

Project:

Project_Guj

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student / weti-lab-vt10@hs-flensburg.de

Calculated:

12/18/2024 10:52 AM/4.0.547

PARK - Main Result

Calculation: SUZLON_2.1*6_Resource

Wake Model

N.O. Jensen (RISØ/EMD) Park 2 2018

Calculation performed in UTM (north)-WGS84 Zone: 44

At the site centre the difference between grid north and true north is: -0.5°

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: BEGAMPET V3 2014

Base temperature: 26.6 °C at 545.0 m

Base pressure: 1013.3 hPa at 0.0 m

Air density for Site center in key hub height: 0.0 m + 112.0 m = 1.152 kg/m³ -> 94.0 % of Std

Relative humidity: 0.0 %

Wake Model Parameters

Wake decay constant

0.090 DTU default onshore

Hub height independent

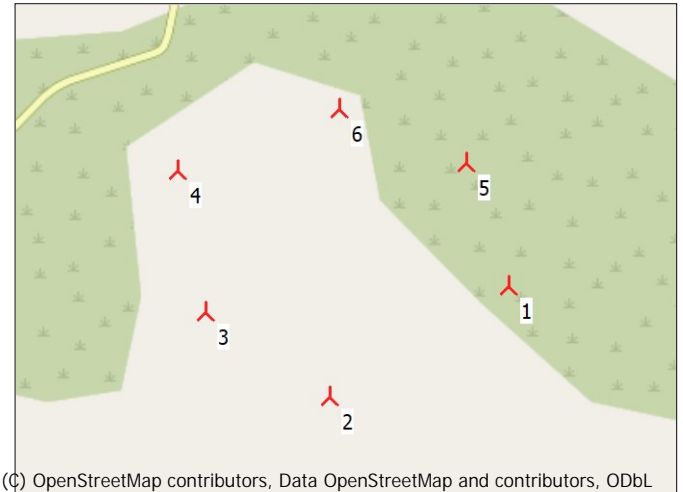
Omnidirectional displacement height from objects

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



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

Scale 1:40,000

New WTG

Resource file(s)

C:\Users\student\Desktop\Soni_Patil_10\PROJECT_GUJ\Project_Guj_Res_50_Hub_135.0_150.0_110.0_0.rsf

Calculated Annual Energy for Wind Farm

WTG combination	Result		GROSS (no loss)	Wake loss	Specific results=)			Full load hours	Mean wind speed @hub height
	PARK	Free WTGs			Capacity factor	Mean WTG result			
	[MWh/y]	[MWh/y]		[%]	[%]	[MWh/y]	[Hours/year]		[m/s]
Wind farm	39,026.7	39,924.5		2.2	35.3	6,504.5	3,097		6.9

=) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 6 new WTGs with total 12.6 MW rated power

Links	WTG type		Type-generator	Power, rated	Rotor diameter	Hub height	Power curve		Annual Energy Result	Wake loss	Free mean wind speed
	Valid	Manufact.					Creator	Name			
				[kW]	[m]	[m]			[MWh/y]	[%]	[m/s]
1 A	Yes	Suzlon	S97-2,100	2,100	97.0	112.0	EMD	Level 0 - Calculated - SB47 S97 - 03-2013	6,420.5	3.7	6.88
2 A	Yes	Suzlon	S97-2,100	2,100	97.0	112.0	EMD	Level 0 - Calculated - SB47 S97 - 03-2013	6,519.8	2.2	6.88
3 A	Yes	Suzlon	S97-2,100	2,100	97.0	112.0	EMD	Level 0 - Calculated - SB47 S97 - 03-2013	6,441.5	1.4	6.82
4 A	Yes	Suzlon	S97-2,100	2,100	97.0	112.0	EMD	Level 0 - Calculated - SB47 S97 - 03-2013	6,472.3	0.4	6.81
5 A	Yes	Suzlon	S97-2,100	2,100	97.0	112.0	EMD	Level 0 - Calculated - SB47 S97 - 03-2013	6,598.3	3.2	6.95
6 A	Yes	Suzlon	S97-2,100	2,100	97.0	112.0	EMD	Level 0 - Calculated - SB47 S97 - 03-2013	6,574.2	2.5	6.92

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

WTG siting

UTM (north)-WGS84 Zone: 44

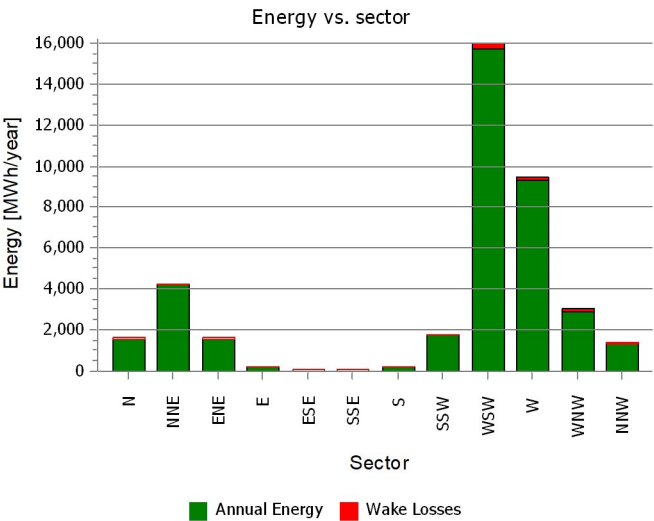
Easting Northing Z Row data/Description
[m]

1 New	527,077	2,550,325	109.9	Suzlon S97 2100 97.0 !O!	hub: 112.0 m (TOT: 160.5 m) (11)
2 New	526,132	2,549,743	100.0	Suzlon S97 2100 97.0 !O!	hub: 112.0 m (TOT: 160.5 m) (12)
3 New	525,475	2,550,184	97.5	Suzlon S97 2100 97.0 !O!	hub: 112.0 m (TOT: 160.5 m) (13)
4 New	525,328	2,550,923	107.5	Suzlon S97 2100 97.0 !O!	hub: 112.0 m (TOT: 160.5 m) (14)
5 New	526,852	2,550,966	120.0	Suzlon S97 2100 97.0 !O!	hub: 112.0 m (TOT: 160.5 m) (15)
6 New	526,178	2,551,250	120.0	Suzlon S97 2100 97.0 !O!	hub: 112.0 m (TOT: 160.5 m) (16)

PARK - Production Analysis

Calculation: SUZLON_2.1*6_Resource WTG: All new WTGs, Air density varies with WTG position 1.139 kg/m³ - 1.142 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
Roughness based energy [MWh]	1,647.7	4,273.2	1,609.9	258.0	91.2	110.2	258.9	1,801.2	15,991.6	9,454.3	3,046.4	1,381.7	39,924.5
-Decrease due to wake losses [MWh]	70.2	69.1	48.7	5.7	3.6	2.6	8.0	23.0	276.8	175.0	161.4	53.7	897.8
Resulting energy [MWh]	1,577.5	4,204.2	1,561.1	252.3	87.6	107.6	250.9	1,778.2	15,714.9	9,279.3	2,885.0	1,328.1	39,026.7
Specific energy [kWh/m²]													880
Specific energy [kWh/kW]													3,097
Decrease due to wake losses [%]	4.3	1.6	3.0	2.2	4.0	2.4	3.1	1.3	1.7	1.9	5.3	3.9	2.25
Utilization [%]	40.6	42.2	41.6	38.9	31.3	27.4	29.2	36.5	34.4	41.0	41.4	41.5	37.9
Operational [Hours/year]	517	904	491	148	61	51	86	376	2,341	1,985	946	536	8,441
Full Load Equivalent [Hours/year]	125	334	124	20	7	9	20	141	1,247	736	229	105	3,097



PARK - Power Curve Analysis

Calculation: SUZLON_2.1*6_Resource WTG: 1 - Suzlon S97 2100 97.0 !O!, Hub height: 112.0 m

Name: Level 0 - Calculated - SB47 S97 - 03-2013

Source: Manufacturer

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m ²
3/20/2013	EMD	2/19/2013	4/23/2013	20.0	Pitch	User defined	Variable	0.28

According to document PDG-CD-S-PDO-00679.

Turbulence intensity for power curve: 10%

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	3,708	5,590	7,384	8,964	10,285	11,334
Suzlon S97 2100 97.0 !O! Level 0 - Calculated - SB47 S97 - 03-2013	[MWh]	3,648	5,559	7,347	8,839	9,949	10,664
Check value	[%]	2	1	1	1	3	6

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/m²) 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	14.3	0.07	3.5	0.82
4.0	65.4	0.23	4.0	0.80
4.5	130.6	0.32	4.5	0.80
5.0	224.0	0.40	5.0	0.80
5.5	334.5	0.44	5.5	0.79
6.0	449.8	0.46	6.0	0.79
6.5	570.3	0.46	6.5	0.80
7.0	719.8	0.46	7.0	0.80
7.5	898.7	0.47	7.5	0.80
8.0	1,074.1	0.46	8.0	0.78
8.5	1,279.4	0.46	8.5	0.76
9.0	1,474.9	0.45	9.0	0.72
9.5	1,679.8	0.43	9.5	0.68
10.0	1,844.2	0.41	10.0	0.63
10.5	1,968.0	0.38	10.5	0.57
11.0	2,041.9	0.34	11.0	0.49
11.5	2,076.4	0.30	11.5	0.43
12.0	2,092.1	0.27	12.0	0.37
12.5	2,097.3	0.24	12.5	0.32
13.0	2,100.0	0.21	13.0	0.28
13.5	2,100.0	0.19	13.5	0.24
14.0	2,100.0	0.17	14.0	0.22
14.5	2,100.0	0.15	14.5	0.19
15.0	2,100.0	0.14	15.0	0.17
15.5	2,100.0	0.12	15.5	0.16
16.0	2,100.0	0.11	16.0	0.14
16.5	2,100.0	0.10	16.5	0.13
17.0	2,100.0	0.09	17.0	0.12
17.5	2,100.0	0.09	17.5	0.11
18.0	2,100.0	0.08	18.0	0.10
18.5	2,100.0	0.07	18.5	0.09
19.0	2,100.0	0.07	19.0	0.09
19.5	2,100.0	0.06	19.5	0.08
20.0	2,100.0	0.06	20.0	0.07

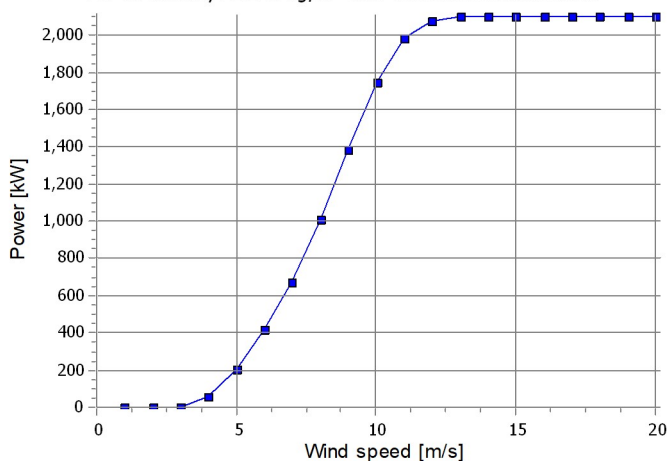
Power, Efficiency and energy vs. wind speed

Data used in calculation, Air density: 1.140 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	1.7	1.7	0.0
4.0	55.4	0.21	3.50- 4.50	55.2	56.9	0.9
5.0	201.3	0.38	4.50- 5.50	237.3	294.1	4.6
6.0	416.1	0.46	5.50- 6.50	538.6	832.7	13.0
7.0	668.8	0.46	6.50- 7.50	877.0	1,709.7	26.6
8.0	1,005.3	0.47	7.50- 8.50	1,122.6	2,832.3	44.1
9.0	1,382.8	0.45	8.50- 9.50	1,155.5	3,987.7	62.1
10.0	1,746.2	0.41	9.50-10.50	971.7	4,959.4	77.2
11.0	1,984.9	0.35	10.50-11.50	676.7	5,636.1	87.8
12.0	2,076.8	0.29	11.50-12.50	401.9	6,037.9	94.0
13.0	2,096.6	0.23	12.50-13.50	212.3	6,250.2	97.3
14.0	2,100.0	0.18	13.50-14.50	101.8	6,352.0	98.9
15.0	2,100.0	0.15	14.50-15.50	43.7	6,395.7	99.6
16.0	2,100.0	0.12	15.50-16.50	16.6	6,412.3	99.9
17.0	2,100.0	0.10	16.50-17.50	5.6	6,417.9	100.0
18.0	2,100.0	0.09	17.50-18.50	1.8	6,419.7	100.0
19.0	2,100.0	0.07	18.50-19.50	0.6	6,420.3	100.0
20.0	2,100.0	0.06	19.50-20.50	0.2	6,420.5	100.0

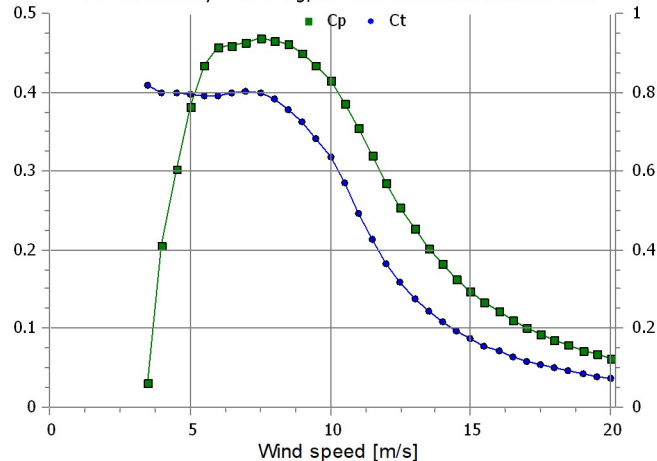
Power curve

For air density: 1.140 kg/m³ and reference climate data



Cp and Ct curve

For air density: 1.140 kg/m³ and reference climate data



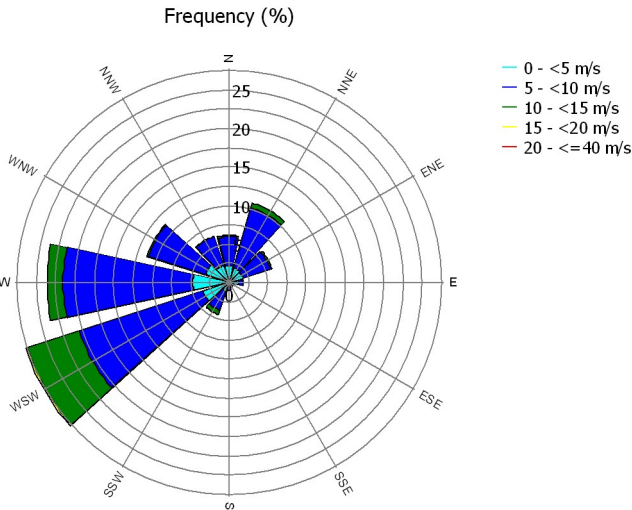
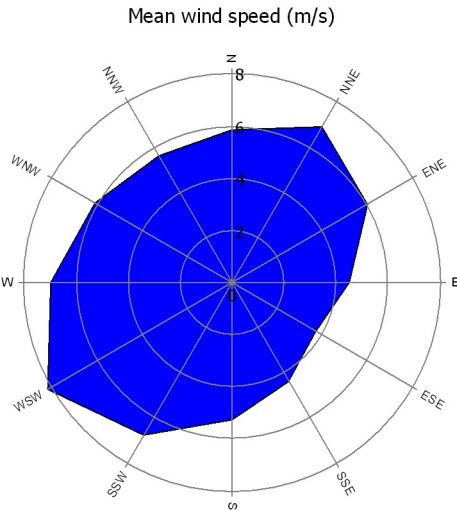
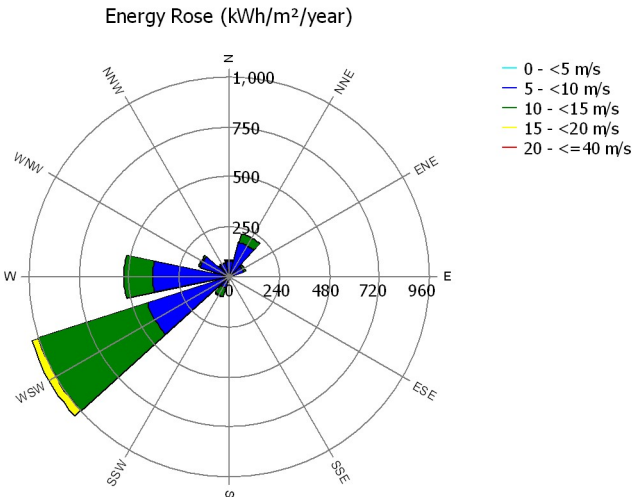
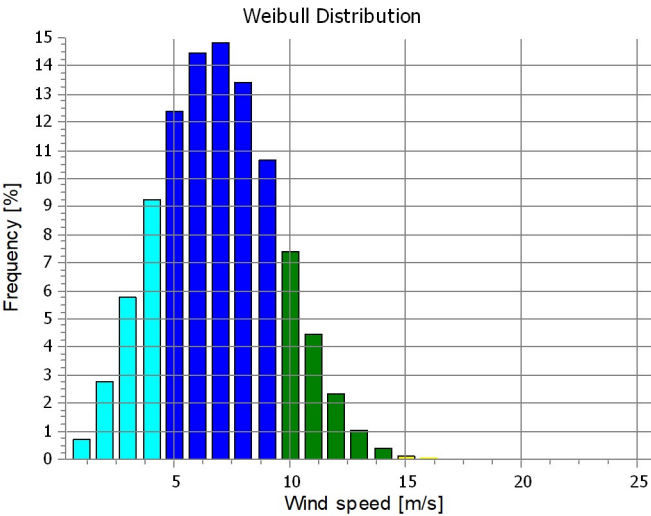
PARK - Wind Data Analysis

Calculation: SUZLON_2.1*6_Resource Wind data: A - Resource file(s); Hub height: 112.0

Site coordinates
UTM (north)-WGS84 Zone: 42
East: 527,077 North: 2,550,325
Suzlon S97 2100 97.0 !O! hub: 112.0 m (TOT: 160.5 m) (11)

Resource file
C:\Users\student\Desktop\Soni_Patil_10\PROJECT_GUJ\Project_Guj_Res_50_Hub_135.0_150.0_110.0_0.rsf

Weibull Data				
Sector	A- parameter [m/s]	Wind speed [m/s]	k- parameter	Frequency [%]
0 N	6.54	5.84	2.967	6.1
1 NNE	7.64	6.90	3.797	10.7
2 ENE	6.73	6.03	3.216	5.8
3 E	5.12	4.54	2.118	1.8
4 ESE	4.02	3.72	1.289	0.7
5 SSE	4.72	4.38	1.278	0.6
6 S	5.83	5.25	1.548	1.0
7 SSW	7.64	6.78	2.588	4.4
8 WSW	9.15	8.20	3.267	27.7
9 W	7.74	6.96	3.457	23.6
10 WNW	6.73	6.07	3.647	11.2
11 NNW	6.23	5.61	3.576	6.3
All	7.72	6.88	2.931	100.0



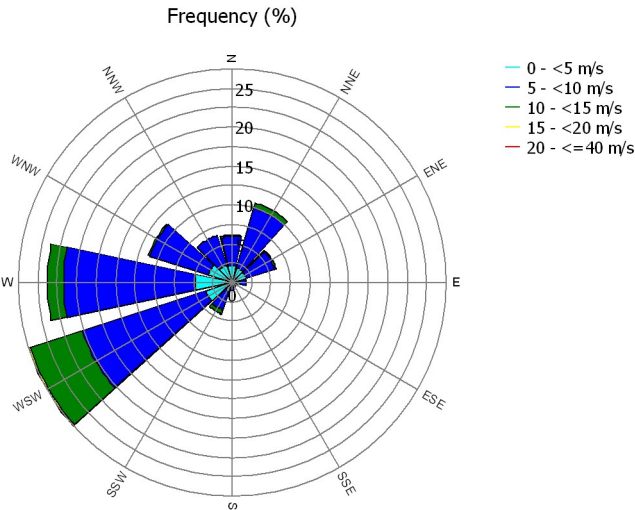
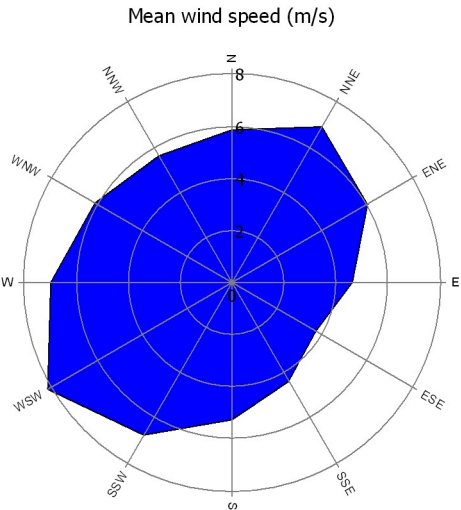
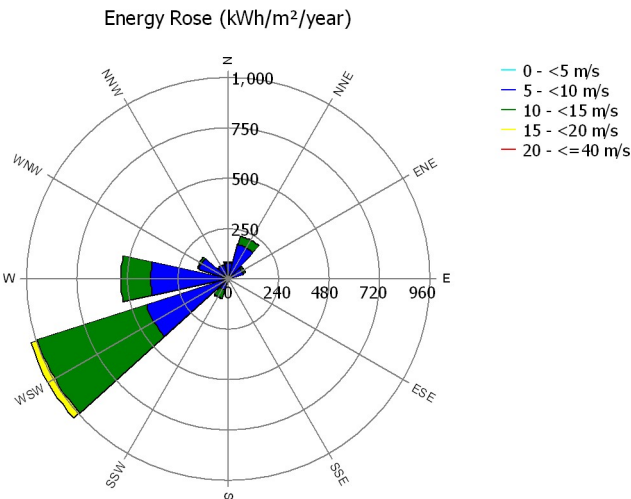
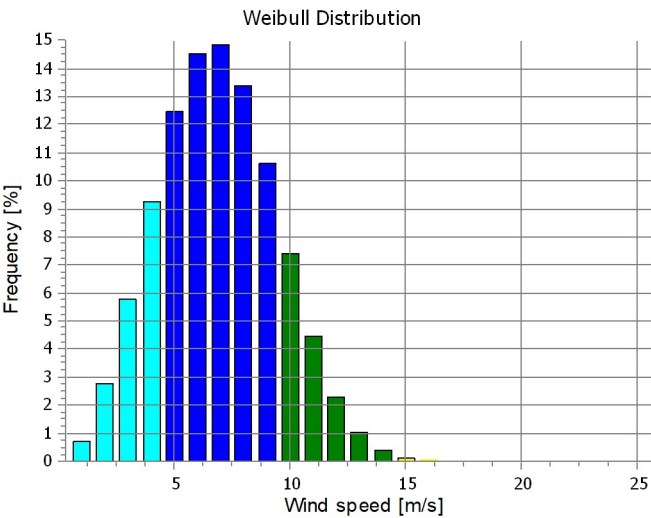
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Site coordinates
UTM (north)-WGS84 Zone: 42
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Weibull Data				
Sector	A- parameter [m/s]	Wind speed [m/s]	k- parameter	Frequency [%]
0 N	6.53	5.83	2.967	6.1
1 NNE	7.64	6.90	3.797	10.6
2 ENE	6.73	6.03	3.217	5.9
3 E	5.22	4.63	2.129	1.8
4 ESE	4.02	3.72	1.289	0.7
5 SSE	4.72	4.38	1.278	0.6
6 S	5.83	5.25	1.547	1.0
7 SSW	7.64	6.78	2.587	4.3
8 WSW	9.15	8.20	3.267	27.5
9 W	7.74	6.96	3.447	23.8
10 WNW	6.73	6.07	3.656	11.3
11 NNW	6.23	5.61	3.567	6.4
All	7.71	6.88	2.931	100.0



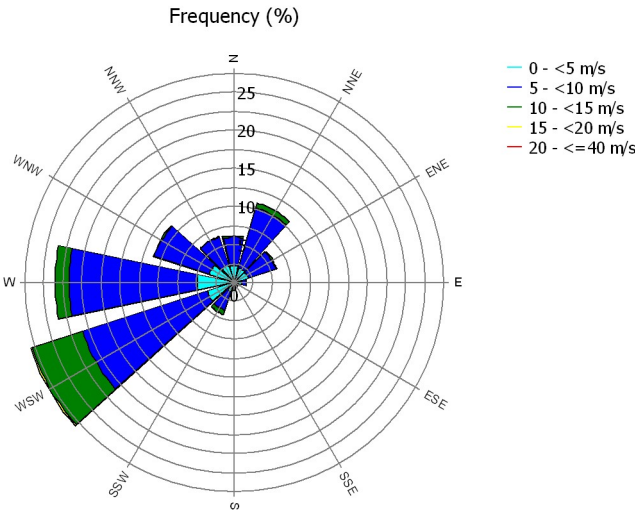
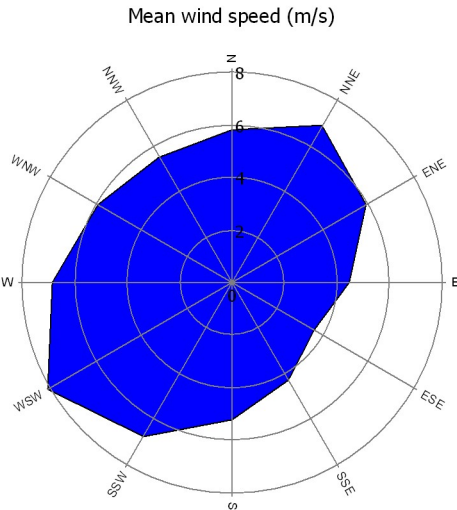
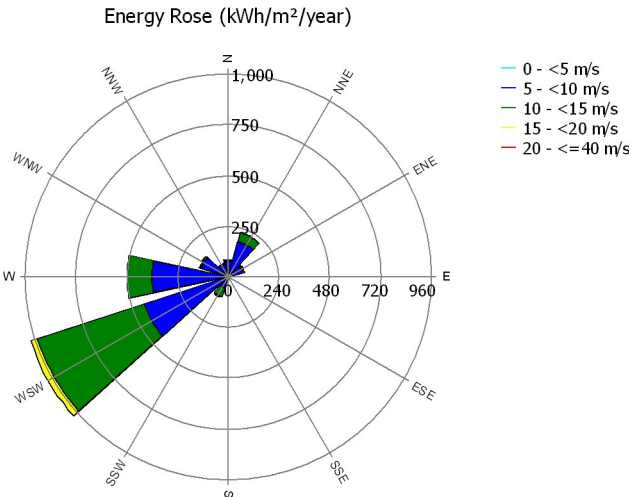
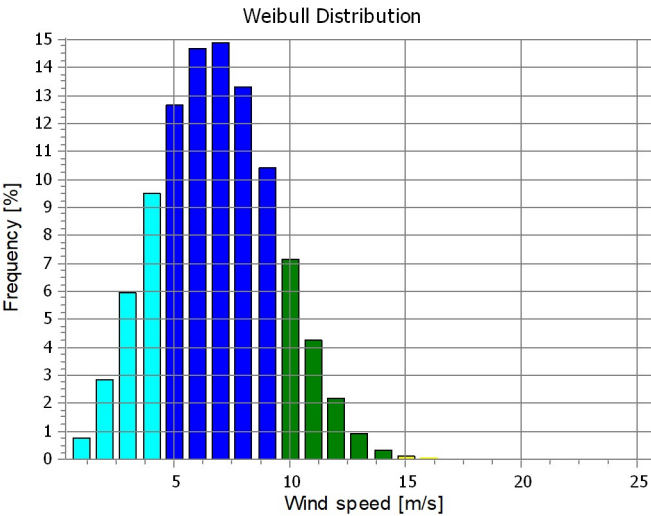
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0 N	6.53	5.83	2.967	6.1
1 NNE	7.64	6.90	3.796	10.8
2 ENE	6.63	5.94	3.207	5.8
3 E	5.02	4.45	2.098	1.7
4 ESE	3.92	3.63	1.286	0.7
5 SSE	4.62	4.29	1.269	0.6
6 S	5.80	5.22	1.538	1.0
7 SSW	7.64	6.78	2.588	4.4
8 WSW	9.08	8.14	3.267	28.0
9 W	7.63	6.86	3.467	23.5
10 WNW	6.56	5.92	3.666	11.1
11 NNW	6.13	5.52	3.584	6.3
All	7.65	6.82	2.921	100.0



PARK - Park power curve

Calculation: SUZLON_2.1*6_Resource

Wind speed	Free WTGs	Park WTGs	N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW
[m/s]	[kW]	[kW]	[kW]	[kW]	[kW]	[kW]	[kW]	[kW]	[kW]	[kW]	[kW]	[kW]	[kW]	[kW]
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5	34	25	25	28	25	26	23	25	25	28	25	26	23	24
4.5	698	659	641	675	659	670	633	654	641	675	659	670	633	654
5.5	1,830	1,751	1,715	1,782	1,750	1,773	1,700	1,741	1,715	1,782	1,750	1,773	1,700	1,741
6.5	3,193	3,090	3,040	3,131	3,088	3,118	3,020	3,075	3,040	3,131	3,089	3,119	3,020	3,075
7.5	5,000	4,830	4,753	4,894	4,827	4,875	4,721	4,805	4,753	4,894	4,827	4,875	4,721	4,805
8.5	7,151	6,950	6,857	7,027	6,947	7,003	6,820	6,921	6,857	7,027	6,947	7,003	6,820	6,921
9.5	9,431	9,237	9,142	9,313	9,234	9,290	9,105	9,209	9,142	9,314	9,234	9,290	9,105	9,208
10.5	11,305	11,189	11,124	11,238	11,189	11,225	11,102	11,172	11,124	11,237	11,188	11,225	11,102	11,172
11.5	12,278	12,240	12,218	12,256	12,240	12,252	12,211	12,234	12,218	12,255	12,239	12,251	12,211	12,234
12.5	12,546	12,539	12,535	12,542	12,538	12,541	12,533	12,537	12,535	12,541	12,538	12,541	12,533	12,537
13.5	12,597	12,596	12,595	12,596	12,596	12,596	12,595	12,596	12,595	12,596	12,596	12,596	12,595	12,596
14.5	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600
15.5	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600
16.5	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600
17.5	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600
18.5	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600
19.5	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600
20.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Description:

The park power curve is similar to a WTG power curve, meaning that when a given wind speed appears in front of the park with same speed in the entire wind farm area (before influence from the park), the output from the park can be found in the park power curve. Another way to say this: The park power curve includes wake losses, but do NOT include terrain given variations in the wind speed over the park area.

Measuring a park power curve is not as simple as measuring a WTG power curve due to the fact that the park power curve depends on the wind direction and that the same wind speed normally will not appear for the entire park area at the same time (only in very flat non-complex terrain). The idea with this version of the park power curve is not to use it for validation based on measurements. This would require at least 2 measurement masts at two sides of the park, unless only a few direction sectors should be tested, AND non complex terrain (normally only useable off shore). Another park power curve version for complex terrain is available in windPRO.

The park power curve can be used for:

1. Forecast systems, based on more rough (approximated) wind data, the park power curve would be an efficient way to make the connection from wind speed (and direction) to power.
2. Construction of duration curves, telling how often a given power output will appear, the park power curve can be used together with the average wind distribution for the Wind farm area in hub height. The average wind distribution can eventually be obtained based on the Weibull parameters for each WTG position. These are found at print menu: >Result to file< in the >Park result< which can be saved to file or copied to clipboard and pasted in Excel.
3. Calculation of wind energy index based on the PARK production (see below).
4. Estimation of the expected PARK production for an existing wind farm based on wind measurements at minimum 2 measurement masts at two sides of wind farm. The masts must be used for obtaining the free wind speed. The free wind speed is used in the simulation of expected energy production with the PARK power curve. This procedure will only work suitable in non complex terrains. For complex terrain another park power curve calculation is available in windPRO (PPV-model).

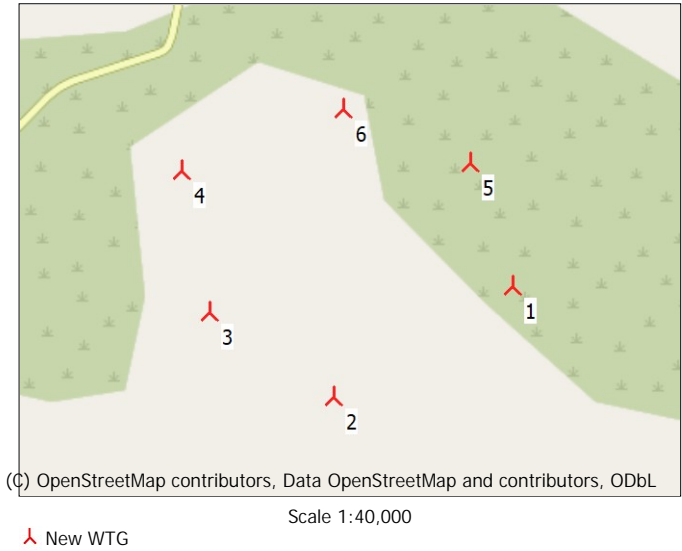
Note:

From the >Result to file< the >Wind Speeds Inside Wind farm< is also available. These can (e.g. via Excel) be used for extracting the wake induced reductions in measured wind speed.

PARK - WTG distances

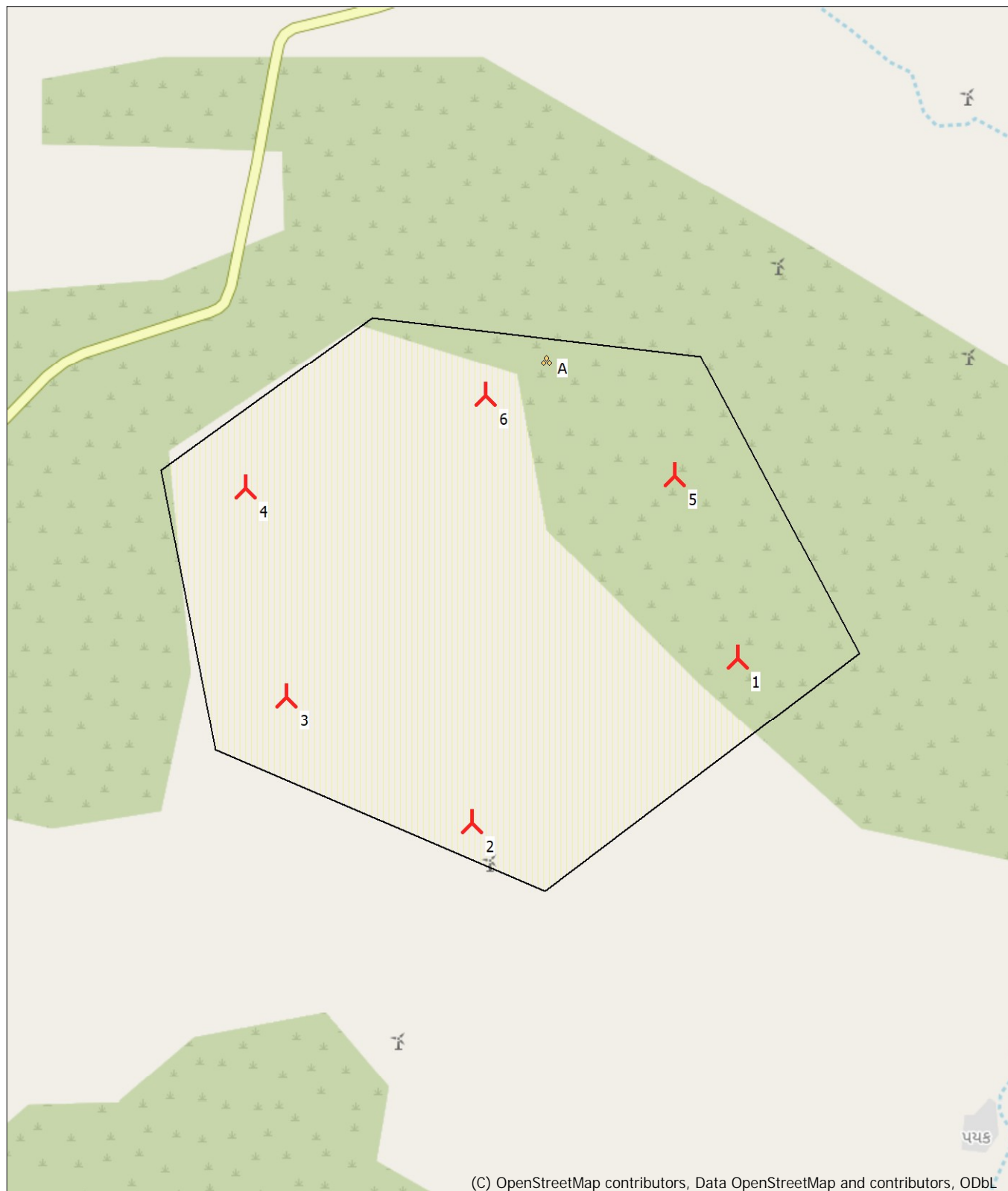
Calculation: SUZLON_2.1*6_Resource
WTG distances

	Z	Nearest WTG	Z	Horizontal distance [m]	Distance in rotor diameters
	[m]		[m]		
1	109.9	5	120.0	680	7.0
2	100.0	3	97.5	791	8.2
3	97.5	4	107.5	754	7.8
4	107.5	3	97.5	754	7.8
5	120.0	1	109.9	680	7.0
6	120.0	5	120.0	731	7.5
Min	97.5		97.5	680	7.0
Max	120.0		120.0	791	8.2



PARK - Map

Calculation: SUZLON_2.1*6_Resource



0 250 500 750 1000m

Map: EMD OpenStreetMap , Print scale 1:20,000, Map center UTM (north)-WGS84 Zone: 42 East: 526,268 North: 2,550,513

⚡ New WTG ⚡ WTG area