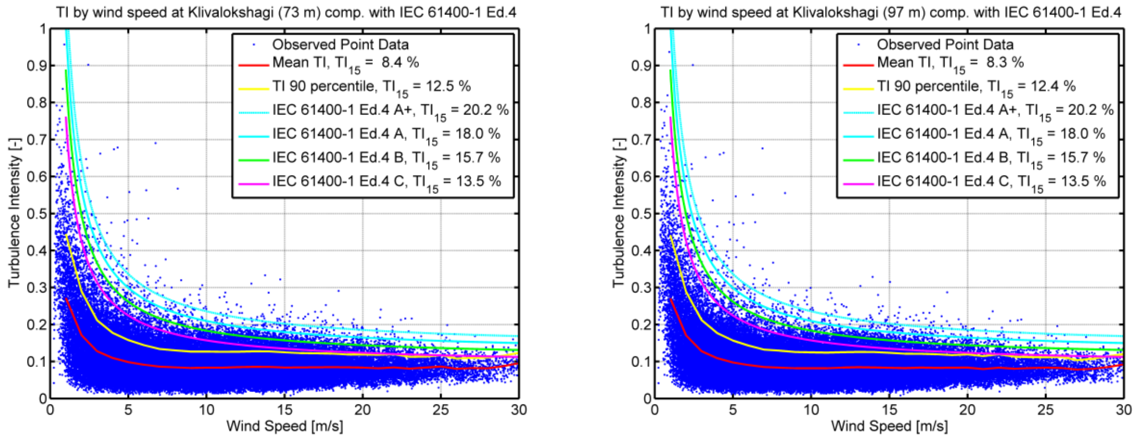


Figure 3. Ambient turbulence intensity as a function of the wind speed.

1.4 Horizontal extrapolation

1.4.1 Flow model

WAsP version 12 [4] has been used in this study.

1.4.2 Orography

Height contour lines from the map survey of Faroe Islands [5], with 2 m and 10 m interval covering an area extended minimum 2 km and 10 km, respectively, in all directions from the turbines, are used in this analysis.

1.4.3 Roughness classification

The roughness classification is manually done based on information from online aerial maps and available digital roughness from the Corine land cover database[1] as well as background maps. The used roughness values are based on the standard values from Aria [6].

The site is located in an area with mostly grassland. Roughness length for grassland is set to 0.03 m.

1.5 Wind resource map

The resulting WAsP wind resource map for the wind farm is presented for different layouts at all evaluated hub heights in Figure 4 - Figure 9. The relative change in terrain steepnes (delta-RIX) has been checked between the met mast position and the turbine positions. The delta-RIX values are below or equal to 1.3 % for all turbine positions, and it is therefore not necessary to make any corrections for the terrain variations.

[1] WindPRO Corine Land Cover products, http://help.emd.dk/mediawiki/index.php?title=Corine_Land_Cover

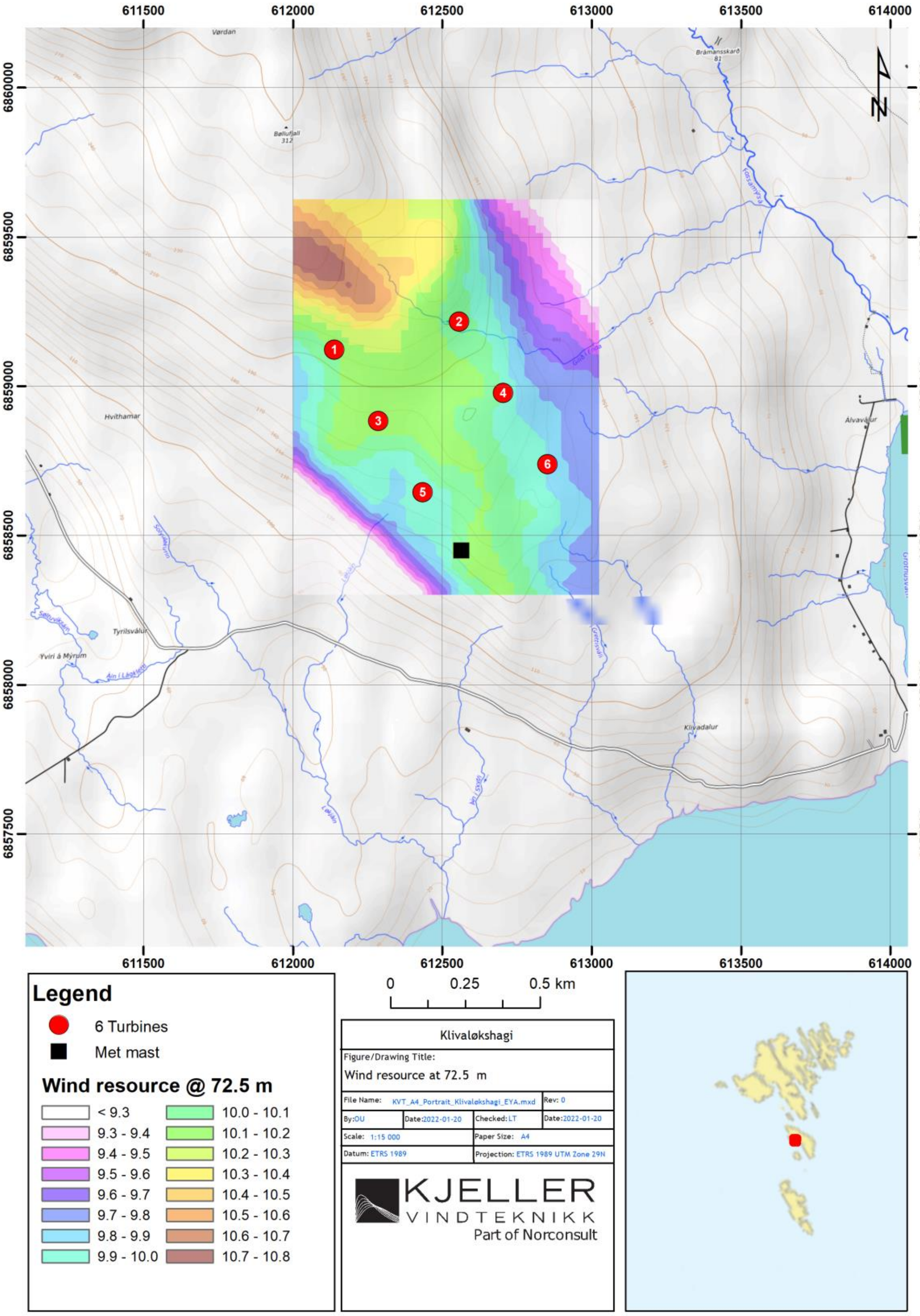


Figure 4. Wind resource map valid at 72.5 m AGL at Klivaløkshagi (together with 6 turbine layout).

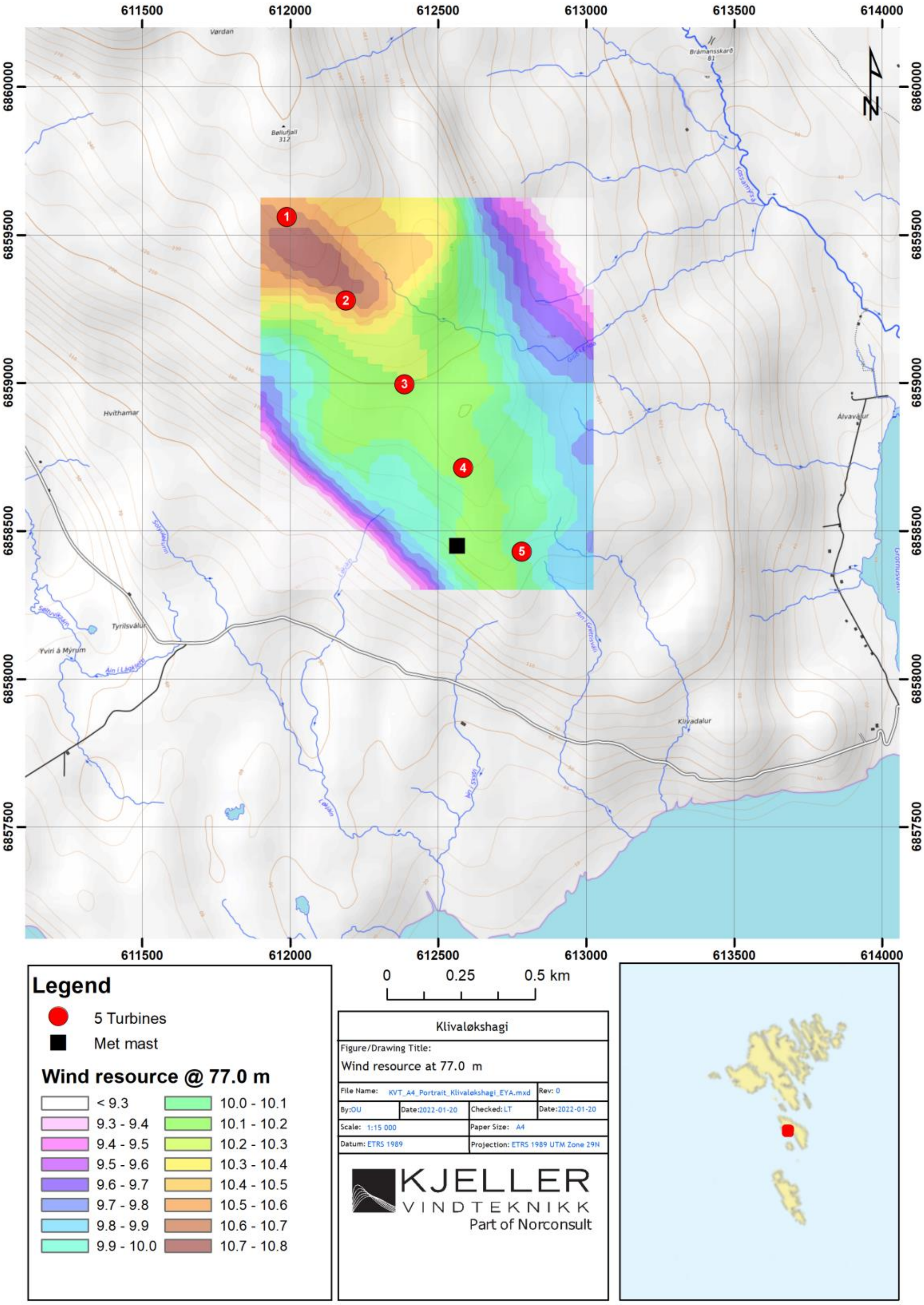


Figure 5. Wind resource map valid at 77 m AGL at Klivaløkshagi (together with 5 turbine layout).

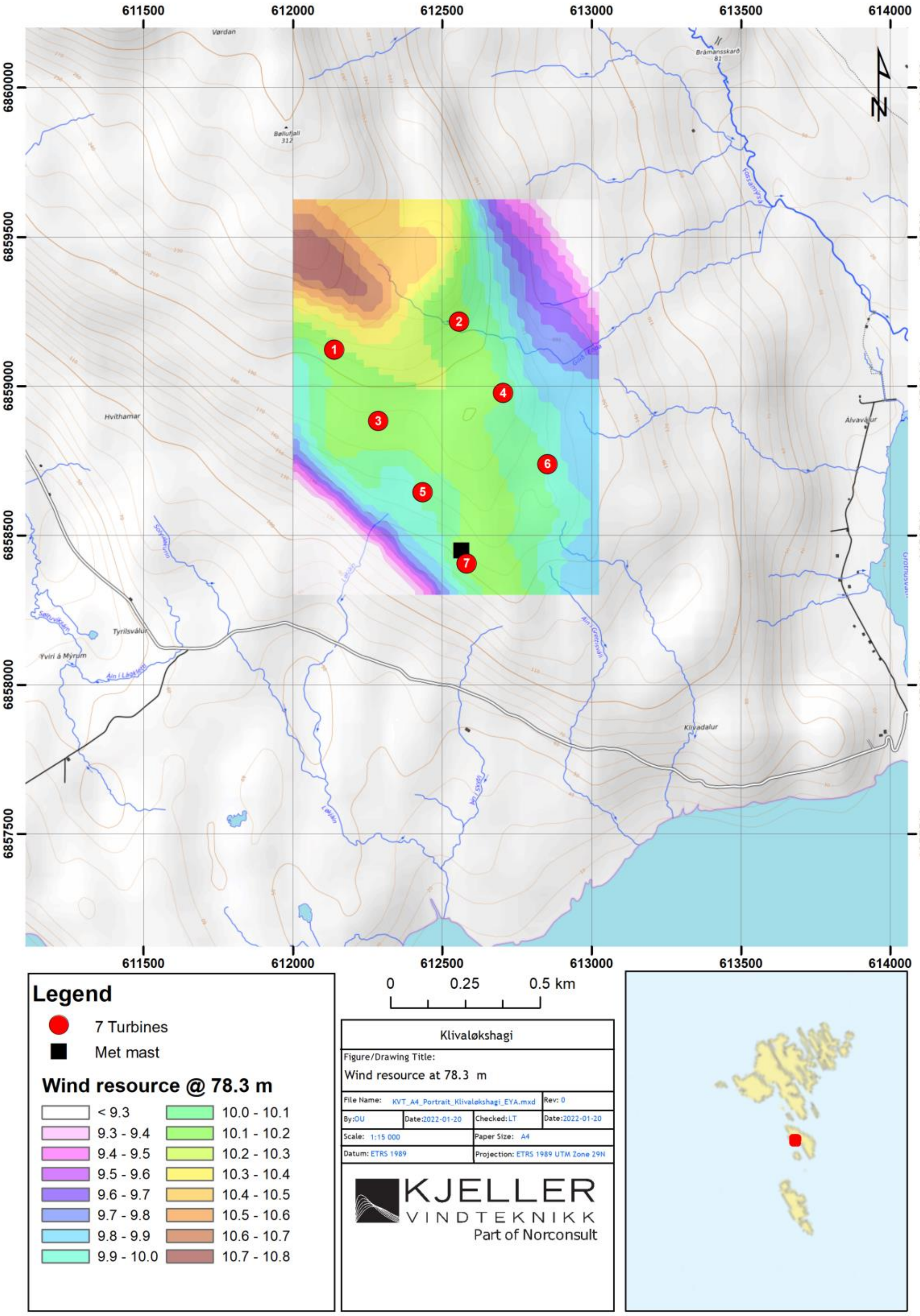


Figure 6. Wind resource map valid at 78.3 m AGL at Klivaløkshagi (together with 7 turbine layout).

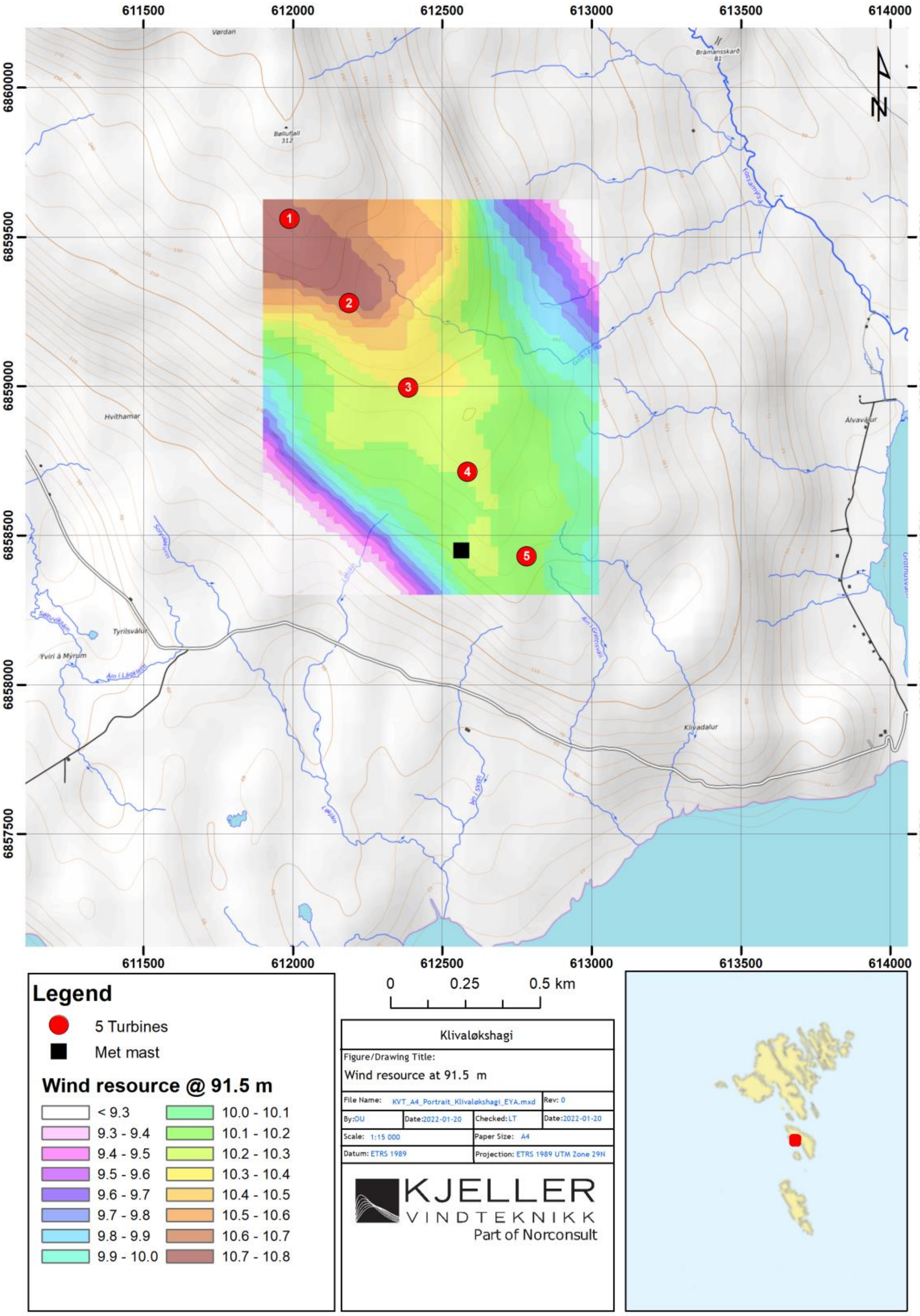


Figure 7. Wind resource map valid at 91.5 m AGL at Klivaløkshagi (together with 5 turbine layout).

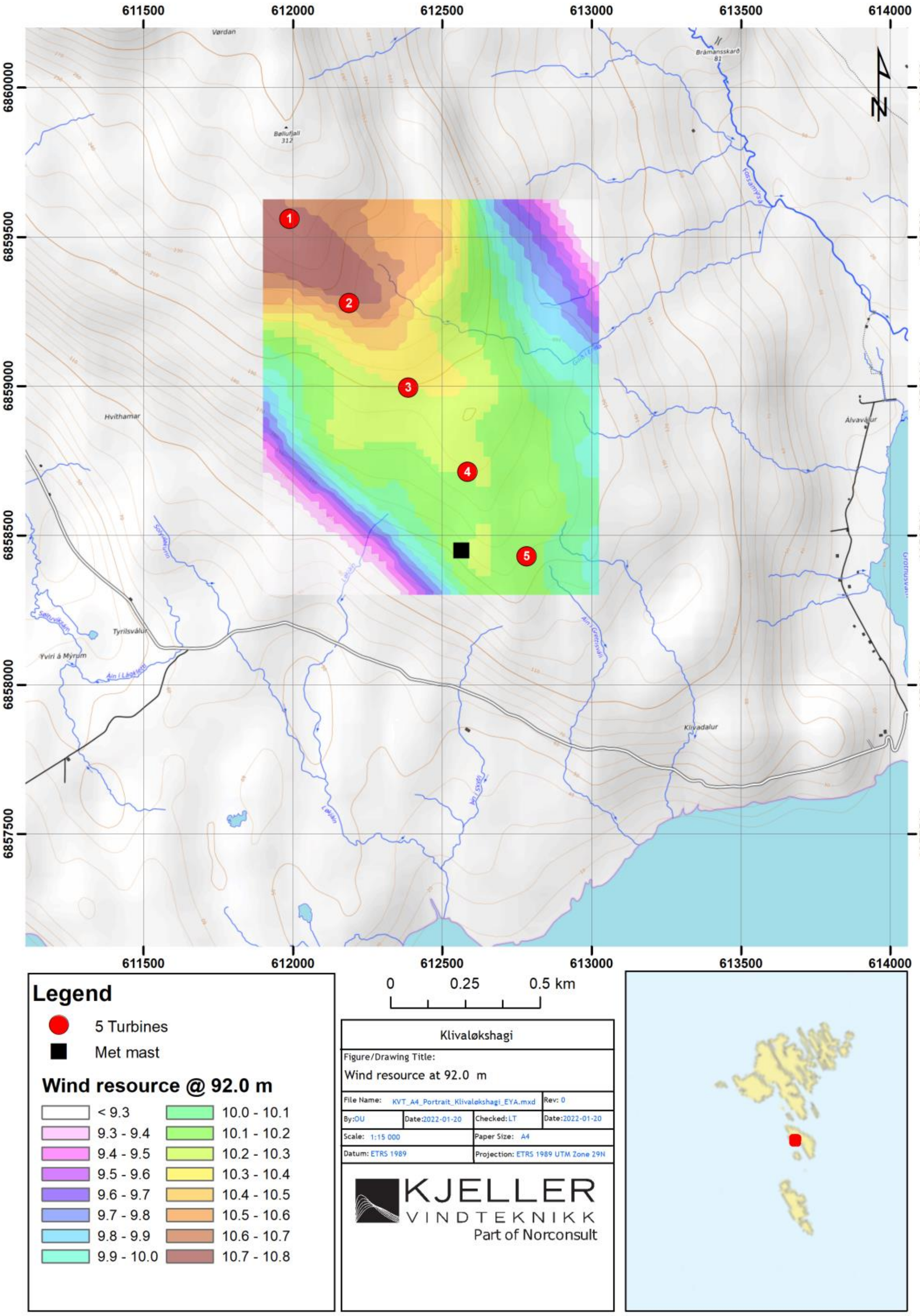


Figure 8. Wind resource map valid at 92 m AGL at Klivaløkshagi (together with 5 turbine layout).

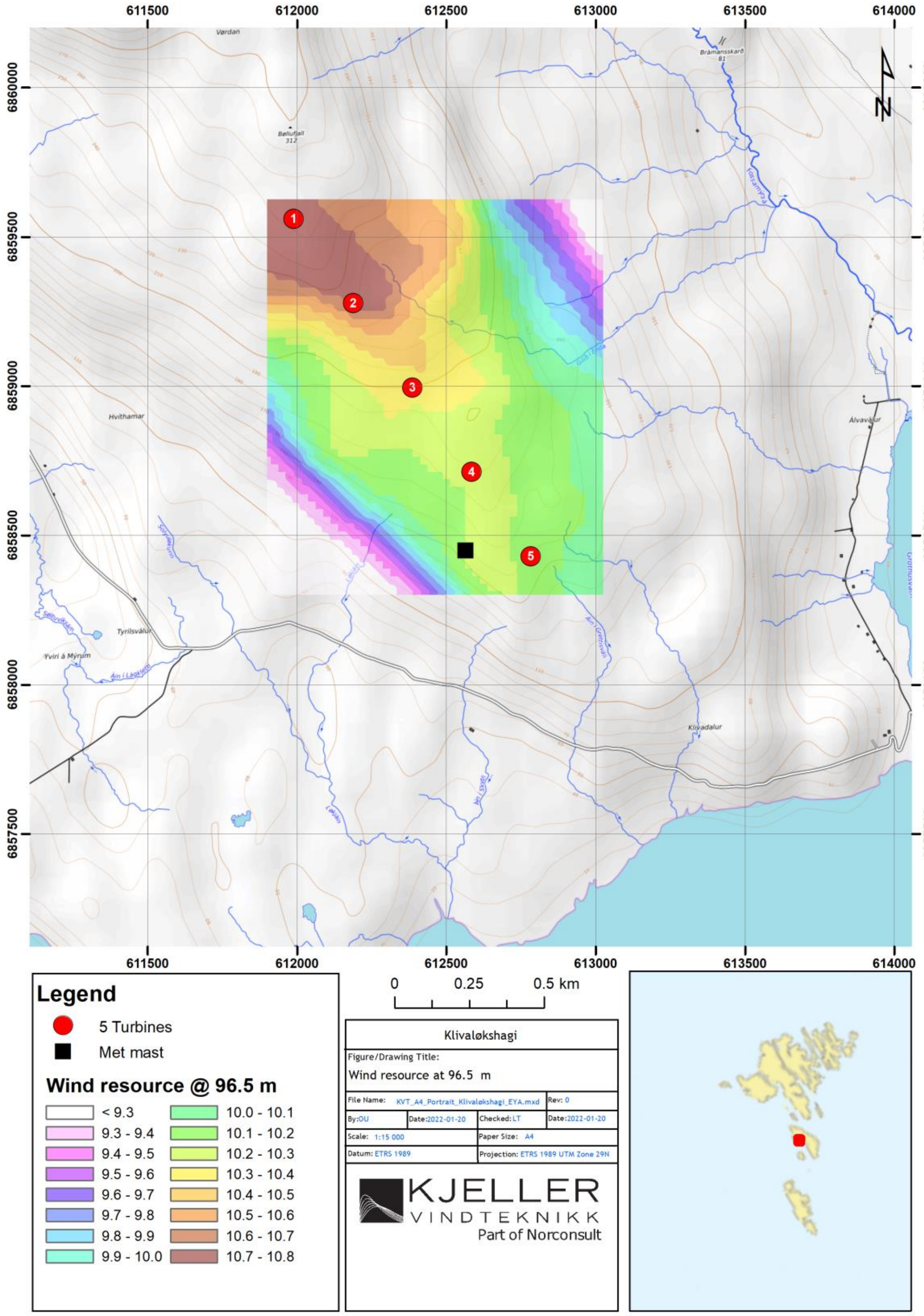


Figure 9. Wind resource map valid at 96.5 m AGL at Klivaløkshagi (together with 5 turbine layout).

1.6 Extreme wind analysis

The record of measurements at the measurement station Klivaløkshagi is about 2 years. To use such short wind data series in a meaningful extreme value analysis, it is recommended to use a reference data set covering minimum 20 years. Hence, we synthesize the met mast data with a quantile regression technique. Further information on the methodology can be found in [3], where it is described as the UN method. We apply a WRF 9km data set from the period 1979-2021 as the reference dataset. Then, the maximum yearly wind speed from this synthesized dataset is used as input to a Gumbel-Lieblein extreme wind analysis [7] [8] [9].

To calculate the sectorial 10-minute extreme winds coefficients, we use the measurement data only. The measurement data are divided in 8 sectors. For each sector, and for the all-sector group, the average of the five highest wind speed observations separated by at least 4 days are calculated. Sector coefficients are then calculated by dividing each sector average with the all-sector value.

The sectorial wind speed extremes are calculated by multiplying the 50-year extreme value (the all-sector value) from the Gumbel-Lieblein analysis with the sector coefficients from the measurement data. This methodology always gives sector extremes that are equal or lower than the all-sector value.

Table 1-6 shows the sector coefficients and the 50-year return value of the 10-min sectorial wind speeds at height of the top sensor (85.1m)

Table 1-6 Sector coefficients at the WRF 4 km data set and extreme values of the 10 min mean wind at Klivaløkshagi 85.1 m above ground level.

	N	NE	E	SE	S	SW	W	NW	Omni
WRF, Sector coefficients	0.58	0.76	0.78	0.69	0.74	0.92	0.96	0.70	
50-yr Klivaløkshagi	28.2	36.7	37.8	33.1	35.7	44.3	46.4	33.8	48.3

2 Energy Yield

2.1 Air density

The onsite air density is calculated using the nearest climate station data available in WindPRO [10] and its information is included in Appendix E as part of WindPRO printout. The calculated average hub height air density is 1.229 kg/m^3, 1.226 kg/m^3, 1.229 kg/m^3, 1.224 kg/m^3, 1.224 kg/m^3, and 1.223 kg/m^3 for the hub heights of 72.5 m, 77.0 m, 78.3 m, 91.5 m, 92.0 m, and 96.5 m, respectively.

2.2 Power curve

Table 2-1 shows the power curves used in the analysis. The original curves used in the J01 version of the report are without an asterisk. These are the curves used in the noise and shadow flicker analysis, as well as the turbine suitability analysis (see chapter 3 and 4).

Table 2-1 Turbine power curves. The power curves with the asterisk are the new curves added in this report.

Turbine type	Operation	Power and thrust curves provided by
E82 E4 3.0 MW	No HWO	Manufacturer - with trailing edge serration (TES)
	HWO*	Manufacturer
V105 3.6 MW	No HWO	WindPro
	HWO*	Manufacturer
E115 EP3 E4 4.26 MW	No HWO*	Based on HWO power curve with a cutout wind speed of 25 m/s
	HWO	WindPro
V117 4.2 MW	No HWO*	WindPro
	HWO	WindPro

The power curves and the thrust curves utilized are valid for an air density of 1.225 kg/m^3. They are adjusted to the air density at the site using WindPRO and included in Appendix E as part of WindPRO printout.

The power curves are valid on the low voltage side of the turbine transformer according to the manufacturer.

2.3 Energy production estimate

The estimates of P50 for Klivaløkshagi are shown in Table 2-2 to Table 2-14 for the chosen turbine types.

Table 2-2. Estimate of the gross AEP, of the expected production losses and of the net AEP for Klivaløkshagi with 6 x V105 3.6 MW with hub height of 72.5 m without HWO/storm control.

Klivaløkshagi - Layout with Vestas V105 3.6 MW HH 72.5 m AGL Energy Yield and Losses			
Number of Turbines		6	
Rated power of each turbine		3.6	MW
Rated power of the wind farm		21.6	MW
Gross AEP		**101.1**	**GWh/annum**
Correction factor applied on the gross energy:			
Weibull fit	100.1 %		
Corrected Gross AEP		**101.2**	**GWh/annum**
Production losses:			
Turbine interaction: Internal wake loss	6.7 %		Specific
Turbine interaction: External wake loss	0.0 %		Not considered
Turbine interaction: Wind farm blockage	0.0 %		Not considered
Electrical loss	2.0 %		Default
Contractual unavailability	3.0 %		Default
Non-contractual unavailability	0.6 %		Default
Environmental: Blade degradation	0.5 %		Specific
Environmental: Icing* without IPS**	0.0 %		Specific
Curtailment: e.g. Noise, shadow flicker, bird protection	0.0 %		not considered
Curtailment: Low temperature downtime	0.0 %		Specific
Curtailment: High wind hysteresis	1.0 %		Specific
Curtailment: other (e.g. grid capacity, site suitability, wind sector management)	0.0 %		not considered
Wind turbine performance	3.0 %		Specific
Total losses	**15.8 %**	**15.9**	**GWh/annum**
Net Annual Energy Yield, P(50)		**85.3**	**GWh/annum**

*Assumes operation with ice on the blades.

** Ice protection system (or blade heating system)

Table 2-3 Estimate of the gross AEP, of the expected production losses and of the net AEP for Klivaløkshagi with 6 x V105 3.6 MW with hub height of 72.5 m with HWO/storm control.

Klivaløkshagi - Layout with Vestas V105 3.6 MW HH 72.5 m AGL Energy Yield and Losses			
Number of Turbines		6	
Rated power of each turbine		3.6	MW
Rated power of the wind farm		21.6	MW
Gross AEP		**101.8**	**GWh/annum**
Correction factor applied on the gross energy:			
Weibull fit	100.0 %		
Corrected Gross AEP		**101.8**	**GWh/annum**
Production losses:			
Turbine interaction: Internal wake loss	6.6 %		Specific
Turbine interaction: External wake loss	0.0 %		Not considered
Turbine interaction: Wind farm blockage	0.0 %		Not considered
Electrical loss	2.0 %		Default
Contractual unavailability	3.0 %		Default
Non-contractual unavailability	0.6 %		Default
Environmental: Blade degradation	0.5 %		Specific
Environmental: Icing* without IPS**	0.0 %		Specific
Curtailment: e.g. Noise, shadow flicker, bird protection	0.0 %		not considered
Curtailment: Low temperature downtime	0.0 %		Specific
Curtailment: High wind hysteresis	0.1 %		Specific
Curtailment: other (e.g. grid capacity, site suitability, wind sector management)	0.0 %		not considered
Wind turbine performance	3.0 %		Specific
Total losses	**14.9 %**	**15.1**	**GWh/annum**
Net Annual Energy Yield, P(50)		**86.7**	**GWh/annum**

*Assumes operation with ice on the blades.

** Ice protection system (or blade heating system)

Table 2-4. Estimate of the gross AEP, of the expected production losses and of the net AEP for Klivaløkshagi with 7 x E-82 E4 3.0 MW with hub height of 78.3 m without HWO/storm control.

Klivaløkshagi - Layout with Enercon E82 E4 3.0 MW HH 78.3 m AGL Energy Yield and Losses			
Number of Turbines		7	
Rated power of each turbine		3	MW
Rated power of the wind farm		21.0	MW
Gross AEP		**86.1**	**GWh/annum**
Correction factor applied on the gross energy:			
Weibull fit	100.6 %		
Corrected Gross AEP		**86.6**	**GWh/annum**
Production losses:			
Turbine interaction: Internal wake loss	6.5 %		Specific
Turbine interaction: External wake loss	0.0 %		Not considered
Turbine interaction: Wind farm blockage	0.0 %		Not considered
Electrical loss	2.0 %		Default
Contractual unavailability	3.0 %		Default
Non-contractual unavailability	0.6 %		Default
Environmental: Blade degradation	0.5 %		Specific
Environmental: Icing* without IPS**	0.0 %		Specific
Curtailment: e.g. Noise, shadow flicker, bird protection	0.0 %		not considered
Curtailment: Low temperature downtime	0.0 %		Specific
Curtailment: High wind hysteresis	1.3 %		Specific
Curtailment: other (e.g. grid capacity, site suitability, wind sector management)	0.0 %		not considered
Wind turbine performance	3.0 %		Specific
Total losses	**15.8 %**	**13.7**	**GWh/annum**
Net Annual Energy Yield, P(50)		**72.9**	**GWh/annum**

*Assumes operation with ice on the blades.

** Ice protection system (or blade heating system)

Table 2-5 Estimate of the gross AEP, of the expected production losses and of the net AEP for Klivaløkshagi with 7 x E-82 E4 3.0 MW with hub height of 78.3 m with HWO/storm control.

Klivaløkshagi - Layout with Enercon E82 E4 3.0 MW HH 78.3 m AGL Energy Yield and Losses			
Number of Turbines		7	
Rated power of each turbine		3	MW
Rated power of the wind farm		21.0	MW
Gross AEP		**87.7**	**GWh/annum**
Correction factor applied on the gross energy:			
Weibull fit	100.4 %		
Corrected Gross AEP		**88.0**	**GWh/annum**
Production losses:			
Turbine interaction: Internal wake loss	6.3 %		Specific
Turbine interaction: External wake loss	0.0 %		Not considered
Turbine interaction: Wind farm blockage	0.0 %		Not considered
Electrical loss	2.0 %		Default
Contractual unavailability	3.0 %		Default
Non-contractual unavailability	0.6 %		Default
Environmental: Blade degradation	0.5 %		Specific
Environmental: Icing* without IPS**	0.0 %		Specific
Curtailment: e.g. Noise, shadow flicker, bird protection	0.0 %		not considered
Curtailment: Low temperature downtime	0.0 %		Specific
Curtailment: High wind hysteresis	0.0 %		Specific
Curtailment: other (e.g. grid capacity, site suitability, wind sector management)	0.0 %		not considered
Wind turbine performance	3.0 %		Specific
Total losses	**14.6 %**	**12.8**	**GWh/annum**
Net Annual Energy Yield, P(50)		**75.2**	**GWh/annum**

*Assumes operation with ice on the blades.

** Ice protection system (or blade heating system)

Table 2-6 Estimate of the gross AEP, of the expected production losses and of the net AEP for Klivaløkshagi with 5 x E-115 4.26 MW with hub height of 77.0 m without HW0/storm control.

Klivaløkshagi - Layout with Enercon E115 EP3 E4 4.26 MW HH 77.0 m AGL Energy Yield and Losses			
Number of Turbines		5	
Rated power of each turbine		4.26	MW
Rated power of the wind farm		21.3	MW
Gross AEP		**102.9**	**GWh/annum**
Correction factor applied on the gross energy:			
Weibull fit	100.0 %		
Corrected Gross AEP		**102.9**	**GWh/annum**
Production losses:			
Turbine interaction: Internal wake loss	3.9 %		Specific
Turbine interaction: External wake loss	0.0 %		Not considered
Turbine interaction: Wind farm blockage	0.0 %		Not considered
Electrical loss	2.0 %		Default
Contractual unavailability	3.0 %		Default
Non-contractual unavailability	0.6 %		Default
Environmental: Blade degradation	0.5 %		Specific
Environmental: Icing* without IPS**	0.0 %		Specific
Curtailment: e.g. Noise, shadow flicker, bird protection	0.0 %		not considered
Curtailment: Low temperature downtime	0.0 %		Specific
Curtailment: High wind hysteresis	1.2 %		Specific
Curtailment: other (e.g. grid capacity, site suitability, wind sector management)	0.0 %		not considered
Wind turbine performance	3.0 %		Specific
Total losses	**13.4 %**	**13.8**	**GWh/annum**
Net Annual Energy Yield, P(50)		**89.1**	**GWh/annum**

*Assumes operation with ice on the blades.

** Ice protection system (or blade heating system)

Table 2-7. Estimate of the gross AEP, of the expected production losses and of the net AEP for Klivaløkshagi with 5 x E-115 4.26 MW with hub height of 77.0 m with HW0/storm control.

Klivaløkshagi - Layout with Enercon E115 EP3 E4 4.26 MW HH 77.0 m AGL Energy Yield and Losses			
Number of Turbines		5	
Rated power of each turbine		4.26	MW
Rated power of the wind farm		21.3	MW
Gross AEP		**104.8**	**GWh/annum**
Correction factor applied on the gross energy:			
Weibull fit	99.8 %		
Corrected Gross AEP		**104.7**	**GWh/annum**
Production losses:			
Turbine interaction: Internal wake loss	3.8 %		Specific
Turbine interaction: External wake loss	0.0 %		Not considered
Turbine interaction: Wind farm blockage	0.0 %		Not considered
Electrical loss	2.0 %		Default
Contractual unavailability	3.0 %		Default
Non-contractual unavailability	0.6 %		Default
Environmental: Blade degradation	0.5 %		Specific
Environmental: Icing* without IPS**	0.0 %		Specific
Curtailment: e.g. Noise, shadow flicker, bird protection	0.0 %		not considered
Curtailment: Low temperature downtime	0.0 %		Specific
Curtailment: High wind hysteresis	0.0 %		Specific
Curtailment: other (e.g. grid capacity, site suitability, wind sector management)	0.0 %		not considered
Wind turbine performance	3.0 %		Specific
Total losses	**12.3 %**	**12.9**	**GWh/annum**
Net Annual Energy Yield, P(50)		**91.8**	**GWh/annum**

*Assumes operation with ice on the blades.

** Ice protection system (or blade heating system)

Table 2-8 Estimate of the gross AEP, of the expected production losses and of the net AEP for Klivaløkshagi with 5 x V117 4.2 MW with hub height of 91.5 m without HWO/storm control.

Klivaløkshagi - Layout with Vestas V117 4.2 MW HH 91.5 m AGL Energy Yield and Losses			
Number of Turbines		5	
Rated power of each turbine		4.2	MW
Rated power of the wind farm		21.0	MW
Gross AEP		**104.6**	**GWh/annum**
Correction factor applied on the gross energy:			
Weibull fit	99.7 %		
Corrected Gross AEP		**104.3**	**GWh/annum**
Production losses:			
Turbine interaction: Internal wake loss	3.6 %		Specific
Turbine interaction: External wake loss	0.0 %		Not considered
Turbine interaction: Wind farm blockage	0.0 %		Not considered
Electrical loss	2.0 %		Default
Contractual unavailability	3.0 %		Default
Non-contractual unavailability	0.6 %		Default
Environmental: Blade degradation	0.5 %		Specific
Environmental: Icing* without IPS**	0.0 %		Specific
Curtailment: e.g. Noise, shadow flicker, bird protection	0.0 %		not considered
Curtailment: Low temperature downtime	0.0 %		Specific
Curtailment: High wind hysteresis	0.7 %		Specific
Curtailment: other (e.g. grid capacity, site suitability, wind sector management)	0.0 %		not considered
Wind turbine performance	3.0 %		Specific
Total losses	**12.6 %**	**13.2**	**GWh/annum**
Net Annual Energy Yield, P(50)		**91.1**	**GWh/annum**

*Assumes operation with ice on the blades.

** Ice protection system (or blade heating system)

Table 2-9. Estimate of the gross AEP, of the expected production losses and of the net AEP for Klivaløkshagi with 5 x V117 4.2 MW with hub height of 91.5 m with HWO/storm control.

Klivaløkshagi - Layout with Vestas V117 4.2 MW HH 91.5 m AGL Energy Yield and Losses			
Number of Turbines		5	
Rated power of each turbine		4.2	MW
Rated power of the wind farm		21.0	MW
Gross AEP		**105.6**	**GWh/annum**
Correction factor applied on the gross energy:			
Weibull fit	99.7 %		
Corrected Gross AEP		**105.3**	**GWh/annum**
Production losses:			
Turbine interaction: Internal wake loss	3.6 %		Specific
Turbine interaction: External wake loss	0.0 %		Not considered
Turbine interaction: Wind farm blockage	0.0 %		Not considered
Electrical loss	2.0 %		Default
Contractual unavailability	3.0 %		Default
Non-contractual unavailability	0.6 %		Default
Environmental: Blade degradation	0.5 %		Specific
Environmental: Icing* without IPS**	0.0 %		Specific
Curtailment: e.g. Noise, shadow flicker, bird protection	0.0 %		not considered
Curtailment: Low temperature downtime	0.0 %		Specific
Curtailment: High wind hysteresis	0.1 %		Specific
Curtailment: other (e.g. grid capacity, site suitability, wind sector management)	0.0 %		not considered
Wind turbine performance	3.0 %		Specific
Total losses	**12.2 %**	**12.9**	**GWh/annum**
Net Annual Energy Yield, P(50)		**92.4**	**GWh/annum**

*Assumes operation with ice on the blades.

** Ice protection system (or blade heating system)

Table 2-10 Estimate of the gross AEP, of the expected production losses and of the net AEP for Klivaløkshagi with 5 x E-115 4.26 MW with hub height of 92.0 m without HWO/storm control.

Klivaløkshagi - Layout with Enercon E115 EP3 E4 4.26 MW HH 92.0 m AGL Energy Yield and Losses			
Number of Turbines		5	
Rated power of each turbine		4.26	MW
Rated power of the wind farm		21.3	MW
Gross AEP		**104.0**	**GWh/annum**
Correction factor applied on the gross energy:			
Weibull fit	100.0 %		
Corrected Gross AEP		**103.9**	**GWh/annum**
Production losses:			
Turbine interaction: Internal wake loss	3.8 %		Specific
Turbine interaction: External wake loss	0.0 %		Not considered
Turbine interaction: Wind farm blockage	0.0 %		Not considered
Electrical loss	2.0 %		Default
Contractual unavailability	3.0 %		Default
Non-contractual unavailability	0.6 %		Default
Environmental: Blade degradation	0.5 %		Specific
Environmental: Icing* without IPS**	0.0 %		Specific
Curtailment: e.g. Noise, shadow flicker, bird protection	0.0 %		not considered
Curtailment: Low temperature downtime	0.0 %		Specific
Curtailment: High wind hysteresis	1.3 %		Specific
Curtailment: other (e.g. grid capacity, site suitability, wind sector management)	0.0 %		not considered
Wind turbine performance	3.0 %		Specific
Total losses	**13.4 %**	**13.9**	**GWh/annum**
Net Annual Energy Yield, P(50)		**90.0**	**GWh/annum**

*Assumes operation with ice on the blades.

** Ice protection system (or blade heating system)

Table 2-11 Estimate of the gross AEP, of the expected production losses and of the net AEP for Klivaløkshagi with 5 x E-115 4.26 MW with hub height of 92.0 m with HWO/storm control.

Klivaløkshagi - Layout with Enercon E115 EP3 E4 4.26 MW HH 92.0 m AGL Energy Yield and Losses			
Number of Turbines		5	
Rated power of each turbine		4.26	MW
Rated power of the wind farm		21.3	MW
Gross AEP		**106.1**	**GWh/annum**
Correction factor applied on the gross energy:			
Weibull fit	99.8 %		
Corrected Gross AEP		**105.8**	**GWh/annum**
Production losses:			
Turbine interaction: Internal wake loss	3.8 %		Specific
Turbine interaction: External wake loss	0.0 %		Not considered
Turbine interaction: Wind farm blockage	0.0 %		Not considered
Electrical loss	2.0 %		Default
Contractual unavailability	3.0 %		Default
Non-contractual unavailability	0.6 %		Default
Environmental: Blade degradation	0.5 %		Specific
Environmental: Icing* without IPS**	0.0 %		Specific
Curtailment: e.g. Noise, shadow flicker, bird protection	0.0 %		not considered
Curtailment: Low temperature downtime	0.0 %		Specific
Curtailment: High wind hysteresis	0.0 %		Specific
Curtailment: other (e.g. grid capacity, site suitability, wind sector management)	0.0 %		not considered
Wind turbine performance	3.0 %		Specific
Total losses	**12.3 %**	**12.9**	**GWh/annum**
Net Annual Energy Yield, P(50)		**92.9**	**GWh/annum**

*Assumes operation with ice on the blades.

** Ice protection system (or blade heating system)

Table 2-12 Estimate of the gross AEP, of the expected production losses and of the net AEP for Klivaløkshagi with 5 x V117 4.2 MW with hub height of 96.5 m without HWO/storm control.

Klivaløkshagi - Layout with Vestas V117 4.2 MW HH 96.5 m AGL Energy Yield and Losses			
Number of Turbines		5	
Rated power of each turbine		4.2	MW
Rated power of the wind farm		21.0	MW
Gross AEP		**104.9**	**GWh/annum**
Correction factor applied on the gross energy:			
Weibull fit	99.7 %		
Corrected Gross AEP		**104.6**	**GWh/annum**
Production losses:			
Turbine interaction: Internal wake loss	3.6 %		Specific
Turbine interaction: External wake loss	0.0 %		Not considered
Turbine interaction: Wind farm blockage	0.0 %		Not considered
Electrical loss	2.0 %		Default
Contractual unavailability	3.0 %		Default
Non-contractual unavailability	0.6 %		Default
Environmental: Blade degradation	0.5 %		Specific
Environmental: Icing* without IPS**	0.0 %		Specific
Curtailment: e.g. Noise, shadow flicker, bird protection	0.0 %		not considered
Curtailment: Low temperature downtime	0.0 %		Specific
Curtailment: High wind hysteresis	0.7 %		Specific
Curtailment: other (e.g. grid capacity, site suitability, wind sector management)	0.0 %		not considered
Wind turbine performance	3.0 %		Specific
Total losses	**12.7 %**	**13.2**	**GWh/annum**
Net Annual Energy Yield, P(50)		**91.4**	**GWh/annum**

*Assumes operation with ice on the blades.

** Ice protection system (or blade heating system)

Table 2-13. Estimate of the gross AEP, of the expected production losses and of the net AEP for Klivaløkshagi with 5 x V117 4.2 MW with hub height of 96.5 m with HWO/storm control.

Klivaløkshagi - Layout with Vestas V117 4.2 MW HH 96.5 m AGL Energy Yield and Losses			
Number of Turbines		5	
Rated power of each turbine		4.2	MW
Rated power of the wind farm		21.0	MW
Gross AEP		**106.0**	**GWh/annum**
Correction factor applied on the gross energy:			
Weibull fit	99.7 %		
Corrected Gross AEP		**105.6**	**GWh/annum**
Production losses:			
Turbine interaction: Internal wake loss	3.6 %		Specific
Turbine interaction: External wake loss	0.0 %		Not considered
Turbine interaction: Wind farm blockage	0.0 %		Not considered
Electrical loss	2.0 %		Default
Contractual unavailability	3.0 %		Default
Non-contractual unavailability	0.6 %		Default
Environmental: Blade degradation	0.5 %		Specific
Environmental: Icing* without IPS**	0.0 %		Specific
Curtailment: e.g. Noise, shadow flicker, bird protection	0.0 %		not considered
Curtailment: Low temperature downtime	0.0 %		Specific
Curtailment: High wind hysteresis	0.1 %		Specific
Curtailment: other (e.g. grid capacity, site suitability, wind sector management)	0.0 %		not considered
Wind turbine performance	3.0 %		Specific
Total losses	**12.2 %**	**12.9**	**GWh/annum**
Net Annual Energy Yield, P(50)		**92.7**	**GWh/annum**

*Assumes operation with ice on the blades.

** Ice protection system (or blade heating system)

Comments on the method corrections and specific losses

Weibull fit correction The gross AEP is estimated based on the assumption that the wind speed distribution can be described by a Weibull distribution. The error in the energy estimate introduced by this assumption is evaluated through the comparison with the energy estimate resultant from the direct use of the measured wind time series scaled to the mean wind speed of the wind farm.

Turbine wake losses The internal wake losses have been calculated using a wake decay constant (WDC) of 0.068 for the three lowest hub heights. The WDC is based on 0.8 * TI, where the TI is 8.5 % for the three lowest hub heights. The TI is 8.4 % for hub height of 96.5 m and implies a WDC of 0.067. The 6 and 7 turbines layouts are designed for E-82 and V105 turbines where the minimum distance between turbines is respectively 3.4 and 2.7 rotor diameters (RD). The 5 turbine layout is designed for the E-115 and V117 turbines where the minimum distance between turbines is 3.0 RD for both types. The five turbine layout is decreasing the wake losses as the turbines are located in one line.

Icing It is assumed that icing will contribute with 0.0 % to the icing losses. This assumption is based on the maritime climate on the Faroe Islands.

High wind hysteresis The cut-out and the recut-in values used in the calculations and the resultant calculated production loss due to the high wind hysteresis is shown below in Table 2-14.

Table 2-14. High wind hysteresis for the turbine types and hub heights chosen for this analysis

WTG	Hub height [m]	Type of operation	Cut out wind speed [m/s]	Cut in wind speed [m/s]	Losses due to high wind hysteresis [%]
V105 3.6 MW	72.5	no HWO	25	22	1.0
		HWO	30	28	0.1
E-82 3.0 MW	78.3	no HWO	25	22	1.3
		HWO	34	31	0.0
E-115 4.26 MW	77.0	no HWO	25	22	1.2
		HWO	34	31	0.0
V117 4.2 MW	91.5	no HWO	27	24	0.7
		HWO	32	29	0.1
E-115 4.26 MW	92.0	no HWO	25	22	1.3
		HWO	34	31	0.0
V117 4.2 MW	96.5	no HWO	27	24	0.7
		HWO	32	29	0.1

Wind turbine performance The production loss due to wind turbine performance is assumed to be 3.0 % of the estimated energy production for this case. This value consists of the sum of the default 2 % loss normally used for highly complex terrain and 1 % loss due to flow stagnation in power curve measurements.

3 Noise and Shadow flicker

All calculations were carried out with the power curves used in the previous report (see section 2.2 for detailed information).

3.1 Noise Calculations

The noise calculations have been carried out by using the model described by the Danish Authorities [11] and explained in the guide from Miljøstyrelsen [12]. This model is simple and is considered conservative, since it assumes constant damping due to atmospheric conditions and the terrain effects are not taken into account. The calculations have been made for both low frequencies and for frequencies in the hearing interval.

Octave data in the hearing range are available for the chosen turbine types. No octave data in the low frequency range has been received from the manufacturer for the E-115 turbine.

Eight locations have been considered for the impact from the turbines, see Table 3-1 and Appendix E. All locations are considered to be in noise sensitive area (residential area) and have to be below the noise demands given in Table 3-1. The noise demand is given for two wind speeds at 10 m above ground; 6 m/s and 8 m/s.

The lowest distances to the noise demand (DND) is 211 m for NSA 3 and for the E-82 layout. The DND is above 100 m for all considered NSA locations and all the turbine types considered, which is regarded as a sufficient buffer to the noise demand when considering the chosen noise model does not take topographic variation and lee effects into account.

Table 3-1. Locations of residents considered for Klivaløkshagi. The noise demand for the hearing range and the distance to the noise demand (DND) in meters is shown for the chosen turbine types and tip heights (TH) with increasing tip height.

Location	Type	Wind speed at 10 m AGL [m/s]	Noise demand [dB(A)]	DND for E-82 TH 119.3 m [m]	DND for V105 TH 123.0 m [m]	DND for E-115 TH 134.5 m [m]	DND for E-115 TH 149.5 m [m]	DND for V117 TH 150.0 m [m]	DND for V117 TH 155.0 m [m]
NSA 1	Cottage	6	37	839	713	796	758	600	589
		8	39	614	634	688	688	598	600
NSA 2	Cottage	6	37	476	327	488	449	284	272
		8	39	253	248	375	375	281	283
NSA 3	Cottage	6	37	443	290	470	430	263	251
		8	39	220	211	356	355	261	263
NSA 4	Residence	6	37	1064	924	1045	1007	846	834
		8	39	840	845	935	935	844	846
NSA 5	Residence	6	37	1239	1099	1220	1182	1021	1010
		8	39	1015	1019	1110	1110	1019	1021
NSA 6	Residence	6	37	1244	1083	1284	1244	1075	1063
		8	39	1021	1004	1169	1168	1073	1075
NSA 7	School	6	37	1195	990	1344	1292	1089	1074
		8	39	964	906	1202	1200	1086	1088
NSA 8	Cottage	6	37	820	623	695	649	461	448
		8	39	597	542	564	564	459	461

Low frequency noise in the frequency range from 10 Hz to 160 Hz is calculated according to the model described by the Danish Authorities [11]. The noise limit is 20 dB(A) for both 6 m/s and 8 m/s. The locations are considered according to the types in Table 3-1 where the school is considered as residence and the parameters according to the model description in [11] are used accordingly.

Detailed printouts for the E-82 IA alternative are given in Appendix E, and the printouts of the remaining turbine alternatives are given in a separate file. The low frequency noise levels at the locations are below 17 dB(A) for the chosen turbine types (see Appendix E and separate files). The calculations show that the demands for low frequency noise is inside the limits with at least 200 m DND.

3.2 Shadow flicker

The exposure to shadow flicker has been considered for the 8 locations presented above in Section 3.1. The Danish guideline [13] states that the shadow flicker is to be considered outdoors for a horizontal area of 15 m x 15 m at 1 m above ground at the locations.

The recommendation from the Danish authorities is that the estimated real case shadow flicker outdoor should be below 10 h/year. Real case shadow flicker is taking the average of sunshine hours per month into account as well as the estimated operational hours from a given wind sector, see Appendix E. The average of sunshine hours per month are taken from sunshine statistic data for Torshavn which are public available from DMI (Danish Meteorological Institute).

The WindPRO printouts and Table 3-2 show that the expected hours of shadow flicker are below 10 h/year at all locations.

It is seen that the locations are exposed to increasing shadow flicker with increasing tip height except for the V117 with tip height of 150.0 m which exposes the locations to shadow flicker slightly less than the E-115 with tip height of 149.5 m. This is due to the power curve for E-115 is valid for a broader wind speed range from 2-34 m/s and results in more operative hours, 8672 hours, than the V117 with wind speed range from 3-32 m/s and operational hours of 8440 hours.

Detailed printouts for the E-82 IA alternative are given in Appendix E, and the printouts of the remaining turbine alternatives are given in a separate file.

Table 3-2. Locations of residents considered for Klivaløkshagi. The expected shadow hours per year is shown for the chosen turbine types and respective tip heights (TH) with increasing tip height. The expected shadow hours are shown with hours:minute per year.

Location	E-82 TH 119.3 m	V105 TH 123.0 m	E-115 TH 134.5 m	E-115 TH 149.5 m	V117 TH 150.0 m	V117 TH 155.0 m
NSA 1	01:20	01:21	04:40	05:13	05:08	05:14
NSA 2	00:14	00:20	00:00	00:00	00:00	00:19
NSA 3	01:01	01:32	00:10	00:34	00:33	00:44
NSA 4	03:59	04:54	05:00	05:22	05:18	05:23
NSA 5	03:07	04:01	03:36	03:48	03:46	03:53
NSA 6	01:49	02:05	02:29	02:31	02:30	02:30
NSA 7	00:46	01:02	01:05	01:25	01:24	01:30
NSA 8	01:22	01:29	02:11	03:04	03:01	03:21

4 Turbine suitability

All calculations were carried out with the power curves used in the previous report (see section 2.2 for detailed information).

The turbine types which will be analysed in this chapter are the same as previous in this report. The wind farm consists of 5-7 turbine positions at Klivaløkshagi, and it is identical with the layout used for energy estimation and can be seen in Figure 4 - Figure 9.

The turbine types are all assumed to be in IEC Class IA in order to withstand the wind climate on the Faroe Islands. However, the IEC class listed on the manufacturer's web sites are in some cases different from IEC IA. The manufacturer classification is checked as well, see Table 4-1 below, where the manufacturer classification is given with an asterisk. The tower height of the V117 with a hub height of 96.5 m is not in the portfolio from Vestas, but it is analysed here to check the combination of a relatively high hub height and a large rotor for the suitability in the climate of the Faroe Islands.

The type abbreviation in Table 4-1 is used throughout this Chapter.

Table 4-1. IEC Class for the chosen turbine types. Manufacturer classification is given with an asterisk.

Turbine type	IEC Class checked	Hub height [m]	Type Abreviation	Operation
E-82 3.0 MW	IA*	78.3	E-82 IA 78.3m	No HWO
E-82 3.0 MW	IIA*	78.3	E-82 IIA 78.3m	No HWO
V105 3.6 MW	IA*	72.5	V105 IA 72.5m	No HWO
E-115 4.26 MW	IA*	77.0	E-115 IA 77m	HWO
V117 4.2 MW	IA	91.5	V117 IA 91.5m	HWO
V117 4.2 MW	IB*	91.5	V117 IB 91.5m	HWO
E-115 4.26 MW	IA*	92.0	E-115 IA 92m	HWO
V117 4.2 MW	IA	96.5	V117 IA 96.5m	HWO
V117 4.2 MW	IB*	96.5	V117 IB 96.5m	HWO

4.1 Extreme wind speed

The calculated extreme wind speed in the met mast position is given in Section 1.6. Westerly winds are seen to be the most important extreme wind direction. For the purpose of this evaluation, only the westerly component is evaluated and treated as if this was the only direction contributing to the omnidirectional extreme wind speed. This leads to omnidirectional extreme wind speed values in each turbine location in accordance with Table 4-2.

Table 4-2. Extreme wind speed at turbine locations. IEC 61400-1 limits class I is 50 m/s and class II is 42.5 m/s. Green means below limit, orange means a minor exceedance (less than 1 m/s) and red means a larger exceedance (more than 1 m/s).

WTG #	E-82 IA 78.3m	E-82 IIA 78.3m	V105 IA 72.5m	E-115 IA 77m	V117 IA 91.5m	V117 IB 91.5m	E-115 IA 92m	V117 IA 96.5m	V117 IB 96.5m
1	49.0	49.0	48.7	50.5	50.6	50.6	50.6	50.6	50.6
2	46.3	46.3	46.1	49.9	50.0	50.0	50.0	50.1	50.1
3	48.5	48.5	48.3	48.2	48.5	48.5	48.5	48.7	48.7
4	45.9	45.9	45.6	47.8	48.1	48.1	48.1	48.0	48.0
5	47.1	47.1	46.9	47.0	47.6	47.6	47.6	47.6	47.6
6	45.9	45.9	45.6						
7	48.2	48.2							

4.2 IEC Check

The IEC checks have been carried out in the module Site Compliance in WindPRO [10]. The checks are based on measured data in the data period from 05.09.2019 to 31.08.2021 and the model WAsP Engineering, which calculates several parameters such as turbulence intensity, flow inclination etc. at the turbine positions.

Table 4-3. Check of ambient conditions according to IEC standard for the chosen turbine types.

	E-82 IA 78.3m	**E-82 IIA 78.3m**	**V105 IA 72.5m**	**E-115 IA 77m**	**V117 IA 91.5m**	**V117 IB 91.5m**	**E-115 IA 92m**	**V117 IA 96.5m**	**V117 IB 96.5m**
Terrain complexity									
Fatigue/Normal conditions									
a) Wind distributions									
b) Effective turbulence									
c) Flow inclination									
d) Wind shear									
e) Air density									
Ultima/Extreme conditions									
a) Ambient 90 % turbulence									
b) Extreme wind*									
c) Ambient extreme turbulence									
d) Max centre-wake 90 % turbulence									
Other IEC checks									
Temperature range									

*Extreme wind is presented in Section 4.1.

Table 4-3 show the results of the IEC check. The check will be shown as green if the parameter is inside the design envelope, orange if it is outside the design envelope with minor exceedances, and red if the parameter is critically outside the design envelope.

It can be seen in Table 4-3 that it is important, that the IEC classification is IEC IA. It is important to ensure the turbine type is designed for the wind climate on the Faroe Islands. If the turbine type is an IEC IB turbine, the wind distribution and the max centre-wake 90 % turbulence are exceeding the design limits significantly. This also applies when the IEC class is IIA, where the extreme wind with 50 years return period are exceeding the design limit significantly, in addition to the wind distribution and the effective turbulence.

The standard wind speed distribution follows a Rayleigh distribution, which equals a Weibull shape parameter equal to 2. At Klivaløkshagi, the Weibull shape parameter is 1.93 (Section 1.3.1), resulting in higher frequencies at higher wind speeds. The wind speed distribution is evaluated from 9 – 17 m/s for the class II turbines, which causes the frequency of E-82 IIA to exceed the IEC demand from 11 – 17 m/s. The wind speed distribution is evaluated from 10 – 20 m/s for the class I turbines, which causes the frequency to exceed the IEC demand slightly from 19 -20 m/s for E-82 IA and V105 IA shown as orange, and a bit more from 17-20 m/s for the remaining IA layouts shown as red.

The smallest rotor of 82 m fits the wind climate, however, not without caution. All layout alternatives except E-82 IA 78.3 m have significant exceedances for at least one parameter for the turbines analysed. Detailed printouts for the E-82 IA alternative are given in Appendix E, and the printouts of the remaining turbine alternatives are given in a separate file.

4.3 Load response

The load response calculations approximate WTG loads using a response surface method based on pre-run aero-elastic simulations for generic turbines [10]. This means that the estimated loads from the response surface are, thus, subject to a model uncertainty. Only the manufacturer has their detailed specifications for their turbine models. We therefore recommend consulting the manufacturer for final verification of suitability.

The following load components are covered in the evaluation:

- Blades: “Root in-plane bending” and “Root out-of-plane bending”.
- Tower: “Bottom side-to-side bending” and “Bottom for-aft bending”.
- Nacelle: “Yaw bearing tilt bending” and “Yaw bearing yaw bending”.
- Shaft: “Low speed shaft torque” and “Low speed shaft torque load duration distribution”.

The results of the fatigue analysis can be seen in Table 4-4, where the calculated fatigue life for each turbine component is shown, and in Table 4-5, where the corresponding load index is shown for each turbine component. For each of the turbine components in the list, the worst load component is given in the tables.

Table 4-4. Fatigue life time in years for the chosen turbine types

	Fatigue life time [years]								
	E-82 IA 78.3m	E-82 IIA 78.3m	V105 IA 72.5m	E-115 IA 77m	V117 IA 91.5m	V117 IB 91.5m	E-115 IA 92m	V117 IA 96.5m	V117 IB 96.5m
Blade	24.6	21.0	23.6	29.0	29.2	24.7	29.0	29.4	24.9
Tower	33.2	19.5	28.3	49.7	> 50.0	30.3	49.7	> 50.0	31.0
Nacelle	31.4	24.3	26.5	> 50.0	> 50.0	32.5	> 50.0	> 50.0	33.1
Shaft	20.3	15.2	20.3	20.1	20.2	20.1	20.1	20.2	20.1

It can be seen in Table 4-4 that only the class IIA version of E-82 3.0 MW with hub height 78.3 m fails to meet the required 20 year life time. However, all other turbine alternatives have a shaft life close to the 20 year limit.

Table 4-4 also show the importance of keeping the turbine design in accordance with IEC I. The calculations carried out for IEC II show significant exceedance of design load, and a corresponding reduction in the turbine fatigue life. This is not surprising since the mean wind on the site is around 10 m/s, which is at the upper limit of IEC I classification. Class A results in a rather good margin to the design limit for the components blade, tower and nacelle, which causes the turbulence in accordance with Class B to also be a feasible solution.

Figure 10 shows the calculated fatigue life of the turbine shaft as function of the turbine rotor diameter for the IEC IA alternatives. The dependency on rotor size is low for the different turbine alternatives.

Concluding remarks:

- The fatigue life of the turbines is found to have negligible dependence on rotor diameter.
- It is important that the layout is designed for the turbine type with sufficient distance between turbines.
- Regardless of turbine types, special attention is needed to ensure a turbine classification suitable for the site resulting in the required expected fatigue life of the turbines, especially for the shaft which is close to 20 years for all alternatives.
- A good dialogue with the manufacturer is recommended to ensure the turbines are designed according to the site condition on the Faroe Islands.

Table 4-5. Load index in percent for worst component for the chosen turbine types

	Load Index [%]								
	E-82 IA 78.3m	E-82 IIA 78.3m	V105 IA 72.5m	E-115 IA 77m	V117 IA 91.5m	V117 IB 91.5m	E-115 IA 92m	V117 IA 96.5m	V117 IB 96.5m
Blade	97.9	99.5	98.4	96.4	96.3	97.9	96.4	96.2	97.8
Tower	88.1	100.6	91.7	79.7	79.1	90.1	79.7	78.6	89.6
Nacelle	89.3	95.2	93.2	78.5	78.1	88.6	78.5	77.7	88.1
Shaft	99.8	104.7	99.7	99.9	99.8	99.9	99.9	99.9	99.9

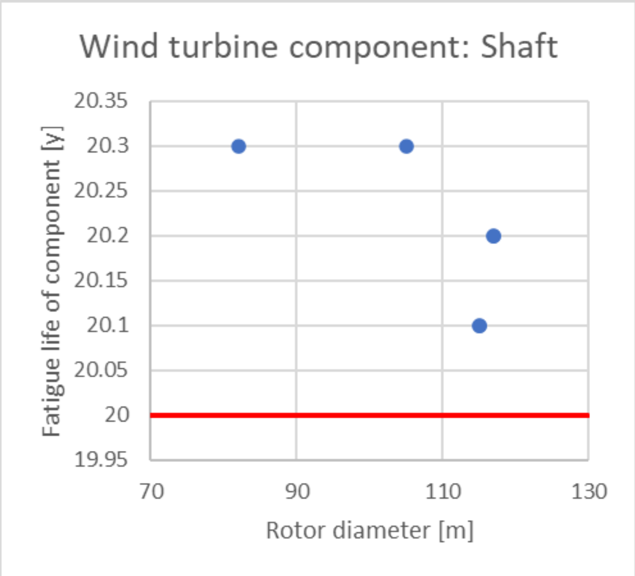


Figure 10. Fatigue life of the shaft as function of rotor diameter (RD) for all IEC IA alternatives.

5 References

[1] Kjeller Vindteknikk, “KVT/2021/R024/KW Klivalokshagi, Sandøy, Faro Islands, Installation Report,” 2021.

[2] K. Harstveit, “Estimating long-term wind distribution from short-term data set using a reference station,” in *European Community Wind Energy Conference, EWEC*, London, 2004.

[3] S. Liléo, E. Berge, O. Undheim, R. Klinkert and R. E. Bredesen, “Long-term correction of wind measurements. State-of-the-art, guidelines and future work.,” Elforsk report 13:18, 2013.

[4] N. G. Mortensen, D. N. Heathfield, O. Rathmann and M. Nielsen, "Wind Atlas Analysis and Application Program. WAsP 10 Help Facility.," Riso National Laboratory, Roskilde, Denmark, 2011.

[5] Føroyakort, “Strikukort,” 26 02 2021. [Online]. Available: https://www.foroyakort.fo/tak-datur-nidur/tak-nidur-strikukort/.

[6] S. P. Arya, Introduction to micrometeorology, California: Academic Press, 1988.

[7] E. Gumbel, Statistics of extremes, Columbia University Press, 1958.

[8] J. Lieblein, Efficient Methods of Extreme-Value Methodology, Washington: National Bureau of Standards, NBSIR 74-602, 1974.

[9] R. Harris, “Gumbel re-visited - a new look at extreme value statistics applied to wind speeds,” *Journal of Industrial Aerodynamics,* pp. Volume 59, Pages 1-22, doi: 10.1016/0167-6105(95)00029-1, 1996.

[10] EMD International A/S, “WindPRO,” 2021. [Online]. Available: https://www.emd-international.com/windpro/.

[11] Miljø- og Fødevareministeriet, “Bekjendtgørelse om støj fra vindmøller,” 07 02 2019. [Online]. Available: https://www.retsinformation.dk/eli/lta/2019/135.

[12] Miljøstyrelsen, “Støj fra vindmøller - Vejledning fra Miljøstyrelsen,” Miljøministeriet, Odense, 2021.

[13] Naturstyrelsen, Miljøministeriet, “Vejledning om planlægning om planlægning opstilling af vindmøller,” 2015.

Appendix A – KVTMeso

The Weather Research and Forecast (WRF) model is a state-of-the-art meso-scale numerical weather prediction system, aiming at both operational forecasting and atmospheric research needs. Numerous WRF simulations are performed at Kjeller Vindteknikk, covering different areas and time periods.

A detailed description of the modelling system can be found at the WRF home page[2]. The development of the WRF-model is supported by a strong scientific and administrative community in U.S.A. The number of users is large and it is growing rapidly. In addition, the code is accessible for the public.

Model setup

In this work the KVT dataset NSF09 is applied, utilizing the WRF version 4.1.2 with improvements of wet snow behaviour documented by Iversen et al. (2021)[3]. The model has been set up with 9 km x 9 km horizontal resolution and the modelled area is shown in Figure A-1. The model is run with 32 layers in the vertical with four layers in the lower 200 m. We have used the Thompson aerosol-aware microphysics scheme and the Mellor-Yamada Nakanishi and Niino (MYNN) Level 2.5 PBL scheme for boundary layer mixing. Surface layer physics is done according to the Quasi-Normal Scale Elimination PBL scheme's surface layer option, and land surface physics scheme is the Noah Land Surface Model. Radiation physics is done by the RRTMG scheme with the cloud fraction option by Sundqvist et al (1989)[4]. The simulation outputs hourly data starting from 1979-01-01 and is updated continuously.

Figure A-1: Model set up for the WRF simulations of Scandinavia.

[2] https://www.mmm.ucar.edu/weather-research-and-forecasting-model
[3] Emilie C. Iversen, Gregory Thompson and Bjørn Egil Nygaard, 2021: Improvements to melting snow behavior in a bulk microphysics scheme, Atmospheric Research, vol. 253, 105471, doi: 10.1016/j.atmosres.2021.105471.
[4] Sundqvist H, Berge E. and J. E. Kristjánsson, 1989: Condensation and cloud parameterization studies with a Mesoscale Numerical Weather Prediction Model, Monthly Weather Review (117)

Input data

The most important input data are geographical data and meteorological data. The geographical data is from the National Oceanic and Atmospheric Administration (NOAA). The data includes topography, surface data, albedo and vegetation. These parameters have high influence for the wind speed in the layers close to the ground. The model setup has been updated with a more detailed land use classification data set from the CORINE Land Cover mapping project[5].

For the solving of the model equations it requires boundary conditions of the area considered. In this model setup data from the ERA5[6,7] reanalysis data with approximately 0.25-degree resolution, available from Copernicus Climate Change Service (C3S) is used. The simulations are set up to use input data with a 3 hours interval. In addition to the lateral input updated every 3 hours spectral nudging is used at the higher atmospheric levels.

ERA5 is a reanalysis dataset resultant from the assimilation of all available observation data globally into a numerical weather prediction model in order to create a description of the state of the atmosphere on a uniform horizontal grid and at uniformly spaced time instants. The assimilation model incorporates data from several thousand ground-based observation stations, vertical profiles from radiosondes, aircrafts, and satellites.

[5] http://www.eea.europa.eu/publications/COR0-landcover

[6] Copernicus Climate Change Service (C3S) (2017): ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS). https://cds.climate.copernicus.eu/cdsapp#!/home

[7] https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5

Appendix B – Documentation of Measurements

- The mast has been installed and operated by Kjeller Vindteknikk, see the installation report [1].

Appendix C – Monthly Data Coverage

Table C-5-1. Klivaløkshagi met mast; Anemometer B: Monthly percentages of the missing and the removed data for the main top sensor. The months with data coverage larger than 90 % are coloured in green; months with data coverage between 50 and 90 % are coloured in yellow and months with availability lower than 50 % are coloured in red. (The availability of the first and the last months are calculated by assuming partial months as full months.)

Years	Months	Technical availability (%)	Removed by filtering (%)	Final availability (%)
2019	Sep	24.5	0.0	24.5
	Oct	35.1	0.0	35.1
	Nov	54.9	6.6	48.3
	Dec	96.1	1.6	94.4
2020	Jan	13.1	0.0	13.1
	Feb	0.0	0.0	0.0
	Mar	9.4	0.0	9.4
	Apr	96.4	0.0	96.4
	May	91.9	1.5	90.4
	Jun	80.7	0.0	80.7
	Jul	53.2	0.0	53.2
	Aug	87.8	0.0	87.8
	Sep	97.5	0.0	97.5
	Oct	93.2	1.6	91.7
	Nov	74.6	1.0	73.6
	Dec	93.5	0.2	93.3
2021	Jan	96.2	2.1	94.1
	Feb	93.2	1.1	92.1
	Mar	99.7	0.0	99.7
	Apr	99.8	0.0	99.8
	May	100.0	1.5	98.5
	Jun	100.0	0.0	100.0
	Jul	100.0	0.0	100.0
	Aug	100.0	0.0	100.0

Appendix D – Expected production losses

This appendix presents a detailed description of the different items presented in the production loss table.

Gross AEP Estimated gross annual energy production excluding all possible losses. This value is obtained from the WindPRO calculations.

Correction factor applied on the gross AEP

Weibull fit The gross AEP is estimated based on the assumption that the wind speed distribution can be described by a Weibull function. The error in the energy estimate introduced by this assumption is evaluated through the comparison with the energy estimate resultant from the direct use of the measured wind time series scaled to the mean wind speed of the wind farm.

Production losses

Turbine interaction: Internal wake loss The internal wake loss is defined as the production loss caused by the wake effect generated by the wind turbines of the wind farm.

Turbine interaction: External wake loss The external wake loss is caused by the wake effect generated by existing or planned neighbour wind farms.

Turbine interaction: Wind farm blockage loss The wind farm blockage loss is defined as the production loss of the first row of the wind farm caused by the pressure field formed by the turbines behind the first row.

Electrical loss Power loss occurs at the transformer located in each wind turbine and along the electric cables connecting the turbines to the substation where the generated power is delivered to the grid (connection point). Moreover, electrical loss is also associated with the substation itself. Different transformer models and different cable types (diameter and length) are associated with different amounts of dissipated energy. Spengemann and Borget (2008)[8] have shown that electrical loss is typically about 2 % to 3 % of the produced energy. For large wind farms higher electrical losses may be expected. Kjeller Vindteknikk assumes a default value of 2.0 % if no other information is given by the customer.

Contractual unavailability Historically wind turbine availability warranties have had a 97 % availability coverage and therefore this is Kjeller Vindteknikk's default unless other contractual warranty details are provided.

Non-contractual unavailability It has been Kjeller Vindteknikk's experience that there are additional availability losses not covered by the warranty such as availability of balance of plant, site access and start-up losses for WTG from standstill and therefore Kjeller Vindteknikk applies 0.4 % non-contractual unavailability loss.

Grid availability is included in the non contractual unavailability and Kjeller Vindteknikk estimates 0.2 % loss for grid unavailability but recognizes that this can differ depending on location. It is recommended that a grid study is undertaken and the result of such could be included in the calculation.

Blade degradation Production loss occurs due to the successive degradation of the blade surface caused by wear and tear and exposition to icing and dirt. The production loss associated with blade degradation is assumed by default to be 0.5 %.

[8] P. Spengemann and V. Borget, "Review and analysis of wind farm operational data Validation of the predicted energy yield of wind farms based on real energy production data," DEWI GmbH, 2008.

Icing The energy production of a wind farm may be affected by the formation of ice on the blades of the wind turbines. Icing will change the lift characteristics of the blades and will therefore affect the energy output of the turbines. The expected icing loss is estimated specifically for the site.

Low temperature downtime At low ambient temperatures, the wind turbine system can shut down or produce at reduced efficiency. The standard operating temperature range varies depending on the turbine model. The expected production loss caused by low temperature downtime is estimated specifically for each site and for each considered turbine model, taking into account the site specific temperature long-term variation, and the turbine's operating temperature range.

High wind hysteresis Production loss occurs when the wind speed exceeds the defined value for maximum operating wind speed. The turbines will stop when the wind speed exceeds the cut-out value, and it will restart when the wind speed is lower than the defined recut-in value. The high wind hysteresis loss is estimated by analyzing the estimated long-term time series of the wind speed at the measurement height scaled to the average wind speed of the wind farm at hub height. The cut-out and the recut-in wind speeds specific for the considered turbine model are used.

Wind turbine performance The wind turbine performance is dependent on the wind conditions; such as wind shear, turbulence, inflow angle and wind veer[9,10]. The wind turbine design requirements defined in the IEC 61400-1 standard[11] specify wind turbine type classes with certain wind conditions such as the wind speed profile shall be given by the power law with the wind shear exponent α equal to 0.2 with three different turbulence categories. At sites where the wind conditions do not match to the standard classes, the site-specific adjustments are made (i.e. called as class S) to define more suitable wind turbines. However, the real life operating wind conditions at the wind farm sites do not always go into these pre-defined design profiles, therefore there will be discrepancies between the calculated and the actual power values. To count for the influence of the non-standard wind conditions in the power production; the standard loss assumptions used by Kjeller Vindteknikk are 0 % in simple terrain, 1 % in forested and/or complex terrain, and 2 % in highly complex terrain.

In addition to the above stated wind conditions, the power curve measurements carried out in accordance with best practice in IEC 61400-12-1 standard[12] are subject to blockage effects on the wind speed as 1-1.5 %[13] . Due to varying inflow directions, this is not expected to be valid for all involved directions in a power curve measurement campaign. As this is the general basis for the used power curves, this difference propagates to the pre-construction analyses as a loss. Therefore, an additional 1 % added as the estimate of the corresponding production loss.

Net AEP Estimated net annual energy production including all the considered production losses.

---

[9] Turkyilmaz et. al., Assessment and optimization of the energy production of operational wind farms - Part 2: Use of remote sensing for performance optimization, Energiforsk, 2016
[10] Lindvall et. al., Load Monitor 1 - Measuring and modeling vibrations and loads on wind turbines, Energiforsk, 2018
[11] IEC 61400-1 Ed.4, "Internationl standard. Wind energy generation systems - Part 1: Design requirements," The International Electrotechnical Commission (IEC), 2019.
[12] IEC 61400-12-1 Ed.2, "International standard. Wind energy generation systems - Part 12-1: Power performance measurments of electricity producing wind tubines. Edition 2.0," The International Electrotechnical Commission (IEC), Geneva, 2017.
[13] A. Tindal, C. Johnson, M. LeBlanc, K. Harman, E. Rareshide och A. M. Graves, "SITE-SPECIFIC ADJUSTMENTS TO WIND TURBINE POWER CURVES," i *Poster presentation at the AWEA WINDPOWER Conference, Houston*, Garrad Hassan America, Inc., 2008.

Appendix E – WindPRO printouts

Project:
Sandoy_uV_20181121

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2021-12-14 11:20/3.5.552

PARK - Main Result

Calculation: 7 x E82 E4 3p0 MW HH 78p3 m

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: 1.9°

Power curve correction method
New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>
Air density calculation method
Height dependent, temperature from climate station
Station: THORSHAVN V3 2014
Base temperature: 6.0 °C at 55.0 m
Base pressure: 1013.3 hPa at 0.0 m
Air density for Site center in key hub height: 207.5 m + 78.0 m = 1.228 kg/m³ -> 100.2 % of Std
Relative humidity: 0.0 %

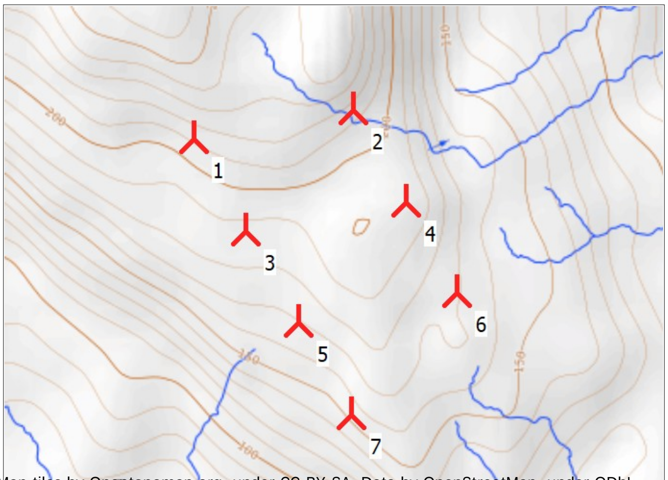
Wake Model Parameters

Terrain type	Wake decay constant
User defined	0.068

Omnidirectional displacement height from objects

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0.5	360.0	1.0	0.5	30.5	1.0



Map tiles by Opentopomap.org, under CC-BY-SA. Data by OpenStreetMap, under ODbL.

Scale 1:20 000

New WTG

Resource file(s)

L:\KUNDER\535_Energy_Directorate_FO\001_Klivalokshagi\Analyses\2021_11_Site_Suitability\04_WAsP\03_Wind_maps\Klivalokshagi_HH78p3m_corr_1.012.wrg

Calculated Annual Energy for Wind Farm

				Specific results¤)			
WTG combination	Result PARK	GROSS (no loss) Free WTGs	Wake loss	Capacity factor	Mean WTG result	Full load hours	Mean wind speed @hub height
	[MWh/y]	[MWh/y]	[%]	[%]	[MWh/y]	[Hours/year]	[m/s]
Wind farm	80 548.4	86 115.6	6.5	43.8	11 506.9	3 836	10.1

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 7 new WTGs with total 21.0 MW rated power

	WTG type						Power curve		Annual Energy		
Links	Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Creator	Name	Result	Wake loss	Free mean wind speed
				[kW]	[m]	[m]			[MWh/y]	[%]	[m/s]
1 A	Yes	ENERCON	E-82 E4 TES-3 000	3 000	82.0	78.3	USER	Mode 0 TES 10/2017	11 737.4	5.2	10.23
2 A	Yes	ENERCON	E-82 E4 TES-3 000	3 000	82.0	78.3	USER	Mode 0 TES 10/2017	11 448.5	6.7	10.11
3 A	Yes	ENERCON	E-82 E4 TES-3 000	3 000	82.0	78.3	USER	Mode 0 TES 10/2017	11 533.8	7.2	10.22
4 A	Yes	ENERCON	E-82 E4 TES-3 000	3 000	82.0	78.3	USER	Mode 0 TES 10/2017	11 234.8	8.2	10.05
5 A	Yes	ENERCON	E-82 E4 TES-3 000	3 000	82.0	78.3	USER	Mode 0 TES 10/2017	11 322.5	7.2	10.02
6 A	Yes	ENERCON	E-82 E4 TES-3 000	3 000	82.0	78.3	USER	Mode 0 TES 10/2017	11 407.3	6.4	9.98
7 A	Yes	ENERCON	E-82 E4 TES-3 000	3 000	82.0	78.3	USER	Mode 0 TES 10/2017	11 864.1	4.5	10.18

Annual Energy result includes shown losses. Additional losses and uncertainty must be considered for an investment decision.

WTG siting

	UTM (north)-WGS84 Zone: 29			
	Easting	Northing	Z [m]	Row data/Description
1 New	612 139	6 859 122	225.3	KLH101
2 New	612 557	6 859 216	218.1	KLH102
3 New	612 286	6 858 883	207.6	KLH103
4 New	612 704	6 858 977	200.6	KLH104
5 New	612 434	6 858 645	183.0	KLH105
6 New	612 852	6 858 739	181.3	KLH106
7 New	612 582	6 858 406	171.6	KLH107

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2021-12-14 11:20/3.5.552

PARK - Power Curve Analysis

Calculation: 7 x E82 E4 3p0 MW HH 78p3 mWTG: 1 - ENERCON E-82 E4 TES 3000 82.0 !O!, Hub height: 78.3 m

Name: Mode 0 TES 10/2017
Source: Manufacturer

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
19.10.2017	USER	2009-11-25	2019-11-27	25.0	Pitch	User defined	Variable	0.57

ENERCON Wind Energy Converter E-82 E4 / 3000 kW with
TES (Trailing Edge Serrations)
Operating mode 0 s and Power-Reduced Operation

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	2 777	4 645	6 731	8 822	10 759	12 433
ENERCON E-82 E4 TES 3000 82.0 !O! Mode 0 TES 10/2017	[MWh]	2 988	4 825	6 848	8 867	10 736	12 347
Check value	[%]	-7	-4	-2	-1	0	1

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTGs performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see the windPRO manual.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement.

Power curve

Original data, Air density: 1.225 kg/m³

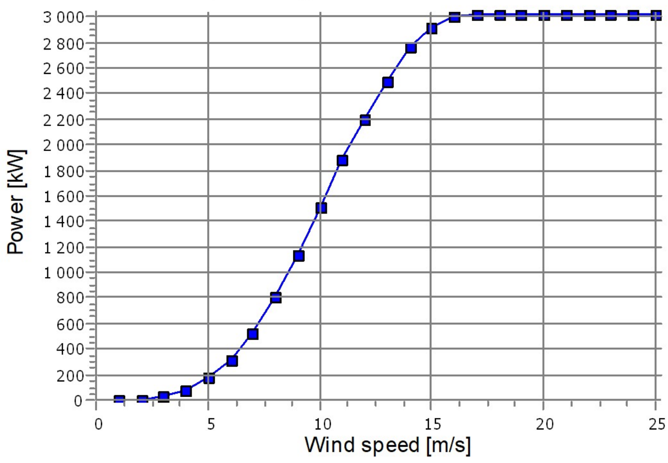
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
0.0	0.0	0.00	0.0	0.00
0.5	0.0	0.00	0.5	0.00
1.0	0.0	0.00	1.0	0.00
1.5	0.0	0.00	1.5	0.00
2.0	0.0	0.00	2.0	0.00
2.5	9.0	0.18	2.5	1.00
3.0	25.0	0.29	3.0	1.00
3.5	50.0	0.36	3.5	0.98
4.0	82.0	0.40	4.0	0.93
4.5	122.0	0.41	4.5	0.95
5.0	174.0	0.43	5.0	0.95
5.5	240.0	0.45	5.5	0.96
6.0	321.0	0.46	6.0	0.96
6.5	415.0	0.47	6.5	0.96
7.0	525.0	0.47	7.0	0.96
7.5	654.0	0.48	7.5	0.95
8.0	800.0	0.48	8.0	0.94
8.5	961.0	0.48	8.5	0.93
9.0	1 135.0	0.48	9.0	0.89
9.5	1 320.0	0.48	9.5	0.86
10.0	1 510.0	0.47	10.0	0.82
10.5	1 700.0	0.45	10.5	0.79
11.0	1 880.0	0.44	11.0	0.77
11.5	2 045.0	0.42	11.5	0.74
12.0	2 200.0	0.39	12.0	0.72
12.5	2 350.0	0.37	12.5	0.70
13.0	2 500.0	0.35	13.0	0.67
13.5	2 647.0	0.33	13.5	0.55
14.0	2 770.0	0.31	14.0	0.47
14.5	2 852.0	0.29	14.5	0.41
15.0	2 910.0	0.27	15.0	0.36
15.5	2 961.0	0.25	15.5	0.32
16.0	3 000.0	0.23	16.0	0.29
16.5	3 017.0	0.21	16.5	0.26
17.0	3 020.0	0.19	17.0	0.24
17.5	3 020.0	0.17	17.5	0.22
18.0	3 020.0	0.16	18.0	0.20
18.5	3 020.0	0.15	18.5	0.18
19.0	3 020.0	0.14	19.0	0.17
19.5	3 020.0	0.13	19.5	0.15
20.0	3 020.0	0.12	20.0	0.14
20.5	3 020.0	0.11	20.5	0.13
21.0	3 020.0	0.10	21.0	0.12
21.5	3 020.0	0.09	21.5	0.12
22.0	3 020.0	0.09	22.0	0.11
22.5	3 020.0	0.08	22.5	0.10
23.0	3 020.0	0.08	23.0	0.09
23.5	3 020.0	0.07	23.5	0.09
24.0	3 020.0	0.07	24.0	0.08
24.5	3 020.0	0.06	24.5	0.08
25.0	3 020.0	0.06	25.0	0.07

Power, Efficiency and energy vs. wind speed

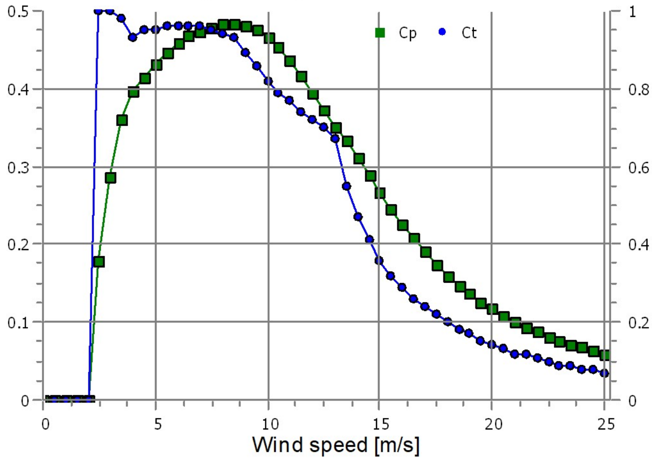
Data used in calculation, Air density: 1.225 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

Wind speed [m/s]	Power [kW]	Cp	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1.0	0.0	0.00	0.50- 1.50	0.0	0.0	0.0
2.0	0.0	0.00	1.50- 2.50	1.4	1.4	0.0
3.0	25.0	0.29	2.50- 3.50	11.8	13.3	0.1
4.0	82.0	0.40	3.50- 4.50	40.9	54.1	0.5
5.0	174.0	0.43	4.50- 5.50	97.6	151.7	1.3
6.0	321.0	0.46	5.50- 6.50	191.1	342.8	2.9
7.0	525.0	0.47	6.50- 7.50	324.6	667.4	5.7
8.0	800.0	0.48	7.50- 8.50	493.5	1 161.0	9.9
9.0	1 135.0	0.48	8.50- 9.50	681.4	1 842.4	15.7
10.0	1 510.0	0.47	9.50-10.50	859.5	2 701.9	23.0
11.0	1 880.0	0.44	10.50-11.50	992.5	3 694.4	31.5
12.0	2 200.0	0.39	11.50-12.50	1 061.6	4 755.9	40.5
13.0	2 500.0	0.35	12.50-13.50	1 078.4	5 834.3	49.7
14.0	2 770.0	0.31	13.50-14.50	1 042.4	6 876.7	58.6
15.0	2 910.0	0.27	14.50-15.50	951.9	7 828.6	66.7
16.0	3 000.0	0.23	15.50-16.50	832.3	8 660.9	73.8
17.0	3 020.0	0.19	16.50-17.50	704.4	9 365.2	79.8
18.0	3 020.0	0.16	17.50-18.50	582.1	9 947.4	84.7
19.0	3 020.0	0.14	18.50-19.50	474.6	10 422.0	88.8
20.0	3 020.0	0.12	19.50-20.50	382.1	10 804.1	92.0
21.0	3 020.0	0.10	20.50-21.50	304.0	11 108.1	94.6
22.0	3 020.0	0.09	21.50-22.50	239.0	11 347.1	96.7
23.0	3 020.0	0.08	22.50-23.50	185.7	11 532.9	98.3
24.0	3 020.0	0.07	23.50-24.50	142.7	11 675.6	99.5
25.0	3 020.0	0.06	24.50-25.50	61.8	11 737.4	100.0

Power curve
For air density: 1.225 kg/m³ and reference climate data



Cp and Ct curve
For air density: 1.225 kg/m³ and reference climate data



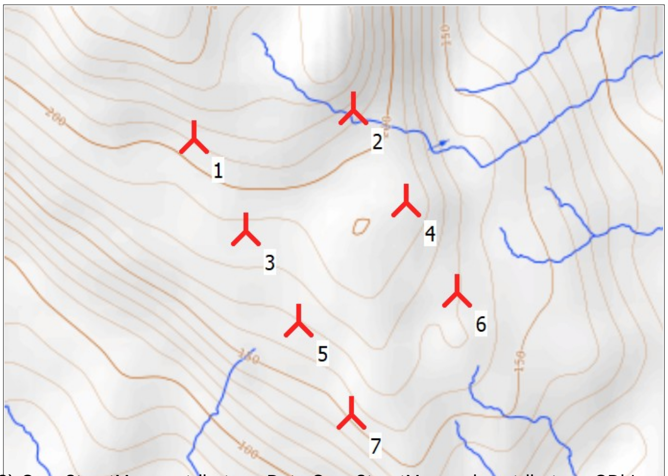
Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2021-12-14 11:20/3.5.552

PARK - WTG distances

Calculation: 7 x E82 E4 3p0 MW HH 78p3 m

WTG distances

	Z [m]	Nearest WTG	Z [m]	Horizontal distance [m]	Distance in rotor diameters
1	225.3	3	207.6	280	3.4
2	218.1	4	200.6	280	3.4
3	207.6	5	183.0	280	3.4
4	200.6	6	181.3	280	3.4
5	183.0	7	171.6	280	3.4
6	181.3	4	200.6	280	3.4
7	171.6	5	183.0	280	3.4
Min	171.6		171.6	280	3.4
Max	225.3		207.6	280	3.4



(C) OpenStreetMap contributors, Data OpenStreetMap and contributors, ODbL

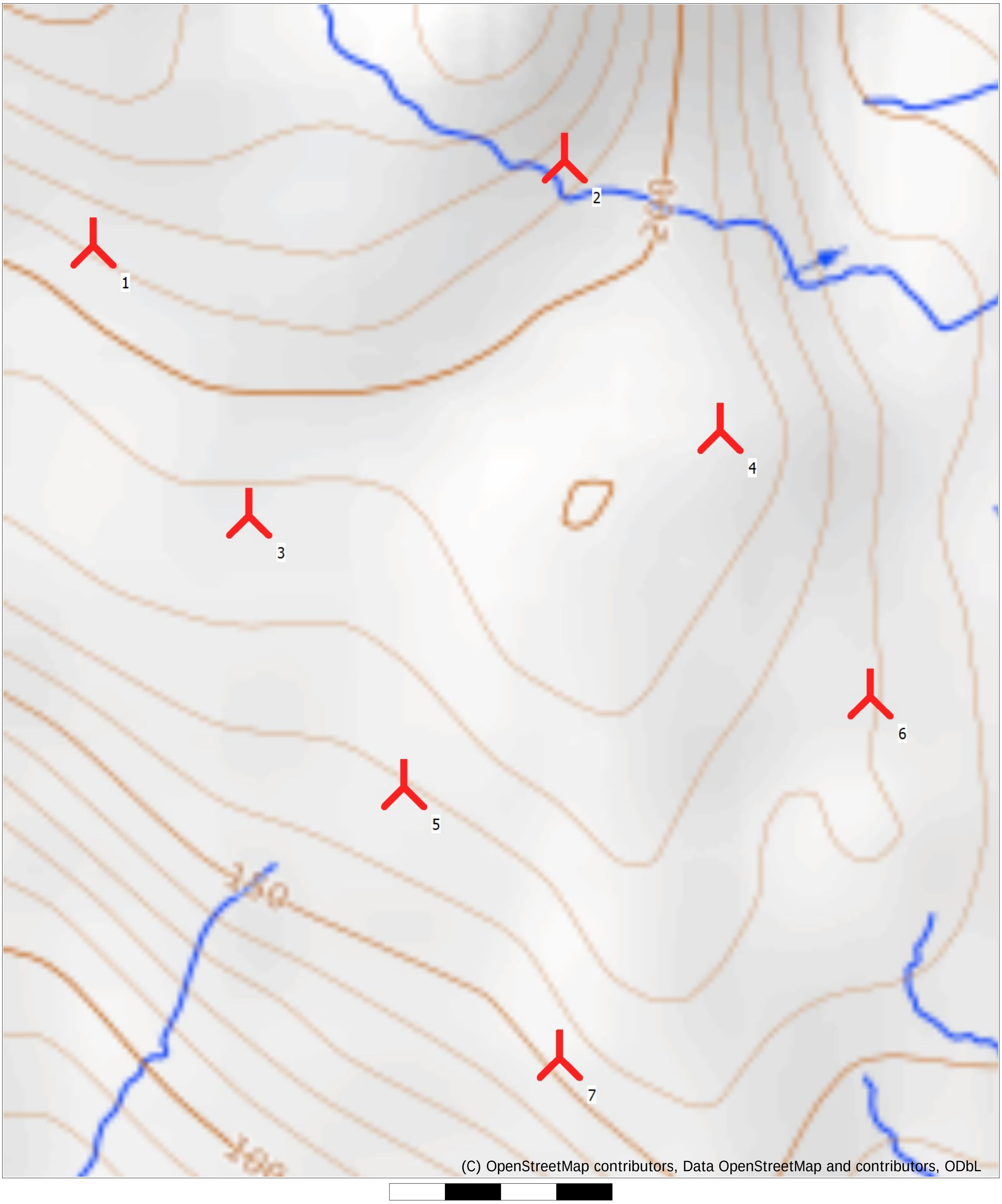
Scale 1:20 000

New WTG

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2021-12-14 11:20/3.5.552

PARK - Map

Calculation: 7 x E82 E4 3p0 MW HH 78p3 m



Map: OpenTopoMap , Print scale 1:5 000, Map center UTM (north)-WGS84 Zone: 29 East: 612 495 North: 6 858 811

New WTG

Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 09:39/3.5.552

PARK - Main Result

Calculation: 7 x E82 E4 3p0 MW HH 78p3 m w Storm Control/HWO

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: 1.9°

Power curve correction method
New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>
Air density calculation method
Height dependent, temperature from climate station
Station: THORSHAVN V3 2014
Base temperature: 6.0 °C at 55.0 m
Base pressure: 1013.3 hPa at 0.0 m
Air density for Site center in key hub height: 207.5 m + 78.0 m = 1.228 kg/m³ -> 100.2 % of Std
Relative humidity: 0.0 %

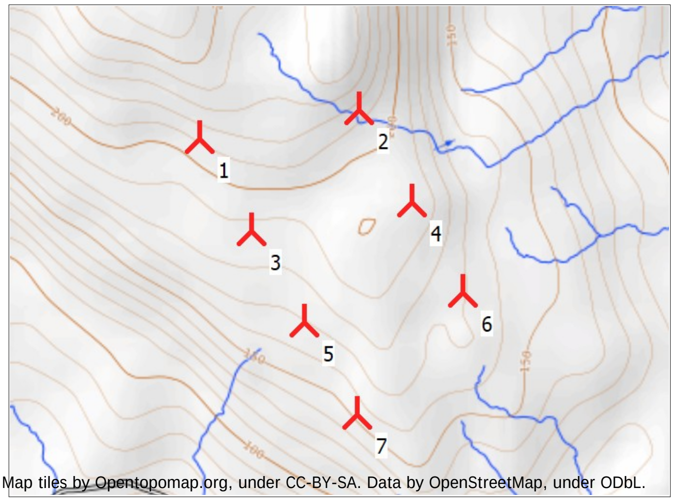
Wake Model Parameters

Terrain type	Wake decay constant
User defined	0.068

Omnidirectional displacement height from objects

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0.5	360.0	1.0	0.5	34.0	1.0



Scale 1:20 000

New WTG

Resource file(s)

L:\KUNDER\535_Energy_Directorate_FO\001_Klivalokshagi\Analyses\2021_11_Site_Suitability\04_WAsP\03_Wind_maps\Klivalokshagi_HH78p3m_corr_1.012.wrg

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Wake loss [%]	Specific results¤) Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	82 126.2	87 685.7	6.3	44.3	11 732.3	3 885	10.1

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 7 new WTGs with total 21.1 MW rated power

Links	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh/y]	Wake loss [%]	Free mean wind speed [m/s]
1 A	Yes	ENERCON	ENERCON E-82 E4/3000-3 020	3 020	82.0	78.3	USER	ENERCON E-82 E4 / 3000 kW	11 996.8	5.1	10.23
2 A	Yes	ENERCON	ENERCON E-82 E4/3000-3 020	3 020	82.0	78.3	USER	ENERCON E-82 E4 / 3000 kW	11 680.2	6.6	10.11
3 A	Yes	ENERCON	ENERCON E-82 E4/3000-3 020	3 020	82.0	78.3	USER	ENERCON E-82 E4 / 3000 kW	11 777.2	7.1	10.22
4 A	Yes	ENERCON	ENERCON E-82 E4/3000-3 020	3 020	82.0	78.3	USER	ENERCON E-82 E4 / 3000 kW	11 447.2	8.0	10.05
5 A	Yes	ENERCON	ENERCON E-82 E4/3000-3 020	3 020	82.0	78.3	USER	ENERCON E-82 E4 / 3000 kW	11 529.7	7.0	10.02
6 A	Yes	ENERCON	ENERCON E-82 E4/3000-3 020	3 020	82.0	78.3	USER	ENERCON E-82 E4 / 3000 kW	11 599.5	6.2	9.98
7 A	Yes	ENERCON	ENERCON E-82 E4/3000-3 020	3 020	82.0	78.3	USER	ENERCON E-82 E4 / 3000 kW	12 095.5	4.5	10.18

Annual Energy result includes shown losses. Additional losses and uncertainty must be considered for an investment decision.

WTG siting

UTM (north)-WGS84 Zone: 29

	Easting	Northing	Z [m]	Row data/Description
1 New	612 139	6 859 122	225.3	KLH101
2 New	612 557	6 859 216	218.1	KLH102
3 New	612 286	6 858 883	207.6	KLH103
4 New	612 704	6 858 977	200.6	KLH104
5 New	612 434	6 858 645	183.0	KLH105
6 New	612 852	6 858 739	181.3	KLH106
7 New	612 582	6 858 406	171.6	KLH107

Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 09:39/3.5.552

PARK - Power Curve Analysis

Calculation: 7 x E82 E4 3p0 MW HH 78p3 m w Storm Control/HWOWTG: 1 - ENERCON ENERCON E-82 E4/3000 3020 82.0 !-!, Hub height: 78.3 m

Name: ENERCON E-82 E4 / 3000 kW
Source: D0602624_1.0_en_Operating modes E-82 E4-3000 kW.pdf

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
2022-02-14	USER	2022-02-14	2022-02-14	34.0	Pitch	User defined	Variable	0.57

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	2 777	4 649	6 743	8 844	10 792	12 478
ENERCON ENERCON E-82 E4/3000 3020 82.0 !-! ENERCON E-82 E4 / 3000 kW	[MWh]	2 988	4 825	6 849	8 878	10 786	12 497
Check value	[%]	-7	-4	-2	0	0	0

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTGs performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see the windPRO manual.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement.

Power curve

Original data, Air density: 1.225 kg/m³

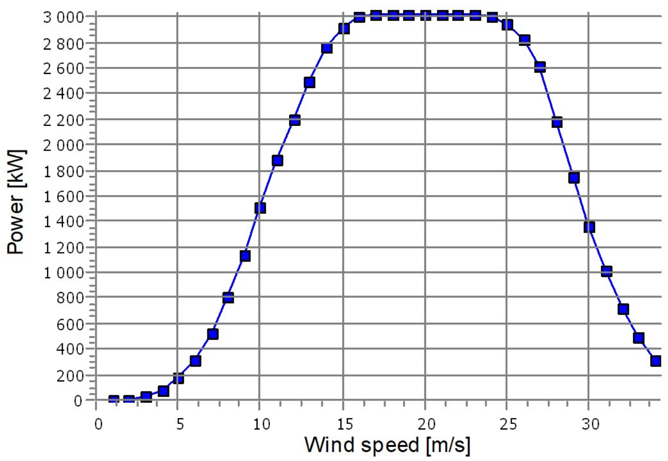
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
0.0	0.0	0.00	0.0	0.00
0.5	0.0	0.00	0.5	0.00
1.0	0.0	0.00	1.0	0.00
1.5	0.0	0.00	1.5	0.00
2.0	0.0	0.00	2.0	0.00
2.5	9.0	0.18	2.5	1.00
3.0	25.0	0.29	3.0	1.00
3.5	50.0	0.36	3.5	0.98
4.0	82.0	0.40	4.0	0.93
4.5	122.0	0.41	4.5	0.95
5.0	174.0	0.43	5.0	0.95
5.5	240.0	0.45	5.5	0.96
6.0	321.0	0.46	6.0	0.96
6.5	415.0	0.47	6.5	0.96
7.0	525.0	0.47	7.0	0.96
7.5	654.0	0.48	7.5	0.95
8.0	800.0	0.48	8.0	0.94
8.5	961.0	0.48	8.5	0.93
9.0	1 135.0	0.48	9.0	0.89
9.5	1 320.0	0.48	9.5	0.86
10.0	1 510.0	0.47	10.0	0.82
10.5	1 700.0	0.45	10.5	0.79
11.0	1 880.0	0.44	11.0	0.77
11.5	2 045.0	0.42	11.5	0.74
12.0	2 200.0	0.39	12.0	0.72
12.5	2 350.0	0.37	12.5	0.70
13.0	2 500.0	0.35	13.0	0.67
13.5	2 647.0	0.33	13.5	0.55
14.0	2 770.0	0.31	14.0	0.47
14.5	2 852.0	0.29	14.5	0.41
15.0	2 910.0	0.27	15.0	0.36
15.5	2 961.0	0.25	15.5	0.32
16.0	3 000.0	0.23	16.0	0.29
16.5	3 017.0	0.21	16.5	0.26
17.0	3 020.0	0.19	17.0	0.24
17.5	3 020.0	0.17	17.5	0.22
18.0	3 020.0	0.16	18.0	0.20
18.5	3 020.0	0.15	18.5	0.18
19.0	3 020.0	0.14	19.0	0.17
19.5	3 020.0	0.13	19.5	0.15
20.0	3 020.0	0.12	20.0	0.14
20.5	3 020.0	0.11	20.5	0.13
21.0	3 020.0	0.10	21.0	0.12
21.5	3 020.0	0.09	21.5	0.12
22.0	3 020.0	0.09	22.0	0.11
22.5	3 020.0	0.08	22.5	0.10
23.0	3 019.0	0.08	23.0	0.10
23.5	3 014.0	0.07	23.5	0.10
24.0	3 002.0	0.07	24.0	0.09
24.5	2 980.0	0.06	24.5	0.08
25.0	2 947.0	0.06	25.0	0.08
25.5	2 895.0	0.05	25.5	0.07
26.0	2 824.0	0.05	26.0	0.07
26.5	2 731.0	0.05	26.5	0.06
27.0	2 615.0	0.04	27.0	0.06
27.5	2 488.0	0.04	27.5	0.05
28.0	2 178.0	0.03	28.0	0.05
28.5	1 952.0	0.03	28.5	0.04
29.0	1 752.0	0.02	29.0	0.04
29.5	1 553.0	0.02	29.5	0.03
30.0	1 357.0	0.02	30.0	0.03
30.5	1 195.0	0.01	30.5	0.02
31.0	1 024.0	0.01	31.0	0.02
31.5	861.0	0.01	31.5	0.02
32.0	712.0	0.01	32.0	0.01
32.5	616.0	0.01	32.5	0.01
33.0	499.0	0.00	33.0	0.01
33.5	395.0	0.00	33.5	0.01
34.0	307.0	0.00	34.0	0.01

Power, Efficiency and energy vs. wind speed

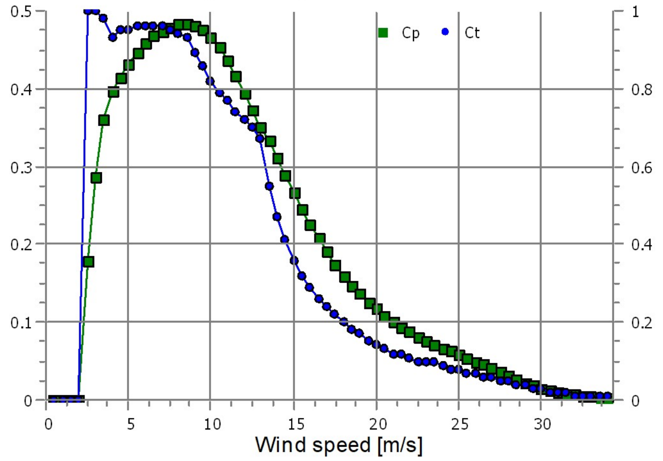
Data used in calculation, Air density: 1.225 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

Wind speed [m/s]	Power [kW]	Cp	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1.0	0.0	0.00	0.50- 1.50	0.0	0.0	0.0
2.0	0.0	0.00	1.50- 2.50	1.4	1.4	0.0
3.0	25.0	0.29	2.50- 3.50	11.8	13.3	0.1
4.0	82.0	0.40	3.50- 4.50	40.9	54.2	0.5
5.0	174.0	0.43	4.50- 5.50	97.7	151.9	1.3
6.0	321.0	0.46	5.50- 6.50	191.3	343.2	2.9
7.0	525.0	0.47	6.50- 7.50	325.0	668.2	5.6
8.0	800.0	0.48	7.50- 8.50	494.1	1 162.3	9.7
9.0	1 135.0	0.48	8.50- 9.50	682.2	1 844.5	15.4
10.0	1 510.0	0.47	9.50-10.50	860.5	2 705.0	22.5
11.0	1 880.0	0.44	10.50-11.50	993.6	3 698.6	30.8
12.0	2 200.0	0.39	11.50-12.50	1 062.8	4 761.4	39.7
13.0	2 500.0	0.35	12.50-13.50	1 079.6	5 841.0	48.7
14.0	2 770.0	0.31	13.50-14.50	1 043.5	6 884.5	57.4
15.0	2 910.0	0.27	14.50-15.50	953.0	7 837.6	65.3
16.0	3 000.0	0.23	15.50-16.50	833.2	8 670.8	72.3
17.0	3 020.0	0.19	16.50-17.50	705.2	9 376.0	78.2
18.0	3 020.0	0.16	17.50-18.50	582.8	9 958.8	83.0
19.0	3 020.0	0.14	18.50-19.50	475.1	10 433.9	87.0
20.0	3 020.0	0.12	19.50-20.50	382.6	10 816.5	90.2
21.0	3 020.0	0.10	20.50-21.50	304.3	11 120.8	92.7
22.0	3 020.0	0.09	21.50-22.50	239.3	11 360.1	94.7
23.0	3 019.0	0.08	22.50-23.50	185.8	11 545.9	96.2
24.0	3 002.0	0.07	23.50-24.50	141.9	11 687.8	97.4
25.0	2 947.0	0.06	24.50-25.50	105.8	11 793.6	98.3
26.0	2 824.0	0.05	25.50-26.50	76.3	11 870.0	98.9
27.0	2 615.0	0.04	26.50-27.50	52.8	11 922.7	99.4
28.0	2 178.0	0.03	27.50-28.50	33.4	11 956.1	99.7
29.0	1 752.0	0.02	28.50-29.50	19.2	11 975.3	99.8
30.0	1 357.0	0.02	29.50-30.50	10.9	11 986.2	99.9
31.0	1 024.0	0.01	30.50-31.50	5.8	11 992.0	100.0
32.0	712.0	0.01	31.50-32.50	3.0	11 994.9	100.0
33.0	499.0	0.00	32.50-33.50	1.4	11 996.4	100.0
34.0	307.0	0.00	33.50-34.50	0.4	11 996.8	100.0

Power curve
For air density: 1.225 kg/m³ and reference climate data



Cp and Ct curve
For air density: 1.225 kg/m³ and reference climate data



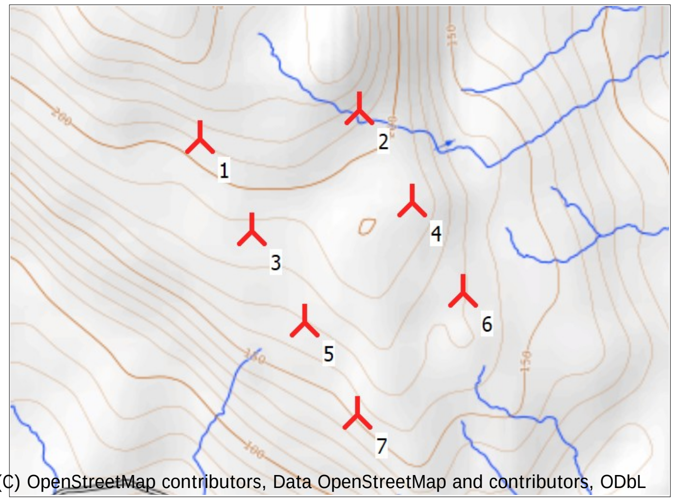
Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 09:39/3.5.552

PARK - WTG distances

Calculation: 7 x E82 E4 3p0 MW HH 78p3 m w Storm Control/HWO

WTG distances

	Z	Nearest WTG	Z	Horizontal distance	Distance in rotor diameters
	[m]		[m]	[m]	
1	225.3	3	207.6	280	3.4
2	218.1	4	200.6	280	3.4
3	207.6	5	183.0	280	3.4
4	200.6	6	181.3	280	3.4
5	183.0	7	171.6	280	3.4
6	181.3	4	200.6	280	3.4
7	171.6	5	183.0	280	3.4
Min	171.6		171.6	280	3.4
Max	225.3		207.6	280	3.4



Scale 1:20 000

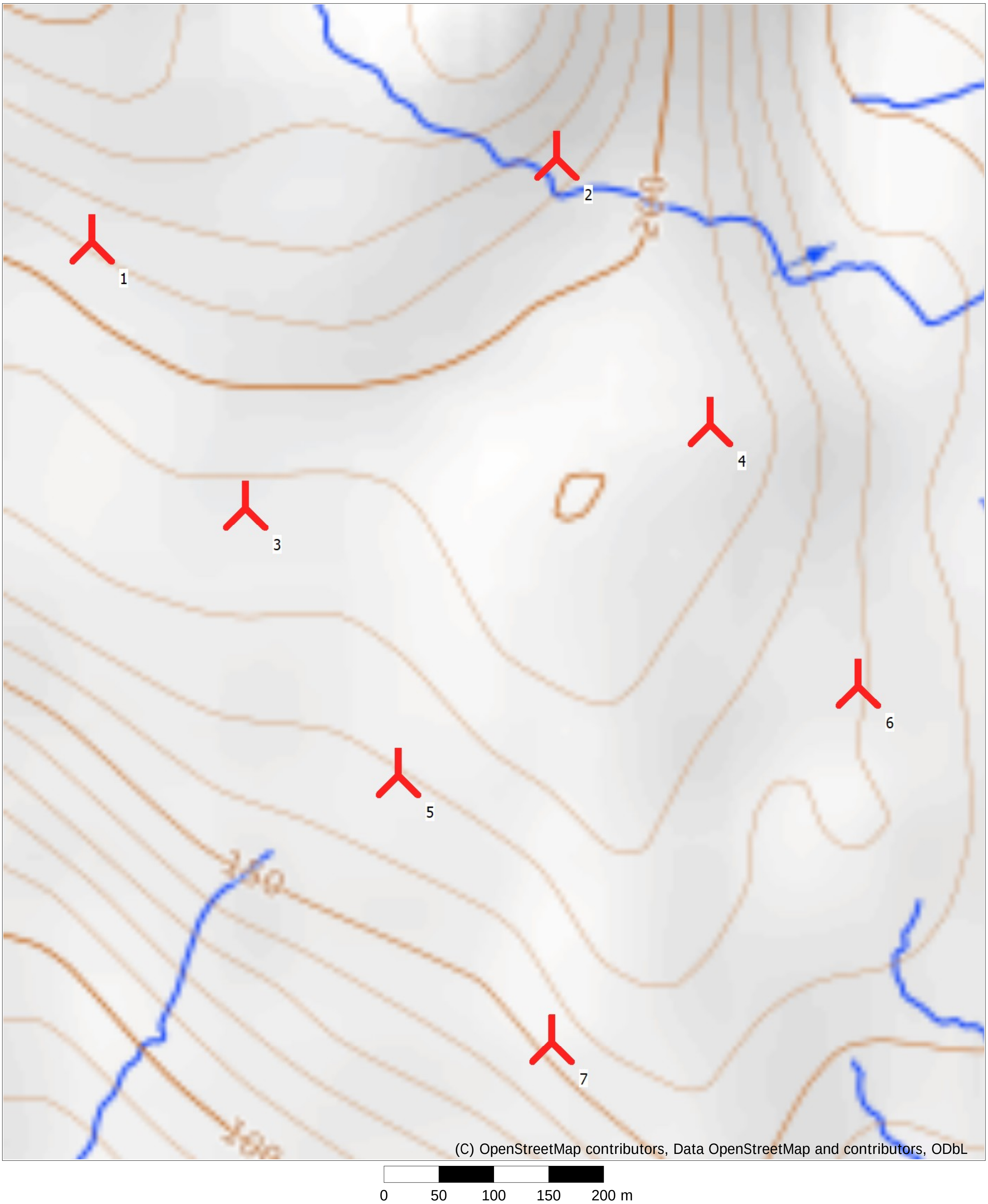
New WTG

Project:
Sandoy_uV_20181121

Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 09:39/3.5.552

PARK - Map

Calculation: 7 x E82 E4 3p0 MW HH 78p3 m w Storm Control/HWO



Map: OpenTopoMap , Print scale 1:5 000, Map center UTM (north)-WGS84 Zone: 29 East: 612 495 North: 6 858 811

New WTG

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no

Calculated:
2022-01-20 12:45/3.5.576

PARK - Main Result

Calculation: 6 x V105 3p6 MW HH 72p5 m

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: 1.9°

Power curve correction method
New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>
Air density calculation method
Height dependent, temperature from climate station
Station: THORSHAVN V3 2014
Base temperature: 6.0 °C at 55.0 m
Base pressure: 1013.3 hPa at 0.0 m
Air density for Site center in key hub height: 207.5 m + 92.0 m = 1.226 kg/m³ -> 100.1 % of Std
Relative humidity: 0.0 %

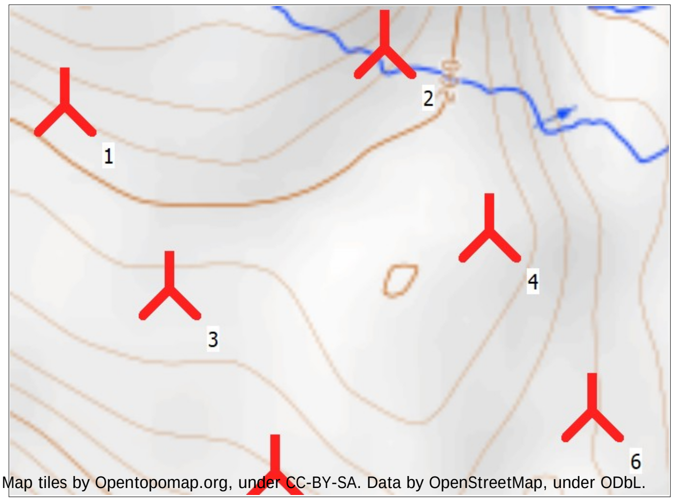
Wake Model Parameters

Terrain type	Wake decay constant
User defined	0.068

Omnidirectional displacement height from objects

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0.5	360.0	1.0	0.5	30.5	1.0



Map tiles by Opentopomap.org, under CC-BY-SA. Data by OpenStreetMap, under ODbL.

Scale 1:10 000

⅄ New WTG

Resource file(s)

L:\KUNDER\535_Energy_Directorate_FO\001_Klivalokshagi\Analyses\2021_11_Site_Suitability\04_WAsP\03_Wind_maps\Klivalokshagi_HH72p5m_corr_1.012.wrg

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Wake loss [%]	Specific results¤) Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	94 331.7	101 124.4	6.7	49.8	15 722.0	4 367	10.0

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 6 new WTGs with total 21.6 MW rated power

Links	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh/y]	Wake loss [%]	Free mean wind speed [m/s]
1 A	Yes	VESTAS	V105-3.6-3 600	3 600	105.0	72.5	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 01-2016	16 019.0	5.5	10.17
2 A	Yes	VESTAS	V105-3.6-3 600	3 600	105.0	72.5	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 01-2016	15 586.7	7.3	10.03
3 A	Yes	VESTAS	V105-3.6-3 600	3 600	105.0	72.5	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 01-2016	15 763.4	7.5	10.15
4 A	Yes	VESTAS	V105-3.6-3 600	3 600	105.0	72.5	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 01-2016	15 398.6	8.5	9.99
5 A	Yes	VESTAS	V105-3.6-3 600	3 600	105.0	72.5	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 01-2016	15 787.7	5.9	9.97
6 A	Yes	VESTAS	V105-3.6-3 600	3 600	105.0	72.5	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 01-2016	15 776.3	5.7	9.89

Annual Energy result includes shown losses. Additional losses and uncertainty must be considered for an investment decision.

WTG siting

	UTM (north)-WGS84 Zone: 29 Easting	Northing	Z [m]	Row data/Description
1 New	612 139	6 859 122	225.3	KLH101
2 New	612 557	6 859 216	218.1	KLH102
3 New	612 286	6 858 883	207.6	KLH103
4 New	612 704	6 858 977	200.6	KLH104
5 New	612 434	6 858 645	183.0	KLH105
6 New	612 852	6 858 739	181.3	KLH106

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-01-20 12:45/3.5.576

PARK - Power Curve Analysis

Calculation: 6 x V105 3p6 MW HH 72p5 mWTG: 1 - VESTAS V105-3.6 3600 105.0 !O!, Hub height: 72.5 m

Name: Level 0 - Calculated - Modes PO1 & PO1-0S - 01-2016
Source: Manufacturer

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
2016-01-15	EMD	2016-04-28	2016-04-28	25.0	Pitch	User defined	Variable	0.42

Document no.: DMS 0056-4779.00.
IEC IA.

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	4 514	7 222	10 037	12 695	15 040	16 991
VESTAS V105-3.6 3600 105.0 !O! Level 0 - Calculated - Modes PO1 & PO1-0S - 01-2016	[MWh]	4 488	7 245	10 113	12 807	15 165	17 099
Check value	[%]	1	0	-1	-1	-1	-1

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTGs performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see the windPRO manual.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement.

Power curve

Original data, Air density: 1.225 kg/m³

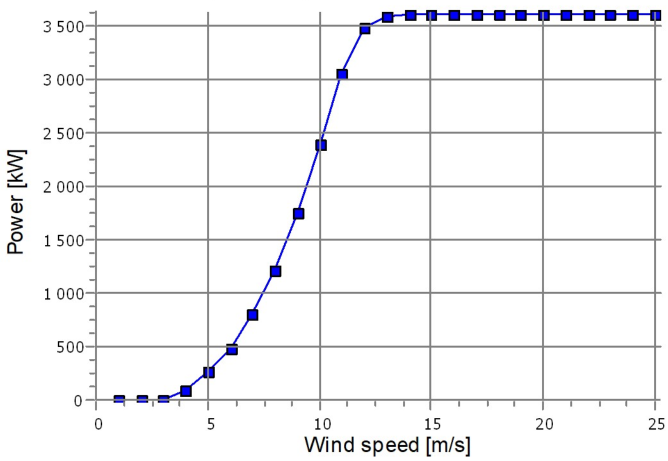
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
3.5	35.0	0.15	3.5	0.88
4.0	96.0	0.28	4.0	0.87
4.5	171.0	0.35	4.5	0.84
5.0	261.0	0.39	5.0	0.83
5.5	364.0	0.41	5.5	0.83
6.0	486.0	0.42	6.0	0.82
6.5	630.0	0.43	6.5	0.82
7.0	800.0	0.44	7.0	0.82
7.5	994.0	0.44	7.5	0.81
8.0	1 216.0	0.45	8.0	0.81
8.5	1 467.0	0.45	8.5	0.81
9.0	1 750.0	0.45	9.0	0.81
9.5	2 054.0	0.45	9.5	0.79
10.0	2 385.0	0.45	10.0	0.78
10.5	2 728.0	0.44	10.5	0.76
11.0	3 040.0	0.43	11.0	0.71
11.5	3 299.0	0.41	11.5	0.65
12.0	3 472.0	0.38	12.0	0.58
12.5	3 557.0	0.34	12.5	0.50
13.0	3 588.0	0.31	13.0	0.43
13.5	3 592.0	0.28	13.5	0.38
14.0	3 597.0	0.25	14.0	0.33
14.5	3 599.0	0.22	14.5	0.30
15.0	3 600.0	0.20	15.0	0.26
15.5	3 600.0	0.18	15.5	0.24
16.0	3 600.0	0.17	16.0	0.21
16.5	3 600.0	0.15	16.5	0.19
17.0	3 600.0	0.14	17.0	0.18
17.5	3 600.0	0.13	17.5	0.16
18.0	3 600.0	0.12	18.0	0.15
18.5	3 600.0	0.11	18.5	0.14
19.0	3 600.0	0.10	19.0	0.13
19.5	3 600.0	0.09	19.5	0.12
20.0	3 600.0	0.08	20.0	0.11
20.5	3 600.0	0.08	20.5	0.10
21.0	3 600.0	0.07	21.0	0.09
21.5	3 600.0	0.07	21.5	0.09
22.0	3 600.0	0.06	22.0	0.08
22.5	3 600.0	0.06	22.5	0.08
23.0	3 600.0	0.06	23.0	0.07
23.5	3 600.0	0.05	23.5	0.07
24.0	3 600.0	0.05	24.0	0.07
24.5	3 600.0	0.05	24.5	0.06
25.0	3 600.0	0.04	25.0	0.06

Power, Efficiency and energy vs. wind speed

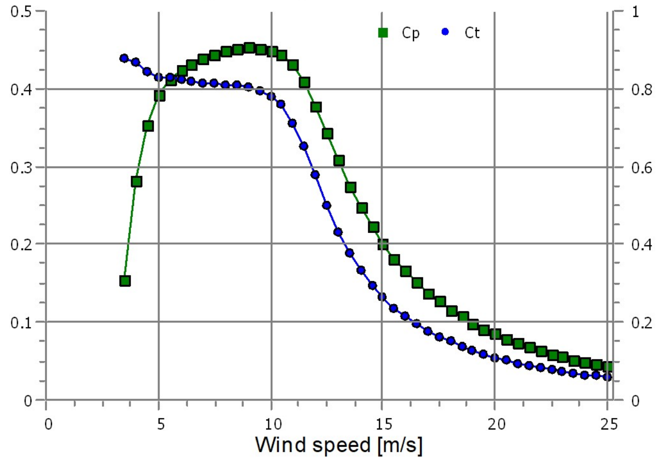
Data used in calculation, Air density: 1.226 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

Wind speed [m/s]	Power [kW]	Cp	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1.0	0.0	0.00	0.50- 1.50	0.0	0.0	0.0
2.0	0.0	0.00	1.50- 2.50	0.0	0.0	0.0
3.0	0.0	0.00	2.50- 3.50	7.3	7.3	0.0
4.0	96.0	0.28	3.50- 4.50	50.3	57.6	0.4
5.0	261.0	0.39	4.50- 5.50	145.3	203.0	1.3
6.0	486.0	0.42	5.50- 6.50	291.5	494.5	3.1
7.0	800.0	0.44	6.50- 7.50	495.1	989.6	6.2
8.0	1 216.0	0.45	7.50- 8.50	754.0	1 743.5	10.9
9.0	1 750.0	0.45	8.50- 9.50	1 052.6	2 796.1	17.5
10.0	2 385.0	0.45	9.50-10.50	1 359.1	4 155.1	25.9
11.0	3 040.0	0.43	10.50-11.50	1 592.3	5 747.5	35.9
12.0	3 472.0	0.38	11.50-12.50	1 650.4	7 397.9	46.2
13.0	3 588.0	0.31	12.50-13.50	1 536.6	8 934.5	55.8
14.0	3 597.0	0.25	13.50-14.50	1 353.3	10 287.8	64.2
15.0	3 600.0	0.20	14.50-15.50	1 166.2	11 454.0	71.5
16.0	3 600.0	0.17	15.50-16.50	988.3	12 442.3	77.7
17.0	3 600.0	0.14	16.50-17.50	825.3	13 267.6	82.8
18.0	3 600.0	0.12	17.50-18.50	679.8	13 947.4	87.1
19.0	3 600.0	0.10	18.50-19.50	552.6	14 500.1	90.5
20.0	3 600.0	0.08	19.50-20.50	443.6	14 943.7	93.3
21.0	3 600.0	0.07	20.50-21.50	351.8	15 295.5	95.5
22.0	3 600.0	0.06	21.50-22.50	275.7	15 571.2	97.2
23.0	3 600.0	0.06	22.50-23.50	213.6	15 784.8	98.5
24.0	3 600.0	0.05	23.50-24.50	163.6	15 948.3	99.6
25.0	3 600.0	0.04	24.50-25.50	70.7	16 019.0	100.0

Power curve
For air density: 1.226 kg/m³ and reference climate data



Cp and Ct curve
For air density: 1.226 kg/m³ and reference climate data

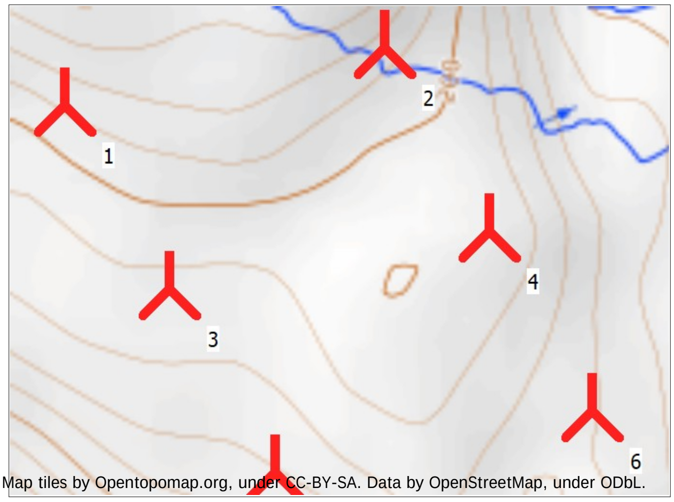


PARK - WTG distances

Calculation: 6 x V105 3p6 MW HH 72p5 m

WTG distances

	Z	Nearest WTG	Z	Horizontal distance	Distance in rotor diameters
	[m]		[m]	[m]	
1	225.3	3	207.6	280	2.7
2	218.1	4	200.6	280	2.7
3	207.6	5	183.0	280	2.7
4	200.6	6	181.3	280	2.7
5	183.0	3	207.6	280	2.7
6	181.3	4	200.6	280	2.7
Min	181.3		181.3	280	2.7
Max	225.3		207.6	280	2.7

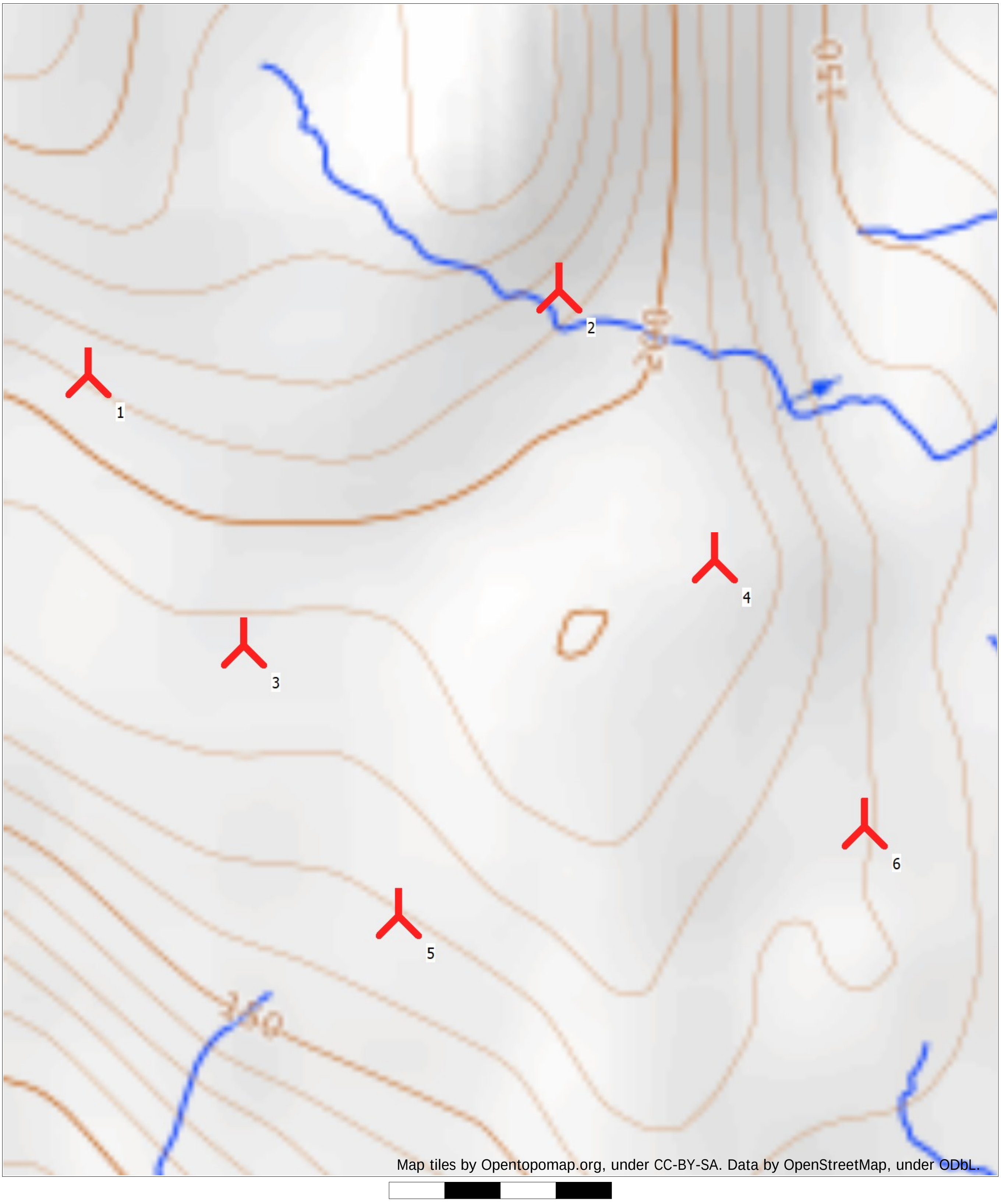


Scale 1:10 000

New WTG

PARK - Map

Calculation: 6 x V105 3p6 MW HH 72p5 m



Map: OpenTopoMap , Print scale 1:5 000, Map center UTM (north)-WGS84 Zone: 29 East: 612 495 North: 6 858 930

New WTG

Project:
Sandoy_uV_20181121

Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-22 09:43/3.5.552

PARK - Main Result

Calculation: 6 x V105 3p6 MW HH 72p5 m w Storm Control/HWO

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: 1.9°

Power curve correction method
New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>
Air density calculation method
Height dependent, temperature from climate station
Station: THORSHAVN V3 2014
Base temperature: 6.0 °C at 55.0 m
Base pressure: 1013.3 hPa at 0.0 m
Air density for Site center in key hub height: 207.5 m + 73.0 m = 1.228 kg/m³ -> 100.3 % of Std
Relative humidity: 0.0 %

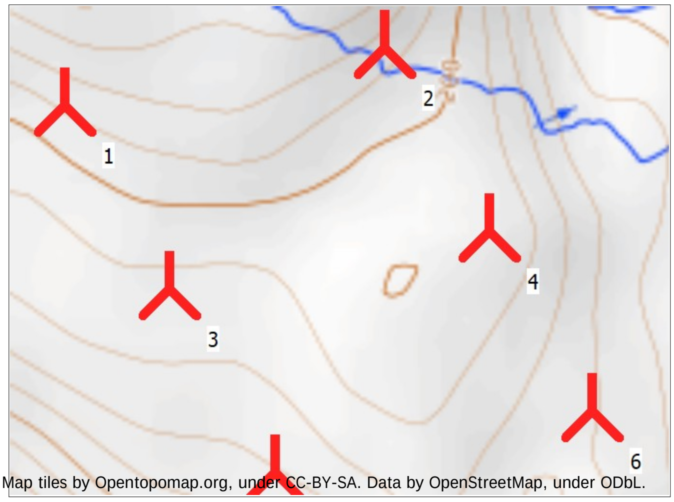
Wake Model Parameters

Terrain type	Wake decay constant
User defined	0.068

Omnidirectional displacement height from objects

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0.5	360.0	1.0	0.5	30.5	1.0



Map tiles by Opentopomap.org, under CC-BY-SA. Data by OpenStreetMap, under ODbL.

Scale 1:10 000

New WTG

Resource file(s)

L:\KUNDER\535_Energy_Directorate_FO\001_Klivalokshagi\Analyses\2021_11_Site_Suitability\04_WAsP\03_Wind_maps\Klivalokshagi_HH72p5m_corr_1.012.wrg

Calculated Annual Energy for Wind Farm

				Specific results¤)			
WTG combination	Result PARK [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Wake loss [%]	Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	95 047.4	101 812.6	6.6	50.2	15 841.2	4 400	10.0

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 6 new WTGs with total 21.6 MW rated power

	WTG type						Power curve		Annual Energy		
Links	Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Creator	Name	Result [MWh/y]	Wake loss [%]	Free mean wind speed [m/s]
1 A	Yes	VESTAS	V105-3.6-3 600	3 600	105.0	72.5	USER	Power Optimized Mode PO1/PO1-0S (HWO)	16 156.9	5.5	10.17
2 A	Yes	VESTAS	V105-3.6-3 600	3 600	105.0	72.5	USER	Power Optimized Mode PO1/PO1-0S (HWO)	15 710.3	7.2	10.03
3 A	Yes	VESTAS	V105-3.6-3 600	3 600	105.0	72.5	USER	Power Optimized Mode PO1/PO1-0S (HWO)	15 893.9	7.4	10.15
4 A	Yes	VESTAS	V105-3.6-3 600	3 600	105.0	72.5	USER	Power Optimized Mode PO1/PO1-0S (HWO)	15 514.0	8.4	9.99
5 A	Yes	VESTAS	V105-3.6-3 600	3 600	105.0	72.5	USER	Power Optimized Mode PO1/PO1-0S (HWO)	15 897.2	5.9	9.97
6 A	Yes	VESTAS	V105-3.6-3 600	3 600	105.0	72.5	USER	Power Optimized Mode PO1/PO1-0S (HWO)	15 875.2	5.6	9.89

Annual Energy result includes shown losses. Additional losses and uncertainty must be considered for an investment decision.

WTG siting

	UTM (north)-WGS84 Zone: 29			
	Easting	Northing	Z [m]	Row data/Description
1 New	612 139	6 859 122	225.3	KLH101
2 New	612 557	6 859 216	218.1	KLH102
3 New	612 286	6 858 883	207.6	KLH103
4 New	612 704	6 858 977	200.6	KLH104
5 New	612 434	6 858 645	183.0	KLH105
6 New	612 852	6 858 739	181.3	KLH106

Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-22 09:43/3.5.552

PARK - Power Curve Analysis

Calculation: 6 x V105 3p6 MW HH 72p5 m w Storm Control/HWOWTG: 1 - VESTAS V105-3.6 3600 105.0 !O!, Hub height: 72.5 m

Name: Power Optimized Mode PO1/PO1-0S (HWO)
Source: 0056-4779_V01 - Performance Specification V105-3.6MW.pdf

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
2022-02-22	USER	2022-02-22	2022-02-22	30.0	Pitch	User defined	Variable	0.42

Only for Klivalokshagi project for client 535_Energy_Directorate_FO

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	4 514	7 222	10 037	12 695	15 040	16 991
VESTAS V105-3.6 3600 105.0 !O! Power Optimized Mode PO1/PO1-0S (HWO)	[MWh]	4 489	7 246	10 115	12 813	15 191	17 179
Check value	[%]	1	0	-1	-1	-1	-1

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTGs performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see the windPRO manual.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement.

Power curve

Original data, Air density: 1.225 kg/m³

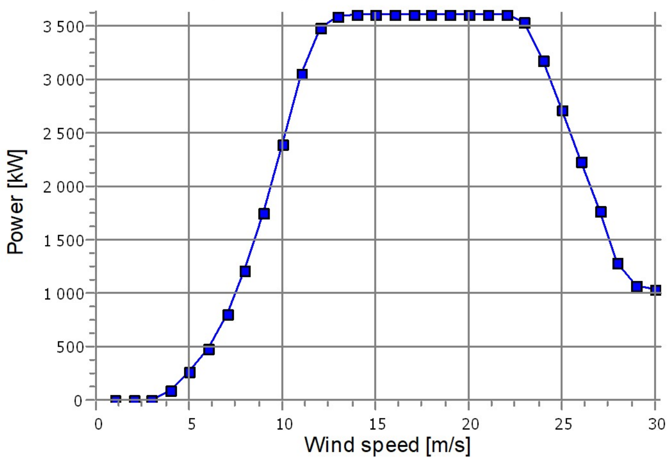
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
3.0	3.0	0.02	3.0	0.78
3.5	35.0	0.15	3.5	0.88
4.0	96.0	0.28	4.0	0.87
4.5	171.0	0.35	4.5	0.84
5.0	261.0	0.39	5.0	0.83
5.5	364.0	0.41	5.5	0.83
6.0	486.0	0.42	6.0	0.82
6.5	630.0	0.43	6.5	0.82
7.0	800.0	0.44	7.0	0.82
7.5	994.0	0.44	7.5	0.81
8.0	1 216.0	0.45	8.0	0.81
8.5	1 468.0	0.45	8.5	0.81
9.0	1 750.0	0.45	9.0	0.81
9.5	2 055.0	0.45	9.5	0.79
10.0	2 385.0	0.45	10.0	0.78
10.5	2 728.0	0.44	10.5	0.76
11.0	3 040.0	0.43	11.0	0.71
11.5	3 299.0	0.41	11.5	0.65
12.0	3 472.0	0.38	12.0	0.58
12.5	3 557.0	0.34	12.5	0.50
13.0	3 588.0	0.31	13.0	0.43
13.5	3 592.0	0.28	13.5	0.38
14.0	3 597.0	0.25	14.0	0.33
14.5	3 599.0	0.22	14.5	0.30
15.0	3 600.0	0.20	15.0	0.26
15.5	3 600.0	0.18	15.5	0.24
16.0	3 600.0	0.17	16.0	0.21
16.5	3 600.0	0.15	16.5	0.19
17.0	3 600.0	0.14	17.0	0.18
17.5	3 600.0	0.13	17.5	0.16
18.0	3 600.0	0.12	18.0	0.15
18.5	3 600.0	0.11	18.5	0.14
19.0	3 600.0	0.10	19.0	0.13
19.5	3 600.0	0.09	19.5	0.12
20.0	3 600.0	0.08	20.0	0.11
20.5	3 600.0	0.08	20.5	0.10
21.0	3 600.0	0.07	21.0	0.10
21.5	3 600.0	0.07	21.5	0.09
22.0	3 600.0	0.06	22.0	0.08
22.5	3 591.0	0.06	22.5	0.08
23.0	3 520.0	0.05	23.0	0.07
23.5	3 385.0	0.05	23.5	0.07
24.0	3 181.0	0.04	24.0	0.06
24.5	2 949.0	0.04	24.5	0.05
25.0	2 713.0	0.03	25.0	0.05
25.5	2 472.0	0.03	25.5	0.04
26.0	2 234.0	0.02	26.0	0.04
26.5	1 999.0	0.02	26.5	0.03
27.0	1 756.0	0.02	27.0	0.03
27.5	1 500.0	0.01	27.5	0.02
28.0	1 275.0	0.01	28.0	0.02
28.5	1 132.0	0.01	28.5	0.02
29.0	1 062.0	0.01	29.0	0.01
29.5	1 039.0	0.01	29.5	0.01
30.0	1 036.0	0.01	30.0	0.01

Power, Efficiency and energy vs. wind speed

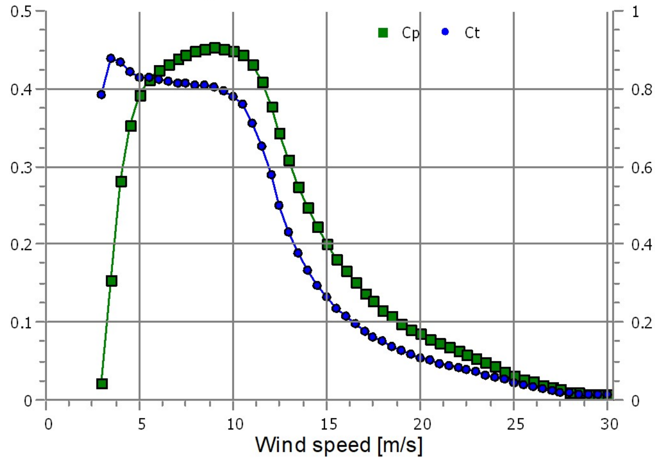
Data used in calculation, Air density: 1.226 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

Wind speed [m/s]	Power [kW]	Cp	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1.0	0.0	0.00	0.50- 1.50	0.0	0.0	0.0
2.0	0.0	0.00	1.50- 2.50	0.0	0.0	0.0
3.0	3.0	0.02	2.50- 3.50	7.3	7.3	0.0
4.0	96.0	0.28	3.50- 4.50	50.3	57.7	0.4
5.0	261.0	0.39	4.50- 5.50	145.4	203.1	1.3
6.0	486.0	0.42	5.50- 6.50	291.7	494.8	3.1
7.0	800.0	0.44	6.50- 7.50	495.4	990.2	6.1
8.0	1 216.0	0.45	7.50- 8.50	754.8	1 745.0	10.8
9.0	1 750.0	0.45	8.50- 9.50	1 053.9	2 798.8	17.3
10.0	2 385.0	0.45	9.50-10.50	1 360.2	4 159.1	25.7
11.0	3 040.0	0.43	10.50-11.50	1 593.4	5 752.5	35.6
12.0	3 472.0	0.38	11.50-12.50	1 651.5	7 404.0	45.8
13.0	3 588.0	0.31	12.50-13.50	1 537.6	8 941.6	55.3
14.0	3 597.0	0.25	13.50-14.50	1 354.2	10 295.8	63.7
15.0	3 600.0	0.20	14.50-15.50	1 166.9	11 462.7	70.9
16.0	3 600.0	0.17	15.50-16.50	989.0	12 451.7	77.1
17.0	3 600.0	0.14	16.50-17.50	825.9	13 277.5	82.2
18.0	3 600.0	0.12	17.50-18.50	680.2	13 957.8	86.4
19.0	3 600.0	0.10	18.50-19.50	553.0	14 510.8	89.8
20.0	3 600.0	0.08	19.50-20.50	443.9	14 954.7	92.6
21.0	3 600.0	0.07	20.50-21.50	352.0	15 306.7	94.7
22.0	3 600.0	0.06	21.50-22.50	275.6	15 582.3	96.4
23.0	3 520.0	0.05	22.50-23.50	207.9	15 790.2	97.7
24.0	3 181.0	0.04	23.50-24.50	145.3	15 935.5	98.6
25.0	2 713.0	0.03	24.50-25.50	94.5	16 030.0	99.2
26.0	2 234.0	0.02	25.50-26.50	58.5	16 088.5	99.6
27.0	1 756.0	0.02	26.50-27.50	34.1	16 122.6	99.8
28.0	1 275.0	0.01	27.50-28.50	18.8	16 141.4	99.9
29.0	1 062.0	0.01	28.50-29.50	11.1	16 152.5	100.0
30.0	1 036.0	0.01	29.50-30.50	4.4	16 156.9	100.0

Power curve
For air density: 1.226 kg/m³ and reference climate data



Cp and Ct curve
For air density: 1.226 kg/m³ and reference climate data



Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no

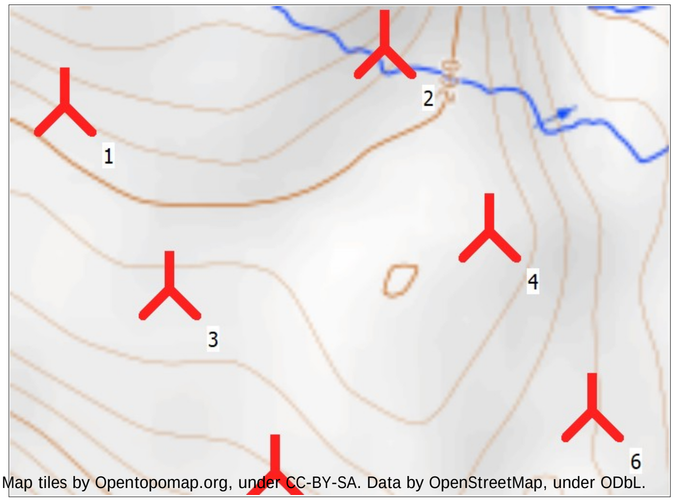
Calculated:
2022-02-22 09:43/3.5.552

PARK - WTG distances

Calculation: 6 x V105 3p6 MW HH 72p5 m w Storm Control/HWO

WTG distances

	Z [m]	Nearest WTG	Z [m]	Horizontal distance [m]	Distance in rotor diameters
1	225.3	3	207.6	280	2.7
2	218.1	4	200.6	280	2.7
3	207.6	5	183.0	280	2.7
4	200.6	6	181.3	280	2.7
5	183.0	3	207.6	280	2.7
6	181.3	4	200.6	280	2.7
Min	181.3		181.3	280	2.7
Max	225.3		207.6	280	2.7



Scale 1:10 000

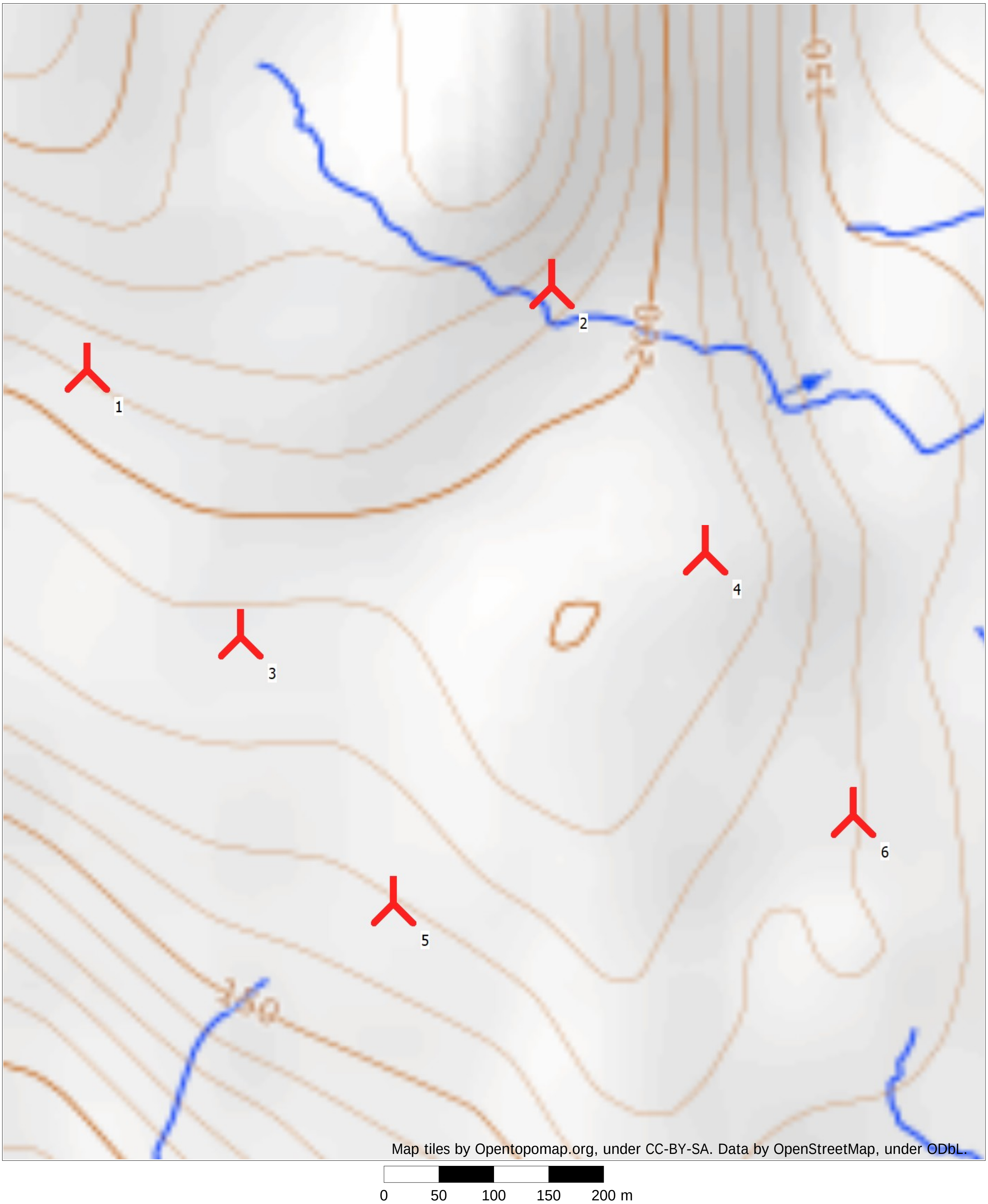
New WTG

Project:
Sandoy_uV_20181121

Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-22 09:43/3.5.552

PARK - Map

Calculation: 6 x V105 3p6 MW HH 72p5 m w Storm Control/HWO



Map: OpenTopoMap , Print scale 1:5 000, Map center UTM (north)-WGS84 Zone: 29 East: 612 495 North: 6 858 930

New WTG

Project:
Sandoy_uV_20181121

Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 11:54/3.5.552

PARK - Main Result

Calculation: 5 x V117 4p2 MW HH 91p5 m no HWO

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: 1.9°

Power curve correction method
New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>
Air density calculation method
Height dependent, temperature from climate station
Station: THORSHAVN V3 2014
Base temperature: 6.0 °C at 55.0 m
Base pressure: 1013.3 hPa at 0.0 m
Air density for Site center in key hub height: 207.5 m + 96.0 m = 1.225 kg/m³ -> 100.0 % of Std
Relative humidity: 0.0 %

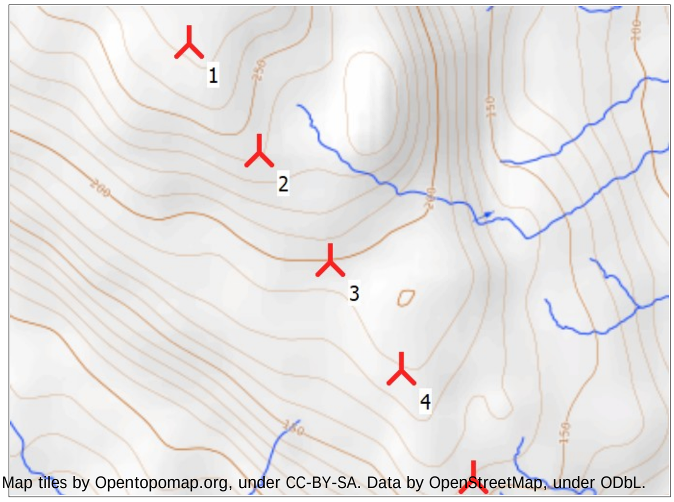
Wake Model Parameters

Terrain type	Wake decay constant
User defined	0.067

Omnidirectional displacement height from objects

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0.5	360.0	1.0	0.5	30.5	1.0



Scale 1:20 000

New WTG

Resource file(s)

L:\KUNDER\535_Energy_Directorate_FO\001_Klivalokshagi\Analyses\2021_11_Site_Suitability\04_WAsP\03_Wind_maps\Klivalokshagi_HH91p5m_corr_1.012.wrg

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Wake loss [%]	Specific results¤) Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	100 816.4	104 565.1	3.6	54.8	20 163.3	4 801	10.5

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 5 new WTGs with total 21.0 MW rated power

Links	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh/y]	Wake loss [%]	Free mean wind speed [m/s]
1 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	91.5	EMD	PO1 - Calculated - Modes PO1 & PO1-0S - 09-2018	20 744.2	2.9	10.78
2 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	91.5	EMD	PO1 - Calculated - Modes PO1 & PO1-0S - 09-2018	20 503.0	4.0	10.78
3 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	91.5	EMD	PO1 - Calculated - Modes PO1 & PO1-0S - 09-2018	19 856.8	4.4	10.39
4 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	91.5	EMD	PO1 - Calculated - Modes PO1 & PO1-0S - 09-2018	19 797.4	4.1	10.29
5 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	91.5	EMD	PO1 - Calculated - Modes PO1 & PO1-0S - 09-2018	19 915.0	2.5	10.15

Annual Energy result includes shown losses. Additional losses and uncertainty must be considered for an investment decision.

WTG siting

	UTM (north)-WGS84 Zone: 29 Easting	Northing	Z [m]	Row data/Description
1 New	611 989	6 859 561	276.6	KLH201
2 New	612 188	6 859 278	258.3	KLH202
3 New	612 386	6 858 996	218.1	KLH203
4 New	612 584	6 858 713	194.2	KLH204
5 New	612 782	6 858 430	167.8	KLH205

Project:

Sandoy_uV_20181121

Licensed user:

Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no

Calculated:

2022-02-14 11:54/3.5.552

PARK - Power Curve Analysis

Calculation: 5 x V117 4p2 MW HH 91p5 m no HWOWTG: 1 - VESTAS V117-4.2 4200 117.0 !O!, Hub height: 91.5 m

Name: PO1 - Calculated - Modes PO1 & PO1-0S - 09-2018
Source: Manufacturer

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
2018-09-10	EMD	2017-08-10	2019-07-24	27.0	Pitch	User defined	Variable	0.39

Documents no. DMS 0067-7063 V05 & DMS 0067-7064 V06.

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	5 574	8 843	12 195	15 322	18 055	20 310
VESTAS V117-4.2 4200 117.0 !O! PO1 - Calculated - Modes PO1 & PO1-0S - 09-2018	[MWh]	5 548	8 808	12 161	15 298	18 062	20 385
Check value	[%]	0	0	0	0	0	0

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTGs performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see the windPRO manual.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement.

Power curve

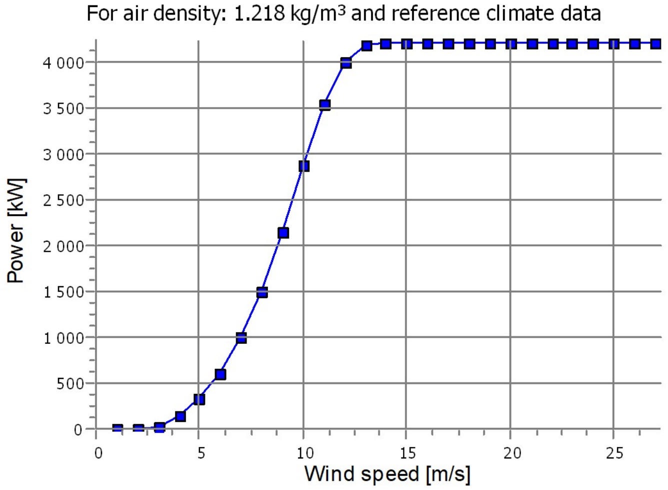
Original data, Air density: 1.225 kg/m³

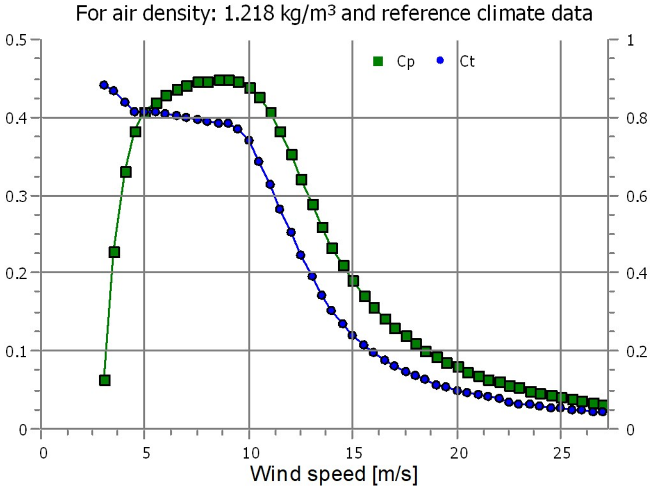
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
3.0	12.0	0.07	3.0	0.88
3.5	65.0	0.23	3.5	0.87
4.0	140.0	0.33	4.0	0.84
4.5	230.0	0.38	4.5	0.81
5.0	336.0	0.41	5.0	0.81
5.5	460.0	0.42	5.5	0.81
6.0	610.0	0.43	6.0	0.81
6.5	788.0	0.44	6.5	0.80
7.0	996.0	0.44	7.0	0.80
7.5	1 236.0	0.44	7.5	0.79
8.0	1 507.0	0.45	8.0	0.79
8.5	1 814.0	0.45	8.5	0.79
9.0	2 155.0	0.45	9.0	0.78
9.5	2 521.0	0.45	9.5	0.77
10.0	2 892.0	0.44	10.0	0.74
10.5	3 245.0	0.43	10.5	0.69
11.0	3 556.0	0.41	11.0	0.63
11.5	3 815.0	0.38	11.5	0.57
12.0	4 008.0	0.35	12.0	0.51
12.5	4 124.0	0.32	12.5	0.45
13.0	4 178.0	0.29	13.0	0.39
13.5	4 187.0	0.26	13.5	0.35
14.0	4 196.0	0.23	14.0	0.31
14.5	4 200.0	0.21	14.5	0.27
15.0	4 200.0	0.19	15.0	0.24
15.5	4 200.0	0.17	15.5	0.22
16.0	4 200.0	0.16	16.0	0.20
16.5	4 200.0	0.14	16.5	0.18
17.0	4 200.0	0.13	17.0	0.16
17.5	4 200.0	0.12	17.5	0.15
18.0	4 200.0	0.11	18.0	0.14
18.5	4 200.0	0.10	18.5	0.13
19.0	4 200.0	0.09	19.0	0.12
19.5	4 200.0	0.09	19.5	0.11
20.0	4 200.0	0.08	20.0	0.10
20.5	4 200.0	0.07	20.5	0.09
21.0	4 200.0	0.07	21.0	0.09
21.5	4 200.0	0.06	21.5	0.08
22.0	4 200.0	0.06	22.0	0.08
22.5	4 200.0	0.06	22.5	0.07
23.0	4 200.0	0.05	23.0	0.07
23.5	4 200.0	0.05	23.5	0.06
24.0	4 200.0	0.05	24.0	0.06
24.5	4 200.0	0.04	24.5	0.06
25.0	4 200.0	0.04	25.0	0.05
25.5	4 200.0	0.04	25.5	0.05
26.0	4 200.0	0.04	26.0	0.05
26.5	4 200.0	0.03	26.5	0.05
27.0	4 200.0	0.03	27.0	0.04

Power, Efficiency and energy vs. wind speed

Data used in calculation, Air density: 1.218 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

Wind speed [m/s]	Power [kW]	Cp	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1.0	0.0	0.00	0.50- 1.50	0.0	0.0	0.0
2.0	0.0	0.00	1.50- 2.50	0.0	0.0	0.0
3.0	11.3	0.06	2.50- 3.50	12.4	12.4	0.1
4.0	138.7	0.33	3.50- 4.50	65.7	78.1	0.4
5.0	333.8	0.41	4.50- 5.50	173.9	252.0	1.2
6.0	606.2	0.43	5.50- 6.50	343.5	595.5	2.9
7.0	989.8	0.44	6.50- 7.50	586.3	1 181.7	5.7
8.0	1 497.7	0.45	7.50- 8.50	900.3	2 082.0	10.0
9.0	2 140.7	0.45	8.50- 9.50	1 267.9	3 349.9	16.1
10.0	2 871.9	0.44	9.50-10.50	1 631.3	4 981.2	24.0
11.0	3 533.7	0.41	10.50-11.50	1 892.6	6 873.8	33.1
12.0	3 990.7	0.35	11.50-12.50	1 979.6	8 853.4	42.7
13.0	4 172.6	0.29	12.50-13.50	1 893.2	10 746.7	51.8
14.0	4 195.0	0.23	13.50-14.50	1 711.4	12 458.1	60.1
15.0	4 200.0	0.19	14.50-15.50	1 508.6	13 966.6	67.3
16.0	4 200.0	0.16	15.50-16.50	1 307.7	15 274.3	73.6
17.0	4 200.0	0.13	16.50-17.50	1 117.5	16 391.8	79.0
18.0	4 200.0	0.11	17.50-18.50	942.3	17 334.1	83.6
19.0	4 200.0	0.09	18.50-19.50	784.7	18 118.8	87.3
20.0	4 200.0	0.08	19.50-20.50	645.5	18 764.3	90.5
21.0	4 200.0	0.07	20.50-21.50	524.9	19 289.2	93.0
22.0	4 200.0	0.06	21.50-22.50	422.1	19 711.3	95.0
23.0	4 200.0	0.05	22.50-23.50	335.7	20 047.0	96.6
24.0	4 200.0	0.05	23.50-24.50	264.2	20 311.2	97.9
25.0	4 200.0	0.04	24.50-25.50	205.7	20 516.9	98.9
26.0	4 200.0	0.04	25.50-26.50	158.5	20 675.5	99.7
27.0	4 200.0	0.03	26.50-27.50	68.8	20 744.2	100.0





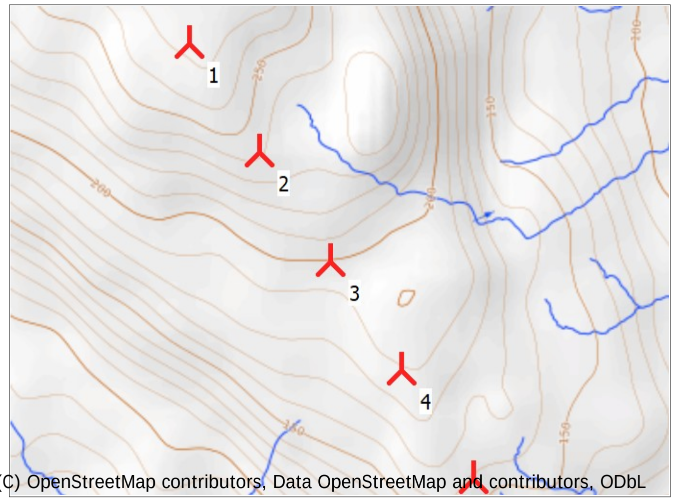
Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 11:54/3.5.552

PARK - WTG distances

Calculation: 5 x V117 4p2 MW HH 91p5 m no HWO

WTG distances

	Z	Nearest WTG	Z	Horizontal distance	Distance in rotor diameters
	[m]		[m]	[m]	
1	276.6	2	258.3	345	3.0
2	258.3	1	276.6	345	3.0
3	218.1	4	194.2	345	3.0
4	194.2	5	167.8	345	3.0
5	167.8	4	194.2	345	3.0
Min	167.8		167.8	345	3.0
Max	276.6		276.6	345	3.0



Scale 1:20 000

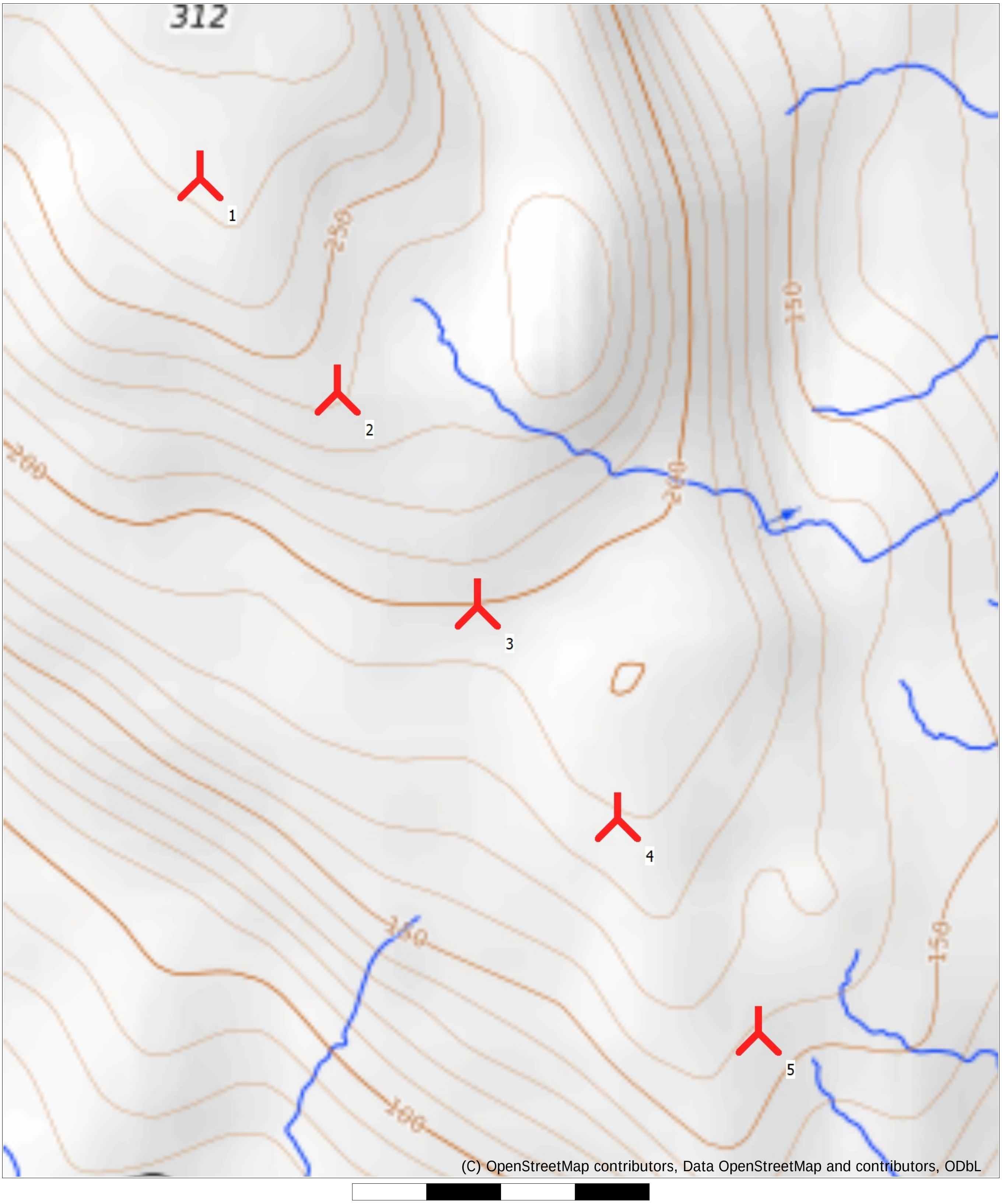
New WTG

Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no

Calculated:
2022-02-14 11:54/3.5.552

PARK - Map

Calculation: 5 x V117 4p2 MW HH 91p5 m no HWO



Map: OpenTopoMap , Print scale 1:7 500, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

New WTG

Project:
Sandoy_uV_20181121

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-01-12 11:29/3.5.552

PARK - Main Result

Calculation: 5 x V117 4p2 MW HH 91p5 m

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: 1.9°

Power curve correction method
New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>
Air density calculation method
Height dependent, temperature from climate station
Station: THORSHAVN V3 2014
Base temperature: 6.0 °C at 55.0 m
Base pressure: 1013.3 hPa at 0.0 m
Air density for Site center in key hub height: 207.5 m + 96.0 m = 1.225 kg/m³ -> 100.0 % of Std
Relative humidity: 0.0 %

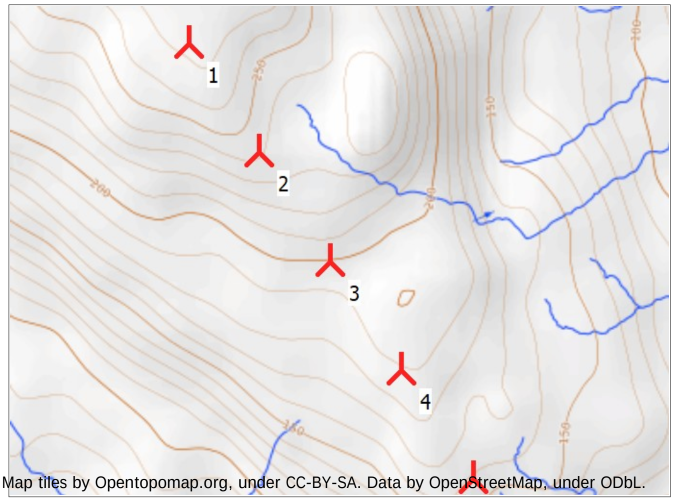
Wake Model Parameters

Terrain type	Wake decay constant
User defined	0.067

Omnidirectional displacement height from objects

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0.5	360.0	1.0	0.5	32.0	1.0



Scale 1:20 000

New WTG

Resource file(s)

L:\KUNDER\535_Energy_Directorate_FO\001_Klivalokshagi\Analyses\2021_11_Site_Suitability\04_WAsP\03_Wind_maps\Klivalokshagi_HH91p5m_corr_1.012.wrg

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Wake loss [%]	Specific results¤) Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	101 843.9	105 627.6	3.6	55.3	20 368.8	4 850	10.5

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 5 new WTGs with total 21.0 MW rated power

Links	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh/y]	Wake loss [%]	Free mean wind speed [m/s]
1 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	91.5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	21 002.8	2.9	10.78
2 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	91.5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	20 762.5	4.0	10.78
3 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	91.5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	20 048.4	4.4	10.39
4 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	91.5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	19 969.4	4.1	10.29
5 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	91.5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	20 060.9	2.5	10.15

Annual Energy result includes shown losses. Additional losses and uncertainty must be considered for an investment decision.

WTG siting

	UTM (north)-WGS84 Zone: 29 Easting	Northing	Z [m]	Row data/Description
1 New	611 989	6 859 561	276.6	KLH201
2 New	612 188	6 859 278	258.3	KLH202
3 New	612 386	6 858 996	218.1	KLH203
4 New	612 584	6 858 713	194.2	KLH204
5 New	612 782	6 858 430	167.8	KLH205

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-01-12 11:29/3.5.552

PARK - Power Curve Analysis

Calculation: 5 x V117 4p2 MW HH 91p5 mWTG: 1 - VESTAS V117-4.2 4200 117.0 !O!, Hub height: 91.5 m

Name: PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018
Source: Manufacturer

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
10.09.2018	USER	2017-08-10	2021-12-13	32.0	Pitch	User defined	Variable	0.39

Documents no. DMS 0067-7063 V05 & DMS 0067-7064 V06.

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	5 574	8 843	12 195	15 322	18 055	20 310
VESTAS V117-4.2 4200 117.0 !O! PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	[MWh]	5 548	8 808	12 161	15 301	18 087	20 475
Check value	[%]	0	0	0	0	0	-1

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTGs performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see the windPRO manual.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement.

Power curve

Original data, Air density: 1.225 kg/m³

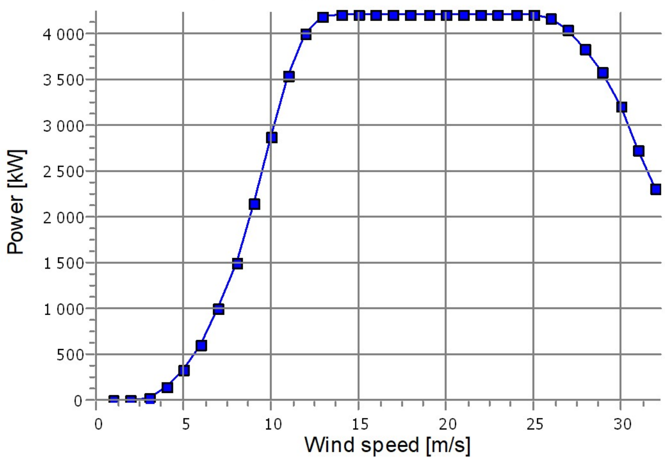
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
3.0	12.0	0.07	3.0	0.88
3.5	65.0	0.23	3.5	0.87
4.0	140.0	0.33	4.0	0.84
4.5	230.0	0.38	4.5	0.81
5.0	336.0	0.41	5.0	0.81
5.5	460.0	0.42	5.5	0.81
6.0	610.0	0.43	6.0	0.81
6.5	788.0	0.44	6.5	0.80
7.0	996.0	0.44	7.0	0.80
7.5	1 236.0	0.44	7.5	0.79
8.0	1 507.0	0.45	8.0	0.79
8.5	1 814.0	0.45	8.5	0.79
9.0	2 155.0	0.45	9.0	0.78
9.5	2 521.0	0.45	9.5	0.77
10.0	2 892.0	0.44	10.0	0.74
10.5	3 245.0	0.43	10.5	0.69
11.0	3 556.0	0.41	11.0	0.63
11.5	3 815.0	0.38	11.5	0.57
12.0	4 008.0	0.35	12.0	0.51
12.5	4 124.0	0.32	12.5	0.45
13.0	4 178.0	0.29	13.0	0.39
13.5	4 187.0	0.26	13.5	0.35
14.0	4 196.0	0.23	14.0	0.31
14.5	4 200.0	0.21	14.5	0.27
15.0	4 200.0	0.19	15.0	0.24
15.5	4 200.0	0.17	15.5	0.22
16.0	4 200.0	0.16	16.0	0.20
16.5	4 200.0	0.14	16.5	0.18
17.0	4 200.0	0.13	17.0	0.16
17.5	4 200.0	0.12	17.5	0.15
18.0	4 200.0	0.11	18.0	0.14
18.5	4 200.0	0.10	18.5	0.13
19.0	4 200.0	0.09	19.0	0.12
19.5	4 200.0	0.09	19.5	0.11
20.0	4 200.0	0.08	20.0	0.10
20.5	4 200.0	0.07	20.5	0.09
21.0	4 200.0	0.07	21.0	0.09
21.5	4 200.0	0.06	21.5	0.08
22.0	4 200.0	0.06	22.0	0.08
22.5	4 200.0	0.06	22.5	0.07
23.0	4 200.0	0.05	23.0	0.07
23.5	4 200.0	0.05	23.5	0.06
24.0	4 200.0	0.05	24.0	0.06
24.5	4 200.0	0.04	24.5	0.06
25.0	4 200.0	0.04	25.0	0.05
25.5	4 191.0	0.04	25.5	0.05
26.0	4 165.0	0.04	26.0	0.05
26.5	4 107.0	0.03	26.5	0.04
27.0	4 039.0	0.03	27.0	0.04
27.5	3 934.0	0.03	27.5	0.04
28.0	3 834.0	0.03	28.0	0.04
28.5	3 723.0	0.02	28.5	0.03
29.0	3 586.0	0.02	29.0	0.03
29.5	3 415.0	0.02	29.5	0.03
30.0	3 212.0	0.02	30.0	0.03
30.5	2 981.0	0.02	30.5	0.02
31.0	2 729.0	0.01	31.0	0.02
31.5	2 492.0	0.01	31.5	0.02
32.0	2 315.0	0.01	32.0	0.02

Power, Efficiency and energy vs. wind speed

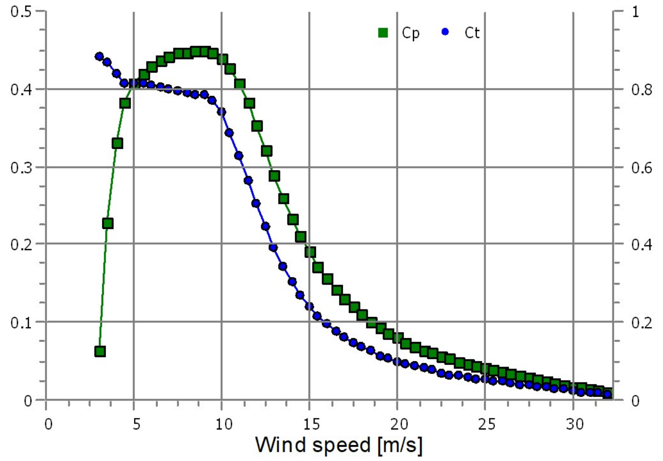
Data used in calculation, Air density: 1.218 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

Wind speed [m/s]	Power [kW]	Cp	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1.0	0.0	0.00	0.50- 1.50	0.0	0.0	0.0
2.0	0.0	0.00	1.50- 2.50	0.0	0.0	0.0
3.0	11.3	0.06	2.50- 3.50	12.4	12.4	0.1
4.0	138.7	0.33	3.50- 4.50	65.7	78.1	0.4
5.0	333.8	0.41	4.50- 5.50	173.8	251.9	1.2
6.0	606.2	0.43	5.50- 6.50	343.5	595.4	2.8
7.0	989.8	0.44	6.50- 7.50	586.2	1 181.6	5.6
8.0	1 497.7	0.45	7.50- 8.50	900.2	2 081.9	9.9
9.0	2 140.7	0.45	8.50- 9.50	1 267.8	3 349.7	15.9
10.0	2 871.9	0.44	9.50-10.50	1 631.2	4 980.9	23.7
11.0	3 533.7	0.41	10.50-11.50	1 892.4	6 873.3	32.7
12.0	3 990.7	0.35	11.50-12.50	1 979.5	8 852.8	42.2
13.0	4 172.6	0.29	12.50-13.50	1 893.1	10 745.9	51.2
14.0	4 195.0	0.23	13.50-14.50	1 711.3	12 457.2	59.3
15.0	4 200.0	0.19	14.50-15.50	1 508.5	13 965.7	66.5
16.0	4 200.0	0.16	15.50-16.50	1 307.6	15 273.2	72.7
17.0	4 200.0	0.13	16.50-17.50	1 117.4	16 390.6	78.0
18.0	4 200.0	0.11	17.50-18.50	942.3	17 332.9	82.5
19.0	4 200.0	0.09	18.50-19.50	784.6	18 117.5	86.3
20.0	4 200.0	0.08	19.50-20.50	645.5	18 763.0	89.3
21.0	4 200.0	0.07	20.50-21.50	524.9	19 287.9	91.8
22.0	4 200.0	0.06	21.50-22.50	422.1	19 709.9	93.8
23.0	4 200.0	0.05	22.50-23.50	335.7	20 045.6	95.4
24.0	4 200.0	0.05	23.50-24.50	264.2	20 309.8	96.7
25.0	4 200.0	0.04	24.50-25.50	205.5	20 515.3	97.7
26.0	4 165.0	0.04	25.50-26.50	156.8	20 672.2	98.4
27.0	4 039.0	0.03	26.50-27.50	116.1	20 788.2	99.0
28.0	3 834.0	0.03	27.50-28.50	83.6	20 871.8	99.4
29.0	3 586.0	0.02	28.50-29.50	58.4	20 930.2	99.7
30.0	3 212.0	0.02	29.50-30.50	38.9	20 969.0	99.8
31.0	2 729.0	0.01	30.50-31.50	24.5	20 993.5	100.0
32.0	2 315.0	0.01	31.50-32.50	9.3	21 002.8	100.0

Power curve
For air density: 1.218 kg/m³ and reference climate data



Cp and Ct curve
For air density: 1.218 kg/m³ and reference climate data



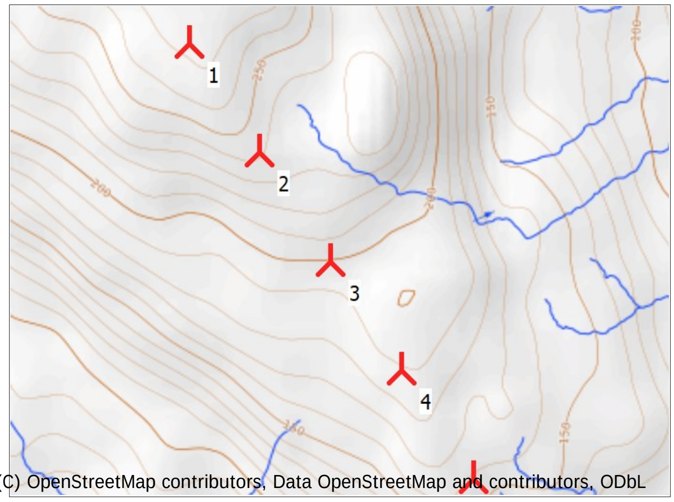
Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-01-12 11:29/3.5.552

PARK - WTG distances

Calculation: 5 x V117 4p2 MW HH 91p5 m

WTG distances

	Z [m]	Nearest WTG	Z [m]	Horizontal distance [m]	Distance in rotor diameters
1	276.6	2	258.3	345	3.0
2	258.3	1	276.6	345	3.0
3	218.1	4	194.2	345	3.0
4	194.2	5	167.8	345	3.0
5	167.8	4	194.2	345	3.0
Min	167.8		167.8	345	3.0
Max	276.6		276.6	345	3.0



Scale 1:20 000

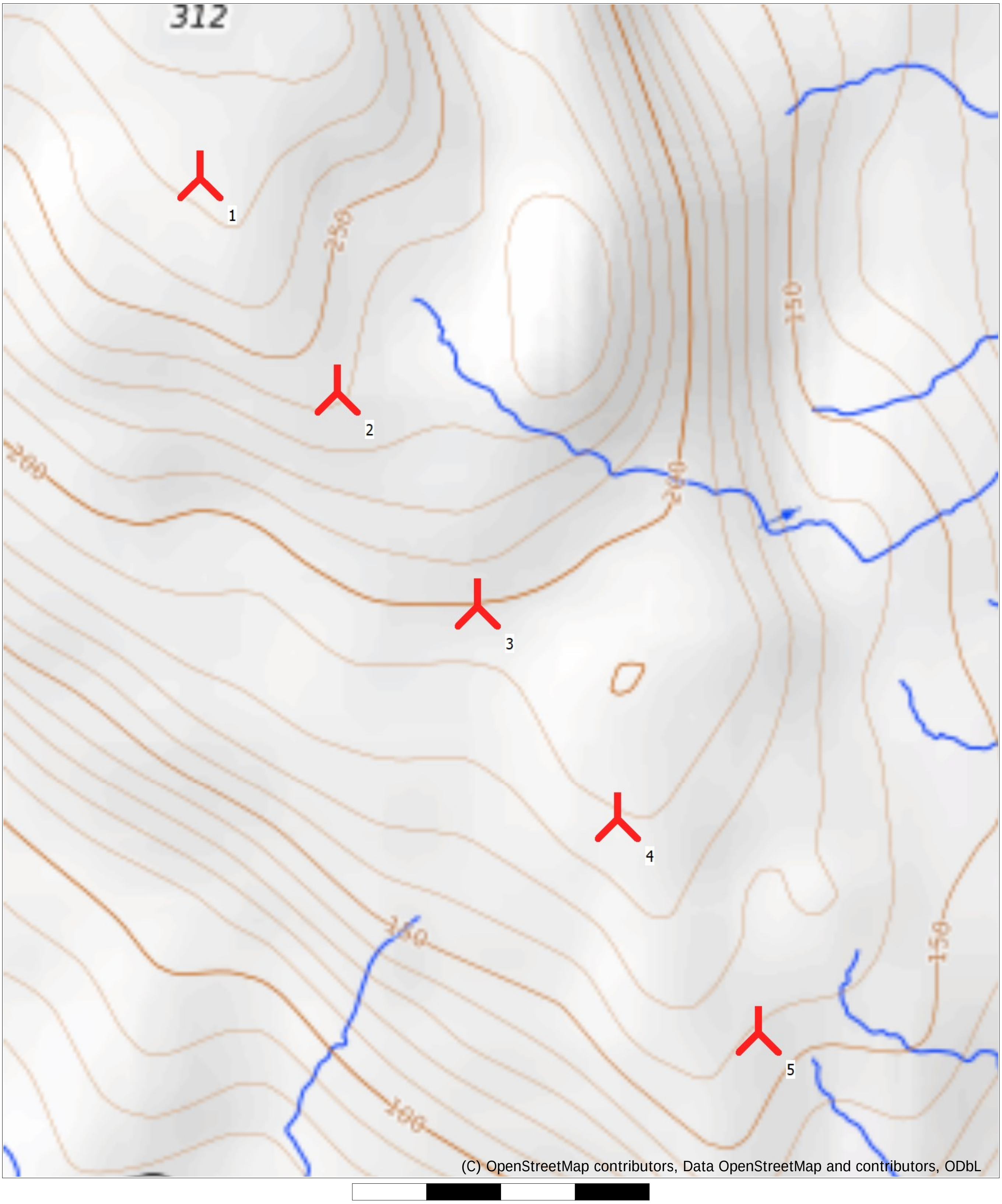
New WTG

Project:
Sandoy_uV_20181121

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-01-12 11:29/3.5.552

PARK - Map

Calculation: 5 x V117 4p2 MW HH 91p5 m



Map: OpenTopoMap , Print scale 1:7 500, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

⅄ New WTG

Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 11:52/3.5.552

PARK - Main Result

Calculation: 5 x V117 4p2 MW HH 96p5 m no HWO

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: 1.9°

Power curve correction method
New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>
Air density calculation method
Height dependent, temperature from climate station
Station: THORSHAVN V3 2014
Base temperature: 6.0 °C at 55.0 m
Base pressure: 1013.3 hPa at 0.0 m
Air density for Site center in key hub height: 207.5 m + 96.0 m = 1.225 kg/m³ -> 100.0 % of Std
Relative humidity: 0.0 %

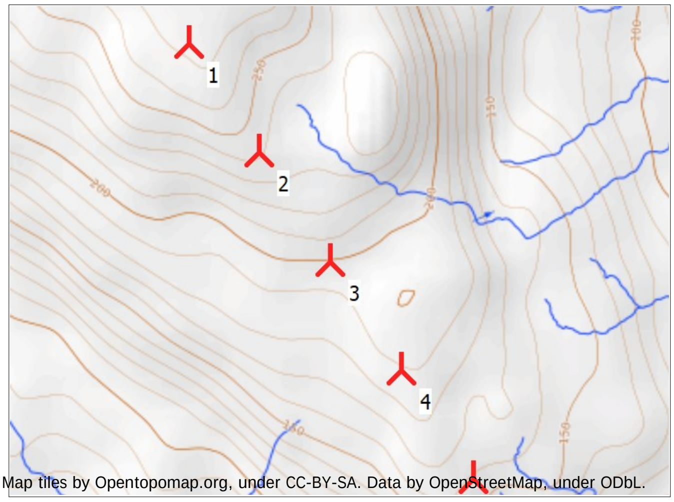
Wake Model Parameters

Terrain type	Wake decay constant
User defined	0.067

Omnidirectional displacement height from objects

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0.5	360.0	1.0	0.5	30.5	1.0



Scale 1:20 000

New WTG

Resource file(s)

L:\KUNDER\535_Energy_Directorate_FO\001_Klivalokshagi\Analyses\2021_11_Site_Suitability\04_WAsP\03_Wind_maps\Klivalokshagi_HH96p5m_corr_1.012.wrg

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Wake loss [%]	Specific results¤ Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	101 152.4	104 917.6	3.6	54.9	20 230.5	4 817	10.5

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 5 new WTGs with total 21.0 MW rated power

Links	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh/y]	Wake loss [%]	Free mean wind speed [m/s]
1 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	96.5	USER	PO1 - Calculated - Modes PO1 & PO1-0S - 09-2018	20 796.6	2.9	10.80
2 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	96.5	USER	PO1 - Calculated - Modes PO1 & PO1-0S - 09-2018	20 549.4	4.0	10.80
3 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	96.5	USER	PO1 - Calculated - Modes PO1 & PO1-0S - 09-2018	19 914.5	4.4	10.42
4 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	96.5	USER	PO1 - Calculated - Modes PO1 & PO1-0S - 09-2018	19 855.7	4.1	10.31
5 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	96.5	USER	PO1 - Calculated - Modes PO1 & PO1-0S - 09-2018	20 036.2	2.5	10.20

Annual Energy result includes shown losses. Additional losses and uncertainty must be considered for an investment decision.

WTG siting

	UTM (north)-WGS84 Zone: 29 Easting	Northing	Z [m]	Row data/Description
1 New	611 989	6 859 561	276.6	KLH201
2 New	612 188	6 859 278	258.3	KLH202
3 New	612 386	6 858 996	218.1	KLH203
4 New	612 584	6 858 713	194.2	KLH204
5 New	612 782	6 858 430	167.8	KLH205

Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 11:52/3.5.552

PARK - Power Curve Analysis

Calculation: 5 x V117 4p2 MW HH 96p5 m no HWOWTG: 1 - VESTAS V117-4.2 4200 117.0 !O!, Hub height: 96.5 m

Name: PO1 - Calculated - Modes PO1 & PO1-0S - 09-2018
Source: Manufacturer

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
2018-09-10	USER	2017-08-10	2019-07-24	27.0	Pitch	User defined	Variable	0.39

Documents no. DMS 0067-7063 V05 & DMS 0067-7064 V06.

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	5 574	8 843	12 195	15 322	18 055	20 310
VESTAS V117-4.2 4200 117.0 !O! PO1 - Calculated - Modes PO1 & PO1-0S - 09-2018	[MWh]	5 548	8 808	12 161	15 298	18 062	20 385
Check value	[%]	0	0	0	0	0	0

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTGs performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see the windPRO manual.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement.

Power curve

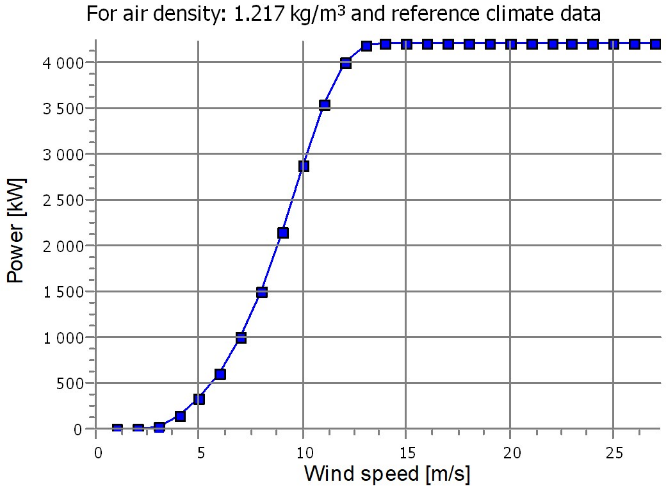
Original data, Air density: 1.225 kg/m³

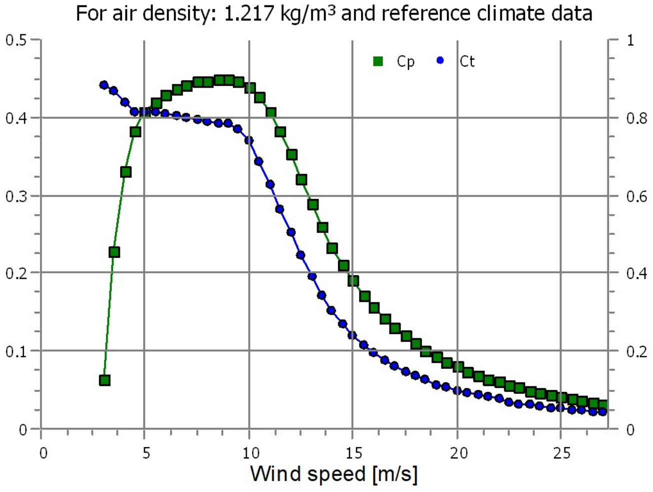
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
3.0	12.0	0.07	3.0	0.88
3.5	65.0	0.23	3.5	0.87
4.0	140.0	0.33	4.0	0.84
4.5	230.0	0.38	4.5	0.81
5.0	336.0	0.41	5.0	0.81
5.5	460.0	0.42	5.5	0.81
6.0	610.0	0.43	6.0	0.81
6.5	788.0	0.44	6.5	0.80
7.0	996.0	0.44	7.0	0.80
7.5	1 236.0	0.44	7.5	0.79
8.0	1 507.0	0.45	8.0	0.79
8.5	1 814.0	0.45	8.5	0.79
9.0	2 155.0	0.45	9.0	0.78
9.5	2 521.0	0.45	9.5	0.77
10.0	2 892.0	0.44	10.0	0.74
10.5	3 245.0	0.43	10.5	0.69
11.0	3 556.0	0.41	11.0	0.63
11.5	3 815.0	0.38	11.5	0.57
12.0	4 008.0	0.35	12.0	0.51
12.5	4 124.0	0.32	12.5	0.45
13.0	4 178.0	0.29	13.0	0.39
13.5	4 187.0	0.26	13.5	0.35
14.0	4 196.0	0.23	14.0	0.31
14.5	4 200.0	0.21	14.5	0.27
15.0	4 200.0	0.19	15.0	0.24
15.5	4 200.0	0.17	15.5	0.22
16.0	4 200.0	0.16	16.0	0.20
16.5	4 200.0	0.14	16.5	0.18
17.0	4 200.0	0.13	17.0	0.16
17.5	4 200.0	0.12	17.5	0.15
18.0	4 200.0	0.11	18.0	0.14
18.5	4 200.0	0.10	18.5	0.13
19.0	4 200.0	0.09	19.0	0.12
19.5	4 200.0	0.09	19.5	0.11
20.0	4 200.0	0.08	20.0	0.10
20.5	4 200.0	0.07	20.5	0.09
21.0	4 200.0	0.07	21.0	0.09
21.5	4 200.0	0.06	21.5	0.08
22.0	4 200.0	0.06	22.0	0.08
22.5	4 200.0	0.06	22.5	0.07
23.0	4 200.0	0.05	23.0	0.07
23.5	4 200.0	0.05	23.5	0.06
24.0	4 200.0	0.05	24.0	0.06
24.5	4 200.0	0.04	24.5	0.06
25.0	4 200.0	0.04	25.0	0.05
25.5	4 200.0	0.04	25.5	0.05
26.0	4 200.0	0.04	26.0	0.05
26.5	4 200.0	0.03	26.5	0.05
27.0	4 200.0	0.03	27.0	0.04

Power, Efficiency and energy vs. wind speed

Data used in calculation, Air density: 1.217 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

Wind speed [m/s]	Power [kW]	Cp	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1.0	0.0	0.00	0.50- 1.50	0.0	0.0	0.0
2.0	0.0	0.00	1.50- 2.50	0.0	0.0	0.0
3.0	11.3	0.06	2.50- 3.50	12.3	12.3	0.1
4.0	138.6	0.33	3.50- 4.50	65.3	77.6	0.4
5.0	333.6	0.41	4.50- 5.50	173.1	250.6	1.2
6.0	605.9	0.43	5.50- 6.50	342.5	593.2	2.9
7.0	989.3	0.44	6.50- 7.50	585.5	1 178.7	5.7
8.0	1 497.0	0.45	7.50- 8.50	900.2	2 078.8	10.0
9.0	2 139.6	0.45	8.50- 9.50	1 269.0	3 347.8	16.1
10.0	2 870.3	0.44	9.50-10.50	1 633.9	4 981.7	24.0
11.0	3 531.9	0.41	10.50-11.50	1 896.9	6 878.6	33.1
12.0	3 989.3	0.35	11.50-12.50	1 985.4	8 864.0	42.6
13.0	4 172.2	0.29	12.50-13.50	1 899.8	10 763.8	51.8
14.0	4 195.0	0.23	13.50-14.50	1 717.8	12 481.6	60.0
15.0	4 200.0	0.19	14.50-15.50	1 514.4	13 996.0	67.3
16.0	4 200.0	0.16	15.50-16.50	1 312.7	15 308.7	73.6
17.0	4 200.0	0.13	16.50-17.50	1 121.7	16 430.4	79.0
18.0	4 200.0	0.11	17.50-18.50	945.8	17 376.2	83.6
19.0	4 200.0	0.09	18.50-19.50	787.4	18 163.6	87.3
20.0	4 200.0	0.08	19.50-20.50	647.7	18 811.3	90.5
21.0	4 200.0	0.07	20.50-21.50	526.6	19 337.8	93.0
22.0	4 200.0	0.06	21.50-22.50	423.3	19 761.1	95.0
23.0	4 200.0	0.05	22.50-23.50	336.6	20 097.8	96.6
24.0	4 200.0	0.05	23.50-24.50	264.8	20 362.6	97.9
25.0	4 200.0	0.04	24.50-25.50	206.2	20 568.8	98.9
26.0	4 200.0	0.04	25.50-26.50	158.9	20 727.7	99.7
27.0	4 200.0	0.03	26.50-27.50	68.9	20 796.6	100.0





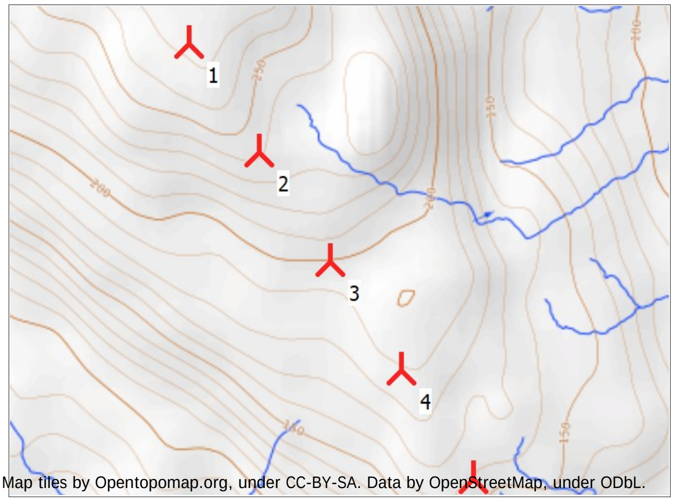
Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 11:52/3.5.552

PARK - WTG distances

Calculation: 5 x V117 4p2 MW HH 96p5 m no HWO

WTG distances

	Z	Nearest WTG	Z	Horizontal distance	Distance in rotor diameters
	[m]		[m]	[m]	
1	276.6	2	258.3	345	3.0
2	258.3	1	276.6	345	3.0
3	218.1	4	194.2	345	3.0
4	194.2	5	167.8	345	3.0
5	167.8	4	194.2	345	3.0
Min	167.8		167.8	345	3.0
Max	276.6		276.6	345	3.0

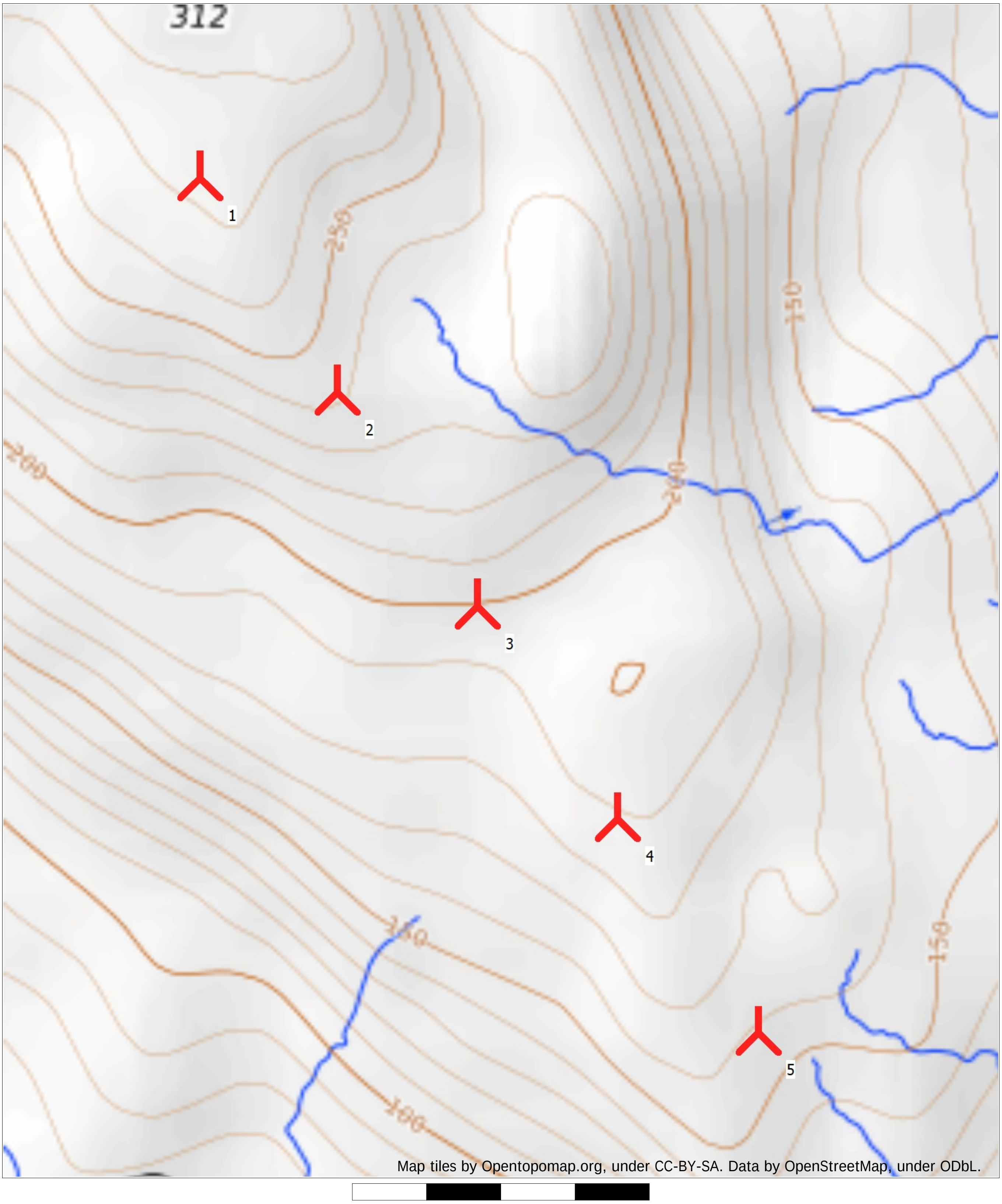


Scale 1:20 000

New WTG

PARK - Map

Calculation: 5 x V117 4p2 MW HH 96p5 m no HWO



Map: OpenTopoMap , Print scale 1:7 500, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

New WTG

Project:

Sandoy_uV_20181121

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no

Calculated:
2022-01-12 11:28/3.5.552

PARK - Main Result

Calculation: 5 x V117 4p2 MW HH 96p5 m

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: 1.9°

Power curve correction method
New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>
Air density calculation method
Height dependent, temperature from climate station
Station: THORSHAVN V3 2014
Base temperature: 6.0 °C at 55.0 m
Base pressure: 1013.3 hPa at 0.0 m
Air density for Site center in key hub height: 207.5 m + 96.0 m = 1.225 kg/m³ -> 100.0 % of Std
Relative humidity: 0.0 %

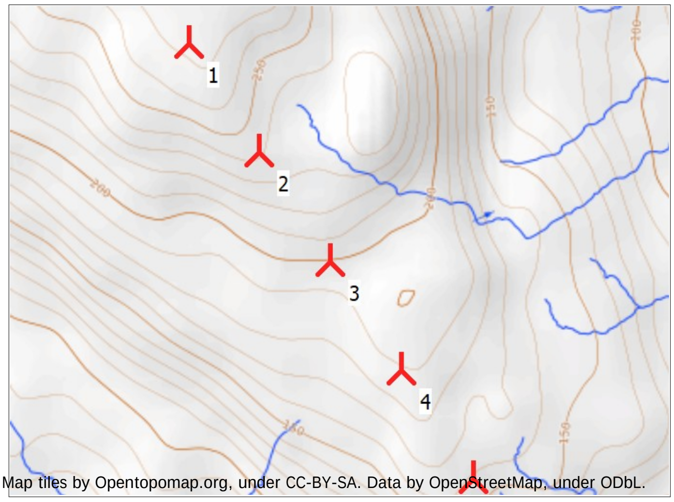
Wake Model Parameters

Terrain type	Wake decay constant
User defined	0.067

Omnidirectional displacement height from objects

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0.5	360.0	1.0	0.5	32.0	1.0



Scale 1:20 000

New WTG

Resource file(s)

L:\KUNDER\535_Energy_Directorate_FO\001_Klivalokshagi\Analyses\2021_11_Site_Suitability\04_WAsP\03_Wind_maps\Klivalokshagi_HH96p5m_corr_1.012.wrg

Calculated Annual Energy for Wind Farm

				Specific results¤			
WTG combination	Result PARK [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Wake loss [%]	Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	102 182.8	105 983.1	3.6	55.5	20 436.6	4 866	10.5

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 5 new WTGs with total 21.0 MW rated power

	WTG type						Power curve		Annual Energy		
Links	Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Creator	Name	Result [MWh/y]	Wake loss [%]	Free mean wind speed [m/s]
1 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	96.5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	21 055.6	2.9	10.80
2 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	96.5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	20 808.2	4.0	10.80
3 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	96.5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	20 108.0	4.4	10.42
4 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	96.5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	20 026.4	4.1	10.31
5 A	Yes	VESTAS	V117-4.2-4 200	4 200	117.0	96.5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	20 184.6	2.5	10.20

Annual Energy result includes shown losses. Additional losses and uncertainty must be considered for an investment decision.

WTG siting

	UTM (north)-WGS84 Zone: 29			
	Easting	Northing	Z [m]	Row data/Description
1 New	611 989	6 859 561	276.6	KLH201
2 New	612 188	6 859 278	258.3	KLH202
3 New	612 386	6 858 996	218.1	KLH203
4 New	612 584	6 858 713	194.2	KLH204
5 New	612 782	6 858 430	167.8	KLH205

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-01-12 11:28/3.5.552

PARK - Power Curve Analysis

Calculation: 5 x V117 4p2 MW HH 96p5 mWTG: 1 - VESTAS V117-4.2 4200 117.0 !O!, Hub height: 96.5 m

Name: PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018
Source: Manufacturer

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
10.09.2018	USER	2017-08-10	2021-12-13	32.0	Pitch	User defined	Variable	0.39

Documents no. DMS 0067-7063 V05 & DMS 0067-7064 V06.

HP curve comparison - Note: For standard air density

		5	6	7	8	9	10
Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	5 574	8 843	12 195	15 322	18 055	20 310
VESTAS V117-4.2 4200 117.0 !O! PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	[MWh]	5 548	8 808	12 161	15 301	18 087	20 475
Check value	[%]	0	0	0	0	0	-1

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTGs performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see the windPRO manual.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement.

Power curve

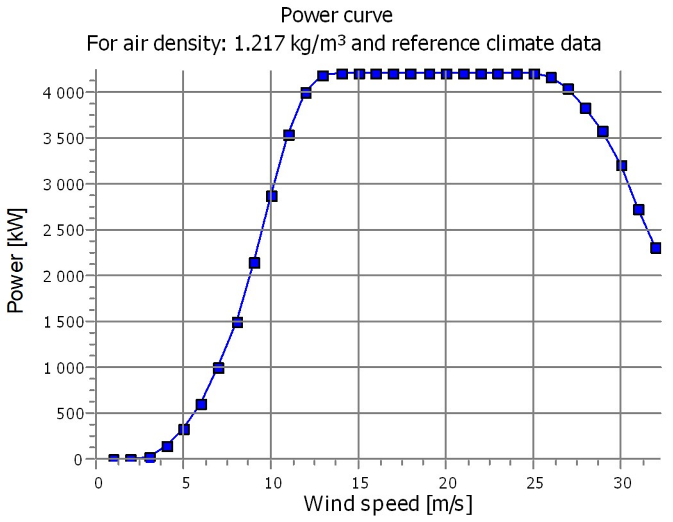
Original data, Air density: 1.225 kg/m³

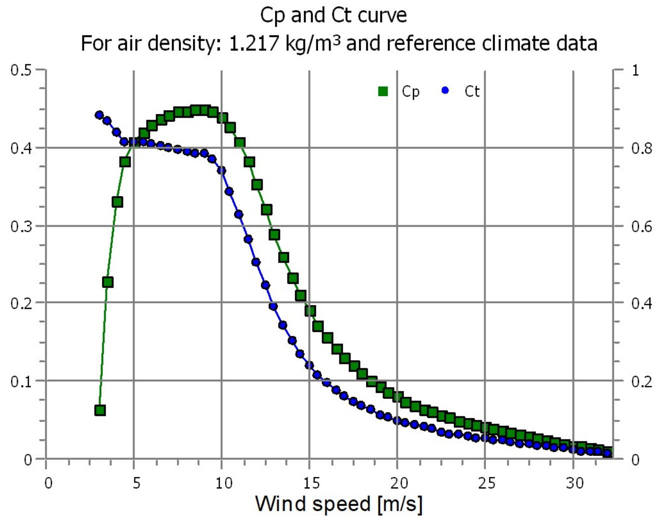
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
3.0	12.0	0.07	3.0	0.88
3.5	65.0	0.23	3.5	0.87
4.0	140.0	0.33	4.0	0.84
4.5	230.0	0.38	4.5	0.81
5.0	336.0	0.41	5.0	0.81
5.5	460.0	0.42	5.5	0.81
6.0	610.0	0.43	6.0	0.81
6.5	788.0	0.44	6.5	0.80
7.0	996.0	0.44	7.0	0.80
7.5	1 236.0	0.44	7.5	0.79
8.0	1 507.0	0.45	8.0	0.79
8.5	1 814.0	0.45	8.5	0.79
9.0	2 155.0	0.45	9.0	0.78
9.5	2 521.0	0.45	9.5	0.77
10.0	2 892.0	0.44	10.0	0.74
10.5	3 245.0	0.43	10.5	0.69
11.0	3 556.0	0.41	11.0	0.63
11.5	3 815.0	0.38	11.5	0.57
12.0	4 008.0	0.35	12.0	0.51
12.5	4 124.0	0.32	12.5	0.45
13.0	4 178.0	0.29	13.0	0.39
13.5	4 187.0	0.26	13.5	0.35
14.0	4 196.0	0.23	14.0	0.31
14.5	4 200.0	0.21	14.5	0.27
15.0	4 200.0	0.19	15.0	0.24
15.5	4 200.0	0.17	15.5	0.22
16.0	4 200.0	0.16	16.0	0.20
16.5	4 200.0	0.14	16.5	0.18
17.0	4 200.0	0.13	17.0	0.16
17.5	4 200.0	0.12	17.5	0.15
18.0	4 200.0	0.11	18.0	0.14
18.5	4 200.0	0.10	18.5	0.13
19.0	4 200.0	0.09	19.0	0.12
19.5	4 200.0	0.09	19.5	0.11
20.0	4 200.0	0.08	20.0	0.10
20.5	4 200.0	0.07	20.5	0.09
21.0	4 200.0	0.07	21.0	0.09
21.5	4 200.0	0.06	21.5	0.08
22.0	4 200.0	0.06	22.0	0.08
22.5	4 200.0	0.06	22.5	0.07
23.0	4 200.0	0.05	23.0	0.07
23.5	4 200.0	0.05	23.5	0.06
24.0	4 200.0	0.05	24.0	0.06
24.5	4 200.0	0.04	24.5	0.06
25.0	4 200.0	0.04	25.0	0.05
25.5	4 191.0	0.04	25.5	0.05
26.0	4 165.0	0.04	26.0	0.05
26.5	4 107.0	0.03	26.5	0.04
27.0	4 039.0	0.03	27.0	0.04
27.5	3 934.0	0.03	27.5	0.04
28.0	3 834.0	0.03	28.0	0.04
28.5	3 723.0	0.02	28.5	0.03
29.0	3 586.0	0.02	29.0	0.03
29.5	3 415.0	0.02	29.5	0.03
30.0	3 212.0	0.02	30.0	0.03
30.5	2 981.0	0.02	30.5	0.02
31.0	2 729.0	0.01	31.0	0.02
31.5	2 492.0	0.01	31.5	0.02
32.0	2 315.0	0.01	32.0	0.02

Power, Efficiency and energy vs. wind speed

Data used in calculation, Air density: 1.217 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

Wind speed [m/s]	Power [kW]	Cp	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1.0	0.0	0.00	0.50- 1.50	0.0	0.0	0.0
2.0	0.0	0.00	1.50- 2.50	0.0	0.0	0.0
3.0	11.3	0.06	2.50- 3.50	12.3	12.3	0.1
4.0	138.6	0.33	3.50- 4.50	65.3	77.6	0.4
5.0	333.6	0.41	4.50- 5.50	173.1	250.6	1.2
6.0	605.9	0.43	5.50- 6.50	342.5	593.1	2.8
7.0	989.3	0.44	6.50- 7.50	585.4	1 178.6	5.6
8.0	1 497.0	0.45	7.50- 8.50	900.1	2 078.7	9.9
9.0	2 139.6	0.45	8.50- 9.50	1 268.9	3 347.6	15.9
10.0	2 870.3	0.44	9.50-10.50	1 633.8	4 981.4	23.7
11.0	3 531.9	0.41	10.50-11.50	1 896.8	6 878.1	32.7
12.0	3 989.3	0.35	11.50-12.50	1 985.3	8 863.4	42.1
13.0	4 172.2	0.29	12.50-13.50	1 899.6	10 763.0	51.1
14.0	4 195.0	0.23	13.50-14.50	1 717.7	12 480.7	59.3
15.0	4 200.0	0.19	14.50-15.50	1 514.3	13 995.0	66.5
16.0	4 200.0	0.16	15.50-16.50	1 312.6	15 307.6	72.7
17.0	4 200.0	0.13	16.50-17.50	1 121.6	16 429.3	78.0
18.0	4 200.0	0.11	17.50-18.50	945.7	17 375.0	82.5
19.0	4 200.0	0.09	18.50-19.50	787.3	18 162.3	86.3
20.0	4 200.0	0.08	19.50-20.50	647.6	18 809.9	89.3
21.0	4 200.0	0.07	20.50-21.50	526.5	19 336.4	91.8
22.0	4 200.0	0.06	21.50-22.50	423.3	19 759.7	93.8
23.0	4 200.0	0.05	22.50-23.50	336.6	20 096.4	95.4
24.0	4 200.0	0.05	23.50-24.50	264.8	20 361.2	96.7
25.0	4 200.0	0.04	24.50-25.50	206.0	20 567.2	97.7
26.0	4 165.0	0.04	25.50-26.50	157.2	20 724.4	98.4
27.0	4 039.0	0.03	26.50-27.50	116.3	20 840.7	99.0
28.0	3 834.0	0.03	27.50-28.50	83.7	20 924.5	99.4
29.0	3 586.0	0.02	28.50-29.50	58.5	20 982.9	99.7
30.0	3 212.0	0.02	29.50-30.50	38.9	21 021.9	99.8
31.0	2 729.0	0.01	30.50-31.50	24.5	21 046.4	100.0
32.0	2 315.0	0.01	31.50-32.50	9.3	21 055.6	100.0



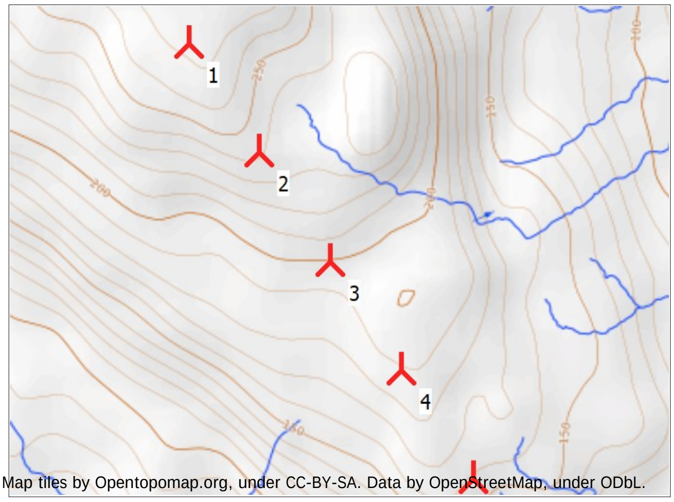


PARK - WTG distances

Calculation: 5 x V117 4p2 MW HH 96p5 m

WTG distances

	Z [m]	Nearest WTG	Z [m]	Horizontal distance [m]	Distance in rotor diameters
1	276.6	2	258.3	345	3.0
2	258.3	1	276.6	345	3.0
3	218.1	4	194.2	345	3.0
4	194.2	5	167.8	345	3.0
5	167.8	4	194.2	345	3.0
Min	167.8		167.8	345	3.0
Max	276.6		276.6	345	3.0



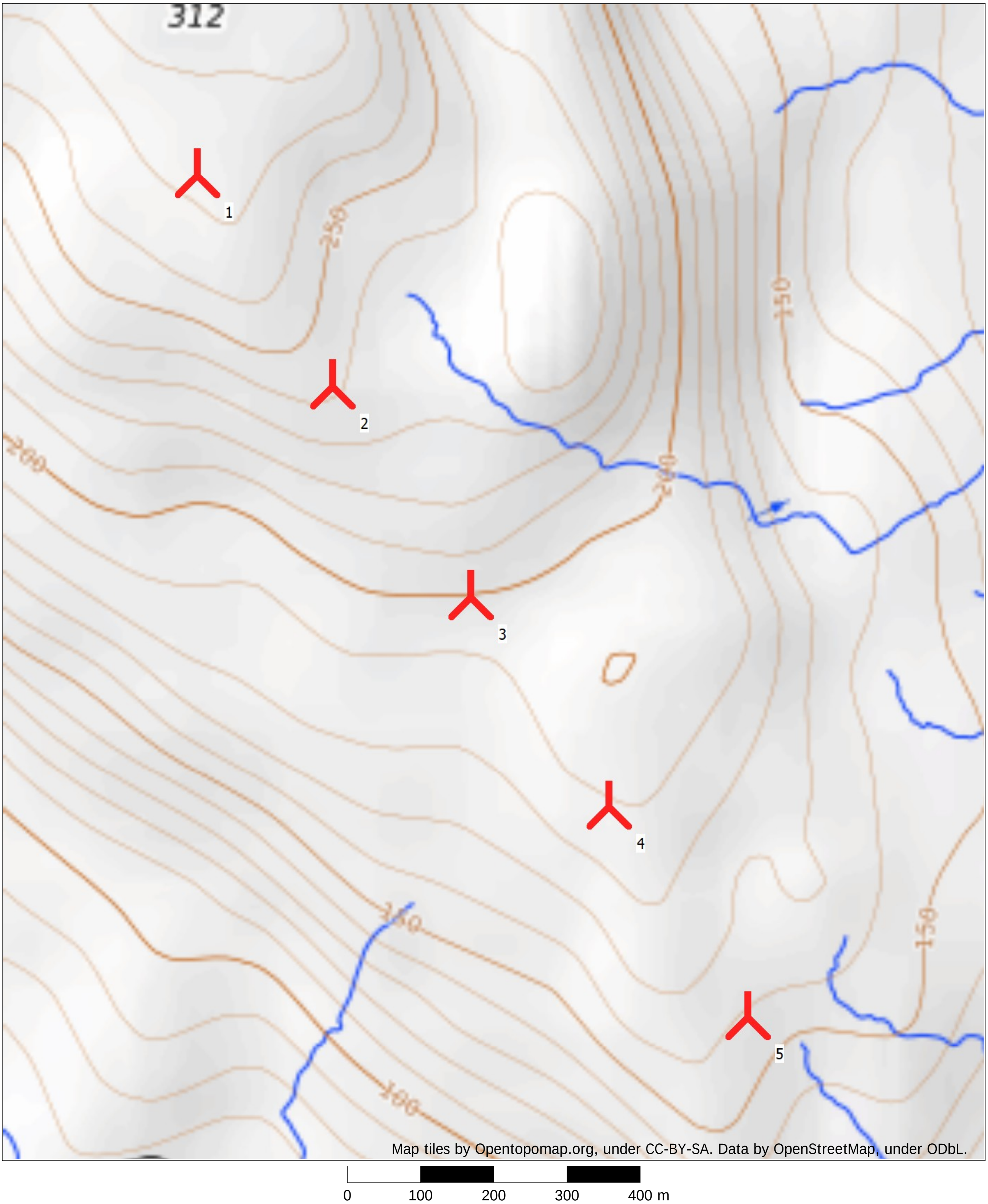
Scale 1:20 000

New WTG

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-01-12 11:28/3.5.552

PARK - Map

Calculation: 5 x V117 4p2 MW HH 96p5 m



Map: OpenTopoMap , Print scale 1:7 500, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

New WTG

Project:
Sandoy_uV_20181121

Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 13:07/3.5.552

PARK - Main Result

Calculation: 5 x E115 EP3 4p26 MW HH 77 m no HWO

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: 1.9°

Power curve correction method
New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>
Air density calculation method
Height dependent, temperature from climate station
Station: THORSHAVN V3 2014
Base temperature: 6.0 °C at 55.0 m
Base pressure: 1013.3 hPa at 0.0 m
Air density for Site center in key hub height: 207.5 m + 92.0 m = 1.226 kg/m³ -> 100.1 % of Std
Relative humidity: 0.0 %

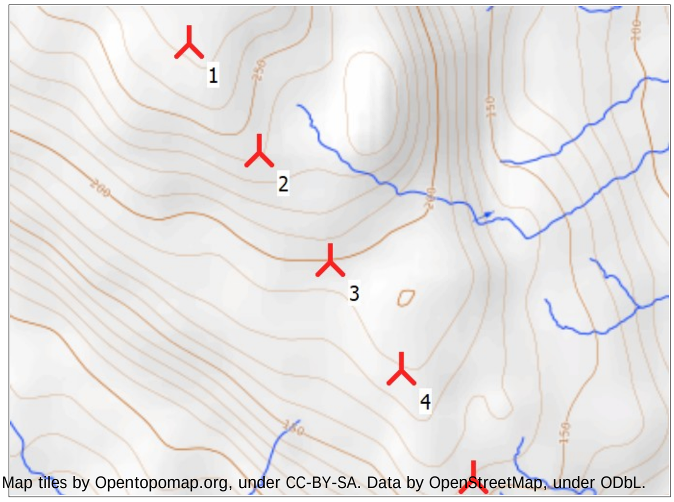
Wake Model Parameters

Terrain type	Wake decay constant
User defined	0.068

Omnidirectional displacement height from objects

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0.5	360.0	1.0	0.5	30.5	1.0



Scale 1:20 000

New WTG

Resource file(s)

L:\KUNDER\535_Energy_Directorate_FO\001_Klivalokshagi\Analyses\2021_11_Site_Suitability\04_WAsP\03_Wind_maps\Klivalokshagi_HH77p0m_corr_1.012.wrg

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Wake loss [%]	Specific results¤) Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	98 863.4	102 863.4	3.9	52.9	19 772.7	4 641	10.3

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 5 new WTGs with total 21.3 MW rated power

Links	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh/y]	Wake loss [%]	Free mean wind speed [m/s]
1 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	77.0	USER	Mode 00 -OM 0 s (4260 kW) no HWO	20 318.5	3.1	10.65
2 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	77.0	USER	Mode 00 -OM 0 s (4260 kW) no HWO	20 141.5	4.4	10.70
3 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	77.0	USER	Mode 00 -OM 0 s (4260 kW) no HWO	19 403.3	4.8	10.24
4 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	77.0	USER	Mode 00 -OM 0 s (4260 kW) no HWO	19 431.4	4.4	10.16
5 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	77.0	USER	Mode 00 -OM 0 s (4260 kW) no HWO	19 568.7	2.7	10.01

Annual Energy result includes shown losses. Additional losses and uncertainty must be considered for an investment decision.

WTG siting

	UTM (north)-WGS84 Zone: 29 Easting	Northing	Z [m]	Row data/Description
1 New	611 989	6 859 561	276.6	KLH201
2 New	612 188	6 859 278	258.3	KLH202
3 New	612 386	6 858 996	218.1	KLH203
4 New	612 584	6 858 713	194.2	KLH204
5 New	612 782	6 858 430	167.8	KLH205

Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 13:07/3.5.552

PARK - Power Curve Analysis

Calculation: 5 x E115 EP3 4p26 MW HH 77 m no HWOWTG: 1 - ENERCON E-115 EP3 E4 4260 115.7 !O!, Hub height: 77.0 m

Name: Mode 00 -OM 0 s (4260 kW) no HWO
Source: Mode 00 -OM 0 s (4260 kW)

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
2022-02-14	USER	2022-02-14	2022-02-14	25.0	Pitch	User defined	Variable	0.41

Created manually!!
Taken from the PC with storm control but capped at 25m/s and kept at rated power until 25 m/s.
Used in the Klivaløkshagi wind farm, Sandoy, Faroe Islands
Assignment no.: 52109455

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	5 462	8 716	12 082	15 242	18 020	20 321
ENERCON E-115 EP3 E4 4260 115.7 !O! Mode 00 -OM 0 s (4260 kW) no HWO	[MWh]	5 787	9 007	12 320	15 423	18 140	20 372
Check value	[%]	-6	-3	-2	-1	-1	0

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTGs performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see the windPRO manual.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement.

Power curve

Original data, Air density: 1.225 kg/m³

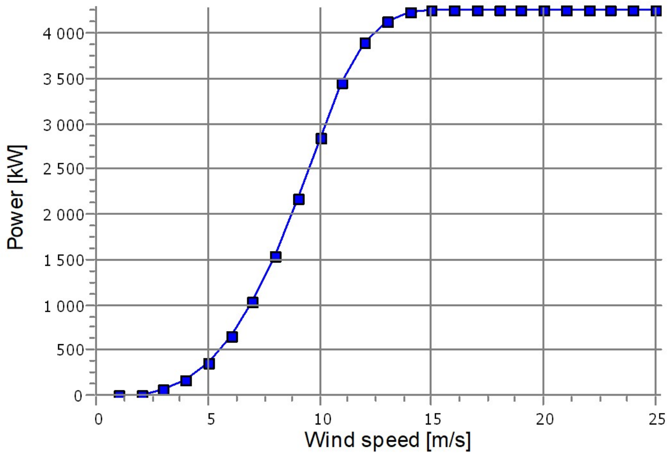
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
2.0	9.0	0.17	2.0	0.78
2.5	29.0	0.29	2.5	1.04
3.0	60.0	0.35	3.0	1.01
3.5	106.0	0.38	3.5	0.95
4.0	172.0	0.42	4.0	0.91
4.5	260.0	0.44	4.5	0.89
5.0	366.0	0.45	5.0	0.88
5.5	496.0	0.46	5.5	0.88
6.0	650.0	0.47	6.0	0.87
6.5	832.0	0.47	6.5	0.87
7.0	1 042.0	0.47	7.0	0.87
7.5	1 282.0	0.47	7.5	0.86
8.0	1 554.0	0.47	8.0	0.86
8.5	1 856.0	0.47	8.5	0.85
9.0	2 182.0	0.46	9.0	0.83
9.5	2 522.0	0.46	9.5	0.80
10.0	2 861.0	0.44	10.0	0.76
10.5	3 183.0	0.43	10.5	0.72
11.0	3 472.0	0.41	11.0	0.66
11.5	3 714.0	0.38	11.5	0.61
12.0	3 905.0	0.35	12.0	0.55
12.5	4 047.0	0.32	12.5	0.49
13.0	4 146.0	0.29	13.0	0.44
13.5	4 211.0	0.27	13.5	0.39
14.0	4 251.0	0.24	14.0	0.35
14.5	4 260.0	0.22	14.5	0.31
15.0	4 260.0	0.20	15.0	0.28
15.5	4 260.0	0.18	15.5	0.25
16.0	4 260.0	0.16	16.0	0.23
16.5	4 260.0	0.15	16.5	0.21
17.0	4 260.0	0.13	17.0	0.19
17.5	4 260.0	0.12	17.5	0.17
18.0	4 260.0	0.11	18.0	0.16
18.5	4 260.0	0.10	18.5	0.14
19.0	4 260.0	0.10	19.0	0.13
19.5	4 260.0	0.09	19.5	0.12
20.0	4 260.0	0.08	20.0	0.11
20.5	4 260.0	0.08	20.5	0.11
21.0	4 260.0	0.07	21.0	0.10
21.5	4 260.0	0.07	21.5	0.09
22.0	4 260.0	0.06	22.0	0.09
22.5	4 260.0	0.06	22.5	0.08
23.0	4 260.0	0.05	23.0	0.08
23.5	4 260.0	0.05	23.5	0.07
24.0	4 260.0	0.05	24.0	0.07
24.5	4 260.0	0.04	24.5	0.06
25.0	4 260.0	0.04	25.0	0.06

Power, Efficiency and energy vs. wind speed

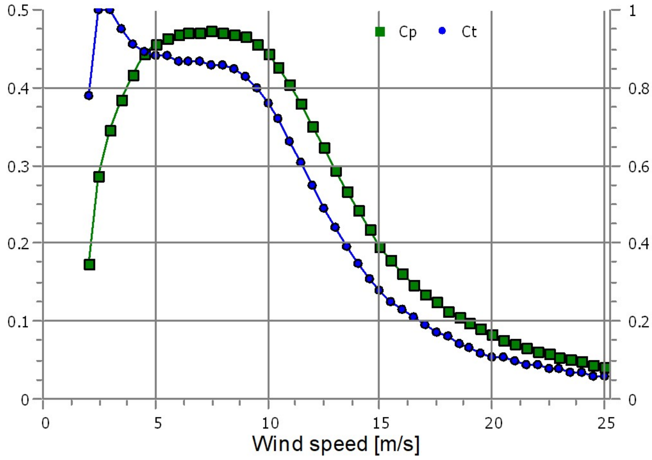
Data used in calculation, Air density: 1.219 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

Wind speed [m/s]	Power [kW]	Cp	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1.0	0.0	0.00	0.50- 1.50	0.0	0.0	0.0
2.0	8.9	0.17	1.50- 2.50	4.3	4.3	0.0
3.0	59.7	0.34	2.50- 3.50	25.1	29.4	0.1
4.0	171.1	0.42	3.50- 4.50	82.4	111.8	0.6
5.0	364.3	0.45	4.50- 5.50	194.2	306.0	1.5
6.0	647.0	0.47	5.50- 6.50	372.3	678.3	3.3
7.0	1 037.3	0.47	6.50- 7.50	622.3	1 300.6	6.4
8.0	1 546.9	0.47	7.50- 8.50	938.9	2 239.5	11.0
9.0	2 171.6	0.46	8.50- 9.50	1 294.0	3 533.5	17.4
10.0	2 846.9	0.44	9.50-10.50	1 625.2	5 158.7	25.4
11.0	3 456.2	0.41	10.50-11.50	1 853.2	7 011.9	34.5
12.0	3 891.9	0.35	11.50-12.50	1 928.9	8 940.7	44.0
13.0	4 138.5	0.29	12.50-13.50	1 863.0	10 803.8	53.2
14.0	4 247.7	0.24	13.50-14.50	1 703.9	12 507.6	61.6
15.0	4 260.0	0.20	14.50-15.50	1 501.9	14 009.5	68.9
16.0	4 260.0	0.16	15.50-16.50	1 295.3	15 304.8	75.3
17.0	4 260.0	0.14	16.50-17.50	1 101.3	16 406.1	80.7
18.0	4 260.0	0.11	17.50-18.50	924.0	17 330.2	85.3
19.0	4 260.0	0.10	18.50-19.50	765.6	18 095.7	89.1
20.0	4 260.0	0.08	19.50-20.50	626.7	18 722.5	92.1
21.0	4 260.0	0.07	20.50-21.50	507.2	19 229.7	94.6
22.0	4 260.0	0.06	21.50-22.50	405.9	19 635.5	96.6
23.0	4 260.0	0.05	22.50-23.50	321.3	19 956.8	98.2
24.0	4 260.0	0.05	23.50-24.50	251.6	20 208.4	99.5
25.0	4 260.0	0.04	24.50-25.50	110.1	20 318.5	100.0

Power curve
For air density: 1.219 kg/m³ and reference climate data



Cp and Ct curve
For air density: 1.219 kg/m³ and reference climate data



Project:
Sandoy_uV_20181121

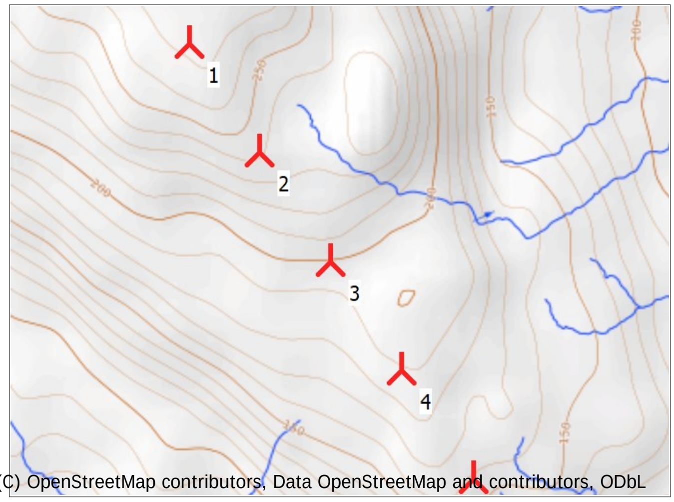
Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 13:07/3.5.552

PARK - WTG distances

Calculation: 5 x E115 EP3 4p26 MW HH 77 m no HWO

WTG distances

	Z	Nearest WTG	Z	Horizontal distance	Distance in rotor diameters
	[m]		[m]	[m]	
1	276.6	2	258.3	345	3.0
2	258.3	1	276.6	345	3.0
3	218.1	4	194.2	345	3.0
4	194.2	5	167.8	345	3.0
5	167.8	4	194.2	345	3.0
Min	167.8		167.8	345	3.0
Max	276.6		276.6	345	3.0



Scale 1:20 000

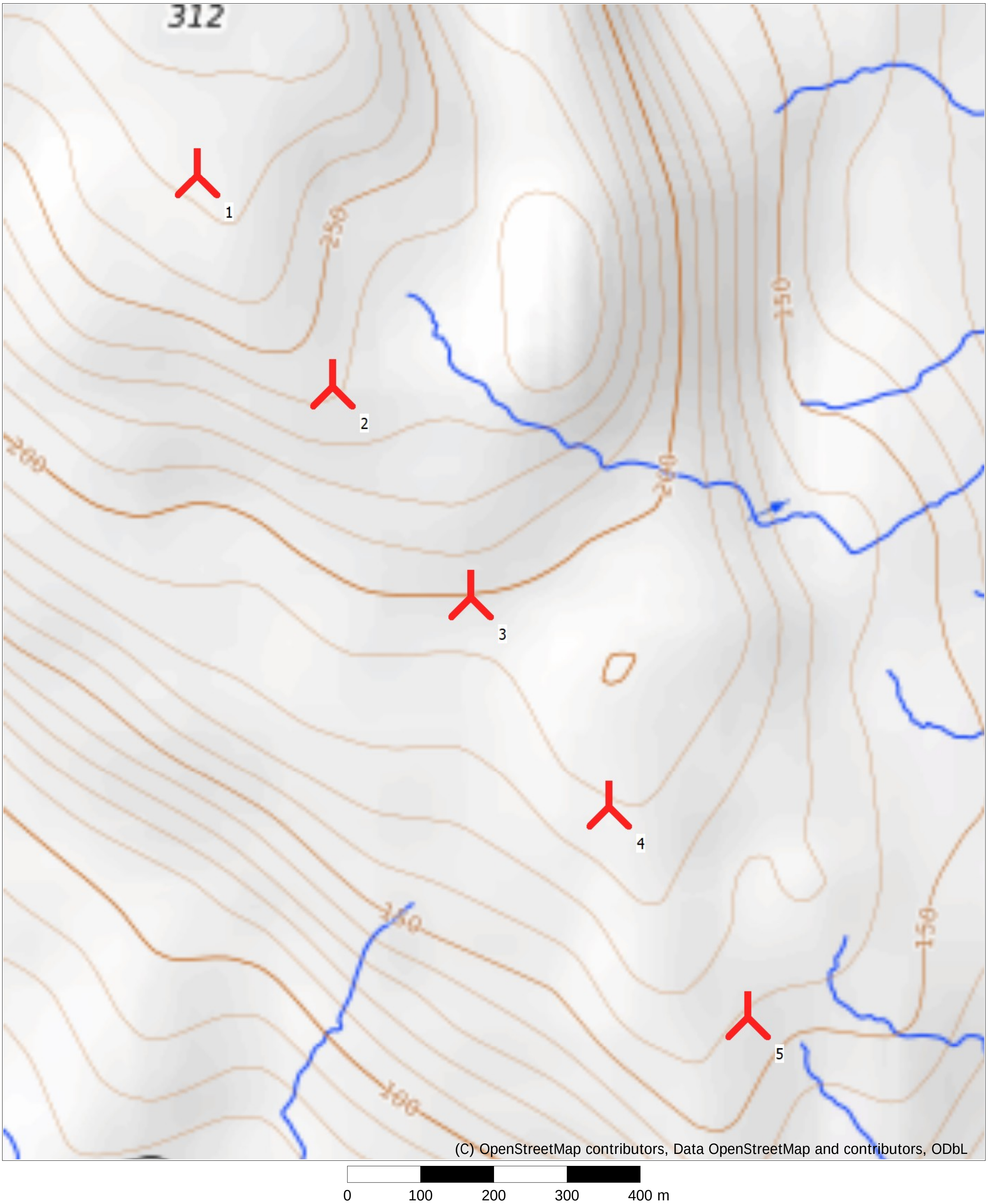
New WTG

Project:
Sandoy_uV_20181121

Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 13:07/3.5.552

PARK - Map

Calculation: 5 x E115 EP3 4p26 MW HH 77 m no HWO



Map: OpenTopoMap , Print scale 1:7 500, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

New WTG

Project:
Sandoy_uV_20181121

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-01-12 11:29/3.5.552

PARK - Main Result

Calculation: 5 x E115 EP3 4p26 MW HH 77 m

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: 1.9°

Power curve correction method
New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>
Air density calculation method
Height dependent, temperature from climate station
Station: THORSHAVN V3 2014
Base temperature: 6.0 °C at 55.0 m
Base pressure: 1013.3 hPa at 0.0 m
Air density for Site center in key hub height: 207.5 m + 92.0 m = 1.226 kg/m³ -> 100.1 % of Std
Relative humidity: 0.0 %

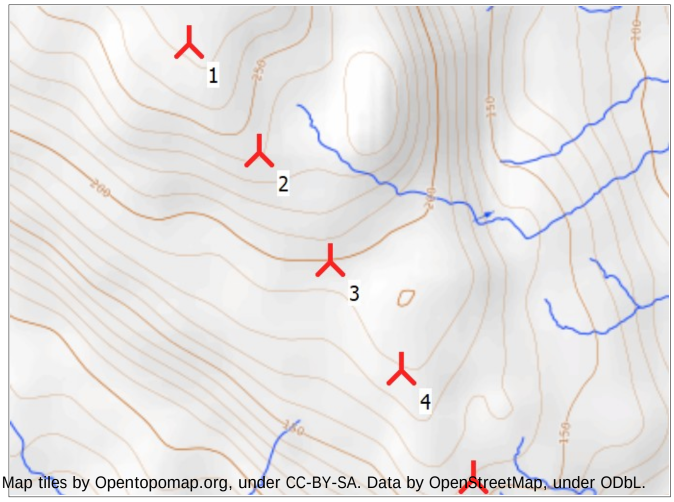
Wake Model Parameters

Terrain type	Wake decay constant
User defined	0.068

Omnidirectional displacement height from objects

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0.5	360.0	1.0	0.5	34.0	1.0



Scale 1:20 000

New WTG

Resource file(s)

L:\KUNDER\535_Energy_Directorate_FO\001_Klivalokshagi\Analyses\2021_11_Site_Suitability\04_WAsP\03_Wind_maps\Klivalokshagi_HH77p0m_corr_1.012.wrg

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Wake loss [%]	Specific results¤ Capacity factor [%]	Specific results¤ Mean WTG result [MWh/y]	Specific results¤ Full load hours [Hours/year]	Specific results¤ Mean wind speed @hub height [m/s]
Wind farm	100 832.5	104 834.8	3.8	54.0	20 166.5	4 734	10.3

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 5 new WTGs with total 21.3 MW rated power

Links	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh/y]	Wake loss [%]	Free mean wind speed [m/s]
1 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	77.0	USER	Mode 00 - OM 0 s (4260 kW)	20 803.1	3.1	10.65
2 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	77.0	USER	Mode 00 - OM 0 s (4260 kW)	20 642.8	4.3	10.70
3 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	77.0	USER	Mode 00 - OM 0 s (4260 kW)	19 768.8	4.7	10.24
4 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	77.0	USER	Mode 00 - OM 0 s (4260 kW)	19 764.9	4.3	10.16
5 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	77.0	USER	Mode 00 - OM 0 s (4260 kW)	19 852.9	2.7	10.01

Annual Energy result includes shown losses. Additional losses and uncertainty must be considered for an investment decision.

WTG siting

UTM (north)-WGS84 Zone: 29

	Easting	Northing	Z [m]	Row data/Description
1 New	611 989	6 859 561	276.6	KLH201
2 New	612 188	6 859 278	258.3	KLH202
3 New	612 386	6 858 996	218.1	KLH203
4 New	612 584	6 858 713	194.2	KLH204
5 New	612 782	6 858 430	167.8	KLH205

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-01-12 11:29/3.5.552

PARK - Power Curve Analysis

Calculation: 5 x E115 EP3 4p26 MW HH 77 mWTG: 1 - ENERCON E-115 EP3 E4 4260 115.7 !O!, Hub height: 77.0 m

Name: Mode 00 - OM 0 s (4260 kW)
Source: ENERCON GmbH

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
26.08.2021	USER	2021-09-01	2021-12-16	34.0	Pitch	User defined	Variable	0.41

D1018687_2.1_en_Operating Mode E-115 EP3 E4-4260 kW with TES.pdf

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	5 462	8 716	12 082	15 242	18 020	20 321
ENERCON E-115 EP3 E4 4260 115.7 !O! Mode 00 - OM 0 s (4260 kW)	[MWh]	5 787	9 007	12 321	15 438	18 211	20 587
Check value	[%]	-6	-3	-2	-1	-1	-1

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTGs performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see the windPRO manual.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement.

Power curve

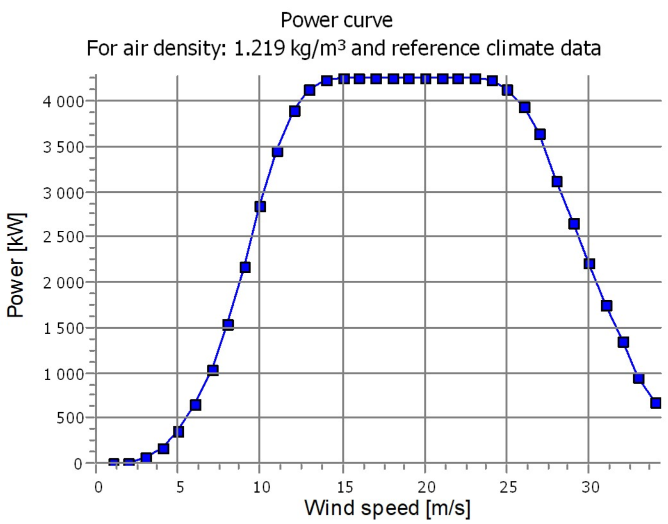
Original data, Air density: 1.225 kg/m³

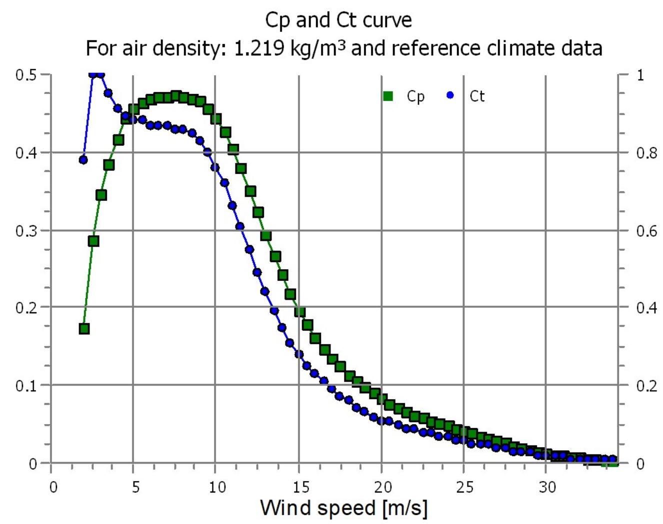
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
2.0	9.0	0.17	2.0	0.78
2.5	29.0	0.29	2.5	1.04
3.0	60.0	0.35	3.0	1.01
3.5	106.0	0.38	3.5	0.95
4.0	172.0	0.42	4.0	0.91
4.5	260.0	0.44	4.5	0.89
5.0	366.0	0.45	5.0	0.88
5.5	496.0	0.46	5.5	0.88
6.0	650.0	0.47	6.0	0.87
6.5	832.0	0.47	6.5	0.87
7.0	1 042.0	0.47	7.0	0.87
7.5	1 282.0	0.47	7.5	0.86
8.0	1 554.0	0.47	8.0	0.86
8.5	1 856.0	0.47	8.5	0.85
9.0	2 182.0	0.46	9.0	0.83
9.5	2 522.0	0.46	9.5	0.80
10.0	2 861.0	0.44	10.0	0.76
10.5	3 183.0	0.43	10.5	0.72
11.0	3 472.0	0.41	11.0	0.66
11.5	3 714.0	0.38	11.5	0.61
12.0	3 905.0	0.35	12.0	0.55
12.5	4 047.0	0.32	12.5	0.49
13.0	4 146.0	0.29	13.0	0.44
13.5	4 211.0	0.27	13.5	0.39
14.0	4 251.0	0.24	14.0	0.35
14.5	4 260.0	0.22	14.5	0.31
15.0	4 260.0	0.20	15.0	0.28
15.5	4 260.0	0.18	15.5	0.25
16.0	4 260.0	0.16	16.0	0.23
16.5	4 260.0	0.15	16.5	0.21
17.0	4 260.0	0.13	17.0	0.19
17.5	4 260.0	0.12	17.5	0.17
18.0	4 260.0	0.11	18.0	0.16
18.5	4 260.0	0.10	18.5	0.14
19.0	4 260.0	0.10	19.0	0.13
19.5	4 260.0	0.09	19.5	0.12
20.0	4 260.0	0.08	20.0	0.11
20.5	4 260.0	0.08	20.5	0.11
21.0	4 260.0	0.07	21.0	0.10
21.5	4 260.0	0.07	21.5	0.09
22.0	4 260.0	0.06	22.0	0.09
22.5	4 260.0	0.06	22.5	0.08
23.0	4 260.0	0.05	23.0	0.08
23.5	4 260.0	0.05	23.5	0.07
24.0	4 244.0	0.05	24.0	0.07
24.5	4 200.0	0.04	24.5	0.06
25.0	4 137.0	0.04	25.0	0.06
25.5	4 053.0	0.04	25.5	0.05
26.0	3 943.0	0.03	26.0	0.05
26.5	3 807.0	0.03	26.5	0.05
27.0	3 649.0	0.03	27.0	0.04
27.5	3 477.0	0.03	27.5	0.04
28.0	3 131.0	0.02	28.0	0.03
28.5	2 878.0	0.02	28.5	0.03
29.0	2 652.0	0.02	29.0	0.03
29.5	2 416.0	0.01	29.5	0.02
30.0	2 215.0	0.01	30.0	0.02
30.5	1 983.0	0.01	30.5	0.02
31.0	1 743.0	0.01	31.0	0.02
31.5	1 502.0	0.01	31.5	0.01
32.0	1 359.0	0.01	32.0	0.01
32.5	1 150.0	0.01	32.5	0.01
33.0	949.0	0.00	33.0	0.01
33.5	765.0	0.00	33.5	0.01
34.0	678.0	0.00	34.0	0.01

Power, Efficiency and energy vs. wind speed

Data used in calculation, Air density: 1.219 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

Wind speed [m/s]	Power [kW]	Cp	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1.0	0.0	0.00	0.50- 1.50	0.0	0.0	0.0
2.0	8.9	0.17	1.50- 2.50	4.3	4.3	0.0
3.0	59.7	0.34	2.50- 3.50	25.1	29.4	0.1
4.0	171.1	0.42	3.50- 4.50	82.5	111.9	0.5
5.0	364.3	0.45	4.50- 5.50	194.4	306.2	1.5
6.0	647.0	0.47	5.50- 6.50	372.5	678.8	3.3
7.0	1 037.3	0.47	6.50- 7.50	622.8	1 301.6	6.3
8.0	1 546.9	0.47	7.50- 8.50	939.5	2 241.1	10.8
9.0	2 171.6	0.46	8.50- 9.50	1 294.9	3 536.0	17.0
10.0	2 846.9	0.44	9.50-10.50	1 626.3	5 162.3	24.8
11.0	3 456.2	0.41	10.50-11.50	1 854.5	7 016.8	33.7
12.0	3 891.9	0.35	11.50-12.50	1 930.2	8 947.0	43.0
13.0	4 138.5	0.29	12.50-13.50	1 864.3	10 811.3	52.0
14.0	4 247.7	0.24	13.50-14.50	1 705.0	12 516.3	60.2
15.0	4 260.0	0.20	14.50-15.50	1 502.9	14 019.3	67.4
16.0	4 260.0	0.16	15.50-16.50	1 296.2	15 315.5	73.6
17.0	4 260.0	0.14	16.50-17.50	1 102.1	16 417.6	78.9
18.0	4 260.0	0.11	17.50-18.50	924.7	17 342.3	83.4
19.0	4 260.0	0.10	18.50-19.50	766.1	18 108.4	87.0
20.0	4 260.0	0.08	19.50-20.50	627.2	18 735.6	90.1
21.0	4 260.0	0.07	20.50-21.50	507.5	19 243.1	92.5
22.0	4 260.0	0.06	21.50-22.50	406.1	19 649.2	94.5
23.0	4 260.0	0.05	22.50-23.50	321.5	19 970.7	96.0
24.0	4 246.2	0.05	23.50-24.50	250.2	20 220.9	97.2
25.0	4 137.0	0.04	24.50-25.50	189.4	20 410.4	98.1
26.0	3 943.0	0.04	25.50-26.50	138.6	20 549.0	98.8
27.0	3 649.0	0.03	26.50-27.50	97.7	20 646.7	99.2
28.0	3 131.0	0.02	27.50-28.50	64.5	20 711.2	99.6
29.0	2 652.0	0.02	28.50-29.50	39.9	20 751.2	99.8
30.0	2 215.0	0.01	29.50-30.50	24.5	20 775.6	99.9
31.0	1 743.0	0.01	30.50-31.50	14.2	20 789.9	99.9
32.0	1 359.0	0.01	31.50-32.50	7.8	20 797.7	100.0
33.0	949.0	0.00	32.50-33.50	4.1	20 801.8	100.0
34.0	678.0	0.00	33.50-34.50	1.3	20 803.1	100.0





Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no

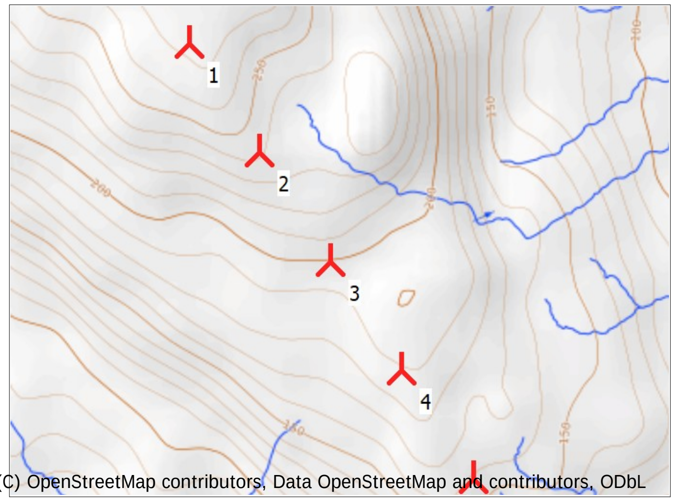
Calculated:
2022-01-12 11:29/3.5.552

PARK - WTG distances

Calculation: 5 x E115 EP3 4p26 MW HH 77 m

WTG distances

	Z [m]	Nearest WTG	Z [m]	Horizontal distance [m]	Distance in rotor diameters
1	276.6	2	258.3	345	3.0
2	258.3	1	276.6	345	3.0
3	218.1	4	194.2	345	3.0
4	194.2	5	167.8	345	3.0
5	167.8	4	194.2	345	3.0
Min	167.8		167.8	345	3.0
Max	276.6		276.6	345	3.0



(C) OpenStreetMap contributors, Data OpenStreetMap and contributors, ODbL

Scale 1:20 000

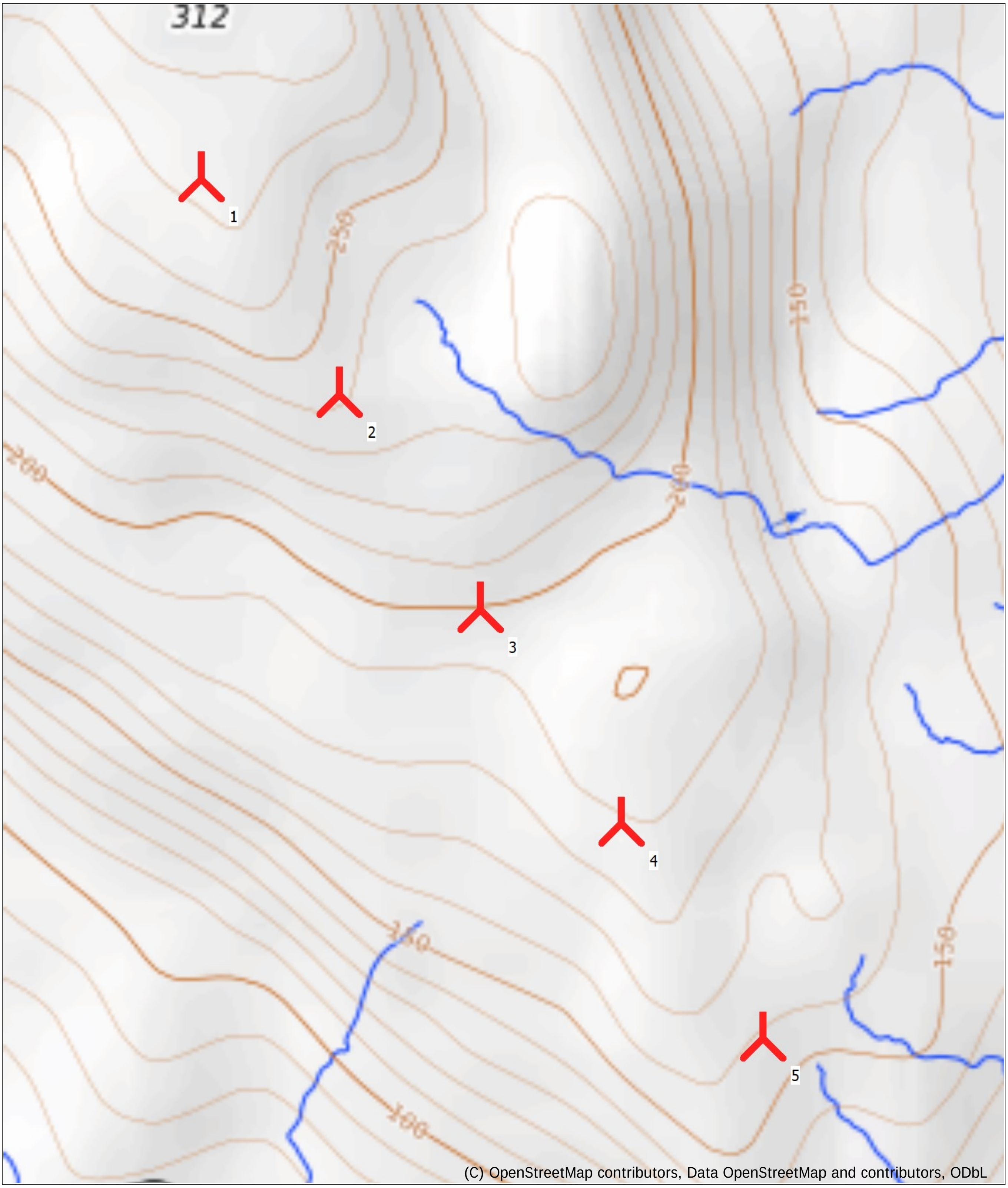
New WTG

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no

Calculated:
2022-01-12 11:29/3.5.552

PARK - Map

Calculation: 5 x E115 EP3 4p26 MW HH 77 m



0 100 200 300 400 m

Map: OpenTopoMap , Print scale 1:7 500, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

New WTG

PARK - Main Result

Calculation: 5 x E115 EP3 4p26 MW HH 92 m no HWO

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: 1.9°

Power curve correction method
New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>
Air density calculation method
Height dependent, temperature from climate station
Station: THORSHAVN V3 2014
Base temperature: 6.0 °C at 55.0 m
Base pressure: 1013.3 hPa at 0.0 m
Air density for Site center in key hub height: 207.5 m + 92.0 m = 1.226 kg/m³ -> 100.1 % of Std
Relative humidity: 0.0 %

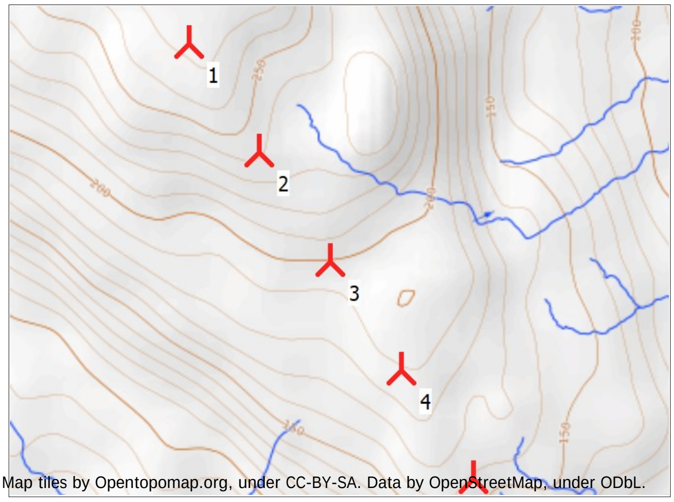
Wake Model Parameters

Terrain type	Wake decay constant
User defined	0.068

Omnidirectional displacement height from objects

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0.5	360.0	1.0	0.5	30.5	1.0



Scale 1:20 000

New WTG

Resource file(s)

L:\KUNDER\535_Energy_Directorate_FO\001_Klivalokshagi\Analyses\2021_11_Site_Suitability\04_WAsP\03_Wind_maps\Klivalokshagi_HH92p0m_corr_1.012.wrg

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Wake loss [%]	Specific results¤) Capacity factor [%]	Specific results¤) Mean WTG result [MWh/y]	Specific results¤) Full load hours [Hours/year]	Specific results¤) Mean wind speed @hub height [m/s]
Wind farm	99 969.2	103 954.9	3.8	53.5	19 993.8	4 693	10.5

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 5 new WTGs with total 21.3 MW rated power

Links	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh/y]	Wake loss [%]	Free mean wind speed [m/s]
1 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	92.0	USER	Mode 00 -OM 0 s (4260 kW) no HWO	20 534.7	3.1	10.78
2 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	92.0	USER	Mode 00 -OM 0 s (4260 kW) no HWO	20 257.4	4.3	10.76
3 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	92.0	USER	Mode 00 -OM 0 s (4260 kW) no HWO	19 688.1	4.7	10.38
4 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	92.0	USER	Mode 00 -OM 0 s (4260 kW) no HWO	19 656.2	4.3	10.29
5 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	92.0	USER	Mode 00 -OM 0 s (4260 kW) no HWO	19 832.9	2.7	10.15

Annual Energy result includes shown losses. Additional losses and uncertainty must be considered for an investment decision.

WTG siting

	UTM (north)-WGS84 Zone: 29 Easting	Northing	Z [m]	Row data/Description
1 New	611 989	6 859 561	276.6	KLH201
2 New	612 188	6 859 278	258.3	KLH202
3 New	612 386	6 858 996	218.1	KLH203
4 New	612 584	6 858 713	194.2	KLH204
5 New	612 782	6 858 430	167.8	KLH205

Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 13:09/3.5.552

PARK - Power Curve Analysis

Calculation: 5 x E115 EP3 4p26 MW HH 92 m no HWOWTG: 1 - ENERCON E-115 EP3 E4 4260 115.7 !O!, Hub height: 92.0 m

Name: Mode 00 -OM 0 s (4260 kW) no HWO
Source: Mode 00 -OM 0 s (4260 kW)

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
2022-02-14	USER	2022-02-14	2022-02-14	25.0	Pitch	User defined	Variable	0.41

Created manually!!
Taken from the PC with storm control but capped at 25m/s and kept at rated power until 25 m/s.
Used in the Klivaløkshagi wind farm, Sandoy, Faroe Islands
Assignment no.: 52109455

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	5 462	8 716	12 082	15 242	18 020	20 321
ENERCON E-115 EP3 E4 4260 115.7 !O! Mode 00 -OM 0 s (4260 kW) no HWO	[MWh]	5 787	9 007	12 320	15 423	18 140	20 372
Check value	[%]	-6	-3	-2	-1	-1	0

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTGs performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see the windPRO manual.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement.

Power curve

Original data, Air density: 1.225 kg/m³

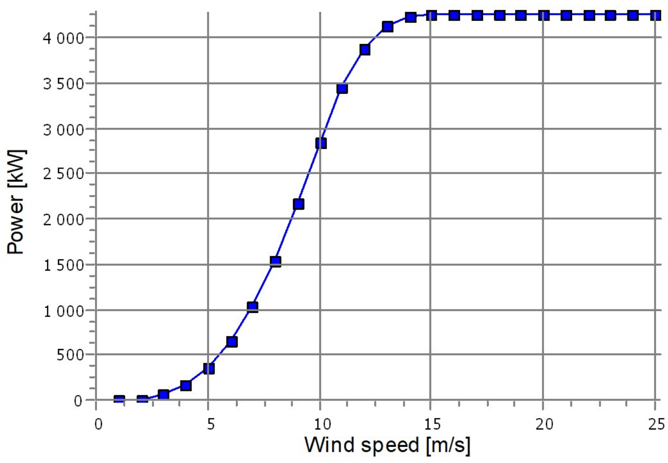
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
2.0	9.0	0.17	2.0	0.78
2.5	29.0	0.29	2.5	1.04
3.0	60.0	0.35	3.0	1.01
3.5	106.0	0.38	3.5	0.95
4.0	172.0	0.42	4.0	0.91
4.5	260.0	0.44	4.5	0.89
5.0	366.0	0.45	5.0	0.88
5.5	496.0	0.46	5.5	0.88
6.0	650.0	0.47	6.0	0.87
6.5	832.0	0.47	6.5	0.87
7.0	1 042.0	0.47	7.0	0.87
7.5	1 282.0	0.47	7.5	0.86
8.0	1 554.0	0.47	8.0	0.86
8.5	1 856.0	0.47	8.5	0.85
9.0	2 182.0	0.46	9.0	0.83
9.5	2 522.0	0.46	9.5	0.80
10.0	2 861.0	0.44	10.0	0.76
10.5	3 183.0	0.43	10.5	0.72
11.0	3 472.0	0.41	11.0	0.66
11.5	3 714.0	0.38	11.5	0.61
12.0	3 905.0	0.35	12.0	0.55
12.5	4 047.0	0.32	12.5	0.49
13.0	4 146.0	0.29	13.0	0.44
13.5	4 211.0	0.27	13.5	0.39
14.0	4 251.0	0.24	14.0	0.35
14.5	4 260.0	0.22	14.5	0.31
15.0	4 260.0	0.20	15.0	0.28
15.5	4 260.0	0.18	15.5	0.25
16.0	4 260.0	0.16	16.0	0.23
16.5	4 260.0	0.15	16.5	0.21
17.0	4 260.0	0.13	17.0	0.19
17.5	4 260.0	0.12	17.5	0.17
18.0	4 260.0	0.11	18.0	0.16
18.5	4 260.0	0.10	18.5	0.14
19.0	4 260.0	0.10	19.0	0.13
19.5	4 260.0	0.09	19.5	0.12
20.0	4 260.0	0.08	20.0	0.11
20.5	4 260.0	0.08	20.5	0.11
21.0	4 260.0	0.07	21.0	0.10
21.5	4 260.0	0.07	21.5	0.09
22.0	4 260.0	0.06	22.0	0.09
22.5	4 260.0	0.06	22.5	0.08
23.0	4 260.0	0.05	23.0	0.08
23.5	4 260.0	0.05	23.5	0.07
24.0	4 260.0	0.05	24.0	0.07
24.5	4 260.0	0.04	24.5	0.06
25.0	4 260.0	0.04	25.0	0.06

Power, Efficiency and energy vs. wind speed

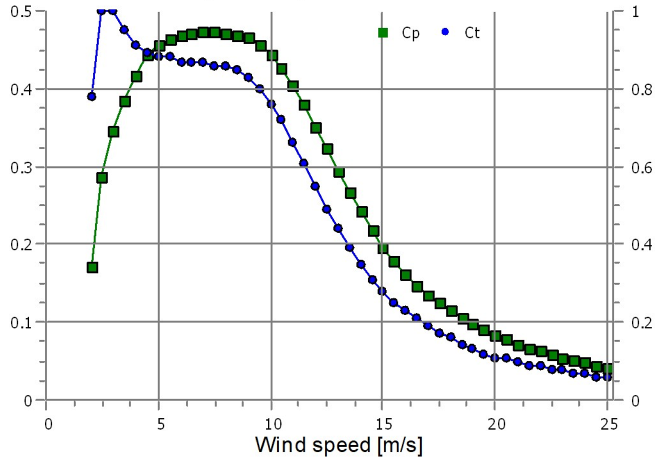
Data used in calculation, Air density: 1.217 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

Wind speed [m/s]	Power [kW]	Cp	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1.0	0.0	0.00	0.50- 1.50	0.0	0.0	0.0
2.0	8.8	0.17	1.50- 2.50	4.2	4.2	0.0
3.0	59.6	0.34	2.50- 3.50	24.5	28.7	0.1
4.0	170.9	0.42	3.50- 4.50	80.4	109.1	0.5
5.0	363.7	0.45	4.50- 5.50	190.0	299.1	1.5
6.0	646.1	0.47	5.50- 6.50	365.1	664.2	3.2
7.0	1 035.7	0.47	6.50- 7.50	612.0	1 276.2	6.2
8.0	1 544.6	0.47	7.50- 8.50	926.2	2 202.4	10.7
9.0	2 168.3	0.46	8.50- 9.50	1 280.9	3 483.3	17.0
10.0	2 842.5	0.44	9.50-10.50	1 614.8	5 098.1	24.8
11.0	3 451.1	0.41	10.50-11.50	1 849.1	6 947.2	33.8
12.0	3 887.8	0.35	11.50-12.50	1 933.3	8 880.5	43.2
13.0	4 136.1	0.29	12.50-13.50	1 876.3	10 756.7	52.4
14.0	4 246.7	0.24	13.50-14.50	1 724.3	12 481.1	60.8
15.0	4 260.0	0.20	14.50-15.50	1 527.1	14 008.2	68.2
16.0	4 260.0	0.16	15.50-16.50	1 323.1	15 331.3	74.7
17.0	4 260.0	0.14	16.50-17.50	1 130.1	16 461.4	80.2
18.0	4 260.0	0.11	17.50-18.50	952.4	17 413.8	84.8
19.0	4 260.0	0.10	18.50-19.50	792.6	18 206.4	88.7
20.0	4 260.0	0.08	19.50-20.50	651.7	18 858.1	91.8
21.0	4 260.0	0.07	20.50-21.50	529.7	19 387.8	94.4
22.0	4 260.0	0.06	21.50-22.50	425.7	19 813.4	96.5
23.0	4 260.0	0.05	22.50-23.50	338.4	20 151.8	98.1
24.0	4 260.0	0.05	23.50-24.50	266.1	20 417.9	99.4
25.0	4 260.0	0.04	24.50-25.50	116.8	20 534.7	100.0

Power curve
For air density: 1.217 kg/m³ and reference climate data



Cp and Ct curve
For air density: 1.217 kg/m³ and reference climate data



Project:
Sandoy_uV_20181121

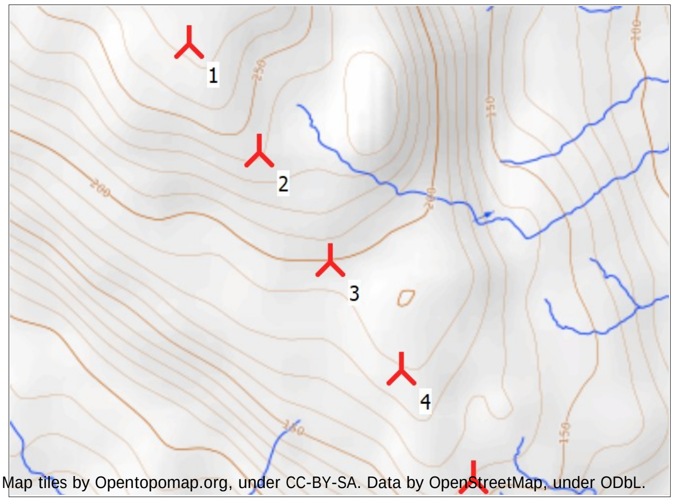
Licensed user:
Norconsult AS
Postboks 8984
NO-7439 Trondheim
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-02-14 13:09/3.5.552

PARK - WTG distances

Calculation: 5 x E115 EP3 4p26 MW HH 92 m no HWO

WTG distances

	Z	Nearest WTG	Z	Horizontal distance	Distance in rotor diameters
	[m]		[m]	[m]	
1	276.6	2	258.3	345	3.0
2	258.3	1	276.6	345	3.0
3	218.1	4	194.2	345	3.0
4	194.2	5	167.8	345	3.0
5	167.8	4	194.2	345	3.0
Min	167.8		167.8	345	3.0
Max	276.6		276.6	345	3.0

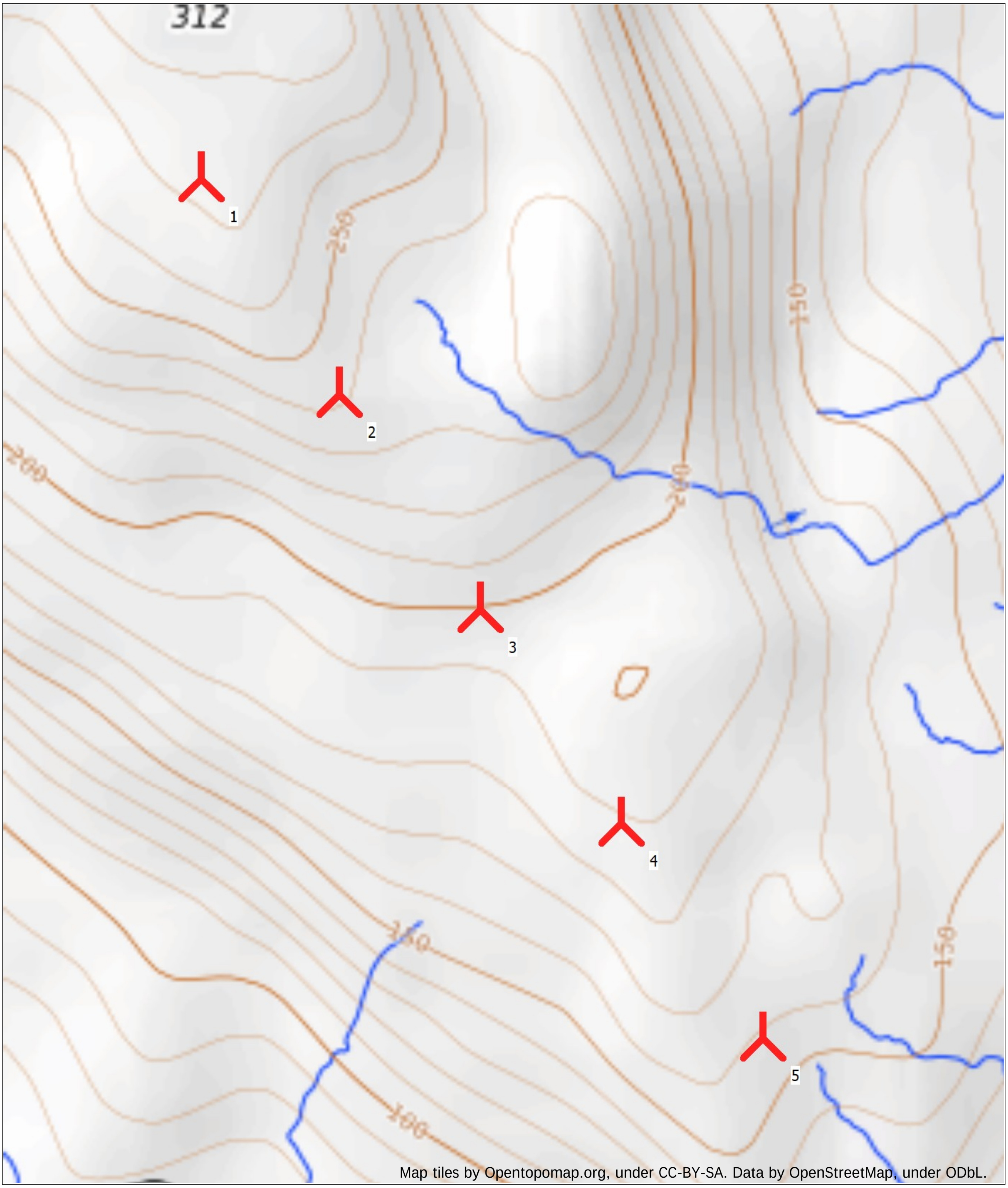


Scale 1:20 000

New WTG

PARK - Map

Calculation: 5 x E115 EP3 4p26 MW HH 92 m no HWO



0 100 200 300 400 m

Map: OpenTopoMap , Print scale 1:7 500, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

⅄ New WTG

Project:
Sandoy_uV_20181121

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-01-12 11:27/3.5.552

PARK - Main Result

Calculation: 5 x E115 EP3 4p26 MW HH 92 m

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: 1.9°

Power curve correction method
New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>
Air density calculation method
Height dependent, temperature from climate station
Station: THORSHAVN V3 2014
Base temperature: 6.0 °C at 55.0 m
Base pressure: 1013.3 hPa at 0.0 m
Air density for Site center in key hub height: 207.5 m + 92.0 m = 1.226 kg/m³ -> 100.1 % of Std
Relative humidity: 0.0 %

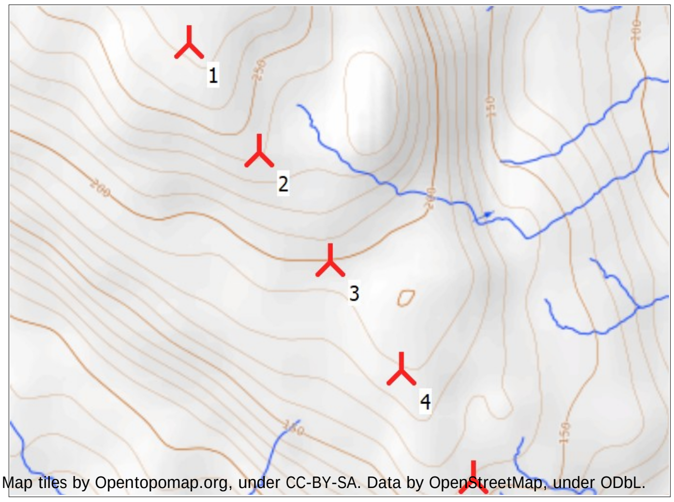
Wake Model Parameters

Terrain type	Wake decay constant
User defined	0.068

Omnidirectional displacement height from objects

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0.5	360.0	1.0	0.5	34.0	1.0



Scale 1:20 000

New WTG

Resource file(s)

L:\KUNDER\535_Energy_Directorate_FO\001_Klivalokshagi\Analyses\2021_11_Site_Suitability\04_WAsP\03_Wind_maps\Klivalokshagi_HH92p0m_corr_1.012.wrg

Calculated Annual Energy for Wind Farm

				Specific results¤)			
WTG combination	Result PARK [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Wake loss [%]	Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	102 078.9	106 067.1	3.8	54.7	20 415.8	4 792	10.5

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 5 new WTGs with total 21.3 MW rated power

	WTG type						Power curve		Annual Energy		
Links	Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Creator	Name	Result [MWh/y]	Wake loss [%]	Free mean wind speed [m/s]
1 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	92.0	USER	Mode 00 - OM 0 s (4260 kW)	21 054.2	3.0	10.78
2 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	92.0	USER	Mode 00 - OM 0 s (4260 kW)	20 774.8	4.2	10.76
3 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	92.0	USER	Mode 00 - OM 0 s (4260 kW)	20 083.7	4.6	10.38
4 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	92.0	USER	Mode 00 - OM 0 s (4260 kW)	20 019.1	4.3	10.29
5 A	Yes	ENERCON	E-115 EP3 E4-4 260	4 260	115.7	92.0	USER	Mode 00 - OM 0 s (4260 kW)	20 147.2	2.6	10.15

Annual Energy result includes shown losses. Additional losses and uncertainty must be considered for an investment decision.

WTG siting

	UTM (north)-WGS84 Zone: 29			
	Easting	Northing	Z [m]	Row data/Description
1 New	611 989	6 859 561	276.6	KLH201
2 New	612 188	6 859 278	258.3	KLH202
3 New	612 386	6 858 996	218.1	KLH203
4 New	612 584	6 858 713	194.2	KLH204
5 New	612 782	6 858 430	167.8	KLH205

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-01-12 11:27/3.5.552

PARK - Power Curve Analysis

Calculation: 5 x E115 EP3 4p26 MW HH 92 mWTG: 1 - ENERCON E-115 EP3 E4 4260 115.7 !O!, Hub height: 92.0 m

Name: Mode 00 - OM 0 s (4260 kW)
Source: ENERCON GmbH

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
26.08.2021	USER	2021-09-01	2021-12-16	34.0	Pitch	User defined	Variable	0.41

D1018687_2.1_en_Operating Mode E-115 EP3 E4-4260 kW with TES.pdf

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	5 462	8 716	12 082	15 242	18 020	20 321
ENERCON E-115 EP3 E4 4260 115.7 !O! Mode 00 - OM 0 s (4260 kW)	[MWh]	5 787	9 007	12 321	15 438	18 211	20 587
Check value	[%]	-6	-3	-2	-1	-1	-1

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTGs performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see the windPRO manual.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement.

Power curve

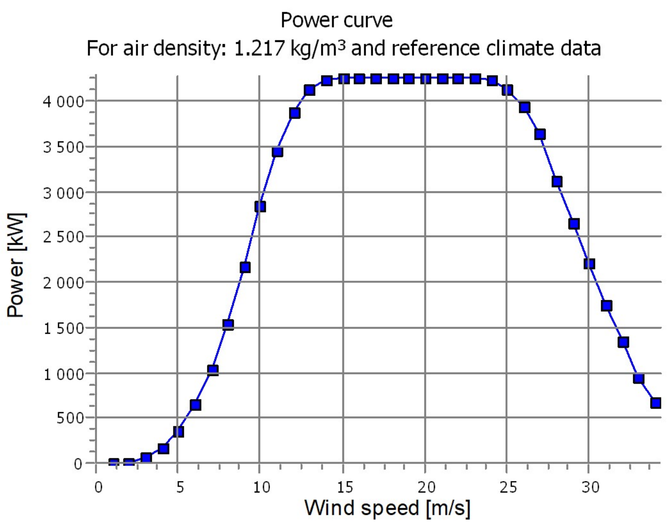
Original data, Air density: 1.225 kg/m³

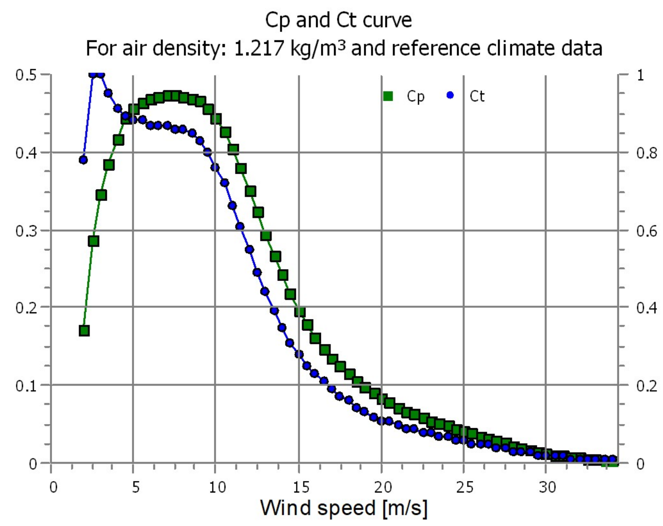
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
2.0	9.0	0.17	2.0	0.78
2.5	29.0	0.29	2.5	1.04
3.0	60.0	0.35	3.0	1.01
3.5	106.0	0.38	3.5	0.95
4.0	172.0	0.42	4.0	0.91
4.5	260.0	0.44	4.5	0.89
5.0	366.0	0.45	5.0	0.88
5.5	496.0	0.46	5.5	0.88
6.0	650.0	0.47	6.0	0.87
6.5	832.0	0.47	6.5	0.87
7.0	1 042.0	0.47	7.0	0.87
7.5	1 282.0	0.47	7.5	0.86
8.0	1 554.0	0.47	8.0	0.86
8.5	1 856.0	0.47	8.5	0.85
9.0	2 182.0	0.46	9.0	0.83
9.5	2 522.0	0.46	9.5	0.80
10.0	2 861.0	0.44	10.0	0.76
10.5	3 183.0	0.43	10.5	0.72
11.0	3 472.0	0.41	11.0	0.66
11.5	3 714.0	0.38	11.5	0.61
12.0	3 905.0	0.35	12.0	0.55
12.5	4 047.0	0.32	12.5	0.49
13.0	4 146.0	0.29	13.0	0.44
13.5	4 211.0	0.27	13.5	0.39
14.0	4 251.0	0.24	14.0	0.35
14.5	4 260.0	0.22	14.5	0.31
15.0	4 260.0	0.20	15.0	0.28
15.5	4 260.0	0.18	15.5	0.25
16.0	4 260.0	0.16	16.0	0.23
16.5	4 260.0	0.15	16.5	0.21
17.0	4 260.0	0.13	17.0	0.19
17.5	4 260.0	0.12	17.5	0.17
18.0	4 260.0	0.11	18.0	0.16
18.5	4 260.0	0.10	18.5	0.14
19.0	4 260.0	0.10	19.0	0.13
19.5	4 260.0	0.09	19.5	0.12
20.0	4 260.0	0.08	20.0	0.11
20.5	4 260.0	0.08	20.5	0.11
21.0	4 260.0	0.07	21.0	0.10
21.5	4 260.0	0.07	21.5	0.09
22.0	4 260.0	0.06	22.0	0.09
22.5	4 260.0	0.06	22.5	0.08
23.0	4 260.0	0.05	23.0	0.08
23.5	4 260.0	0.05	23.5	0.07
24.0	4 244.0	0.05	24.0	0.07
24.5	4 200.0	0.04	24.5	0.06
25.0	4 137.0	0.04	25.0	0.06
25.5	4 053.0	0.04	25.5	0.05
26.0	3 943.0	0.03	26.0	0.05
26.5	3 807.0	0.03	26.5	0.05
27.0	3 649.0	0.03	27.0	0.04
27.5	3 477.0	0.03	27.5	0.04
28.0	3 131.0	0.02	28.0	0.03
28.5	2 878.0	0.02	28.5	0.03
29.0	2 652.0	0.02	29.0	0.03
29.5	2 416.0	0.01	29.5	0.02
30.0	2 215.0	0.01	30.0	0.02
30.5	1 983.0	0.01	30.5	0.02
31.0	1 743.0	0.01	31.0	0.02
31.5	1 502.0	0.01	31.5	0.01
32.0	1 359.0	0.01	32.0	0.01
32.5	1 150.0	0.01	32.5	0.01
33.0	949.0	0.00	33.0	0.01
33.5	765.0	0.00	33.5	0.01
34.0	678.0	0.00	34.0	0.01

Power, Efficiency and energy vs. wind speed

Data used in calculation, Air density: 1.217 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

Wind speed [m/s]	Power [kW]	Cp	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1.0	0.0	0.00	0.50- 1.50	0.0	0.0	0.0
2.0	8.8	0.17	1.50- 2.50	4.2	4.2	0.0
3.0	59.6	0.34	2.50- 3.50	24.5	28.7	0.1
4.0	170.9	0.42	3.50- 4.50	80.5	109.2	0.5
5.0	363.7	0.45	4.50- 5.50	190.1	299.3	1.4
6.0	646.1	0.47	5.50- 6.50	365.3	664.7	3.2
7.0	1 035.7	0.47	6.50- 7.50	612.5	1 277.1	6.1
8.0	1 544.6	0.47	7.50- 8.50	926.9	2 204.0	10.5
9.0	2 168.3	0.46	8.50- 9.50	1 281.9	3 485.8	16.6
10.0	2 842.5	0.44	9.50-10.50	1 616.0	5 101.9	24.2
11.0	3 451.1	0.41	10.50-11.50	1 850.4	6 952.3	33.0
12.0	3 887.8	0.35	11.50-12.50	1 934.7	8 887.0	42.2
13.0	4 136.1	0.29	12.50-13.50	1 877.6	10 764.6	51.1
14.0	4 246.7	0.24	13.50-14.50	1 725.6	12 490.2	59.3
15.0	4 260.0	0.20	14.50-15.50	1 528.2	14 018.4	66.6
16.0	4 260.0	0.16	15.50-16.50	1 324.1	15 342.5	72.9
17.0	4 260.0	0.14	16.50-17.50	1 130.9	16 473.4	78.2
18.0	4 260.0	0.11	17.50-18.50	953.1	17 426.5	82.8
19.0	4 260.0	0.10	18.50-19.50	793.2	18 219.7	86.5
20.0	4 260.0	0.08	19.50-20.50	652.2	18 871.9	89.6
21.0	4 260.0	0.07	20.50-21.50	530.0	19 401.9	92.2
22.0	4 260.0	0.06	21.50-22.50	426.0	19 827.9	94.2
23.0	4 260.0	0.05	22.50-23.50	338.6	20 166.5	95.8
24.0	4 247.0	0.05	23.50-24.50	264.7	20 431.2	97.0
25.0	4 137.0	0.04	24.50-25.50	201.2	20 632.4	98.0
26.0	3 943.0	0.04	25.50-26.50	147.9	20 780.3	98.7
27.0	3 649.0	0.03	26.50-27.50	104.7	20 885.0	99.2
28.0	3 131.0	0.02	27.50-28.50	69.4	20 954.4	99.5
29.0	2 652.0	0.02	28.50-29.50	43.2	20 997.5	99.7
30.0	2 215.0	0.01	29.50-30.50	26.6	21 024.1	99.9
31.0	1 743.0	0.01	30.50-31.50	15.5	21 039.7	99.9
32.0	1 359.0	0.01	31.50-32.50	8.6	21 048.2	100.0
33.0	949.0	0.00	32.50-33.50	4.5	21 052.7	100.0
34.0	678.0	0.00	33.50-34.50	1.4	21 054.2	100.0





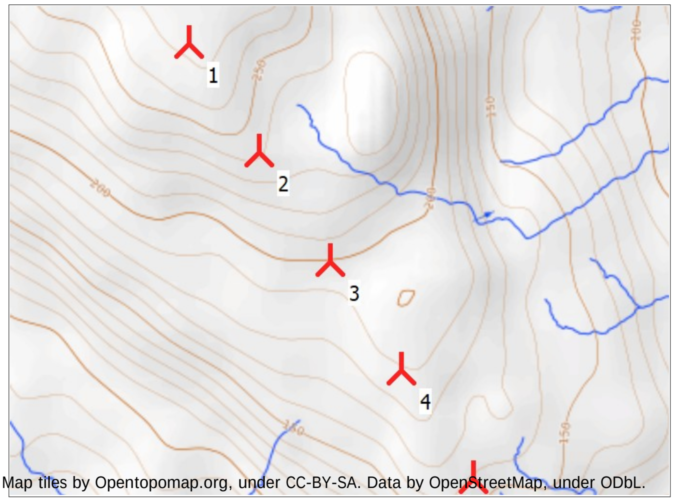
Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no

PARK - WTG distances

Calculation: 5 x E115 EP3 4p26 MW HH 92 m

WTG distances

	Z	Nearest WTG	Z	Horizontal distance	Distance in rotor diameters
	[m]		[m]	[m]	
1	276.6	2	258.3	345	3.0
2	258.3	1	276.6	345	3.0
3	218.1	4	194.2	345	3.0
4	194.2	5	167.8	345	3.0
5	167.8	4	194.2	345	3.0
Min	167.8		167.8	345	3.0
Max	276.6		276.6	345	3.0



Scale 1:20 000

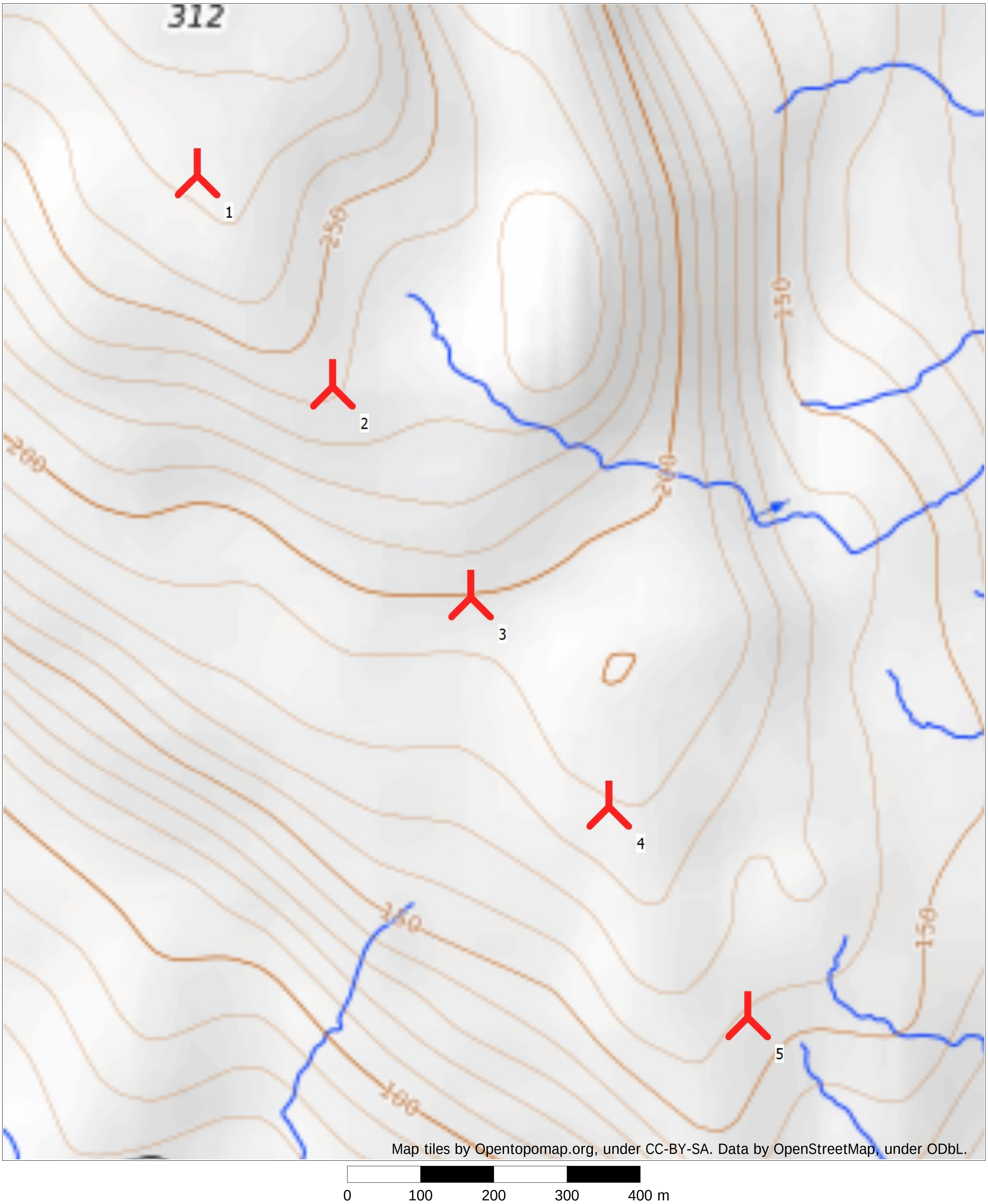
New WTG

Project:
Sandoy_uV_20181121

Licensed user:
Kjeller Vindteknikk
Tærudgata 16
NO-2400 Lillestrøm
(+47) 480 50 480
Ove Undheim / ove.undheim@vindteknikk.no
Calculated:
2022-01-12 11:27/3.5.552

PARK - Map

Calculation: 5 x E115 EP3 4p26 MW HH 92 m



Map: OpenTopoMap , Print scale 1:7 500, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

New WTG