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Calculated:
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PARK - Main Result

Calculation: ÁÃ. ÐÁÑÁÓÊÅÕÇ 1

Wake Model N.O. Jensen (RISO/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 34
At the site centre the difference between grid north and true north is: 0.7°

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: KASTORIA (AIRPORT)
Base temperature: 12.0 °C at 604.0 m
Base pressure: 1013.3 hPa at 0.0 m
Air density for Site center in key hub height: 1730.0 m + 92.0 m = 1.022 kg/m³ -> 83.4 % of Std
Relative humidity: 0.0 %

Wake Model Parameters
Wake decay constant 0.075 DTU default onshore

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

Wind statistics GR ERE1130 - A 30.00 m.wws

WAsP version WAsP 10.2 RVEA0164.dll 3.0.1.100

Scale 1:100 000

New WTG Site Data

Key results for height 92.0 m above ground level

Terrain Greek GGRS87-GGRS87 (GR)

	Y	X	Name of wind distribution	Type	Wind energy [kWh/m²]	Mean wind speed [m/s]	Equivalent roughness
A	334 085	4 478 709	ERE1130	WAsP (WAsP 10.2 RVEA0164.dll 3.0.1.100)	3 244	7.6	Not calculated

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	17 649.8	18 267.8	3.4	33.6	8 824.9	2 942	6.9

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 2 new WTGs with total 6.0 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	No	ENERCON	E-115-3 000	3 000	115.7	92.0	EMD	Level 0 - official - Rev.2_0 - Mode 0 - 3000kW - 06/2014	8 737.2	4.8	6.90
2 A	No	ENERCON	E-115-3 000	3 000	115.7	92.0	EMD	Level 0 - official - Rev.2_0 - Mode 0 - 3000kW - 06/2014	8 912.6	1.9	6.86

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

WTG siting

Greek GGRS87-GGRS87 (GR)

	Y	X	Z [m]	Row data/Description
1 New	334 494	4 474 053	1 450.0	ENERCON E-115 3000 115.7 !O! hub: 92.0 m (TOT: 149.9 m) (1)
2 New	334 105	4 474 015	1 430.0	ENERCON E-115 3000 115.7 !O! hub: 92.0 m (TOT: 149.9 m) (2)

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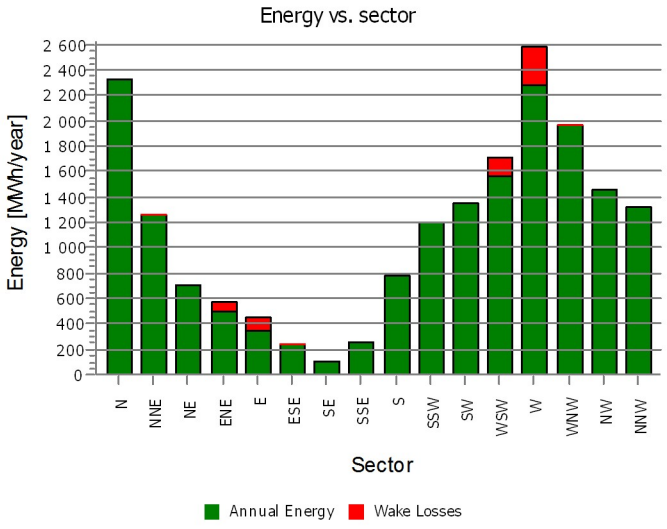
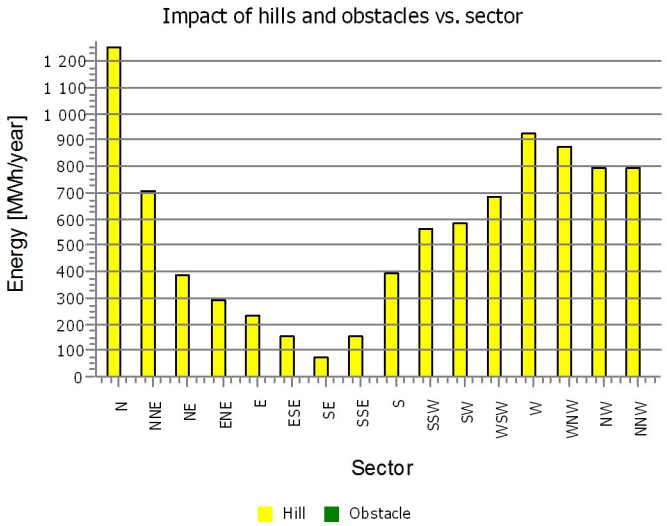
PARK - Production Analysis

Calculation: ÁÃ. ÐÁÑÁÓÊÅÕÇ 1WTG: All new WTGs, Air density varies with WTG position 1.051 kg/m³ - 1.053 kg/m³
Directional Analysis

Sector		0 N	1 NNE	2 NE	3 ENE	4 E	5 ESE	6 SE	7 SSE	8 S	9 SSW	10 SW	11 WSW	12 W	13 WNW	14 NW	15 NNW	Total
Roughness based energy	[MWh]	1 075.7	546.1	321.8	280.2	211.6	92.6	31.5	102.1	384.9	641.4	767.7	1 019.0	1 656.2	1 086.9	664.3	524.7	9 406.5
+Increase due to hills	[MWh]	1 252.7	709.4	388.2	287.7	232.2	154.6	76.3	155.5	395.5	558.2	579.7	685.0	923.4	874.2	792.5	796.3	8 861.3
-Decrease due to wake losses	[MWh]	0.0	0.0	0.0	72.2	99.9	0.5	0.0	0.0	0.0	0.0	0.0	138.8	304.8	1.8	0.0	0.0	618.0
Resulting energy	[MWh]	2 328.4	1 255.5	710.0	495.7	343.9	246.6	107.8	257.5	780.4	1 199.6	1 347.3	1 565.2	2 274.7	1 959.3	1 456.8	1 321.0	17 649.8
Specific energy	[kWh/m²]																	839
Specific energy	[kWh/kW]																	2 942
Increase due to hills	[%]	116.5	129.9	120.6	102.7	109.7	167.0	242.2	152.3	102.8	87.0	75.5	67.2	55.8	80.4	119.3	151.8	94.20
Decrease due to wake losses	[%]	0.0	0.0	0.0	12.7	22.5	0.2	0.0	0.0	0.0	0.0	0.0	8.1	11.8	0.1	0.0	0.0	3.38
Utilization	[%]	37.6	43.7	44.4	38.9	33.7	44.0	43.4	34.7	30.8	33.4	34.6	32.3	26.9	30.7	32.5	37.0	33.8
Operational	[Hours/year]	946	835	667	454	315	226	147	194	370	584	681	778	797	605	515	574	8 689
Full Load Equivalent	[Hours/year]	388	209	118	83	57	41	18	43	130	200	225	261	379	327	243	220	2 942





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PARK - Power Curve Analysis

Calculation: ÁÃ. ÐÁÑÁÓÊÅÕÇ 1WTG: 1 - ENERCON E-115 3000 115.7 !O!, Hub height: 92.0 m

Name: Level 0 - official - Rev.2_0 - Mode 0 - 3000kW - 06/2014
Source: Manufacturer

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
11/06/2014	EMD	08/01/2013	22/04/2015	25.0	Pitch	User defined	Variable	0.29

According to Enercon specification document "D0332605-0_#_ger_#_LK_E-115_3000kW_BM0_berechnet_V2.0.pdf", 2013-06-26

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	5 280	7 965	10 526	12 784	14 672	16 172
ENERCON E-115 3000 115.7 !O! Level 0 - official - Rev.2_0 - Mode 0 - 3000kW - 06/2014	[MWh]	5 417	8 079	10 614	12 846	14 706	16 171
Check value	[%]	-3	-1	-1	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 windPRO manual chapter 3.5.2.
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

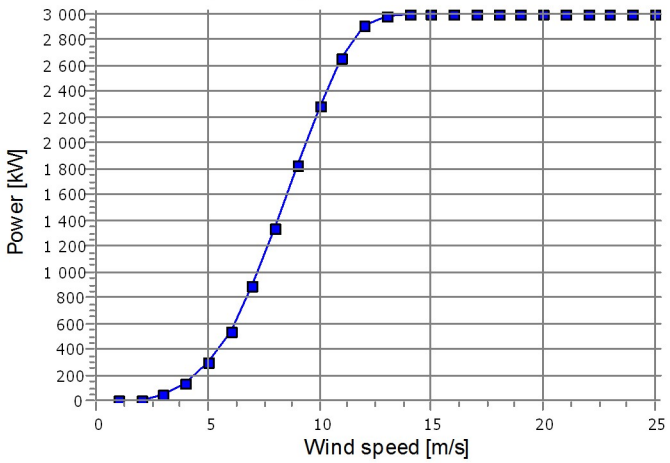
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
1.0	0.0	0.00	2.0	1.00
2.0	3.0	0.06	3.0	1.00
3.0	48.5	0.28	4.0	0.94
4.0	155.0	0.38	5.0	0.91
5.0	339.0	0.42	6.0	0.88
6.0	627.5	0.45	7.0	0.88
7.0	1 035.5	0.47	8.0	0.86
8.0	1 549.0	0.47	9.0	0.83
9.0	2 090.0	0.45	10.0	0.78
10.0	2 580.0	0.40	11.0	0.51
11.0	2 900.0	0.34	12.0	0.37
12.0	3 000.0	0.27	13.0	0.28
13.0	3 000.0	0.21	14.0	0.22
14.0	3 000.0	0.17	15.0	0.18
15.0	3 000.0	0.14	16.0	0.15
16.0	3 000.0	0.11	17.0	0.12
17.0	3 000.0	0.09	18.0	0.11
18.0	3 000.0	0.08	19.0	0.09
19.0	3 000.0	0.07	20.0	0.08
20.0	3 000.0	0.06	21.0	0.07
21.0	3 000.0	0.05	22.0	0.06
22.0	3 000.0	0.04	23.0	0.06
23.0	3 000.0	0.04	24.0	0.05
24.0	3 000.0	0.03	25.0	0.05
25.0	3 000.0	0.03		

Power, Efficiency and energy vs. wind speed

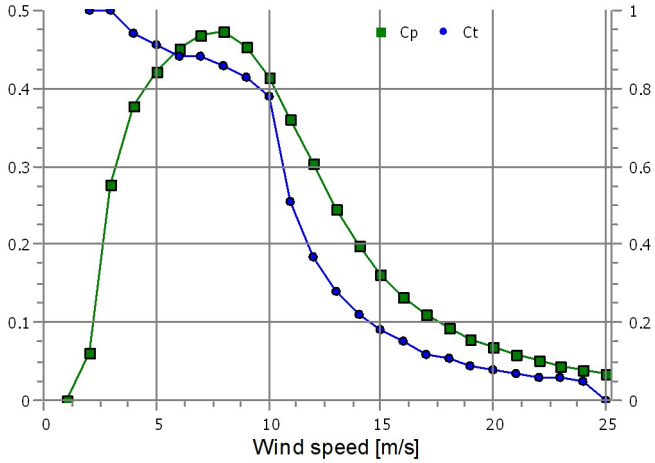
Data used in calculation, Air density: 1.051 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

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	0.1	0.1	0.0
2.0	2.7	0.06	1.50- 2.50	4.8	4.9	0.1
3.0	41.5	0.28	2.50- 3.50	34.7	39.7	0.5
4.0	133.1	0.38	3.50- 4.50	128.0	167.6	1.9
5.0	291.6	0.42	4.50- 5.50	316.6	484.2	5.5
6.0	538.3	0.45	5.50- 6.50	598.2	1 082.4	12.4
7.0	888.4	0.47	6.50- 7.50	914.9	1 997.3	22.9
8.0	1 335.9	0.47	7.50- 8.50	1 169.8	3 167.1	36.2
9.0	1 824.5	0.45	8.50- 9.50	1 275.3	4 442.3	50.8
10.0	2 283.4	0.41	9.50-10.50	1 210.6	5 653.0	64.7
11.0	2 656.3	0.36	10.50-11.50	1 021.3	6 674.3	76.4
12.0	2 904.7	0.30	11.50-12.50	775.2	7 449.4	85.3
13.0	2 985.3	0.25	12.50-13.50	534.7	7 984.2	91.4
14.0	3 000.0	0.20	13.50-14.50	338.3	8 322.5	95.3
15.0	3 000.0	0.16	14.50-15.50	198.9	8 521.4	97.5
16.0	3 000.0	0.13	15.50-16.50	109.6	8 631.0	98.8
17.0	3 000.0	0.11	16.50-17.50	56.7	8 687.7	99.4
18.0	3 000.0	0.09	17.50-18.50	27.6	8 715.2	99.7
19.0	3 000.0	0.08	18.50-19.50	12.6	8 727.9	99.9
20.0	3 000.0	0.07	19.50-20.50	5.5	8 733.4	100.0
21.0	3 000.0	0.06	20.50-21.50	2.3	8 735.7	100.0
22.0	3 000.0	0.05	21.50-22.50	0.9	8 736.6	100.0
23.0	3 000.0	0.04	22.50-23.50	0.4	8 737.0	100.0
24.0	3 000.0	0.04	23.50-24.50	0.2	8 737.2	100.0
25.0	3 000.0	0.03	24.50-25.50	0.0	8 737.2	100.0

Power curve
For air density: 1.051 kg/m³ and reference climate data



Cp and Ct curve
For air density: 1.051 kg/m³ and reference climate data



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PARK - Terrain

Calculation: ÁÃ. ÐÁÑÁÓÊÅÕÇ 1Site Data: A - ERE1130

Obstacles:

0 Obstacles used

Roughness:

Terrain data files used in calculation:
Z:\WIND RESOURCE ASSESSMENT\MES ENERGY\ÊÏÆÁÍÇ\B-GIS Data\roughness\MES ENERGY - ÊÏÆÁÍÇ_most_likely_CLC2000.map
Min X: 563 273, Max X: 613 870, Min Y: 4 446 955, Max Y: 4 503 018, Width: 50 598 m, Height: 56 063 m

Orography:

Terrain data files used in calculation:
Z:\WIND RESOURCE ASSESSMENT\MES ENERGY\ÊÏÆÁÍÇ\E-Wind Pro\CONTOURLINE_ONLINEDATA_0.wpo
Min X: 573 858, Max X: 603 550, Min Y: 4 459 845, Max Y: 4 490 109, Width: 29 692 m, Height: 30 264 m

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PARK - Wind Data Analysis

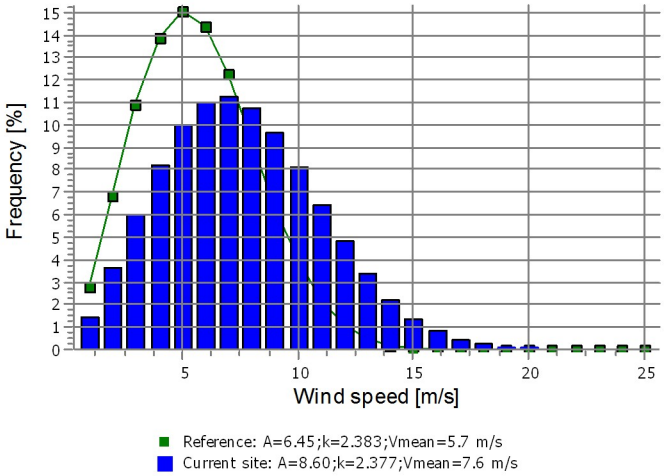
Calculation: ÁÃ. ÐÁÑÁÓÊÅÕÇ 1Wind data: A - ERE1130; Hub height: 92.0

Site coordinates
Greek GGRS87-GGRS87 (GR)
East: 334 085 North: 4 478 709
Wind statistics
GR ERE1130 - A 30.00 m.wws

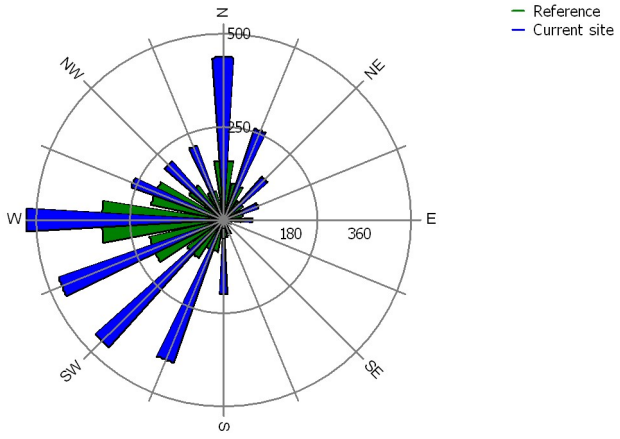
Weibull Data

Sector	Current site A-parameter [m/s]	Wind speed [m/s]	k-parameter	Frequency [%]	Reference: Roughness class 1 A-parameter [m/s]	k-parameter	Frequency [%]
0 N	9.00	8.02	2.889	11.1	6.78	2.982	9.5
1 NNE	7.59	6.77	2.994	11.1	5.76	3.011	9.8
2 NE	7.10	6.35	3.088	8.2	5.19	3.109	8.6
3 ENE	7.19	6.44	3.189	5.1	5.50	3.246	6.2
4 E	7.45	6.64	2.889	3.3	5.96	2.942	4.2
5 ESE	6.33	5.64	2.854	2.1	5.29	2.883	2.7
6 SE	5.40	4.79	2.396	1.5	4.01	2.364	1.6
7 SSE	6.30	5.62	1.678	1.9	4.46	1.708	1.8
8 S	8.80	7.81	1.889	3.9	5.75	1.923	3.5
9 SSW	9.12	8.08	2.115	8.0	5.85	2.109	6.4
10 SW	9.15	8.10	2.174	9.2	6.06	2.119	8.2
11 WSW	9.40	8.33	2.412	9.4	6.95	2.354	9.8
12 W	10.47	9.34	2.900	8.5	8.42	2.835	10.0
13 WNW	9.59	8.55	2.854	5.5	8.08	2.863	6.9
14 NW	8.98	7.99	2.658	5.1	7.21	2.707	5.4
15 NNW	8.52	7.57	2.635	6.0	6.38	2.619	5.4
All	8.60	7.62	2.377	100.0	6.45	2.383	100.0

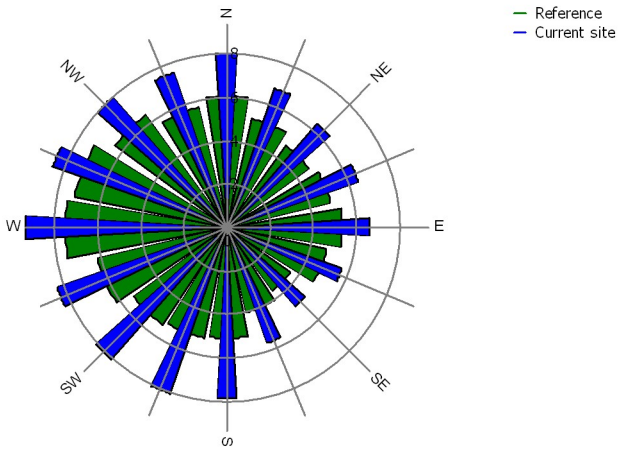
Weibull Distribution



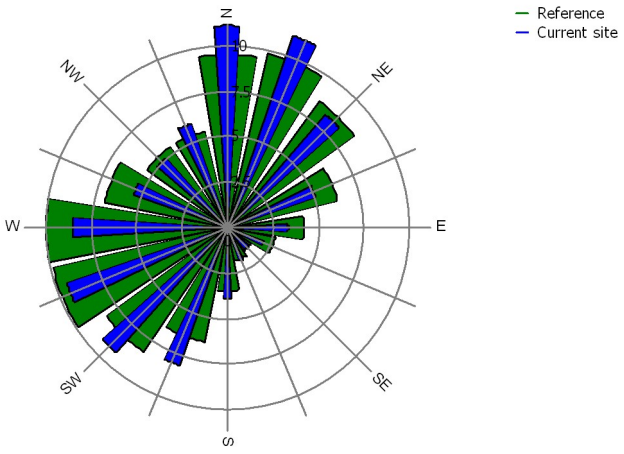
Energy Rose (kWh/m²/year)



Mean wind speed (m/s)



Frequency (%)



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PARK - Park power curve

Calculation: ÁÃ. ÐÁÑÁÓÊÅÕÇ 1

Wind speed [m/s]	Power Free WTGs [kW]	Park WTGs [kW]	N [kW]	NNE [kW]	NE [kW]	ENE [kW]	E [kW]	ESE [kW]	SE [kW]	SSE [kW]	S [kW]	SSW [kW]	SW [kW]	WSW [kW]	W [kW]	WNW [kW]	NW [kW]	NNW [kW]
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	3	2	3	3	3	2	2	3	3	3	3	3	3	2	2	3	3	3
2.5	40	36	40	40	40	30	23	40	40	40	40	40	40	30	23	40	40	40
3.5	165	153	165	165	165	133	108	165	165	165	165	165	165	133	108	165	165	165
4.5	409	384	409	409	409	343	288	408	409	409	409	409	409	343	288	408	409	409
5.5	804	760	804	804	804	688	590	802	804	804	804	804	804	688	590	802	804	804
6.5	1 391	1 319	1 391	1 391	1 391	1 201	1 039	1 388	1 391	1 391	1 391	1 391	1 391	1 202	1 040	1 388	1 391	1 391
7.5	2 190	2 080	2 190	2 190	2 190	1 904	1 652	2 185	2 190	2 190	2 190	2 190	2 190	1 904	1 653	2 185	2 190	2 190
8.5	3 160	3 015	3 160	3 160	3 160	2 784	2 443	3 155	3 160	3 160	3 160	3 160	3 160	2 785	2 444	3 155	3 160	3 160
9.5	4 144	3 982	4 144	4 144	4 144	3 731	3 340	4 139	4 144	4 144	4 144	4 144	4 144	3 731	3 341	4 139	4 144	4 144
10.5	4 991	4 872	4 991	4 991	4 991	4 693	4 396	4 987	4 991	4 991	4 991	4 991	4 991	4 694	4 397	4 987	4 991	4 991
11.5	5 574	5 520	5 574	5 574	5 574	5 443	5 300	5 573	5 574	5 574	5 574	5 574	5 574	5 442	5 300	5 573	5 574	5 574
12.5	5 891	5 873	5 891	5 891	5 891	5 850	5 796	5 891	5 891	5 891	5 891	5 891	5 891	5 849	5 795	5 891	5 891	5 891
13.5	6 000	5 996	6 000	6 000	6 000	5 992	5 978	6 000	6 000	6 000	6 000	6 000	6 000	5 991	5 977	6 000	6 000	6 000
14.5	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000
15.5	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000
16.5	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000
17.5	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000
18.5	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000
19.5	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000
20.5	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000
21.5	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000
22.5	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000
23.5	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000
24.5	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000
25.5	0	0	0	0	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	0	0	0	0
27.5	0	0	0	0	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	0	0	0	0
29.5	0	0	0	0	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.

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Calculated:
06/12/2019 12:15/3.3.274

PARK - WTG distances

Calculation: ÁÃ. ÐÁÑÁÓÊÅÕÇ 1

WTG distances

	Z	Nearest WTG	Z	Horizontal distance	Distance in rotor diameters
	[m]		[m]	[m]	
1	1 450.0	2	1 430.0	391	3.4
2	1 430.0	1	1 450.0	391	3.4
Min	1 430.0		1 430.0	391	3.4
Max	1 450.0		1 450.0	391	3.4

Scale 1:5 000

New WTG

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PARK - Wind statistics info

Calculation: ÁÃ. ÐÁÑÁÓÊÅÕÇ 1

Main data for wind statistic

File	Z:\WIND RESOURCE ASSESSMENT\MES ENERGY\ÊÏÆÁÍÇ\E-Wind Pro\GR ERE1130 - A 30.00 m.wws
Name	ERE1130 - A 30.00 m
Country	Greece
Source	USER
Mast coordinates	Greek GGRS87-GGRS87 (GR) East: 334 085 North: 4 478 709
Created	06/12/2019
Edited	06/12/2019
Sectors	16
WAsP version	WAsP 10.2 RVEA0164.dll 3.0.1.100
Coordinate system	UTM (north)-WGS84 Zone: 34
Displacement height	None

Non-default WAsP parameters

Group	WAsP parameter	Minimum	Maximum	Default	Current value
WAsP wind modelling	Offset heat flux over land	-200.0000	200.0000	-40.0000	-120.0000
WAsP wind modelling	Rms heat flux over land	0.0000	200.0000	100.0000	150.0000

Additional info for wind statistic

Source data	ERE1130
Data from	30/12/1899
Data to	30/12/1899
Measurement length	0.0 Months

Note

To get the most correct calculation results, wind statistics shall be calculated with the SAME model and model parameters, as currently chosen in calculation. For WAsP versions before 10.0, the model is unchanged, but thereafter more model changes affecting the wind statistic is seen. Likewise WAsP CFD should always use WAsP CFD calculated wind statistics.

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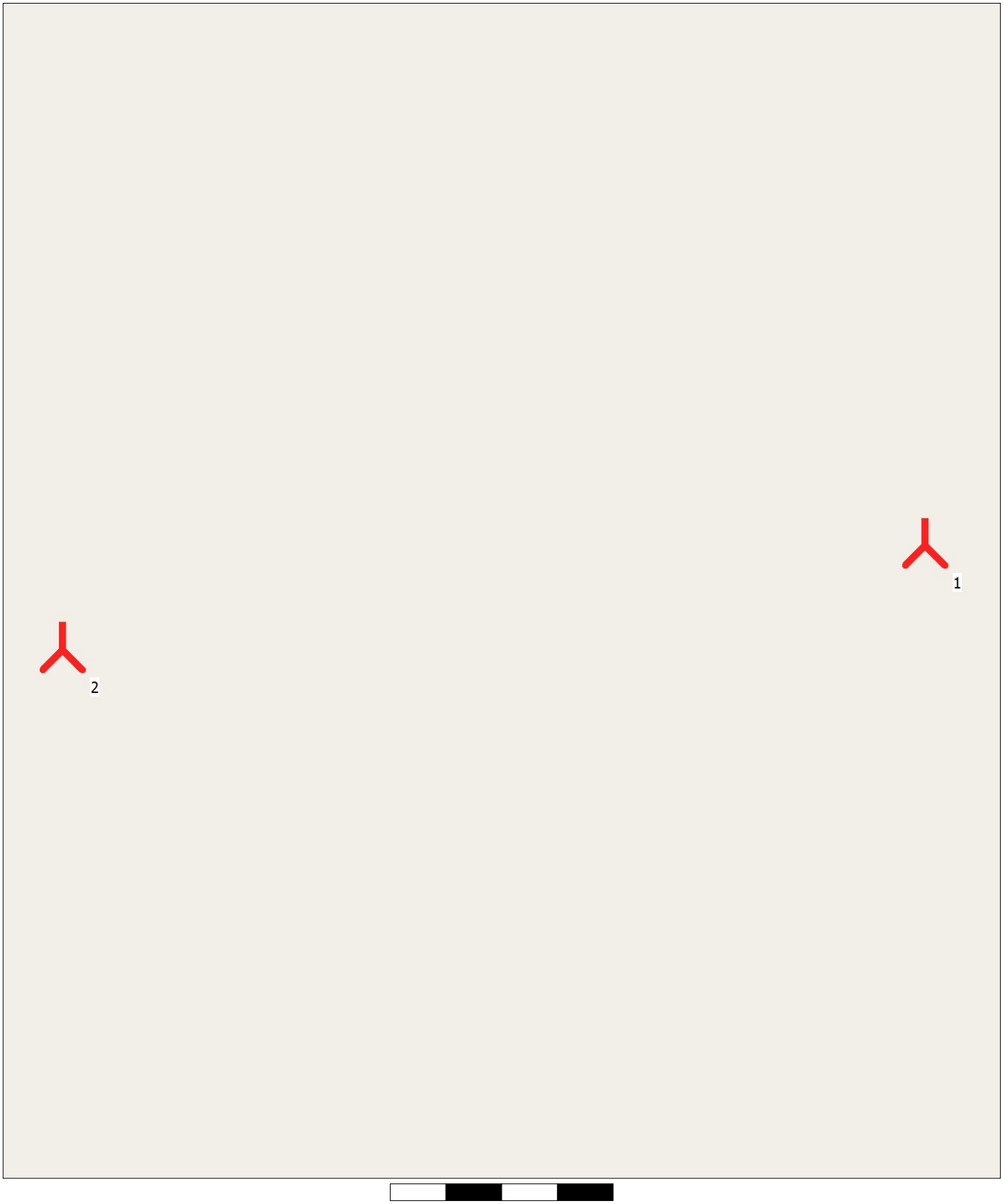
PARK - Map

Calculation: ÁÃ. ÐÁÑÁÓÊÅÕÇ 1



Map: EMD OpenStreetMap , Print scale 1:2 500, Map center Greek GGRS87-GGRS87 (GR) East: 334 299 North: 4 474 034

New WTG