REGIONE PUGLIA
CITTA' METROPOLITANA DI BARI
COMUNE DI RUVO DI PUGLIA

IMPIANTO EOLICO COMPOSTO DA 8 WTG DA 7.2 MW, SISTEMA DI ACCUMULO ELETTROCHIMICO DELL'ENERGIA ELETTRICA E OPERE DI CONNESSIONE ALLA RETE

R39

ANALISI ANEMOLOGICA

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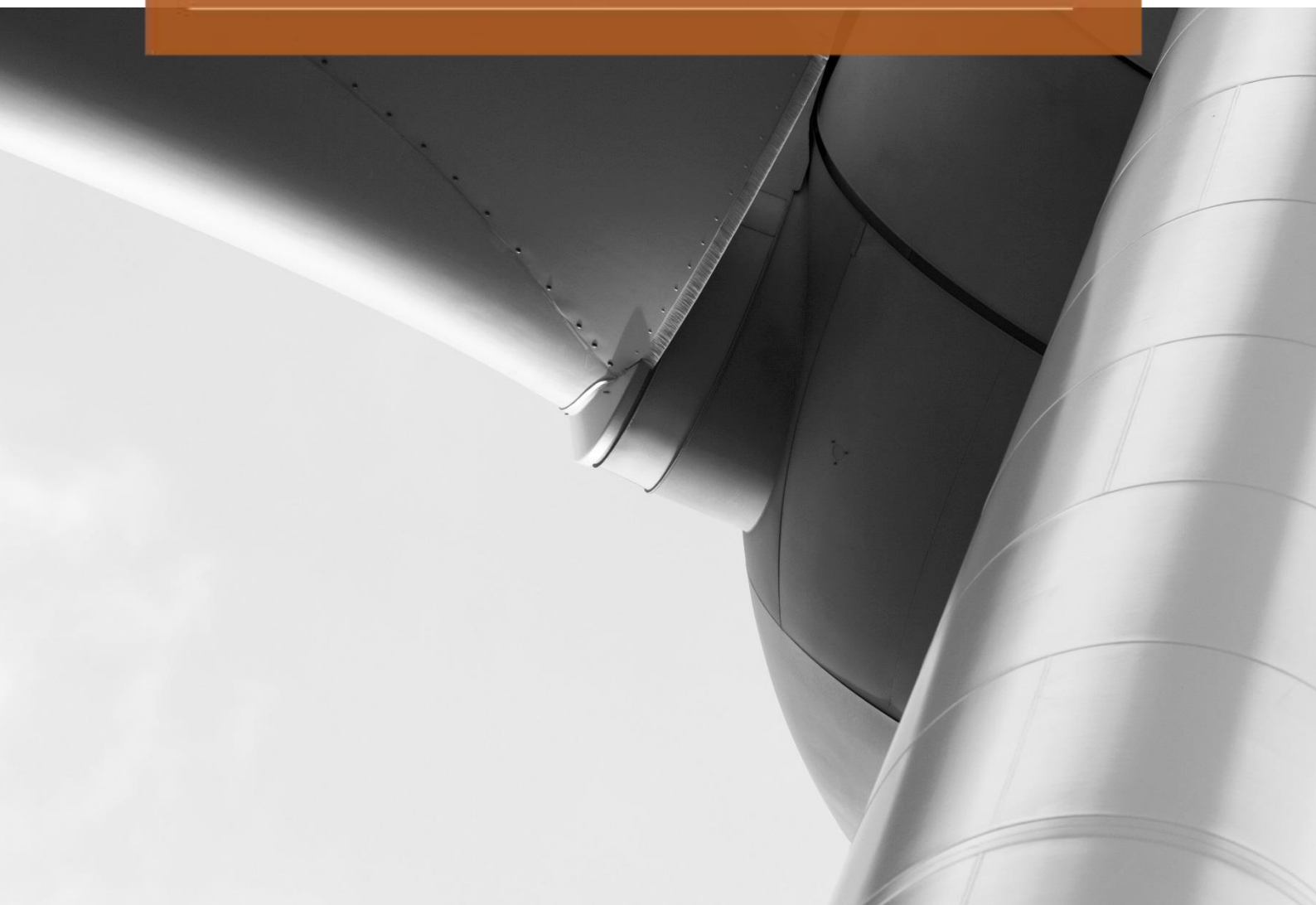
Ruvo di Puglia Wind Farm

Preliminary Energy Yield Assessment

9 OCTOBER 2023



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CLASSIFICATION

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DOCUMENT REVISIONS

Revision	Date	Report no.	Chapter(s)	Description of Purpose/Changes
0	2023-09-12	230912_23142_Ruvo_A_MM_0	All	Initial report
1	2023-09-18	230922_23142_Ruvo_A_MM_1	Ex. Summary and 5	Recalculated el. losses
2	2023-09-22	230922_23142_Ruvo_A_MM_2	Ex. Summary and 5	Updated el. losses
3	2023-10-09	231009_23142_Ruvo_A_SZ_3	All	New layout

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Executive Summary

This report presents the preliminary annual energy production estimate for the Ruvo di Puglia wind farm project in Italy, with a capacity of 57.6 MW.

The calculations have been carried out using high resolution mesoscale data (EMD-WRF Europe+ covering a 20 year-period).

The client provided the layout which consists of 8 wind turbines V172-7.2. Two different hub height solutions have been considered, 114 and 150 m.

No neighbouring wind farms have been considered.

The annual energy production is summarised in Table 1. Wake and electrical grid losses have been calculated and a lump sum for other losses have been estimated.

A number of reasons makes these results preliminary, and to be considered with great care:

- The input is simulated wind data from a mesoscale model, with a horizontal resolution of 3x3 km: these data can be notoriously off compared to ground truth, particularly on complex terrain. Only on-site measurements can guarantee with accuracy an investment of this kind requires.
- The data have been downscaled using previous experience in the region, but in different, distant terrain. While there certainly is value in this procedure (rather than leaving data fully uncalibrated), it still bears a significant uncertainty.

For all the reasons above, the numerical results indicated in Table 1 can only be seen as indicative, and, in terms of production and its derivatives, are affected by uncertainties in the order of 20%.

Table 1. Results Summary.

Project Description		
Layout	1	2
Turbine type	V172-7.2	V172-7.2
Hub Height [m]	114	150
Number of turbines	8	8
Installed Capacity [MW]	57.6	57.6
Preliminary Gross and Net AEP		
Mean long-term wind speed [m/s] @ hub height	6.4	6.6
Gross Production [GWh/y]	**161**	**170**
Net Production (P50) [GWh/y]	**144**	**152**
P50 - Capacity Factor [%]	29	30
Uncertainty, P90		
Uncertainty (20 years) [%]	20	20
P90 (20 years) [GWh/y]	**107**	**113**
P90, Capacity Factor [%]	21	22

Recommendations

To ensure a decrease of the uncertainty and get the estimates to a bankable level, on-site measurements for at least 12 consecutive months shall be undertaken, as recommended in "Technical Guidelines for Wind Turbines, TR6" [1] and MEASNET "Evaluation of Site Specific Wind Conditions" [2].

A proper design of measurement campaign is crucial to maximize the chances for the lowest achievable uncertainty on wind measurement and flow extrapolation.

Depending on social and environmental constraints – which were not disclosed at this stage – there might be room for improving the present layout.

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1 Purpose

This report presents the preliminary annual energy production estimate, based on wind data from a mesoscale model output for the Ruvo di Puglia wind farm project in Italy with a capacity of 57.6 MW.

2 Site Description

2.1 Location

The center of the wind farm is located about 7.5 km South-West of the town of Ruvo di Puglia, in Italy.

Figure 1. OpenTopo map of the region, with the preliminary layout as red symbols.

2.2 Terrain description

The planned turbines lie on a small plateau, with the terrain quickly rising to its South-West, towards the Apennines, and more gently sloping down towards the sea in the opposite direction.

As digital elevation data, the TIN Italy DEM, 10 m gridded data transformed into 5 m equidistant contour lines, has been used 20 x 20 km around the site.

The roughness has been compiled from land cover databases Corine 2018, 100 m grid for an area of 60 x 60 km around the site.

3 Methodology

For the purpose of preliminary energy yield assessment, the use of mesoscale data is deemed suitable.

The calculations have been carried out using 20 years of wind data from one grid node of the high-resolution mesoscale model WRF (EMD-WRF Europe+)[1]. The location of the mesoscale node can be seen in Figure 2.

The mesoscale data have been downscaled to the microscale level of the site using a procedure [3] where mesoscale data are processed by WAsP [4]. The process first uses the mesoscale terrain (provided by EMD) on the mesoscale data, and then the microscale terrain data at the turbines.

Due to the nature of mesoscale data wherein the wind speeds are often offset, the initial wind speed results have been further scaled by a factor (1.018), based on previous experience in the region. This step somehow helps in decreasing the uncertainty, but at the same time it is based on different and distant terrain conditions, and thus in itself bears a significant uncertainty.

The resulting dataset was then extrapolated to each WTG location to assess the specific microclimate, then used to estimate the energy production.

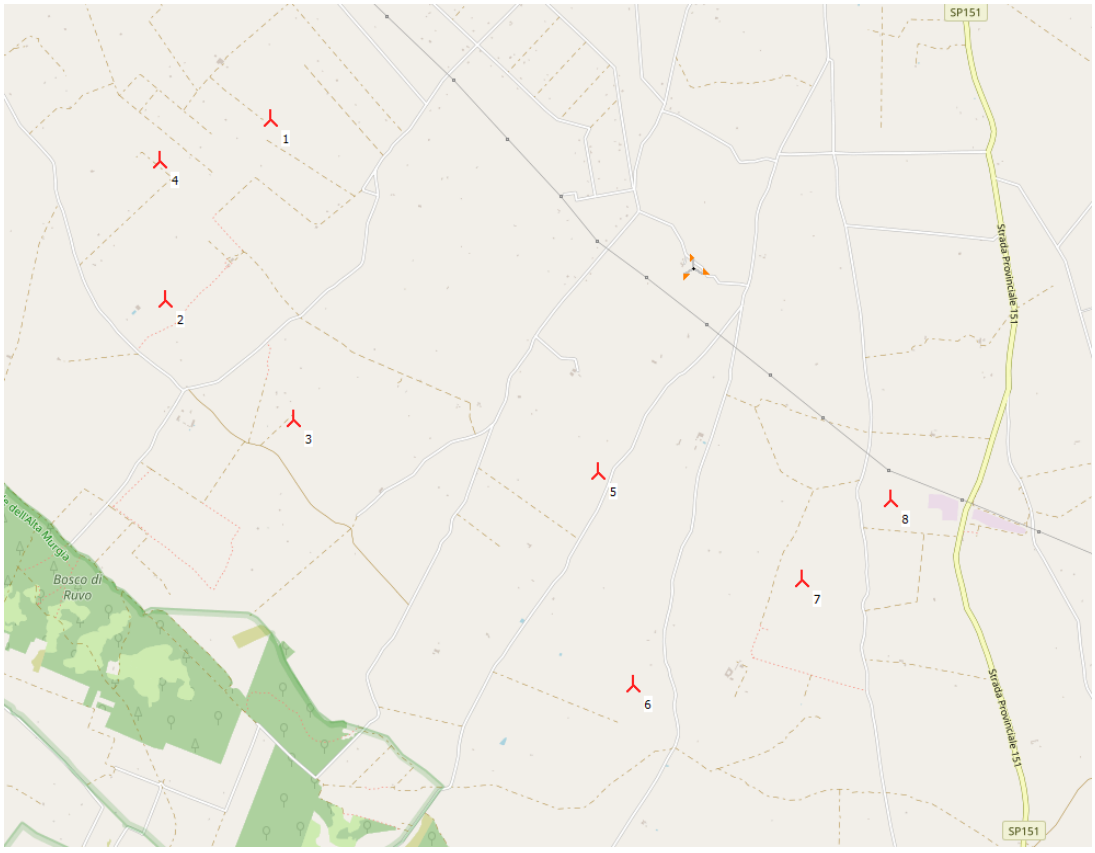

Figure 2. Location of the mesoscale data node (orange symbol) and planned turbines.

[1] EMD-WRF Europe+ high resolution mesoscale data has been obtained. The mesoscale model is at a spatial resolution of 0.03°x0.03° or approximately 3x3 km with hourly temporal resolution. ERA5 data from ECMWF (http://www.ecmwf.int) has been used as the global boundary data set. The modelled heights are 200, 150, 100, 75, 50, 25, 10 m AGL. [5]

4 Wind Data

Following the downscaling method described previously, the long-term wind data used for the preliminary estimates are presented below, for a representative location (WTG 8).

Table 2. Sectorwise mean wind speed and frequency of 20 years wind data at the position of WTG 8, 150 m AGL.

Position	WTG 8	150 m AGL
Sector	Arithmetic mean wind speeds [m/s]	Frequency [%]
0 N	5.6	11.8
1 NNE	4.2	6.7
2 ENE	3.8	4.2
3 E	3.7	3.2
4 ESE	3.8	2.7
5 SSE	6.0	3.9
6 S	9.2	10.3
7 SSW	7.2	8.7
8 WSW	7.7	8
9 W	7.5	8.8
10 WNW	7.0	19.1
11 NNW	5.3	12.6
All	6.4	100

The long-term frequency and energy distribution for the downscaled EMD-WRF Europe+ mesoscale data at 150 m AGL indicate a main wind energy direction from West-North-West (Figure 3).

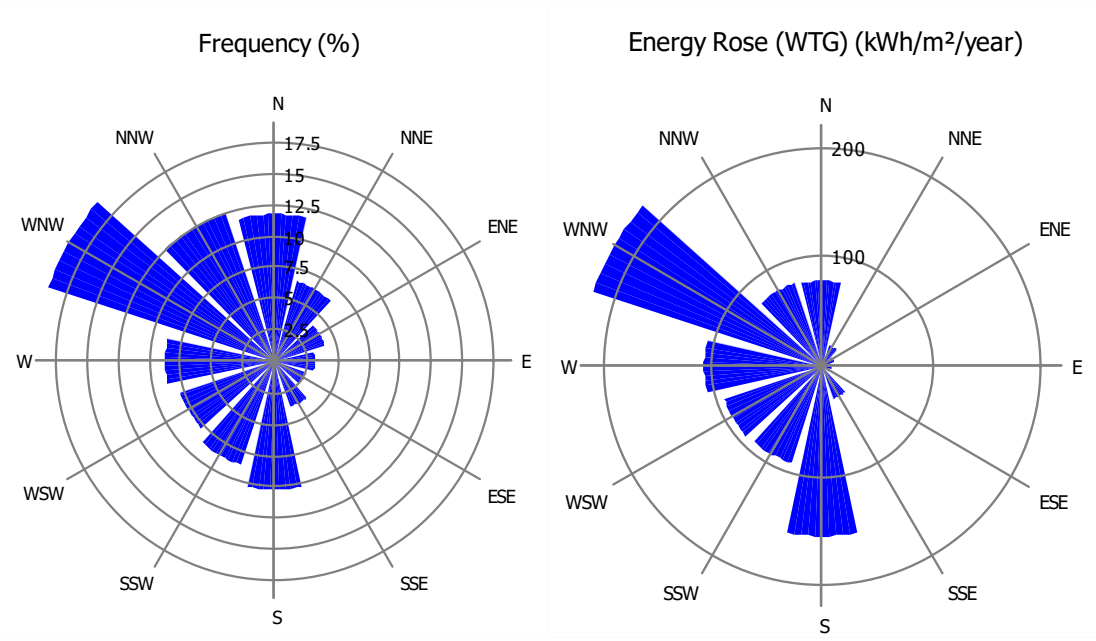

Figure 3. Frequency and energy distribution at WTG 8 position, 150 m AGL based on 20 years of EMD-WRF Europe+ downscaled data.

5 Results

5.1 Energy Yield Predictions

Based on the estimated wind resource, layout, standard power curves and adjusted air density, the preliminary energy prediction has been calculated. The results are presented in Table 3.

Losses have been calculated (wakes and electrical grid) or given a standard value, to get the net production.

The level of uncertainty on the annual energy yield predictions is high due to the use solely of mesoscale data and estimated to be in the order of 20%.

Note that for a preliminary assessment as conducted here, it is not deemed relevant and could even be misleading to present detailed evaluation of losses and uncertainty.

Table 3. Results, P50 and P90.

Results		
Layout	**1 (114 m HH)**	**2 (150 m HH)**
Installed Capacity [MW]	57.6	57.6
Gross Production [GWh/y]	**161**	**170**
Wake losses [%]	2.9	2.6
Total Losses incl. wake losses [%]	10.6	10.4
Net Production (P50) [GWh/y]	**144**	**152**
Uncertainty (20 years) [%]	20	20
P90 (20 years) [GWh/y]	**107**	**113**

LOSS	Method *)	Loss [%]	Loss [GWh/y]
1. Wake effects			
Wake effects, all WTGs	Calculation	2.9	4.7
2. Availability			
Turbine availability	Estimate	3.0	4.8
Balance of plant (Substation)	Estimate	0.2	0.3
3. Turbine performance			
High wind hysteresis	Calculation	0.1	0.1
Other turbine performance	Estimate	1.0	1.6
4. Electrical			
Electrical losses	Estimate	3.2	5.2
5. Environmental			
Performance degradation not due to icing	Estimate	0.5	0.8
High and low temperature	Calculation	0.1	0.2
6. Curtailment			
7. Other			
LOSS, total		**10.6**	**17.0**

LOSS	Method *)	Loss [%]	Loss [GWh/y]
1. Wake effects			
Wake effects, all WTGs	Calculation	2.6	4.5
2. Availability			
Turbine availability	Estimate	3.0	5.1
Balance of plant (Substation)	Estimate	0.2	0.3
3. Turbine performance			
High wind hysteresis	Calculation	0.1	0.1
Other turbine performance	Estimate	1.0	1.7
4. Electrical			
Electrical losses	Estimate	3.3	5.5
5. Environmental			
Performance degradation not due to icing	Estimate	0.5	0.8
High and low temperature	Calculation	0.1	0.2
6. Curtailment			
7. Other			
LOSS, total		**10.4**	**17.6**

Figure 4. Losses included in the calculations, in % and GWh/y: above, for the 114 m hub, below, for the 150 m hub.

6 References

[1] FGW, "Technical Guideline for Wind Turbines Part 6: Determination of Wind Potential and Energy Yield Rev 10," Fördergesellschaft Windenergie, 2017.

[2] MEASNET, Evaluation of Site Specific Wind Conditions v3, 2022.

[3] Badger, "Wind-Climate Estimation Based on Mesoscale and Microscale Modeling: Statistical–Dynamical Downscaling for Wind Energy Applications," DTU Wind Energy, 2014.

[4] I. Troen and E. L. Petersen, "European Wind Atlas," Risø National Laboratory, Denmark, 1989.

[5] L. Svenningsen, "Technical Note: Validation of EMD-WFR EUROPE+ (ERA5) mesoscale dataset," 2020.

Appendix A. Park Calculation – 114 m HH

Project:
Ruvo

Description:
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PARK - Main Result

Calculation: 231006_8xV172 @114 m

Setup
AEP scaled to a full year based on number of samples
Scaling factor from 20.0 years to 1 year: 0.050

Calculation performed in UTM (north)-WGS84 Zone: 33
At the site centre the difference between grid north and true north is: 1.0°

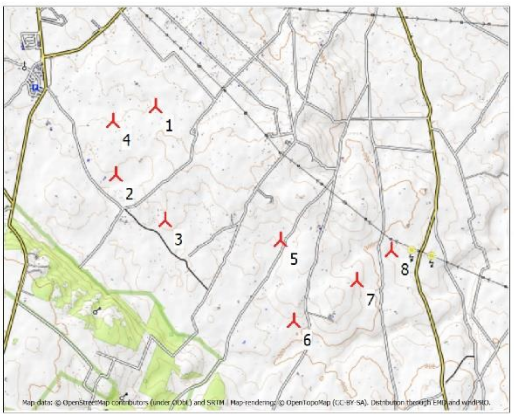
Wake
Wake Model: N.O. Jensen (RISØ/EMD) Park 2 2018
Wake decay constant
Wake decay constant: 0.090 DTU default onshore Hub height independent
Reference WTG: 1

Scaler/wind data

Name	Meso Scaler
Terrain scaling	Meso-scale Data Downscaling
Micro terrain flow model	WAsP IBZ from Site Data
Used period	01/01/2001 01.00.00 - 01/01/2021
Meteo object(s)	EMD-WRF Europe+ (ERA5)_N41.067535_E016.46872 (2)
Displacement height	Omnidirectional from objects
WAsP version	WAsP 12 Version 12.08.0032

Power correction
Power curve correction (adjusted IEC method, improved to match turbine control)

		Min	Max	Avg	Corr. [%]	Neg. corr. [%]	Pos. corr. [%]
Air density							
EMD-WRF Europe+ (ERA5)_N41.067535_E016.46872 (2) - 100.00 m	[°C]	-5.5	39.4	15.5			
From air density settings	[hPa]	956.0	969.7	962.1			
Resulting air density	[kg/m³]	1.076	1.251	1.162			
Relative to 15°C at sea level	[%]	87.6	102.1	94.8	-3.4	-3.4	0.0



Scale 1:100,000
New WTG

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]	Wind speed free [m/s]	Wind speed wake reduced [m/s]
Wind farm	156,205.4	160,914.7	2.9	30.9	19,525.7	2,712	6.4	6.3

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 8 new WTGs with total 57.6 MW rated power

	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 [%]	Wind speed free [m/s]	reduced [m/s]
1	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	114.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	20,061.0	3.1	6.46	6.36
2	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	114.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	19,947.4	2.1	6.40	6.31
3	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	114.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	19,920.2	3.1	6.42	6.32
4	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	114.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	20,115.7	2.1	6.43	6.35
5	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	114.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	19,225.6	2.7	6.29	6.21
6	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	114.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	19,267.3	2.3	6.27	6.20
7	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	114.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	19,318.5	4.6	6.38	6.24
8	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	114.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	18,349.7	3.5	6.17	6.07

Annual Energy results includes shown losses. For expected NET AEP (expected sold production), see report Loss & Uncertainty.

WTG siting

	UTM (north)-WGS84 Zone: 33 Easting	Northing	Z [m]	Row data/Description	Calculation period Start	End
1 New	620,594	4,548,218	344.3	1	01/01/2001	01/01/2021
2 New	619,923	4,547,025	339.4	2	01/01/2001	01/01/2021
3 New	620,781	4,546,252	338.4	3	01/01/2001	01/01/2021
4 New	619,868	4,547,939	340.3	4	01/01/2001	01/01/2021
5 New	622,790	4,545,940	325.0	5	01/01/2001	01/01/2021
6 New	623,046	4,544,553	311.7	6	01/01/2001	01/01/2021
7 New	624,139	4,545,263	315.0	7	01/01/2001	01/01/2021
8 New	624,715	4,545,798	289.5	8	01/01/2001	01/01/2021

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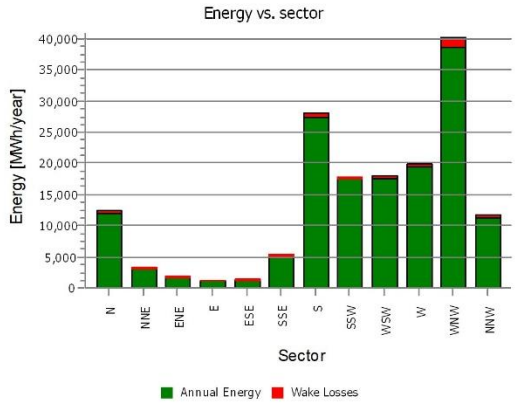
PARK - Production Analysis

Calculation: 231006_8xV172 @114 m **WTG:** All new WTGs, Air density varies with WTG position 1.164 kg/m³ - 1.170 kg/m³

Directional Analysis

Sector		0 N	1 NNE	2 ENE	3 E	4 ESE	5 SSE	6 S	7 SSW	8 WSW	9 W	10 WNW	11 NNW	Total
Model based energy	[MWh]	12,504.1	3,219.8	1,796.8	1,223.7	1,287.0	5,298.1	27,952.5	17,844.9	18,115.4	19,825.0	40,225.3	11,622.0	160,914.7
-Decrease due to wake losses	[MWh]	567.6	91.0	145.5	41.2	69.4	78.5	502.9	319.1	654.6	345.6	1,589.4	304.4	4,709.3
Resulting energy	**[MWh]**	**11,936.5**	**3,128.7**	**1,651.4**	**1,182.6**	**1,217.7**	**5,219.7**	**27,449.6**	**17,525.8**	**17,460.8**	**19,479.3**	**38,635.9**	**11,317.5**	**156,205.4**
Specific energy	[kWh/m²]													840
Specific energy	[kWh/kW]													2,712
Decrease due to wake losses	[%]	4.5	2.8	8.1	3.4	5.4	1.5	1.8	1.8	3.6	1.7	4.0	2.6	2.93
Full Load Equivalent	[Hours/year]	207	54	29	21	21	91	477	304	303	338	671	196	2,712



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PARK - Power Curve Analysis

Calculation: 231006_8xV172 @114 m **WTG:** 1 - VESTAS V172-7.2 7200 172.0 !O!, Hub height: 114.0 m

Name: Level 0 & 0S - Calculated - PO7200 - 07-2022
Source: Manufacturer

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
08/07/2022	EMD	25/02/2022	06/10/2022	25.0	Pitch	User defined	Variable	0.31

Based Vestas Document no.: 0127-1584 V01.

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	11,840	18,085	24,147	29,566	34,148	37,822
VESTAS V172-7.2 7200 172.0 !O! Level 0 & 0S - Calculated - PO7200 - 07-2022	[MWh]	11,639	17,897	23,956	29,281	33,613	36,862
Check value	[%]	2	1	1	1	2	3

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

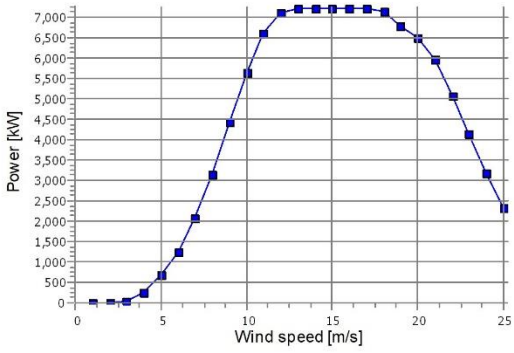
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
3.0	32.0	0.08	3.0	0.97
3.5	129.0	0.21	3.5	0.89
4.0	288.0	0.32	4.0	0.83
4.5	481.0	0.37	4.5	0.82
5.0	715.0	0.40	5.0	0.81
5.5	999.0	0.42	5.5	0.82
6.0	1,340.0	0.44	6.0	0.81
6.5	1,739.0	0.44	6.5	0.81
7.0	2,203.0	0.45	7.0	0.81
7.5	2,729.0	0.45	7.5	0.80
8.0	3,324.0	0.46	8.0	0.79
8.5	3,986.0	0.46	8.5	0.78
9.0	4,685.0	0.45	9.0	0.75
9.5	5,314.0	0.44	9.5	0.69
10.0	5,904.0	0.41	10.0	0.63
10.5	6,441.0	0.39	10.5	0.57
11.0	6,854.0	0.36	11.0	0.51
11.5	7,078.0	0.33	11.5	0.45
12.0	7,160.0	0.29	12.0	0.39
12.5	7,195.0	0.26	12.5	0.34
13.0	7,200.0	0.23	13.0	0.30
13.5	7,200.0	0.21	13.5	0.26
14.0	7,200.0	0.18	14.0	0.24
14.5	7,200.0	0.17	14.5	0.21
15.0	7,200.0	0.15	15.0	0.19
15.5	7,200.0	0.14	15.5	0.17
16.0	7,200.0	0.12	16.0	0.16
16.5	7,200.0	0.11	16.5	0.14
17.0	7,200.0	0.10	17.0	0.13
17.5	7,194.0	0.09	17.5	0.12
18.0	7,124.0	0.09	18.0	0.11
18.5	6,959.0	0.08	18.5	0.10
19.0	6,789.0	0.07	19.0	0.09
19.5	6,630.0	0.06	19.5	0.08
20.0	6,472.0	0.06	20.0	0.07
20.5	6,262.0	0.05	20.5	0.07
21.0	5,946.0	0.05	21.0	0.06
21.5	5,538.0	0.04	21.5	0.05
22.0	5,069.0	0.03	22.0	0.05
22.5	4,597.0	0.03	22.5	0.04
23.0	4,121.0	0.02	23.0	0.03
23.5	3,636.0	0.02	23.5	0.03
24.0	3,169.0	0.02	24.0	0.02
24.5	2,718.0	0.01	24.5	0.02
25.0	2,328.0	0.01	25.0	0.02

Power and efficiency vs. wind speed

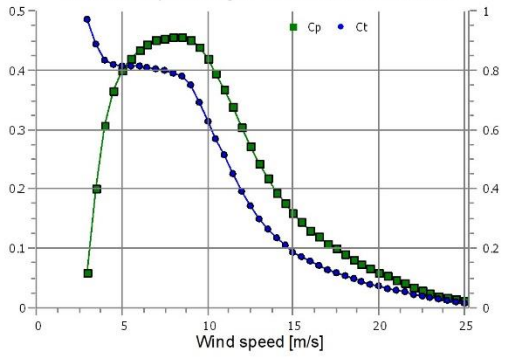
Data used in calculation, Mean air density: 1.160 kg/m³

Wind speed [m/s]	Power [kW]	Cp
1.0	0.0	0.00
2.0	0.0	0.00
3.0	21.1	0.06
4.0	264.2	0.31
5.0	671.3	0.40
6.0	1,263.5	0.43
7.0	2,081.6	0.45
8.0	3,144.6	0.46
9.0	4,430.7	0.45
10.0	5,630.8	0.42
11.0	6,605.2	0.37
12.0	7,097.7	0.30
13.0	7,195.6	0.24
14.0	7,200.0	0.19
15.0	7,200.0	0.16
16.0	7,200.0	0.13
17.0	7,200.0	0.11
18.0	7,124.0	0.09
19.0	6,789.0	0.07
20.0	6,472.0	0.06
21.0	5,946.0	0.05
22.0	5,069.0	0.04
23.0	4,121.0	0.03
24.0	3,169.0	0.02
25.0	2,328.0	0.01

Power curve
For air density: 1.160 kg/m³ and reference climate data



Cp and Ct curve
For air density: 1.160 kg/m³ and reference climate data



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Calculated:
06/10/2023 10.08/4.0.518

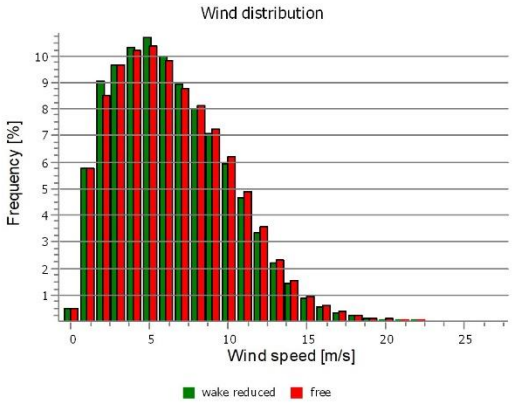
PARK - Wind Data Analysis

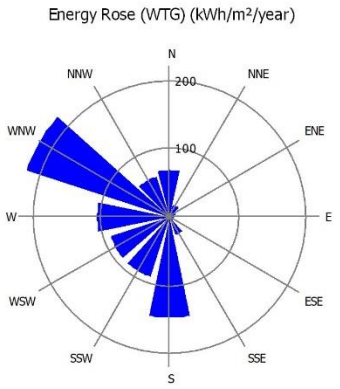
Calculation: 231006_8xV172 @114 m **Wind data:** 1 - 1; Hub height: 114.0

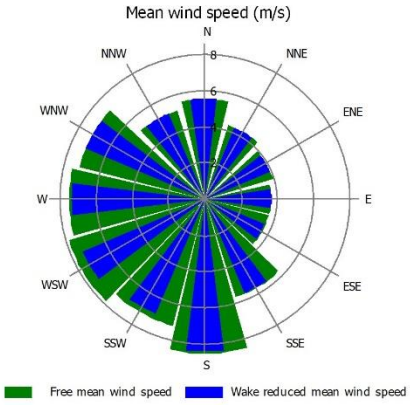
Site coordinates
UTM (north)-WGS84 Zone: 33
East: 620,594 North: 4,548,218
1 - 1
Masts used
Take nearest

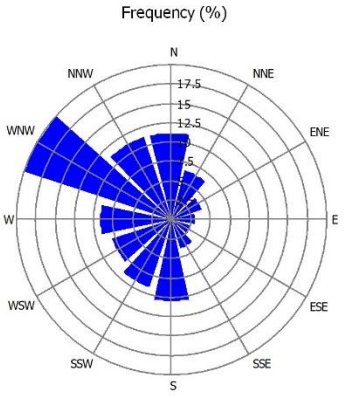
Winddata for site

Sector	Free mean wind speed [m/s]	Wake reduced mean wind speed [m/s]	Frequency [%]
0 N	5.6	5.6	11.2
1 NNE	4.3	4.3	6.6
2 ENE	4.0	4.0	4.1
3 E	3.7	3.7	3.0
4 ESE	3.7	3.6	2.6
5 SSE	5.7	5.7	3.9
6 S	8.6	8.5	10.5
7 SSW	7.3	7.0	9.2
8 WSW	7.9	7.4	8.1
9 W	7.6	7.4	9.2
10 WNW	7.2	7.2	20.0
11 NNW	5.2	5.2	11.3
All	6.5	6.4	100.0









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Calculated:
06/10/2023 10.08/4.0.518

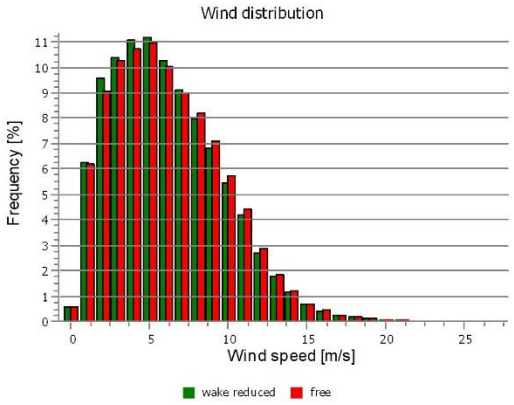
PARK - Wind Data Analysis

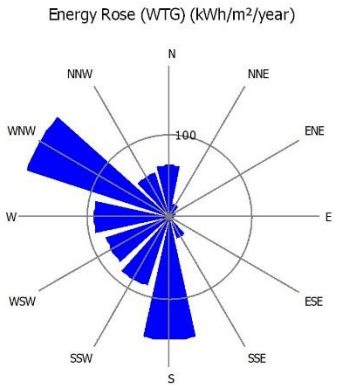
Calculation: 231006_8xV172 @114 m **Wind data:** 8 - 8; Hub height: 114.0

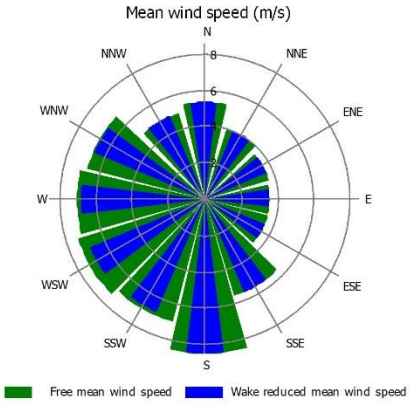
Site coordinates
UTM (north)-WGS84 Zone: 33
East: 624,715 North: 4,545,798
8 - 8
Masts used
Take nearest

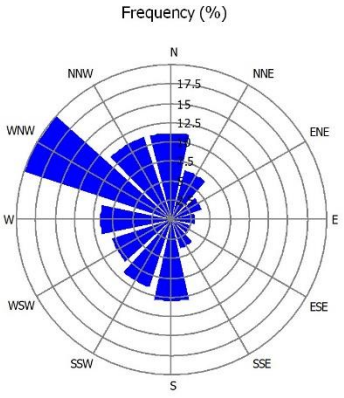
Winddata for site

Sector	Free mean wind speed [m/s]	Wake reduced mean wind speed [m/s]	Frequency [%]
0 N	5.4	5.4	11.2
1 NNE	4.1	4.1	6.6
2 ENE	3.7	3.7	4.1
3 E	3.6	3.6	3.0
4 ESE	3.6	3.6	2.6
5 SSE	5.6	5.6	3.9
6 S	8.6	8.6	10.5
7 SSW	7.0	6.8	9.2
8 WSW	7.4	6.9	8.1
9 W	7.1	6.9	9.2
10 WNW	6.7	6.6	20.0
11 NNW	5.0	5.0	11.3
All	6.2	6.1	100.0









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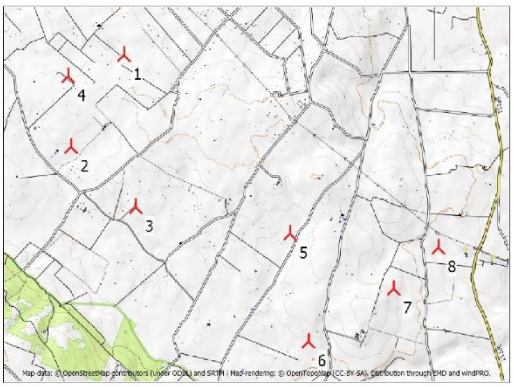
PARK - WTG distances

Calculation: 231006_8xV172 @114 m

WTG distances

	Z	Nearest WTG	Z	Horizontal distance	Distance in rotor diameters
	[m]		[m]	[m]	
1	344.3	4	340.3	777	4.5
2	339.4	4	340.3	915	5.3
3	338.4	2	339.4	1,155	6.7
4	340.3	1	344.3	777	4.5
5	325.0	6	311.7	1,410	8.2
6	311.7	7	315.0	1,303	7.6
7	315.0	8	289.5	786	4.6
8	289.5	7	315.0	786	4.6
Min	**289.5**		**289.5**	**777**	**4.5**
Max	**344.3**		**344.3**	**1,410**	**8.2**



Scale 1:75,000

New WTG

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PARK - Time varying AEP

Calculation: 231006_8xV172 @114 m

Windfarm: 57.6 MW based on 8 turbines of type VESTAS V172-7.2 7200 172.0 !O!.
Selection: All new WTGs
Calculated mean yield per month and hour [MWh]. The result includes wake losses and any curtailment losses.
Values are scaled to a full year, see correction factors at main result page.

Hour/Month [MWh]	1	2	3	4	5	6	7	8	9	10	11	12	Grand Total
0	796	780	831	743	742	540	563	507	511	564	688	798	8,061
1	808	796	833	724	746	577	585	533	541	570	698	793	8,204
2	811	800	832	728	732	601	609	549	551	564	695	784	8,256
3	796	801	841	728	740	630	619	552	565	548	693	794	8,307
4	798	791	849	738	724	639	624	565	566	541	679	800	8,314
5	791	781	866	724	714	628	632	563	570	540	679	789	8,279
6	797	777	852	718	648	535	576	537	551	530	680	795	7,997
7	792	775	832	601	483	363	399	393	469	509	685	787	7,088
8	792	734	695	482	413	314	326	297	331	412	645	785	6,227
9	699	607	576	426	380	266	292	252	283	351	539	707	5,378
10	573	546	552	406	359	243	268	230	260	329	471	600	4,838
11	534	507	531	404	364	266	299	231	249	315	450	571	4,723
12	512	488	517	408	407	328	364	286	254	317	442	542	4,865
13	509	501	524	441	415	346	404	336	278	318	444	537	5,053
14	511	509	543	427	406	339	390	360	298	330	443	517	5,072
15	520	512	560	428	397	322	356	334	296	329	441	508	5,004
16	561	508	558	419	406	289	322	298	285	341	481	548	5,017
17	651	536	550	416	411	274	295	257	263	393	552	625	5,224
18	671	620	596	443	395	237	253	238	284	449	594	683	5,463
19	693	677	672	527	466	248	255	243	320	490	618	706	5,917
20	715	700	748	627	565	309	295	280	378	518	634	728	6,496
21	746	727	797	702	652	376	371	324	419	542	651	751	7,058
22	775	743	811	735	703	446	458	407	453	560	666	768	7,525
23	795	759	827	739	734	501	519	464	482	567	676	777	7,838
Grand Total	16,647	15,973	16,796	13,735	13,002	9,619	10,072	9,036	9,459	10,929	14,243	16,695	156,205

Hour/Month [MW]	1	2	3	4	5	6	7	8	9	10	11	12	Grand Total
0	25.7	27.8	26.8	24.8	23.9	18.0	18.2	16.4	17.0	18.2	22.9	25.7	22.1
1	26.1	28.4	26.9	24.1	24.1	19.2	18.9	17.2	18.0	18.4	23.3	25.6	22.5
2	26.2	28.6	26.8	24.3	23.6	20.0	19.6	17.7	18.4	18.2	23.2	25.3	22.6
3	25.7	28.6	27.1	24.3	23.9	21.0	20.0	17.8	18.8	17.7	23.1	25.6	22.8
4	25.7	28.3	27.4	24.6	23.4	21.3	20.1	18.2	18.9	17.5	22.6	25.8	22.8
5	25.5	27.9	27.9	24.1	23.0	20.9	20.4	18.2	19.0	17.4	22.6	25.5	22.7
6	25.7	27.8	27.5	23.9	20.9	17.8	18.6	17.3	18.4	17.1	22.7	25.6	21.9
7	25.5	27.7	26.8	20.0	15.6	12.1	12.9	12.7	15.6	16.4	22.8	25.4	19.4
8	25.6	26.2	22.4	16.1	13.3	10.5	10.5	9.6	11.0	13.3	21.5	25.3	17.1
9	22.5	21.7	18.6	14.2	12.2	8.9	9.4	8.1	9.4	11.3	18.0	22.8	14.7
10	18.5	19.5	17.8	13.5	11.6	8.1	8.7	7.4	8.7	10.6	15.7	19.3	13.3
11	17.2	18.1	17.1	13.5	11.7	8.9	9.7	7.4	8.3	10.2	15.0	18.4	12.9
12	16.5	17.4	16.7	13.6	13.1	10.9	11.7	9.2	8.5	10.2	14.7	17.5	13.3
13	16.4	17.9	16.9	14.7	13.4	11.5	13.0	10.8	9.3	10.2	14.8	17.3	13.8
14	16.5	18.2	17.5	14.2	13.1	11.3	12.6	11.6	9.9	10.6	14.8	16.7	13.9
15	16.8	18.3	18.1	14.3	12.8	10.7	11.5	10.8	9.9	10.6	14.7	16.4	13.7
16	18.1	18.2	18.0	14.0	13.1	9.6	10.4	9.6	9.5	11.0	16.0	17.7	13.7
17	21.0	19.1	17.7	13.9	13.3	9.1	9.5	8.3	8.8	12.7	18.4	20.2	14.3
18	21.7	22.1	19.2	14.8	12.7	7.9	8.2	7.7	9.5	14.5	19.8	22.0	15.0
19	22.3	24.2	21.7	17.6	15.0	8.3	8.2	7.9	10.7	15.8	20.6	22.8	16.2
20	23.1	25.0	24.1	20.9	18.2	10.3	9.5	9.0	12.6	16.7	21.1	23.5	17.8
21	24.1	25.9	25.7	23.4	21.0	12.5	12.0	10.5	14.0	17.5	21.7	24.2	19.3
22	25.0	26.5	26.2	24.5	22.7	14.9	14.8	13.1	15.1	18.1	22.2	24.8	20.6
23	25.6	27.1	26.7	24.6	23.7	16.7	16.7	15.0	16.1	18.3	22.5	25.1	21.5
Grand Total	22.4	23.8	22.6	19.1	17.5	13.4	13.5	12.1	13.1	14.7	19.8	22.4	17.8

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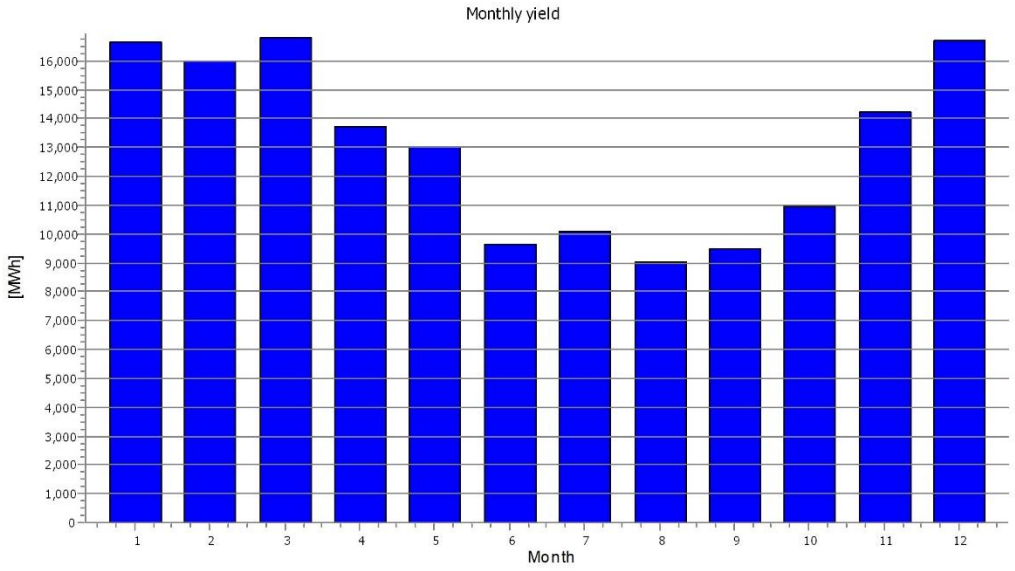
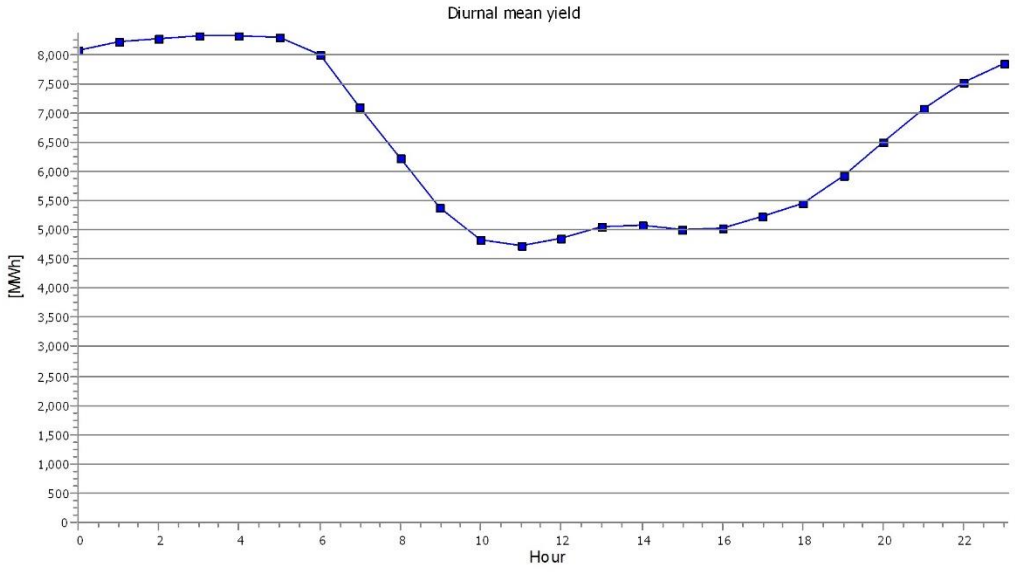
PARK - Time varying AEP

Calculation: 231006_8xV172 @114 m

Windfarm: 57.6 MW based on 8 turbines of type VESTAS V172-7.2 7200 172.0 !O!.
Selection: All new WTGs
Calculated mean yield per month and hour [MWh]. The result includes wake losses and any curtailment losses.
Values are scaled to a full year, see correction factors at main result page.





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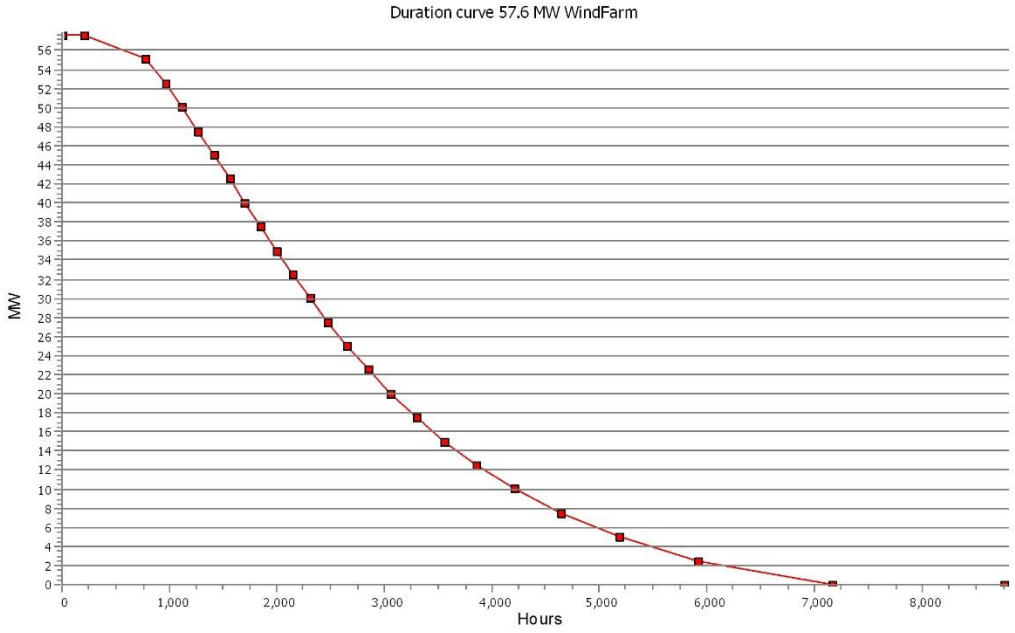
PARK - Time varying AEP

Calculation: 231006_8xV172 @114 m

Windfarm: 57.6 MW based on 8 turbines of type VESTAS V172-7.2 7200 172.0 !O!.
Selection: All new WTGs
Calculated mean yield per month and hour [MWh]. The result includes wake losses and any curtailment losses.

Hours	Hours [%]	Hours accumulated	Power [MW]	Power (MW/WTG)
197	2.2	197	57.6	7.2
576	6.6	772	55.1 - 57.6	6.9 - 7.2
191	2.2	963	52.6 - 55.1	6.6 - 6.9
155	1.8	1118	50.1 - 52.6	6.3 - 6.6
144	1.6	1263	47.6 - 50.1	5.9 - 6.3
147	1.7	1409	45.1 - 47.6	5.6 - 5.9
145	1.7	1555	42.6 - 45.1	5.3 - 5.6
147	1.7	1702	40.1 - 42.6	5.0 - 5.3
146	1.7	1848	37.6 - 40.1	4.7 - 5.0
149	1.7	1997	35.1 - 37.6	4.4 - 4.7
151	1.7	2148	32.6 - 35.1	4.1 - 4.4
155	1.8	2303	30.1 - 32.6	3.8 - 4.1
167	1.9	2470	27.5 - 30.1	3.4 - 3.8
177	2.0	2647	25.0 - 27.5	3.1 - 3.4
198	2.3	2845	22.5 - 25.0	2.8 - 3.1
215	2.5	3060	20.0 - 22.5	2.5 - 2.8
233	2.7	3293	17.5 - 20.0	2.2 - 2.5
257	2.9	3550	15.0 - 17.5	1.9 - 2.2
299	3.4	3849	12.5 - 15.0	1.6 - 1.9
355	4.1	4204	10.0 - 12.5	1.3 - 1.6
437	5.0	4641	7.5 - 10.0	0.9 - 1.3
548	6.2	5188	5.0 - 7.5	0.6 - 0.9
724	8.3	5912	2.5 - 5.0	0.3 - 0.6
1256	14.3	7168	0.0 - 2.5	0.0 - 0.3
1598	18.2	8766	0.0	0.0



Project:
Ruvo

Description:
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Calculated:
06/10/2023 10.08/4.0.518

PARK - Scaling info

Calculation: 231006_8xV172 @114 m

Scaler settings

Name	Meso Scaler
Terrain scaling	Meso-scale Data Downscaling
RIX correction	No RIX correction
Displacement height	from objects
Micro terrain flow model	SDO

Site Data: SDO

Obstacles:

All obstacles used

Roughness:

Terrain data files used in calculation:
C:\Users\sza\Documents\WindPRO Data\Consultancy\Ruvo\ROUGHNESSLINE_Ruvo_0.wpo
Min X: 602,116, Max X: 642,030, Min Y: 4,526,595, Max Y: 4,568,008, Width: 39,913 m, Height: 41,413 m

Orography:

Terrain data files used in calculation:
C:\Users\sza\Documents\WindPRO Data\Consultancy\Ruvo\CONTOURLINE_ONLINEDATA_0.wpo
Min X: 559,556, Max X: 645,341, Min Y: 4,535,728, Max Y: 4,570,857, Width: 85,784 m, Height: 35,129 m

Post calibration

Overall factor	1.0180
Overall offset	0.0000
By sector	No
By month	No
By hour	No
By wind speed	No

Project:
Ruvo

Description:
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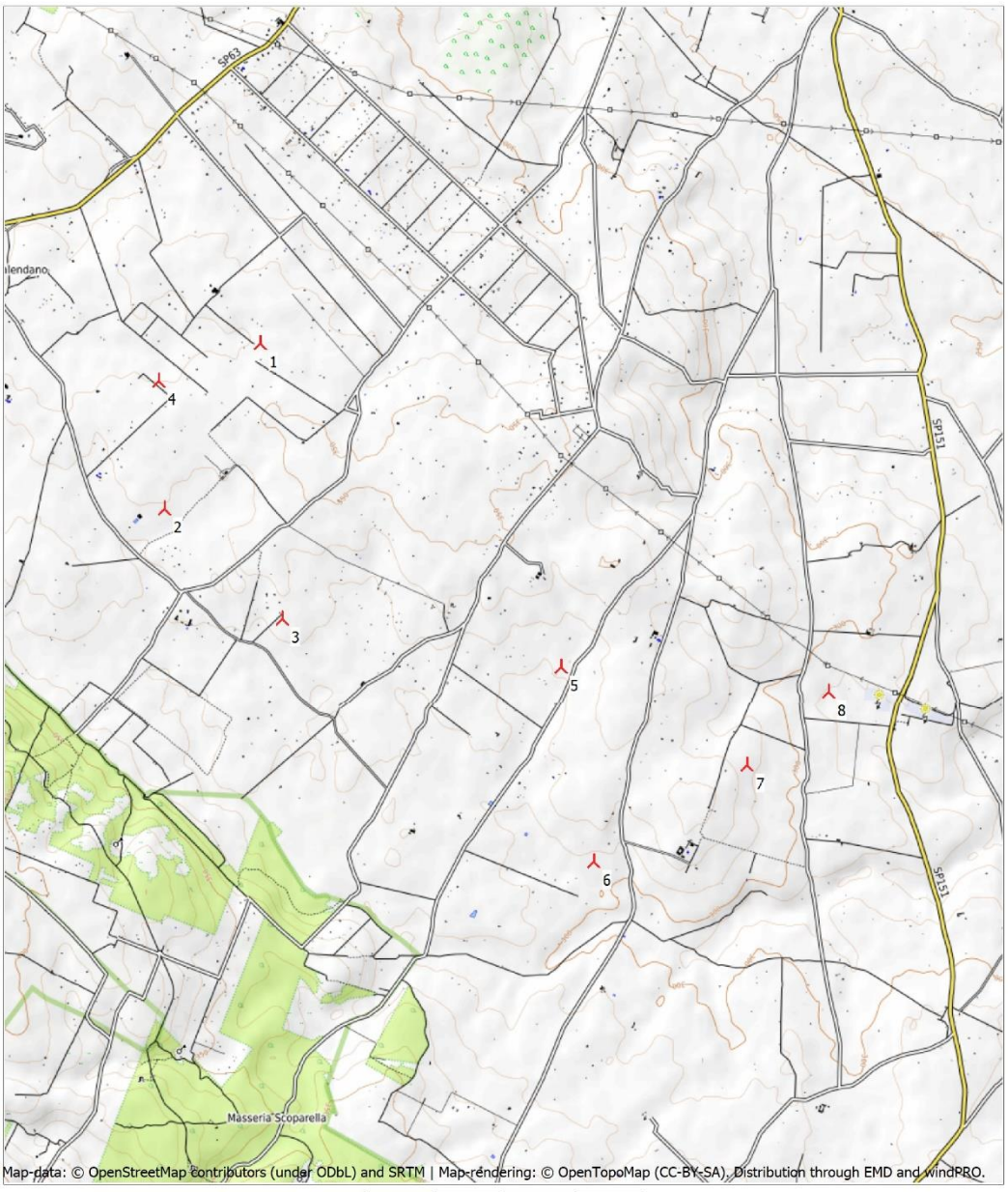
PARK - Map

Calculation: 231006_8xV172 @114 m



Map: OpenTopoMap , Print scale 1:40,000, Map center UTM (north)-WGS84 Zone: 33 East: 622,291 North: 4,546,385

New WTG

Appendix B. Park Calculation – 150 m HH

Project:
Ruvo

Description:
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PARK - Main Result

Calculation: 231006_8xV172 @150 m

Setup
AEP scaled to a full year based on number of samples
Scaling factor from 20.0 years to 1 year: 0.050

Calculation performed in UTM (north)-WGS84 Zone: 33
At the site centre the difference between grid north and true north is: 1.0°

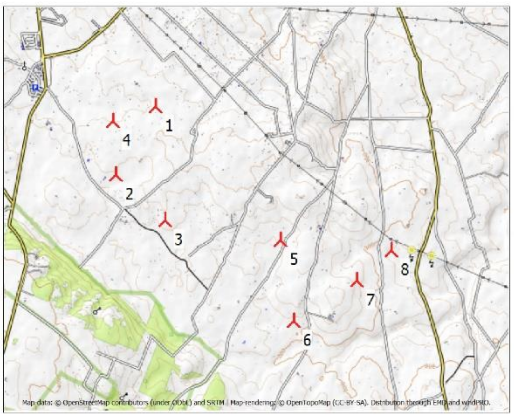
Wake
Wake Model: N.O. Jensen (RISØ/EMD) Park 2 2018
Wake decay constant
Wake decay constant: 0.090 DTU default onshore Hub height independent
Reference WTG: 1

Scaler/wind data

Name	Meso Scaler
Terrain scaling	Meso-scale Data Downscaling
Micro terrain flow model	WAsP IBZ from Site Data
Used period	01/01/2001 01.00.00 - 01/01/2021
Meteo object(s)	EMD-WRF Europe+ (ERA5)_N41.067535_E016.46872 (2)
Displacement height	Omnidirectional from objects
WAsP version	WAsP 12 Version 12.08.0032

Power correction
Power curve correction (adjusted IEC method, improved to match turbine control)

		Min	Max	Avg	Corr. [%]	Neg. corr. [%]	Pos. corr. [%]
Air density							
EMD-WRF Europe+ (ERA5)_N41.067535_E016.46872 (2) - 100.00 m	[°C]	-5.7	39.2	15.3			
From air density settings	[hPa]	951.6	965.9	958.0			
Resulting air density	[kg/m³]	1.072	1.247	1.158			
Relative to 15°C at sea level	[%]	87.5	101.8	94.5	-3.3	-3.3	0.0



Scale 1:100,000
New WTG

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]	Wind speed free [m/s]	Wind speed wake reduced [m/s]
Wind farm	165,422.2	169,925.0	2.6	32.8	20,677.8	2,872	6.6	6.5

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 8 new WTGs with total 57.6 MW rated power

	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 [%]	Wind speed free [m/s]	reduced [m/s]
1	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	21,139.3	2.6	6.68	6.59
2	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	21,013.2	2.1	6.63	6.54
3	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	20,878.0	3.3	6.64	6.53
4	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	21,202.2	1.8	6.65	6.58
5	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	20,484.5	2.3	6.54	6.46
6	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	20,448.3	2.4	6.52	6.43
7	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	20,493.5	3.8	6.60	6.47
8	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	EMD	Level 0 & 0S - Calculated - PO7200 - 07-2022	19,763.3	2.9	6.42	6.33

Annual Energy results includes shown losses. For expected NET AEP (expected sold production), see report Loss & Uncertainty.

WTG siting

	UTM (north)-WGS84 Zone: 33 Easting	Northing	Z [m]	Row data/Description	Calculation period Start	End
1 New	620,594	4,548,218	344.3	1	01/01/2001	01/01/2021
2 New	619,923	4,547,025	339.4	2	01/01/2001	01/01/2021
3 New	620,781	4,546,252	338.4	3	01/01/2001	01/01/2021
4 New	619,868	4,547,939	340.3	4	01/01/2001	01/01/2021
5 New	622,790	4,545,940	325.0	5	01/01/2001	01/01/2021
6 New	623,046	4,544,553	311.7	6	01/01/2001	01/01/2021
7 New	624,139	4,545,263	315.0	7	01/01/2001	01/01/2021
8 New	624,715	4,545,798	289.5	8	01/01/2001	01/01/2021

Project:
Ruvo

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Calculated:
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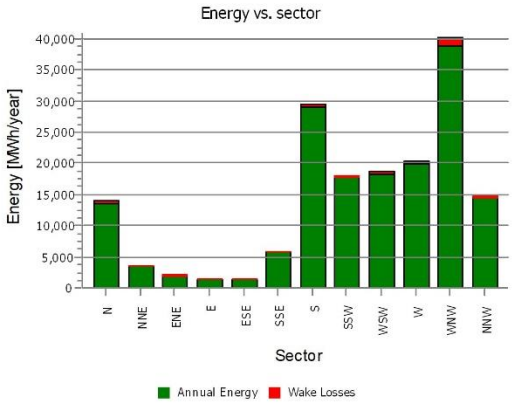
PARK - Production Analysis

Calculation: 231006_8xV172 @150 m **WTG:** All new WTGs, Air density varies with WTG position 1.160 kg/m³ - 1.166 kg/m³

Directional Analysis

Sector		0 N	1 NNE	2 ENE	3 E	4 ESE	5 SSE	6 S	7 SSW	8 WSW	9 W	10 WNW	11 NNW	Total
Model based energy	[MWh]	14,089.0	3,539.5	2,068.4	1,447.1	1,495.9	5,870.6	29,384.1	17,979.6	18,755.8	20,234.8	40,219.9	14,840.2	169,925.0
-Decrease due to wake losses	[MWh]	610.0	94.3	153.3	45.4	73.4	75.3	449.7	292.8	590.3	295.5	1,469.0	353.8	4,502.8
Resulting energy	**[MWh]**	**13,479.0**	**3,445.2**	**1,915.1**	**1,401.7**	**1,422.5**	**5,795.3**	**28,934.4**	**17,686.8**	**18,165.4**	**19,939.3**	**38,751.0**	**14,486.4**	**165,422.3**
Specific energy	[kWh/m²]													890
Specific energy	[kWh/kW]													2,872
Decrease due to wake losses	[%]	4.3	2.7	7.4	3.1	4.9	1.3	1.5	1.6	3.1	1.5	3.7	2.4	2.65
Full Load Equivalent	[Hours/year]	234	60	33	24	25	101	502	307	315	346	673	251	2,872



Project:
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Description:
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Calculated:
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PARK - Power Curve Analysis

Calculation: 231006_8xV172 @150 m **WTG:** 1 - VESTAS V172-7.2 7200 172.0 !O!, Hub height: 150.0 m

Name: Level 0 & 0S - Calculated - PO7200 - 07-2022
Source: Manufacturer

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
08/07/2022	EMD	25/02/2022	06/10/2022	25.0	Pitch	User defined	Variable	0.31

Based Vestas Document no.: 0127-1584 V01.

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	11,840	18,085	24,147	29,566	34,148	37,822
VESTAS V172-7.2 7200 172.0 !O! Level 0 & 0S - Calculated - PO7200 - 07-2022	[MWh]	11,639	17,897	23,956	29,281	33,613	36,862
Check value	[%]	2	1	1	1	2	3

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

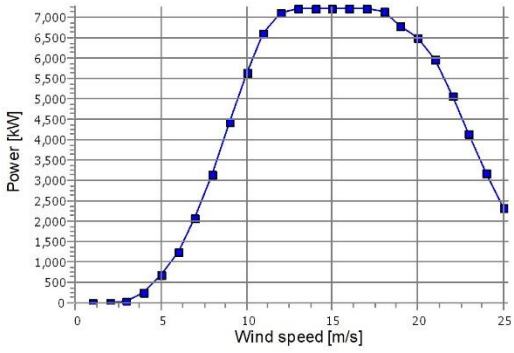
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
3.0	32.0	0.08	3.0	0.97
3.5	129.0	0.21	3.5	0.89
4.0	288.0	0.32	4.0	0.83
4.5	481.0	0.37	4.5	0.82
5.0	715.0	0.40	5.0	0.81
5.5	999.0	0.42	5.5	0.82
6.0	1,340.0	0.44	6.0	0.81
6.5	1,739.0	0.44	6.5	0.81
7.0	2,203.0	0.45	7.0	0.81
7.5	2,729.0	0.45	7.5	0.80
8.0	3,324.0	0.46	8.0	0.79
8.5	3,986.0	0.46	8.5	0.78
9.0	4,685.0	0.45	9.0	0.75
9.5	5,314.0	0.44	9.5	0.69
10.0	5,904.0	0.41	10.0	0.63
10.5	6,441.0	0.39	10.5	0.57
11.0	6,854.0	0.36	11.0	0.51
11.5	7,078.0	0.33	11.5	0.45
12.0	7,160.0	0.29	12.0	0.39
12.5	7,195.0	0.26	12.5	0.34
13.0	7,200.0	0.23	13.0	0.30
13.5	7,200.0	0.21	13.5	0.26
14.0	7,200.0	0.18	14.0	0.24
14.5	7,200.0	0.17	14.5	0.21
15.0	7,200.0	0.15	15.0	0.19
15.5	7,200.0	0.14	15.5	0.17
16.0	7,200.0	0.12	16.0	0.16
16.5	7,200.0	0.11	16.5	0.14
17.0	7,200.0	0.10	17.0	0.13
17.5	7,194.0	0.09	17.5	0.12
18.0	7,124.0	0.09	18.0	0.11
18.5	6,959.0	0.08	18.5	0.10
19.0	6,789.0	0.07	19.0	0.09
19.5	6,630.0	0.06	19.5	0.08
20.0	6,472.0	0.06	20.0	0.07
20.5	6,262.0	0.05	20.5	0.07
21.0	5,946.0	0.05	21.0	0.06
21.5	5,538.0	0.04	21.5	0.05
22.0	5,069.0	0.03	22.0	0.05
22.5	4,597.0	0.03	22.5	0.04
23.0	4,121.0	0.02	23.0	0.03
23.5	3,636.0	0.02	23.5	0.03
24.0	3,169.0	0.02	24.0	0.02
24.5	2,718.0	0.01	24.5	0.02
25.0	2,328.0	0.01	25.0	0.02

Power and efficiency vs. wind speed

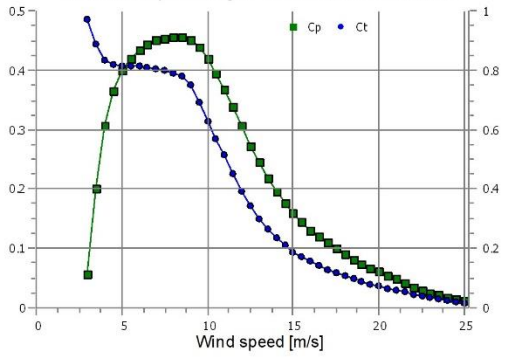
Data used in calculation, Mean air density: 1.156 kg/m³

Wind speed [m/s]	Power [kW]	Cp
1.0	0.0	0.00
2.0	0.0	0.00
3.0	20.4	0.06
4.0	262.7	0.31
5.0	668.5	0.40
6.0	1,258.7	0.43
7.0	2,074.0	0.45
8.0	3,133.4	0.46
9.0	4,415.2	0.45
10.0	5,614.4	0.42
11.0	6,590.6	0.37
12.0	7,094.0	0.31
13.0	7,195.3	0.24
14.0	7,200.0	0.20
15.0	7,200.0	0.16
16.0	7,200.0	0.13
17.0	7,200.0	0.11
18.0	7,124.0	0.09
19.0	6,789.0	0.07
20.0	6,472.0	0.06
21.0	5,946.0	0.05
22.0	5,069.0	0.04
23.0	4,121.0	0.03
24.0	3,169.0	0.02
25.0	2,328.0	0.01

Power curve
For air density: 1.156 kg/m³ and reference climate data



Cp and Ct curve
For air density: 1.156 kg/m³ and reference climate data



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Calculated:
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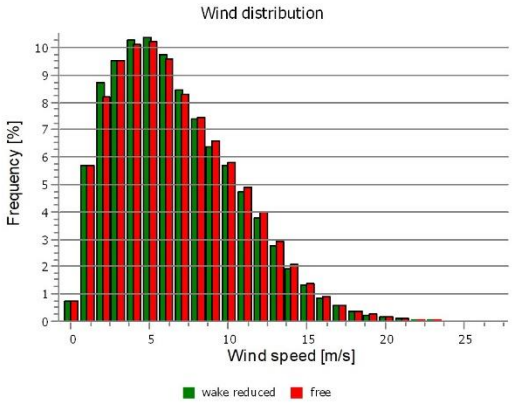
PARK - Wind Data Analysis

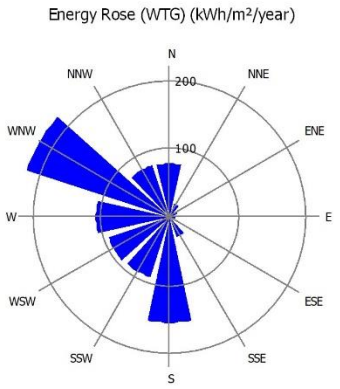
Calculation: 231006_8xV172 @150 m **Wind data:** 1 - 1; Hub height: 150.0

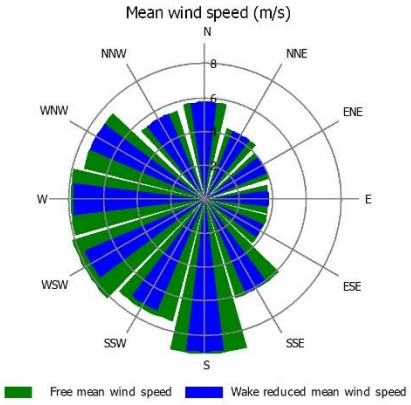
Site coordinates
UTM (north)-WGS84 Zone: 33
East: 620,594 North: 4,548,218
1 - 1
Masts used
Take nearest

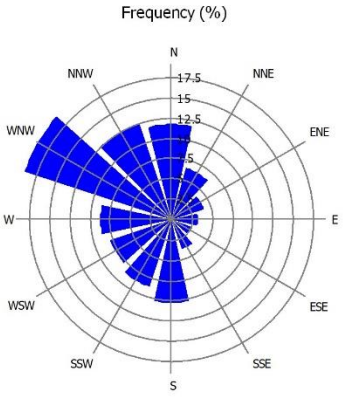
Winddata for site

Sector	Free mean wind speed [m/s]	Wake reduced mean wind speed [m/s]	Frequency [%]
0 N	5.8	5.8	11.8
1 NNE	4.4	4.4	6.7
2 ENE	4.0	4.0	4.2
3 E	3.8	3.8	3.2
4 ESE	3.8	3.8	2.7
5 SSE	6.1	6.1	3.9
6 S	9.2	9.0	10.3
7 SSW	7.5	7.2	8.7
8 WSW	8.2	7.7	8.0
9 W	8.0	7.8	8.8
10 WNW	7.4	7.4	19.1
11 NNW	5.5	5.5	12.6
All	6.7	6.6	100.0









Project:
Ruvo

Description:
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Calculated:
06/10/2023 10.09/4.0.518

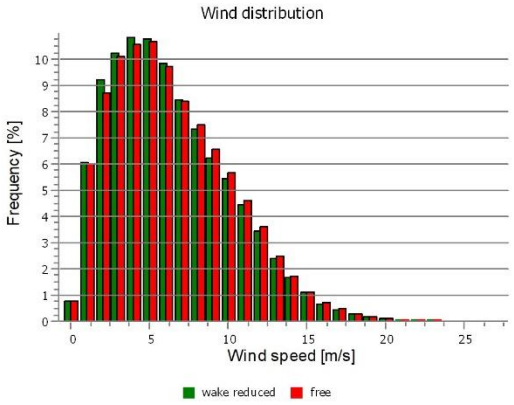
PARK - Wind Data Analysis

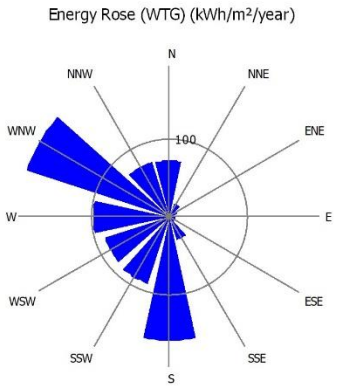
Calculation: 231006_8xV172 @150 m **Wind data:** 8 - 8; Hub height: 150.0

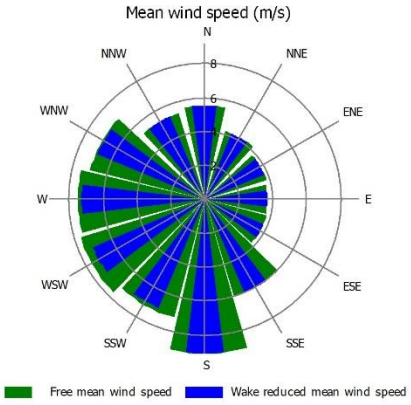
Site coordinates
UTM (north)-WGS84 Zone: 33
East: 624,715 North: 4,545,798
8 - 8
Masts used
Take nearest

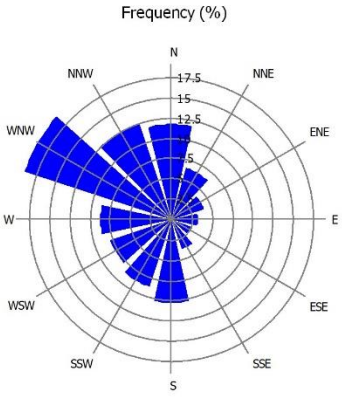
Winddata for site

Sector	Free mean wind speed [m/s]	Wake reduced mean wind speed [m/s]	Frequency [%]
0 N	5.6	5.6	11.8
1 NNE	4.2	4.2	6.7
2 ENE	3.8	3.8	4.2
3 E	3.7	3.7	3.2
4 ESE	3.8	3.8	2.7
5 SSE	6.0	6.0	3.9
6 S	9.2	9.2	10.3
7 SSW	7.2	7.0	8.7
8 WSW	7.7	7.2	8.0
9 W	7.5	7.3	8.8
10 WNW	7.0	6.9	19.1
11 NNW	5.3	5.3	12.6
All	6.4	6.3	100.0









Project:
Ruvo

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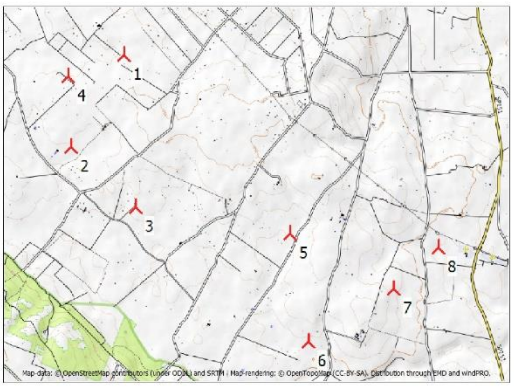
Calculated:
06/10/2023 10.09/4.0.518

PARK - WTG distances

Calculation: 231006_8xV172 @150 m

WTG distances

	Z [m]	Nearest WTG	Z [m]	Horizontal distance [m]	Distance in rotor diameters
1	344.3	4	340.3	777	4.5
2	339.4	4	340.3	915	5.3
3	338.4	2	339.4	1,155	6.7
4	340.3	1	344.3	777	4.5
5	325.0	6	311.7	1,410	8.2
6	311.7	7	315.0	1,303	7.6
7	315.0	8	289.5	786	4.6
8	289.5	7	315.0	786	4.6
Min	**289.5**		**289.5**	**777**	**4.5**
Max	**344.3**		**344.3**	**1,410**	**8.2**



Scale 1:75,000

New WTG

Project:
Ruvo

Description:
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06/10/2023 10.09/4.0.518

PARK - Time varying AEP

Calculation: 231006_8xV172 @150 m

Windfarm: 57.6 MW based on 8 turbines of type VESTAS V172-7.2 7200 172.0 !O!.
Selection: All new WTGs
Calculated mean yield per month and hour [MWh]. The result includes wake losses and any curtailment losses.
Values are scaled to a full year, see correction factors at main result page.

Hour/Month [MWh]	1	2	3	4	5	6	7	8	9	10	11	12	Grand Total
0	842	822	857	758	756	548	576	507	526	583	728	841	8,346
1	850	833	860	745	761	578	590	524	552	591	741	840	8,463
2	856	841	863	747	744	600	607	539	559	580	740	831	8,507
3	836	841	873	748	755	633	621	545	571	570	735	842	8,570
4	836	833	886	754	742	639	624	557	572	561	720	844	8,568
5	836	822	904	743	734	631	632	555	578	559	721	833	8,549
6	834	818	886	750	704	592	617	541	561	546	719	832	8,402
7	827	814	879	678	548	402	437	437	517	533	721	829	7,621
8	841	800	778	535	446	335	346	317	367	475	710	830	6,780
9	790	690	625	457	403	284	311	267	306	392	613	792	5,928
10	643	593	584	431	380	258	285	243	278	355	519	671	5,240
11	580	544	561	428	385	282	316	243	266	337	483	622	5,046
12	552	518	547	432	428	345	383	300	269	337	471	586	5,169
13	548	531	552	466	436	364	425	352	293	338	474	578	5,359
14	552	540	574	453	428	357	411	378	316	351	476	560	5,395
15	567	546	592	455	419	338	375	351	315	356	481	560	5,354
16	622	550	597	449	429	303	340	314	304	375	532	612	5,428
17	714	591	598	453	439	291	312	273	289	436	609	688	5,692
18	730	679	657	497	434	258	272	260	319	500	653	745	6,002
19	745	732	722	575	517	280	284	271	360	532	663	762	6,444
20	764	746	794	675	614	342	328	307	410	549	681	780	6,990
21	794	771	836	739	688	408	406	347	446	573	691	800	7,500
22	823	788	844	762	735	467	483	426	470	587	707	812	7,905
23	842	802	855	761	755	513	535	473	495	593	718	822	8,163
Grand Total	17,824	17,043	17,724	14,492	13,680	10,049	10,518	9,325	9,936	11,610	15,308	17,913	165,422

Hour/Month [MW]	1	2	3	4	5	6	7	8	9	10	11	12	Grand Total
0	27.2	29.4	27.6	25.3	24.4	18.3	18.6	16.4	17.5	18.8	24.3	27.1	22.9
1	27.4	29.7	27.7	24.8	24.5	19.3	19.0	16.9	18.4	19.1	24.7	27.1	23.2
2	27.6	30.0	27.8	24.9	24.0	20.0	19.6	17.4	18.6	18.7	24.7	26.8	23.3
3	27.0	30.0	28.2	24.9	24.4	21.1	20.0	17.6	19.0	18.4	24.5	27.2	23.5
4	27.0	29.7	28.6	25.1	23.9	21.3	20.1	18.0	19.1	18.1	24.0	27.2	23.5
5	27.0	29.4	29.2	24.8	23.7	21.0	20.4	17.9	19.3	18.0	24.0	26.9	23.4
6	26.9	29.2	28.6	25.0	22.7	19.7	19.9	17.5	18.7	17.6	24.0	26.9	23.0
7	26.7	29.1	28.4	22.6	17.7	13.4	14.1	14.1	17.2	17.2	24.0	26.7	20.9
8	27.1	28.6	25.1	17.8	14.4	11.2	11.2	10.2	12.2	15.3	23.7	26.8	18.6
9	25.5	24.6	20.2	15.2	13.0	9.5	10.0	8.6	10.2	12.6	20.4	25.5	16.2
10	20.8	21.2	18.8	14.4	12.3	8.6	9.2	7.8	9.3	11.4	17.3	21.7	14.4
11	18.7	19.4	18.1	14.3	12.4	9.4	10.2	7.8	8.9	10.9	16.1	20.1	13.8
12	17.8	18.5	17.6	14.4	13.8	11.5	12.4	9.7	9.0	10.9	15.7	18.9	14.2
13	17.7	19.0	17.8	15.5	14.1	12.1	13.7	11.4	9.8	10.9	15.8	18.6	14.7
14	17.8	19.3	18.5	15.1	13.8	11.9	13.3	12.2	10.5	11.3	15.9	18.1	14.8
15	18.3	19.5	19.1	15.2	13.5	11.3	12.1	11.3	10.5	11.5	16.0	18.1	14.7
16	20.1	19.7	19.2	15.0	13.8	10.1	11.0	10.1	10.1	12.1	17.7	19.7	14.9
17	23.0	21.1	19.3	15.1	14.2	9.7	10.1	8.8	9.6	14.1	20.3	22.2	15.6
18	23.6	24.2	21.2	16.6	14.0	8.6	8.8	8.4	10.6	16.1	21.8	24.0	16.4
19	24.0	26.1	23.3	19.2	16.7	9.3	9.2	8.7	12.0	17.2	22.1	24.6	17.7
20	24.6	26.7	25.6	22.5	19.8	11.4	10.6	9.9	13.7	17.7	22.7	25.2	19.2
21	25.6	27.5	27.0	24.6	22.2	13.6	13.1	11.2	14.9	18.5	23.0	25.8	20.5
22	26.5	28.1	27.2	25.4	23.7	15.6	15.6	13.7	15.7	18.9	23.6	26.2	21.7
23	27.2	28.6	27.6	25.4	24.3	17.1	17.3	15.2	16.5	19.1	23.9	26.5	22.4
Grand Total	24.0	25.4	23.8	20.1	18.4	14.0	14.1	12.5	13.8	15.6	21.3	24.1	18.9

Project:
Ruvo

Description:
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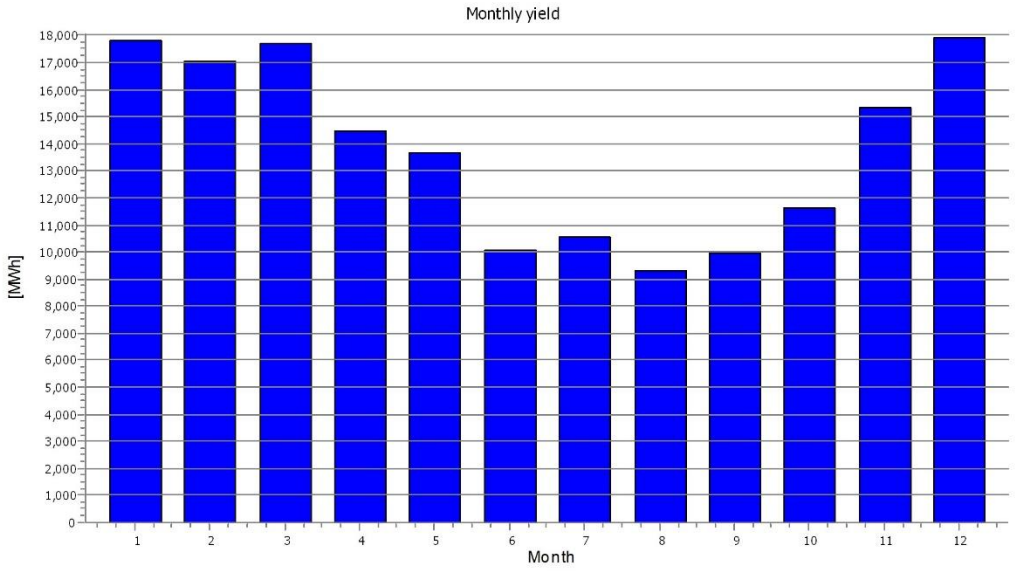
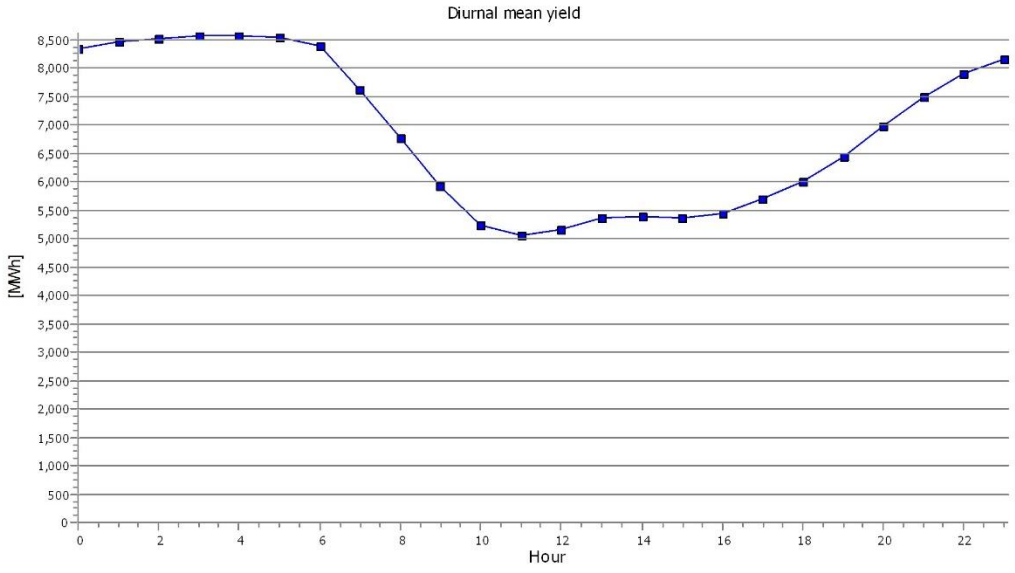
Calculated:
06/10/2023 10.09/4.0.518

PARK - Time varying AEP

Calculation: 231006_8xV172 @150 m

Windfarm: 57.6 MW based on 8 turbines of type VESTAS V172-7.2 7200 172.0 !O!.
Selection: All new WTGs
Calculated mean yield per month and hour [MWh]. The result includes wake losses and any curtailment losses.
Values are scaled to a full year, see correction factors at main result page.





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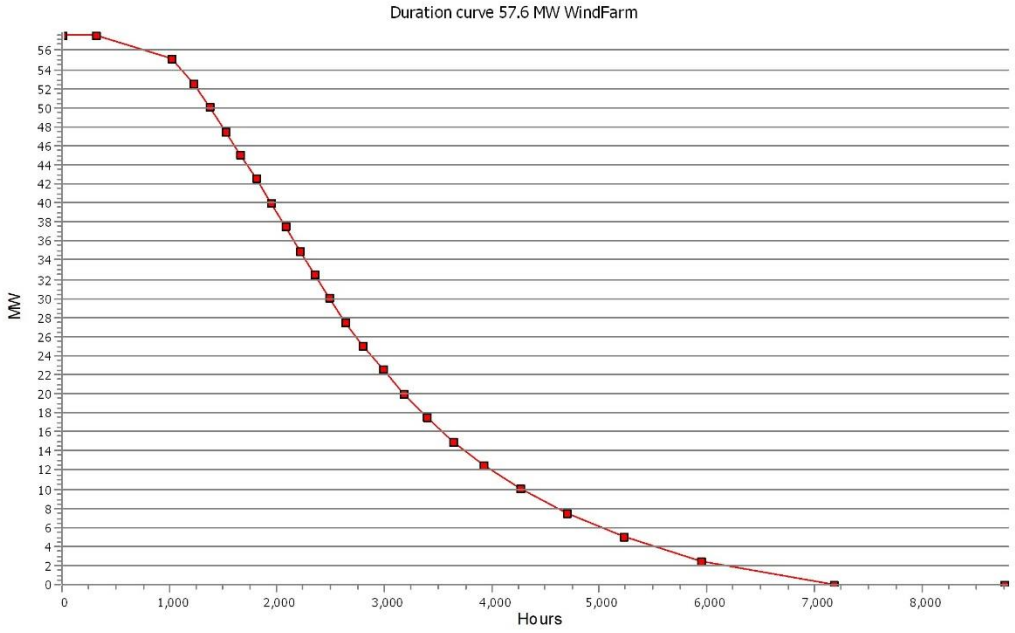
PARK - Time varying AEP

Calculation: 231006_8xV172 @150 m

Windfarm: 57.6 MW based on 8 turbines of type VESTAS V172-7.2 7200 172.0 !O!.
Selection: All new WTGs
Calculated mean yield per month and hour [MWh]. The result includes wake losses and any curtailment losses.

Hours	Hours [%]	Hours accumulated	Power [MW]	Power (MW/WTG)
308	3.5	308	57.6	7.2
709	8.1	1017	55.1 - 57.6	6.9 - 7.2
204	2.3	1221	52.6 - 55.1	6.6 - 6.9
156	1.8	1376	50.1 - 52.6	6.3 - 6.6
144	1.6	1521	47.6 - 50.1	5.9 - 6.3
138	1.6	1658	45.1 - 47.6	5.6 - 5.9
140	1.6	1799	42.6 - 45.1	5.3 - 5.6
136	1.5	1934	40.1 - 42.6	5.0 - 5.3
137	1.6	2071	37.6 - 40.1	4.7 - 5.0
140	1.6	2210	35.1 - 37.6	4.4 - 4.7
135	1.5	2345	32.6 - 35.1	4.1 - 4.4
139	1.6	2485	30.1 - 32.6	3.8 - 4.1
150	1.7	2635	27.5 - 30.1	3.4 - 3.8
163	1.9	2798	25.0 - 27.5	3.1 - 3.4
182	2.1	2980	22.5 - 25.0	2.8 - 3.1
198	2.3	3178	20.0 - 22.5	2.5 - 2.8
212	2.4	3390	17.5 - 20.0	2.2 - 2.5
247	2.8	3636	15.0 - 17.5	1.9 - 2.2
285	3.3	3922	12.5 - 15.0	1.6 - 1.9
346	3.9	4267	10.0 - 12.5	1.3 - 1.6
422	4.8	4689	7.5 - 10.0	0.9 - 1.3
541	6.2	5230	5.0 - 7.5	0.6 - 0.9
715	8.2	5946	2.5 - 5.0	0.3 - 0.6
1228	14.0	7174	0.0 - 2.5	0.0 - 0.3
1592	18.2	8766	0.0	0.0



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PARK - Scaling info

Calculation: 231006_8xV172 @150 m

Scaler settings

Name	Meso Scaler
Terrain scaling	Meso-scale Data Downscaling
RIX correction	No RIX correction
Displacement height	from objects
Micro terrain flow model	SDO

Site Data: SDO

Obstacles:

All obstacles used

Roughness:

Terrain data files used in calculation:
C:\Users\sza\Documents\WindPRO Data\Consultancy\Ruvo\ROUGHNESSLINE_Ruvo_0.wpo
Min X: 602,116, Max X: 642,030, Min Y: 4,526,595, Max Y: 4,568,008, Width: 39,913 m, Height: 41,413 m

Orography:

Terrain data files used in calculation:
C:\Users\sza\Documents\WindPRO Data\Consultancy\Ruvo\CONTOURLINE_ONLINEDATA_0.wpo
Min X: 559,556, Max X: 645,341, Min Y: 4,535,728, Max Y: 4,570,857, Width: 85,784 m, Height: 35,129 m

Post calibration

Overall factor	1.0180
Overall offset	0.0000
By sector	No
By month	No
By hour	No
By wind speed	No

Project:
Ruvo

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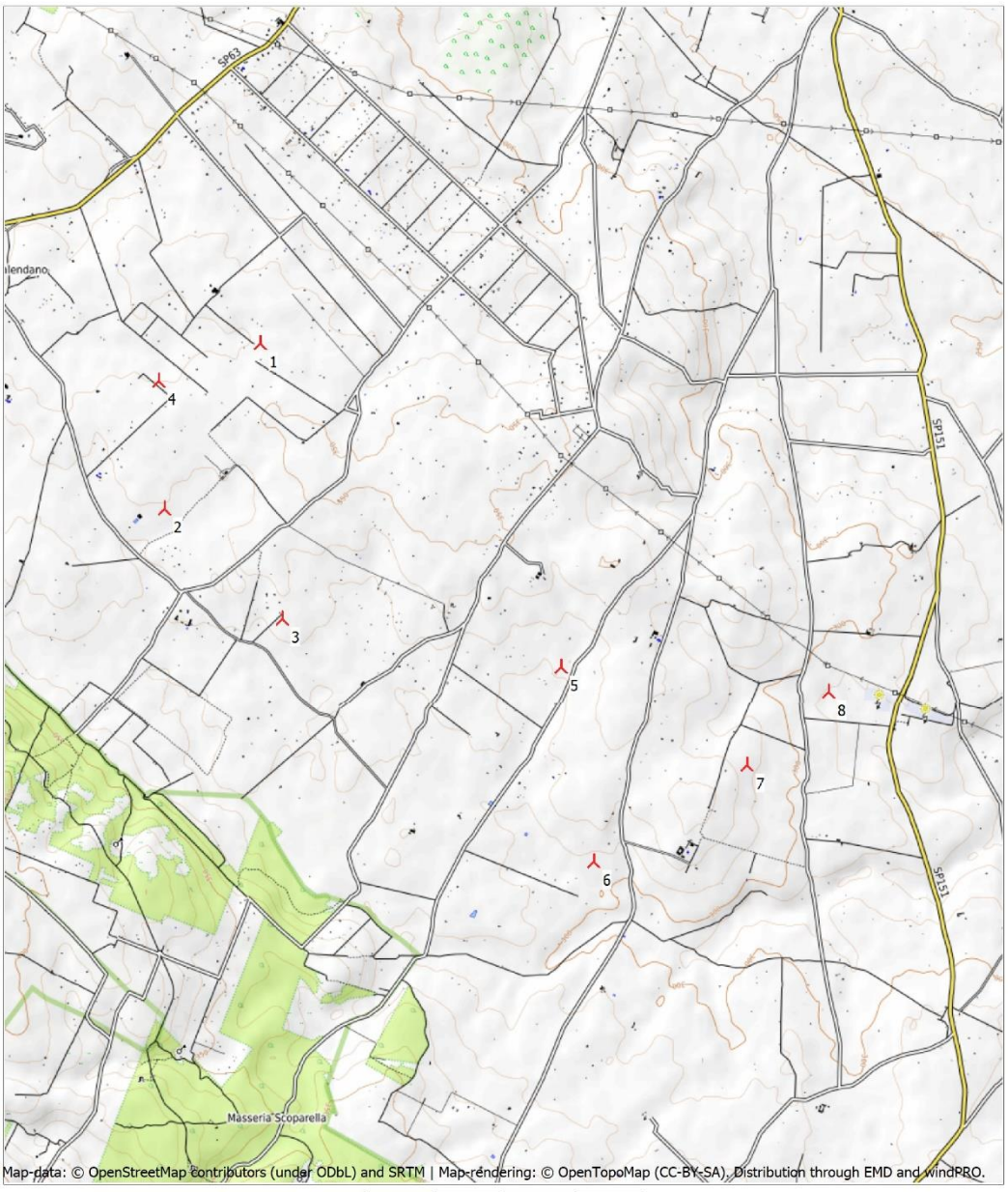
PARK - Map

Calculation: 231006_8xV172 @150 m



Map: OpenTopoMap , Print scale 1:40,000, Map center UTM (north)-WGS84 Zone: 33 East: 622,291 North: 4,546,385

New WTG