Bosch & van Rijn
experts in renewable energy

Titel Studie zog-effecten project Windenergie A16

Datum 15-08-2018

Auteur Aniel Balhari

Inleiding

Het ontwerp van het provinciaal inpassingsplan 'Windenergie A16' heeft van 19 juni t/m 30 juli 2018 ter inzage gelegen. Het windpark dat met dit inpassingsplan mogelijk wordt gemaakt zal bestaan uit 28 windturbines met een maximale ashoogte van 135 meter. De verwachting is dat de windturbines van het project Windenergie A16 door zog-effecten invloed zullen hebben op de productie van de reeds bestaande windturbines in het gebied.

In het kader van de beantwoording van de zienswijzen heeft de provincie Noord-Brabant aan Bosch & van Rijn (BVR) gevraagd om een studie uit te voeren naar de zog-effecten en daarmee gepaard gaande opbrengstverliezen van het project Windenergie A16 op de bestaande windturbines in het gebied.

Het zog-effect van een windturbine is een gebied benedenwinds van een windturbine waarbij de windturbine lokaal zorgt voor een verlaagde windsnelheid en verhoogde turbulentie. Het zog-effect kan zorgen voor een verminderde energieopbrengst als windturbines in de windschaduw van een andere windturbine geplaatst zijn.

In voorliggend memo worden deze zog-effecten in kaart gebracht. We gaan in op de methode, de uitgangspunten en de resultaten.

Opstellingen

Voor het bepalen van de zog-effecten wordt uitgegaan van *referentiewindturbines*. Dit zijn bestaande en beoogde windturbines in de omgeving van de nieuwe windturbines van het A16-project.

Vervolgens zijn zog-effecten van het project Windenergie A16 op de referentiewindturbines bepaald met behulp van WindPRO 3.2 en WAsP 11 software.

De referentiewindturbines zijn merendeels gelegen rondom bedrijventerrein Hazeldonk: 16 windturbines vormen 4 windparken van verschillende exploitanten.

Een enkele bestaande windturbine nabij de waterzuivering Nieuwveer is ook beschouwd. Voor Hazeldonk (in deze studie verder aangeduid met 'zuid') en Nieuwveer (voortaan 'noord') zijn twee aparte windopbrengstberekeningen uitgevoerd, aangezien de afstand tussen beide gebieden ca. 15 kilometer is.

De referentiewindturbines zijn opgenomen in Tabel 1. In Tabel 2 is per windpark te zien wie de uitbater is.

Bij het bepalen van de referentiewindturbines is reeds rekening gehouden met de opschaling van windpark Hoogstraten van 6 x Vestas V80 naar 7 x Vestas V126.

Tabel 1 **Referentiewindturbines. Coördinaten zijn gegeven in het Rijksdriehoeksstelsel (RD).**

Cluster	Wtb	RD x	RD y	Windturbinetype	Ashoogte (m)
Zuid					
1	1	108.551	387.094	Senvion - 3.2M114	143
	2	108.586	386.723	Senvion - 3.2M114	143
	3	108.531	386.311	Senvion - 3.2M114	143
2	4	110.596	388.964	Siemens - SWT-3.2-101	94
	5	110.716	389.414	Siemens - SWT-3.2-101	94
	6	110.856	389.965	Siemens - SWT-3.2-101	94
3	7	109.916	388.736	Vestas V126 3.0	147
	8	109.720	388.255	Vestas V126 3.0	147
	9	109.479	387.531	Vestas V126 3.0	147
	10	109.372	387.115	Vestas V126 3.0	147
	11	109.208	386.577	Vestas V126 3.0	147
	12	109.126	386.232	Vestas V126 3.0	147
	13	109.001	385.623	Vestas V126 3.0	147
4	14	110.028	389.323	Lagerwey - L100-NL 2.5	99
	15	110.383	390.346	Lagerwey - L100-NL 2.5	99
	16	110.747	390.768	Lagerwey - L100-NL 2.5	99
Noord					
	17	108.030	405.018	Vestas V52-850	70

Tabel 2 **Windparken referentiesituatie**

Cluster	Beschrijving	Uitbater	Locatie
Zuid 1	Windpark Meer	Storm	BE
Zuid 2	Windpark van Meer-Hoogstraten	EDF luminus	BE
Zuid 3	Windpark Hoogstraten (opgeschaald)	Electrabel	BE
Zuid 4	Windpark Hazeldonk	Windpark Hazeldonk Breda	NL
Noord 5	Kroetenwind	Eneco	NL

De energieopbrengst van de referentiewindturbines is berekend in twee situaties:

- *Zonder* de A16-windturbines
- *Met* de A16-windturbines in de directe omgeving.

Het verschil tussen deze twee situaties is het zog-effect van de A16-windturbines op de referentiewindturbines.

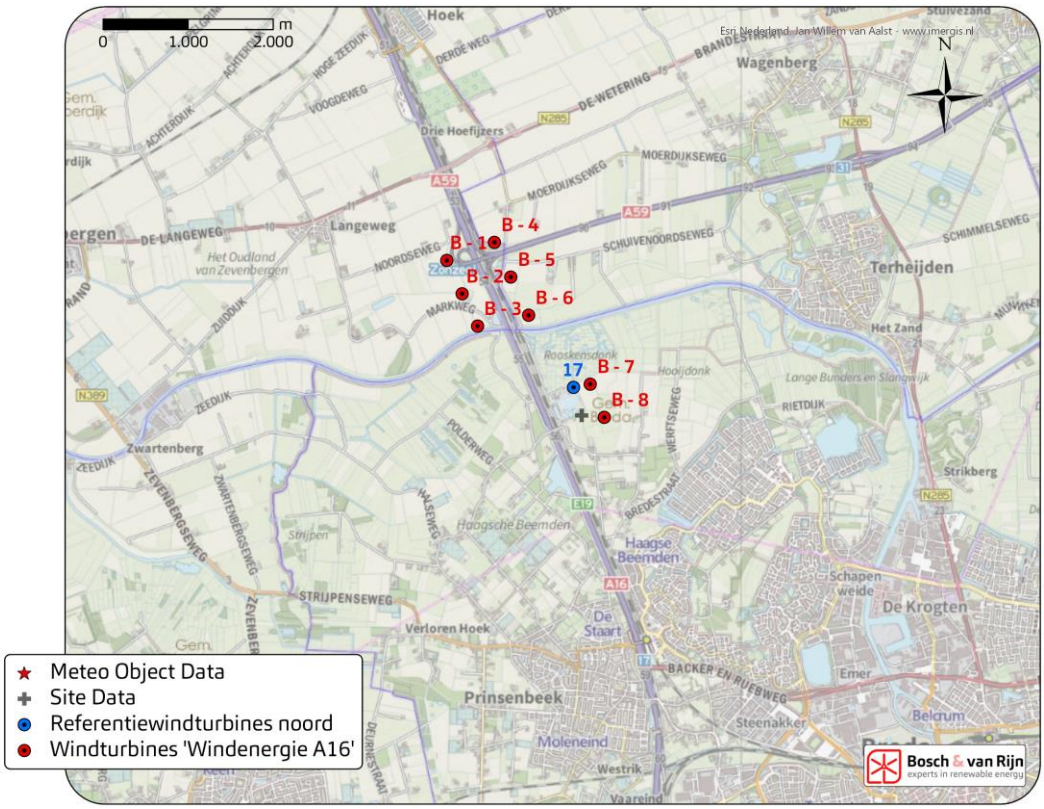
Voor de zog-effecten in 'noord' zijn alle A16-windturbines van deelgebieden B meegenomen. Alle windturbines in deelgebied B zijn van het type Vestas V150 4,2 MW op ashoogte 135 meter. Zie voor de coördinaten Bijlage A.

Voor de zog-effecten in 'zuid' zijn alle A16-windturbines van deelgebieden D en E meegenomen. Voor windturbine E-1 is gerekend met de Vestas V110 2,0 MW op

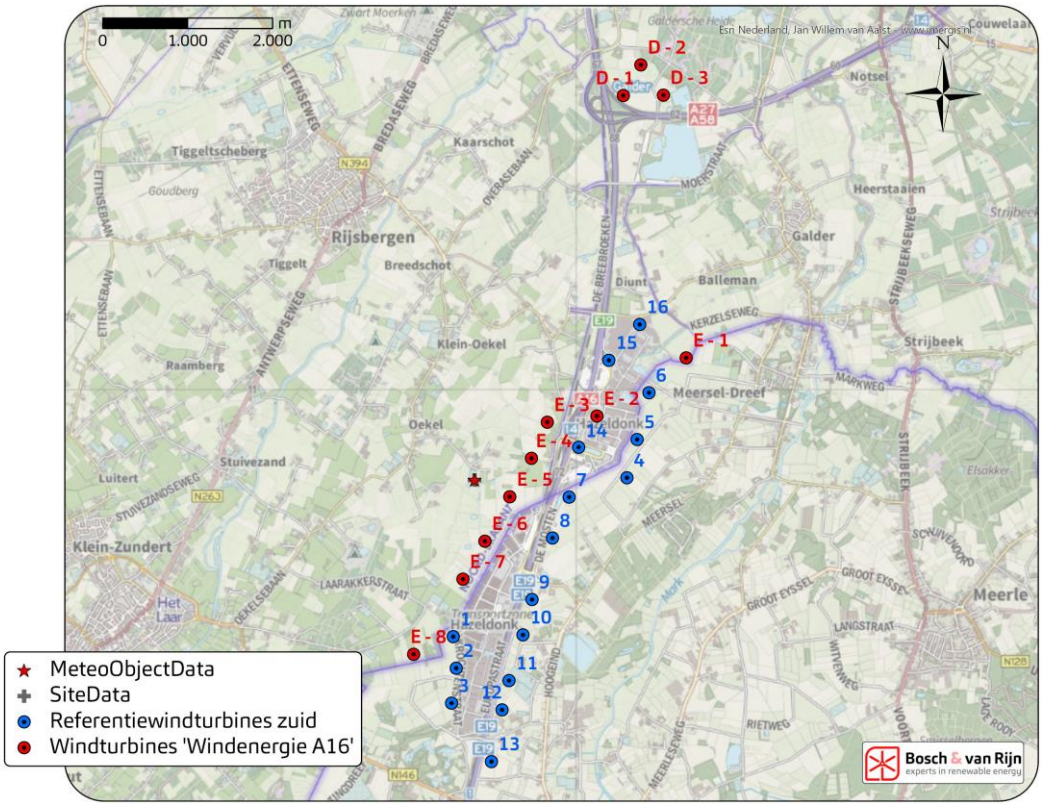
ashoogte 110 meter. Voor windturbine E-2 is gerekend met de Lagerwey L100 2,5 MW op ashoogte 100 meter. Alle overige windturbines zijn van het type Vestas V150 4,2 MW op ashoogte 135 meter. Zie voor de coördinaten Bijlage A.

In Figuur 1 en Figuur 2 zijn respectievelijk de locaties van de noordelijke en zuidelijke referentiewindturbines te zien (blauw) evenals de geplande turbines van het project Windenergie A16 (rood).

Figuur 1 **Opstelling van de noordelijke referentiewindturbines en de nabijgelegen A16-windturbines. Het 'Meteo Object' bevat gegevens van het lokale windklimaat.**



Figuur 2 **Opstelling van de zuidelijke referentiewindturbines en de nabijgelegen A16-windturbines. Het 'Meteo Object' bevat gegevens van het lokale windklimaat.**



Methode

Voor de berekening van zog-effecten is gebruik gemaakt van WindPRO 3.2 software (in deze studie verder aangeduid met 'WindPRO'), in combinatie met het windmodel van WAsP 11 (voortaan 'WAsP'). Eerst zijn de opbrengsten van de referentiewindturbines berekend zonder de A16-windturbines en vervolgens *met*.

Windmodel

Om een windklimaat in WindPRO te creëren is gebruik gemaakt van een windmodel. Het windmodel berekent de gemiddelde energie die de wind jaarlijks kan leveren op een specifieke locatie. Terwijl de hoeveelheid wind van plek tot plek verschilt. Om deze verschillen van plek tot plek te berekenen is een model ontwikkeld met bijbehorend computerprogramma WAsP. Deze software is leidend in de markt en is in deze studie ook door ons gebruikt.

Stel het windmodel (WAsP) voor als een kaart van de omgeving. Door locaties op de kaart aan te wijzen berekent de software het lokale windklimaat. Bijvoorbeeld omdat daar een windturbine komt te staan of omdat daar een windturbine staat.

Voorzie het model op de aangewezen plek van een power curve en de software rekent ook de energieproductie uit.

Om een lokaal windklimaat te berekenen gaat WAsP uit van het volgende principe: een lokaal windklimaat is de optelsom van een regionaal windklimaat en lokale invloeden van het landschap zoals ruwheid, reliëf en obstakels. Zo kan men uit een regionaal windklimaat en een beschrijving van de omgeving een lokaal windklimaat berekenen.

Een regionaal windklimaat wordt berekend met het omgekeerde principe; een regionaal windklimaat is de "omgekeerde" optelsom van het lokale windklimaat en lokale invloeden van het landschap. Zo kan men uit lokale windmetingen en een beschrijving van de omgeving een regionaal windklimaat berekenen.

Het windmodel is de combinatie van gegevens waarmee WAsP het lokale windklimaat kan berekenen op de locatie van de referentiewindturbines. Het is een beschrijving van de omgeving en van een regionaal windklimaat.

Het model heeft een aantal invoergegevens nodig. Ten eerste het windaanbod nodig: een verdeling van windsnelheid en richting. Verder gebruikt het model een kaart van de omgeving. Deze omgeving wordt gekarakteriseerd door ruwheid, orografie en obstakels.

- **Regionaal windklimaat:** Een regionaal windklimaat is een set gegevens die de software WAsP gebruikt om het windklimaat te beschrijven dat geldig is in een groot gebied.
- **Beschrijving van de omgeving:** De omgeving is opgebouwd uit de ruwheid, de orografie en obstakels.
- **Lokaal windklimaat:** Een set gegevens die het windklimaat op een specifieke plek en hoogte beschrijft.

Regionaal windklimaat

Voor het creëren van een regionaal windklimaat is gebruik gemaakt van 2 bronnen:

- daadwerkelijke productiegegevens ('meetwaarden') van een windturbine op 17 kilometer afstand van het zuidelijke gedeelte en op 7 kilometer afstand van het noordelijke gedeelte. De turbine is van het type Enercon E-82 2300 kW met een ashoogte van 98 meter en maakt onderdeel uit van het windpark Van Gogh (Etten-Leur). De gebruikte data betreft de windsnelheid en -richting per uur. De periode van de data is 30 november 2012 tot en met 1 juli 2015, 2 jaar en 7 maanden in totaal.
- Modelgegevens uit MERRA ('modelwaarden') op een hoogte van 50 meter, van 1 januari 1988 tot 1 maart 2016, 28 jaar en 2 maanden in totaal. We nemen aan dat deze dataset representatief is voor het windaanbod.

Correctie
Er is gekozen voor een regressie MCP methode van WindPRO omdat deze methode het beste correleert met de meetwaarden. De regressiemethode beschrijft met welke functie de MERRA[1] dataset de korte termijn dataset kan voorspellen voor de overlappende periode aan windgegevens. Deze functie, die door MCP is bepaald, is vervolgens gebruikt om de MERRA data set te corrigeren om zo tot een lange termijn dataset van het regionale windklimaat te komen.

Luchtdichtheid
Voor het bepalen van de gemiddelde energie die de wind jaarlijks kan leveren op een specifieke locatie is de luchtdichtheid van belang. De gemiddelde luchtdichtheid gebruikt door WindPRO voor de berekening van het lokale windklimaat is afkomstig van een weerstation in Gilze-Rijen om een afstand van 20 kilometer van de referentiewindturbines. De luchtdichtheid om een hoogte van 135 meter boven het maaiveld is 1,229 kilogram per kubieke meter.

Beschrijving van de omgeving

Ruwheid
De ruwheid van het landschap zegt iets over de gladheid van het oppervlak. Hoe gladder, hoe meer wind. De ruwheid, of eigenlijk, ruwheids-lengte wordt uitgedrukt in meters. In het windmodel, WAsP, voeren we landschappelijke eigenschappen in. WAsP accepteert deze eigenschappen in de vorm van ruwheidscontouren. De ruwheden van verschillende landschappen komen uit een dataset van het project Corine[2].

Orografie
Orografie, de beschrijving van gebergten, is in Nederland van minimale invloed op de hoeveelheid wind. Toch voeden we aan ons windmodel met het reliëf dat is gemeten door NASA in het project SRTM[3].

Obstakels
Dit zijn zeer lokale elementen die niet met ruwheid of reliëf zijn gemodelleerd die geacht worden van invloed te zijn op het lokale windklimaat. In de omgeving zijn geen obstakels waargenomen die ⅓ van de ashoogte overstijgen in de nabijheid van de windturbines. Voor de berekeningen in WindPRO zijn daarom geen obstakels meegenomen.

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[1] MERRA (Modern Era Retrospective-analysis for Research and Applications) is een heranalyse dataset van NASA. De wind data is gegenereerd voor een raster van ⅓ lengtegraad bij ½ breedtegraad op 50 meter hoogte. https://gmao.gsfc.nasa.gov/reanalysis/MERRA/

[2] Corine (COoRdinate INformation on the Environment) Land Cover 2012, 100 meter raster. https://www.eea.europa.eu/

[3] SRTM (Shuttle Radar Topography Mission), 1 arc-seconde. http://www2.jpl.nasa.gov/srtm/

Lokaal windklimaat

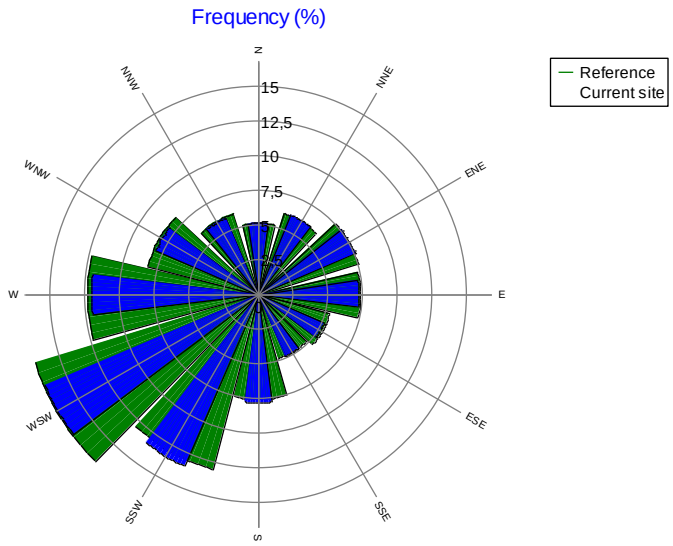
WAsP past een horizontale en verticale extrapolatie toe op het regionale windklimaat om tot het windklimaat op de onderzoekslocatie te komen. WAsP berekent een gemiddelde windsnelheid van 7,1 meter per seconde (model uitkomst van WAsP) op de locatie van de referentiewindturbines op een hoogte van 135 meter. Tabel 3 laat zien wat het windsnelheidsprofiel is dat door WAsP berekend is op de onderzoekslocatie.

Tabel 3 **Windsnelheidsprofiel van het lokale windklimaat door WAsP**

Hoogte in meter	Windsnelheid (m/s)
80	6,2
90	6,4
100	6,6
110	6,8
120	6,9
130	7,0
140	7,2
150	7,3
160	7,4
170	7,5
180	7,6
190	7,7
200	7,7

Figuur 3 laat een windroos zien van het lokale windklimaat door WAsP. De dominante windrichting ligt tussen zuidwest ten westen en westzuidwest.

Figuur 3 **Windroos voor de dominante windrichting op 135 meter hoogte.**



De bovenstaande berekeningen zijn tot stand gekomen door de beschrijving van het landschap te combineren met het regionale windklimaat.

Resultaten

De energieopbrengst van de referentiewindturbines is berekend in twee situaties:

- *Zonder* de A16-windturbines
- *Met* de A16-windturbines in de directe omgeving.

Het verschil tussen deze twee situaties is het zog-effect van de A16-windturbines op de referentiewindturbines. De resultaten zijn weergeven in Tabel 4.

De resultaten zijn in WindPRO berekend met het zog-effecten model van N.O. Jensen met een zog-effecten vervalconstante van 0,075.

Een volledig overzicht van alle WindPRO resultaten is te vinden in Bijlage A.

Tabel 4 **WindPRO resultaten voor de zog-effecten per cluster.**

Cluster	Beschrijving	Uitbater	Energie-opbrengst MWh/jaar	Zog-effect %	Opbrengst-verlies MWh/jaar
Zuid 1	Windpark Meer	Storm	31.580	3,60	1.139
Zuid 2	Windpark van Meer-Hoogstraten	EDF luminus	21.610	5,55	1.199
Zuid 3	Windpark Hoogstraten (opgeschaald)	Electrabel	80.207	3,07	2.459
Zuid 4	Windpark Hazeldonk	Windpark Hazeldonk Breda	19.984	6,45	1.289
Noord 5	Kroetenwind	Eneco	1.709	8,10	139

Bijlage A Resultaten WindPRO

Resultaten cluster noord:

Project:
A16 AEP

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Aniel Balhari / aniel@boschenvanrijn.nl
Calculated:
20-8-2018 16:04/3.2.712

PARK - Main Result

Calculation: PARK_CLUSTER2_V0_MCP_GOG_MERRA

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 31
At the site centre the difference between grid north and true north is: 1,3°

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: GILZE-RIJEN
Base temperature: 9,9 °C at 11,0 m
Base pressure: 1013,3 hPa at 0,0 m
Air density for Site center in key hub height: 10,0 m + 135,0 m = 1,229 kg/m³ -> 100,3 % 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 NL MCP - MCP - [Regression].wws

WAsP version WAsP 11 Version 11.06.0028

Key results for height 135,0 m above ground level

Terrain Dutch Stereo-RD/NAP 2008

	X (east)	Y (north)	Name of wind distribution	Type	Wind energy [kWh/m²]	Mean wind speed [m/s]	Equivalent roughness
A	108.126	404.688	Site data: tweede cluster	WAsP (WAsP 11 Version 11.06.0028)	3.415	7,2	1,8

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	Result-10,0% [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	130.111,4	117.100,2	139.309,6	6,6	38,8	13.011,1	3.399	7,1
New WTGs only	128.540,8	115.686,7	137.600,5	6,6	39,3	14.460,8	3.443	7,2
Existing park WTGs only	1.570,6	1.413,5	1.709,0	8,1	19,0	1.413,5	1.663	6,1
Existing park WTGs without new WTGs	1.709,0	1.538,1	1.709,0	0,0		1.538,1		
Reduction for existing park WTGs caused by new	138,5	124,6						

=) Based on Result-10,0%

Calculated Annual Energy for each of 8 new WTGs with total 33,6 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]	Result-10,0% [MWh/y]	Wake loss [%]	Free mean wind speed [m/s]
2 A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	16.307,8	14.677	5,6	7,23
3 A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	16.126,6	14.514	6,4	7,22
4 A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	15.920,8	14.329	7,7	7,23
5 A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	16.379,7	14.742	4,3	7,20
6 A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	16.538,5	14.885	2,7	7,17
7 A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	15.825,1	14.243	8,3	7,23
8 A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	15.475,8	13.928	10,2	7,23
9 A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	15.966,6	14.370	7,4	7,23

windPRO 3.2.712 by EMD International A/S, Tel. +45 96 35 44 44, www.emd.dk, windpro@emd.dk 20-8-2018 16:06 / 1 windPRO

Project:
A16 AEP

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Aniel Balhari / aniel@boschenvanrijn.nl
Calculated:
20-8-2018 16:04/3.2.712

PARK - Main Result

Calculation: PARK_CLUSTER2_V0_MCP_GOG_MERRA

Calculated Annual Energy for each of 1 existing park WTGs with total 0,9 MW rated power

	WTG type						Power curve		Annual Energy			
Links	Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Creator	Name	Calculated prod. without new WTGs	After New WTGs	Decrease due to new WTGs	Wake loss
				[kW]	[m]	[m]			[MWh/y]	[MWh/y]	[MWh %]	[%]
1 A	Yes	VESTAS	V52-850	850	52,0	70,0	EMD	Level 0 - calculated - 104.2 dB(A) - 07-2006	1.709,0	1.570,6	138,5 8,1	8,1

WTG siting

		Dutch Stereo-RD/NAP 2008			
		X (east)	Y (north)	Z [m]	Row data/Description
1	Exist	108.030	405.018	0,0	Vestas - V52-850 kW
2	New	106.540	406.508	0,0	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (82)
3	New	106.902	405.737	0,0	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (83)
4	New	106.721	406.116	0,0	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (84)
5	New	108.226	405.055	0,0	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (85)
6	New	108.391	404.666	0,0	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (86)
7	New	107.100	406.720	0,0	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (87)
8	New	107.292	406.313	0,0	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (88)
9	New	107.502	405.865	0,0	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (89)

Project:
A16 AEP

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Aniel Balhari / aniel@boschenvanrijn.nl
Calculated:
20-8-2018 16:04/3.2.712

PARK - Reference WTGs

Calculation: PARK_CLUSTER2_V0_MCP_GOG_MERRA
Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 31
At the site centre the difference between grid north and true north is: 1,3°

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: GB.ZE-RLIEN
Base temperature: 9,9 °C at 11,0 m
Base pressure: 1013,3 hPa at 0,0 m
Air density for Site center in key hub height: 10,0 m + 135,0 m = 1,229 kg/m³ -> 100,3 % 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 NL MCP - MCP - [Regression].wws

WAsP version WAsP 11 Version 11.06.0028

Scale 1:25.000
New WTG Existing WTG

Key results for height 135,0 m above ground level

Terrain Dutch Stereo-RD/NAP 2008

	X (east)	Y (north)	Name of wind distribution	Type	Wind energy [kWh/m²]	Mean wind speed [m/s]	Equivalent roughness
A	108.126	404.688	Site data: tweede cluster	WAsP (WAsP 11 Version 11.06.0028)	3.415	7,2	1,8

Calculated Annual Energy for reference WTGs

Calculated prod. without new WTGs	GROSS (no loss) Free WTGs	Wake loss	Specific results Capacity factor	Specific results Mean WTG result	Full load hours	Mean wind speed @hub height	Actual wind corrected energy	Goodness Factor
[MWh/y]	[MWh/y]	[%]	[%]	[MWh/y]	[Hours/year]	[m/s]	[MWh/y]	[%]
1.709,0	1.709,0	8,1	22,9	1.709,0	2.011	6,1	0,0	

Calculated Annual Energy for each of 1 reference WTGs with total 0,9 MW rated power

	WTG type Links	Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Power curve Creator	Name	Calculated prod. without new WTGs	Goodness Factor
					[kW]	[m]	[m]			[MWh/y]	[%]
1	A	Yes	VESTAS	V52-850	850	52,0	70,0	EMD	Level 0 - calculated - 104.2 dB(A) - 07-2006	1.709,0	0

WTG siting

Dutch Stereo-RD/NAP 2008

	X (east)	Y (north)	Z [m]	Row data/Description	Production source	Statistical basis for normalized production: [Months]
1	108.030	405.018	0,0	Vestas - V52-850 kW		

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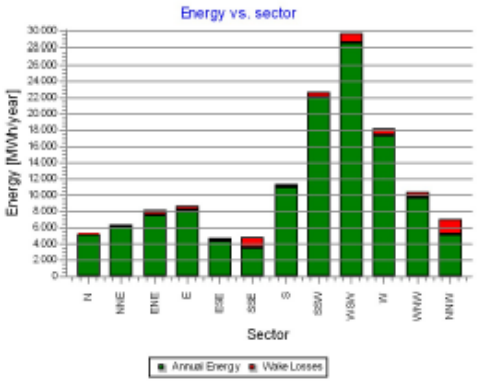
20-8-2018 16:04/3.2.712

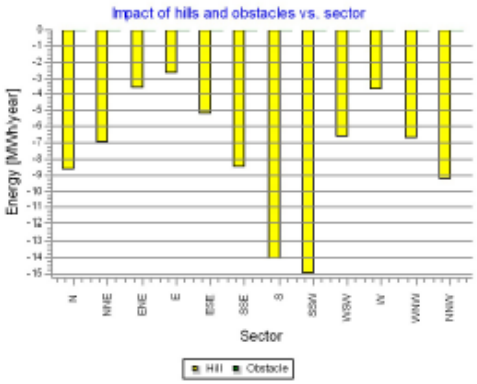
PARK - Production Analysis

Calculation: PARK_CLUSTER2_V0_MCP_GOG_MERRAWTG: All new WTGs, Air density varies with WTG position 1,230 kg/m³ - 1,238 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]	5.417,0	6.419,3	8.187,5	8.728,4	4.692,8	4.910,3	11.359,6	22.800,0	29.740,2	18.185,8	10.289,3	6.961,8	137.692,0
+Increase due to hills	[MWh]	-8,7	-7,0	-3,7	-2,7	-5,2	-8,6	-14,1	-15,0	-6,6	-3,7	-6,7	-9,3	-91,4
-Decrease due to wake losses	[MWh]	253,0	388,4	632,4	501,7	417,9	1.418,7	390,5	780,4	1.227,8	792,9	565,0	1.691,2	9.059,7
Resulting energy	**[MWh]**	**5.155,4**	**6.023,9**	**7.551,4**	**8.224,0**	**4.269,6**	**3.483,1**	**10.955,0**	**22.004,6**	**28.505,7**	**17.389,2**	**9.717,6**	**5.261,3**	**128.540,8**
Specific energy	[kWh/m²]													909
Specific energy	[kWh/kW]													3.826
Increase due to hills	[%]	-0,2	-0,1	0,0	0,0	-0,1	-0,2	-0,1	-0,1	0,0	0,0	-0,1	-0,1	-0,07
Decrease due to wake losses	[%]	4,7	6,1	7,7	5,7	8,9	28,9	3,4	3,4	4,1	4,4	5,5	24,3	6,58
Utilization	[%]	34,9	35,7	36,7	35,1	38,1	27,6	28,5	23,5	21,3	25,3	27,6	25,0	26,2
Operational	[Hours/year]	431	511	634	607	427	408	649	1.124	1.403	1.014	683	506	8.398
Full Load Equivalent	[Hours/year]	153	179	225	245	127	104	326	655	848	518	289	157	3.826





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Calculated:
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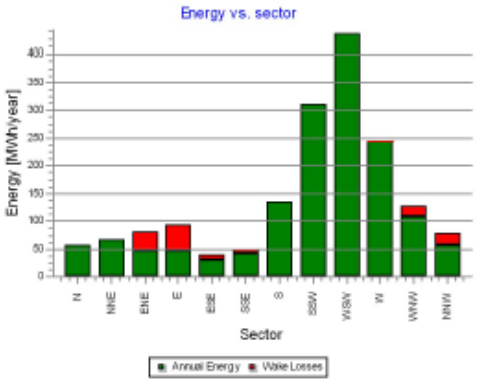
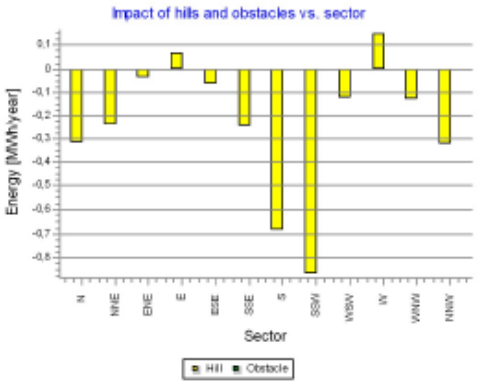
PARK - Production Analysis

Calculation: PARK_CLUSTER2_V0_MCP_GOG_MERRA **WTG:** All existing WTGs, Air density varies with WTG position 1,230 kg/m³ - 1,238 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]	56,6	65,0	81,0	92,3	40,3	49,0	134,7	309,8	434,8	243,8	126,4	78,1	1.711,8
+Increase due to hills	[MWh]	-0,3	-0,2	0,0	0,1	-0,1	-0,2	-0,7	-0,9	-0,1	0,1	-0,1	-0,3	-2,8
-Decrease due to wake losses	[MWh]	0,0	0,0	33,8	46,5	11,1	7,4	0,0	0,0	0,0	0,0	19,1	20,5	138,5
Resulting energy	**[MWh]**	**56,3**	**64,7**	**47,1**	**45,9**	**29,2**	**41,4**	**134,0**	**308,9**	**434,6**	**244,0**	**107,2**	**57,3**	**1.570,6**
Specific energy	[kWh/m²]													740
Specific energy	[kWh/kW]													1.848
Increase due to hills	[%]	-0,6	-0,4	0,0	0,1	-0,2	-0,5	-0,5	-0,3	0,0	0,1	-0,1	-0,4	-0,16
Decrease due to wake losses	[%]	0,0	0,0	41,8	50,3	27,6	15,1	0,0	0,0	0,0	0,0	15,2	26,4	8,10
Utilization	[%]	42,5	42,9	25,3	21,4	31,1	36,4	40,3	36,8	34,6	37,5	33,2	30,3	35,0
Operational	[Hours/year]	381	452	562	538	377	363	576	998	1.242	900	604	448	7.440
Full Load Equivalent	[Hours/year]	66	76	55	54	34	49	158	363	511	287	126	67	1.848





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PARK - Power Curve Analysis

Calculation: PARK_CLUSTER2_V0_MCP_GOG_MERRA**WTG:** 2 - VESTAS V150-4.2 4200 150.0 !O!, Hub height: 135,0 m
Name: Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017
Source: Manufacturer

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
27-7-2017	EMD	10-8-2017	10-8-2017	22,5	Pitch	User defined	Variable	0,24

Document no.: DMS 0067-7067 V04.
IEC S (HH 105 & 155 m)
DIBT WZ2(S) (HH 123 & 166 m)

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	8.530	12.511	16.163	19.289	21.849	23.843
VESTAS V150-4.2 4200 150.0 !O! Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	[MWh]	8.686	12.685	16.332	19.399	21.798	23.511
Check value	[%]	-2	-1	-1	-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 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

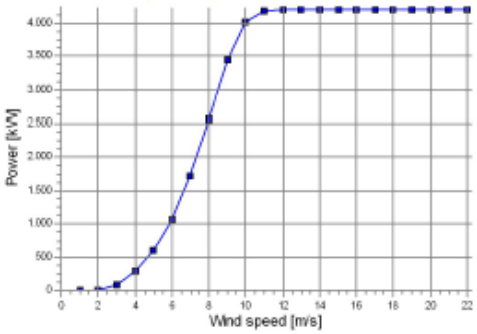
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
2,0	79,0	0,27	2,0	1,00
2,5	172,0	0,37	2,5	0,92
3,0	287,0	0,41	3,0	0,86
3,5	426,0	0,43	3,5	0,85
4,0	601,0	0,44	4,0	0,84
4,5	814,0	0,45	4,5	0,83
5,0	1.069,0	0,46	5,0	0,82
5,5	1.367,0	0,46	5,5	0,82
6,0	1.717,0	0,46	6,0	0,81
6,5	2.110,0	0,46	6,5	0,79
7,0	2.546,0	0,46	7,0	0,78
7,5	3.002,0	0,45	7,5	0,74
8,0	3.428,0	0,43	8,0	0,68
8,5	3.773,0	0,41	8,5	0,61
9,0	4.012,0	0,37	9,0	0,53
9,5	4.151,0	0,33	9,5	0,46
10,0	4.198,0	0,29	10,0	0,39
10,5	4.198,0	0,26	10,5	0,33
11,0	4.200,0	0,22	11,0	0,29
11,5	4.200,0	0,20	11,5	0,25
12,0	4.200,0	0,18	12,0	0,22
12,5	4.200,0	0,16	12,5	0,20
13,0	4.200,0	0,14	13,0	0,18
13,5	4.200,0	0,13	13,5	0,16
14,0	4.200,0	0,11	14,0	0,14
14,5	4.200,0	0,10	14,5	0,13
15,0	4.200,0	0,09	15,0	0,12
15,5	4.200,0	0,09	15,5	0,11
16,0	4.200,0	0,08	16,0	0,10
16,5	4.200,0	0,07	16,5	0,09
17,0	4.200,0	0,07	17,0	0,08
17,5	4.200,0	0,06	17,5	0,08
18,0	4.200,0	0,06	18,0	0,07
18,5	4.200,0	0,05	18,5	0,07
19,0	4.200,0	0,05	19,0	0,06
19,5	4.200,0	0,05	19,5	0,06
20,0	4.200,0	0,05	20,0	0,06
20,5	4.200,0	0,05	20,5	0,06
21,0	4.200,0	0,04	21,0	0,05
21,5	4.200,0	0,04	21,5	0,05
22,0	4.200,0	0,04	22,0	0,05
22,5	4.200,0	0,03	22,5	0,05

Power, Efficiency and energy vs. wind speed

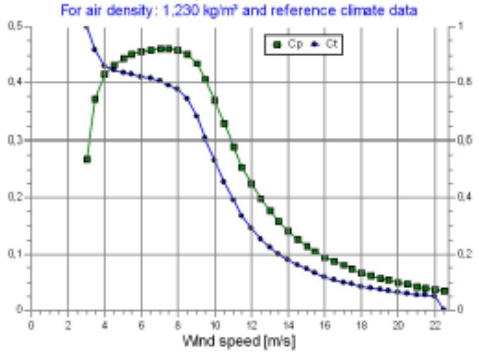
Data used in calculation, Air density: 1,230 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

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	78,8	0,27	2,50- 3,50	58,5	58,5	0,4
4,0	288,6	0,41	3,50- 4,50	244,1	302,6	1,9
5,0	604,0	0,44	4,50- 5,50	587,6	890,1	5,5
6,0	1.074,1	0,46	5,50- 6,50	1.093,3	1.983,5	12,2
7,0	1.724,8	0,46	6,50- 7,50	1.689,1	3.672,6	22,5
8,0	2.556,4	0,46	7,50- 8,50	2.222,9	5.895,5	36,2
9,0	3.437,5	0,43	8,50- 9,50	2.465,3	8.360,8	51,3
10,0	4.016,1	0,37	9,50-10,50	2.275,3	10.636,1	65,2
11,0	4.186,5	0,29	10,50-11,50	1.803,9	12.440,1	76,3
12,0	4.200,0	0,22	11,50-12,50	1.312,6	13.752,7	84,3
13,0	4.200,0	0,18	12,50-13,50	916,7	14.669,4	90,0
14,0	4.200,0	0,14	13,50-14,50	621,1	15.290,5	93,8
15,0	4.200,0	0,11	14,50-15,50	407,7	15.698,1	96,3
16,0	4.200,0	0,09	15,50-16,50	258,3	15.956,4	97,8
17,0	4.200,0	0,08	16,50-17,50	157,4	16.113,8	98,8
18,0	4.200,0	0,07	17,50-18,50	92,0	16.205,8	99,4
19,0	4.200,0	0,06	18,50-19,50	51,4	16.257,2	99,7
20,0	4.200,0	0,05	19,50-20,50	27,5	16.284,7	99,9
21,0	4.200,0	0,04	20,50-21,50	14,0	16.298,7	99,9
22,0	4.200,0	0,04	21,50-22,50	6,8	16.305,6	100,0
23,0	0,0	0,00	22,50-23,50	2,2	16.307,8	100,0

Power curve
For air density: 1,230 kg/m³ and reference climate data



Cp and Ct curve
For air density: 1,230 kg/m³ and reference climate data



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Calculated:
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PARK - Terrain

Calculation: PARK_CLUSTER2_V0_MCP_GOG_MERRA**Site Data:** A - Site data: tweede cluster

Obstacles:

0 Obstacles used

Roughness:

Terrain data files used in calculation:
\\BVR_NAS\NAS Data\GIS bestanden\2016\16095 - A16 MER PIP Vergunningen\AEP\ROUGHNESSLINE_ONLINEDATA_5.wpo
Min X: 572.504, Max X: 655.927, Min Y: 5.666.110, Max Y: 5.753.359, Width: 83.423 m, Height: 87.250 m

Orography:

Terrain data files used in calculation:
\\BVR_NAS\NAS Data\GIS bestanden\2016\16095 - A16 MER PIP Vergunningen\AEP\CONTOURLINE_ONLINEDATA_8.wpo
Min X: 575.120, Max X: 653.542, Min Y: 5.669.031, Max Y: 5.750.848, Width: 78.422 m, Height: 81.816 m

Project:
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Calculated:
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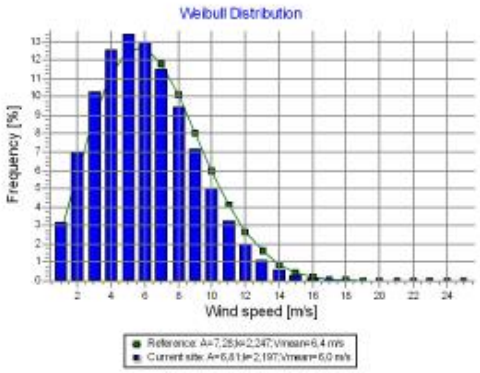
PARK - Wind Data Analysis

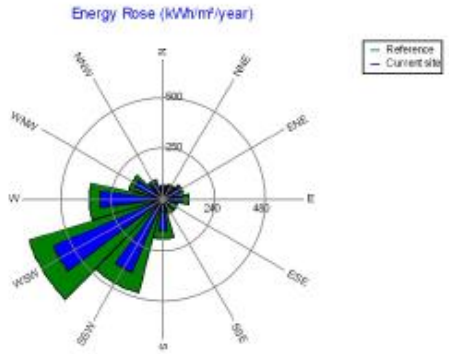
Calculation: PARK_CLUSTER2_V0_MCP_GOG_MERRA**Wind data:** A - Site data: tweede cluster; Hub height: 70,0

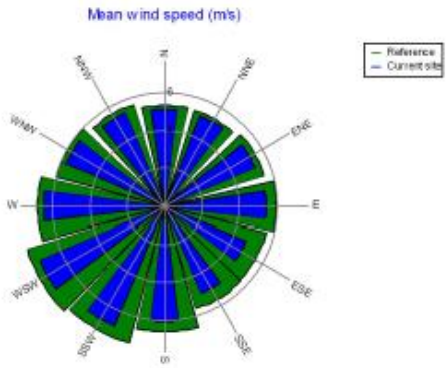
Site coordinates
Dutch Stereo-RD/NAP 2008
East: 108.126 North: 404.688
Wind statistics
NL MCP - MCP - [Regression].wws

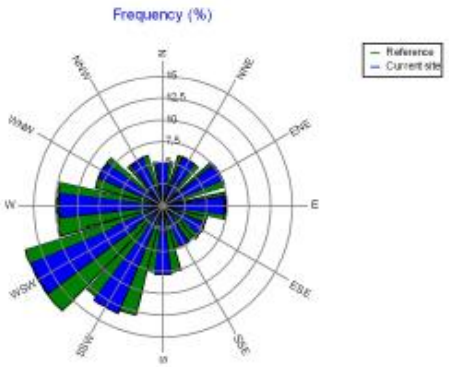
Weibull Data

Sector	Current site A-parameter [m/s]	Current site Wind speed [m/s]	Current site k-parameter	Current site Frequency [%]	Reference: Roughness class 1 A-parameter [m/s]	Reference: Roughness class 1 k-parameter	Reference: Roughness class 1 Frequency [%]
0 N	5,83	5,16	2,365	5,1	6,04	2,371	5,1
1 NNE	5,81	5,16	2,514	6,1	6,02	2,513	6,1
2 ENE	5,90	5,25	2,791	7,5	6,25	2,800	7,5
3 E	6,12	5,44	2,658	7,2	6,71	2,675	7,3
4 ESE	5,30	4,72	2,791	5,1	6,28	2,796	5,3
5 SSE	5,62	4,99	2,482	4,9	6,37	2,550	4,8
6 S	6,86	6,08	2,389	7,7	7,47	2,390	7,5
7 SSW	7,75	6,87	2,365	13,4	8,41	2,379	12,9
8 WSW	8,23	7,29	2,342	16,7	8,68	2,353	16,8
9 W	7,32	6,48	2,232	12,1	7,68	2,244	12,3
10 WNW	6,48	5,74	2,092	8,1	6,76	2,101	8,2
11 NNW	6,08	5,38	2,201	6,0	6,38	2,203	6,1
All	6,81	6,03	2,197	100,0	7,28	2,247	100,0









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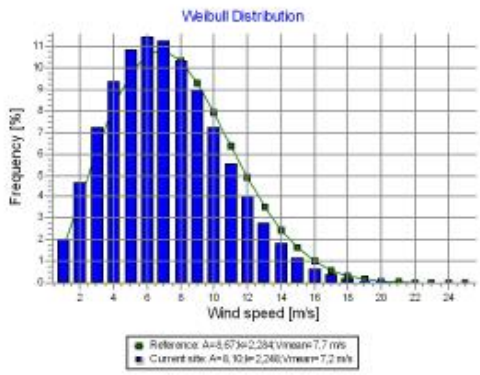
PARK - Wind Data Analysis

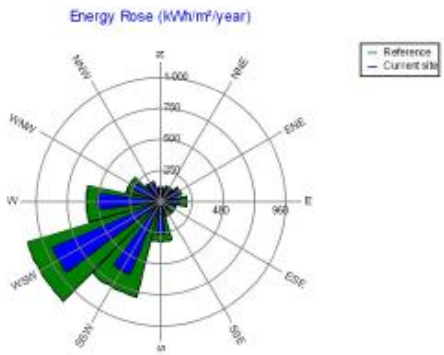
Calculation: PARK_CLUSTER2_V0_MCP_GOG_MERRA**Wind data:** A - Site data: tweede cluster; Hub height: 135,0

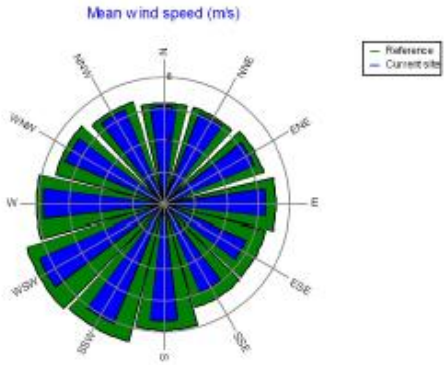
Site coordinates
Dutch Stereo-RD/NAP 2008
East: 108.126 North: 404.688
Wind statistics
NL MCP - MCP - [Regression].wws

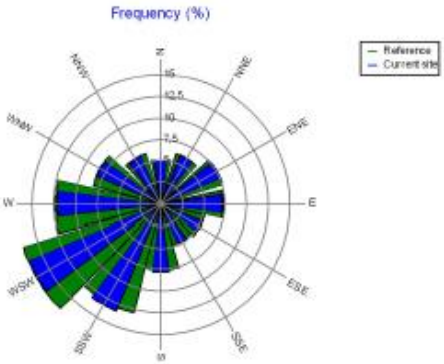
Weibull Data

	Current site				Reference: Roughness class 1		
Sector	A-parameter [m/s]	Wind speed [m/s]	k-parameter	Frequency [%]	A-parameter [m/s]	k-parameter	Frequency [%]
0 N	6,96	6,17	2,396	5,1	7,20	2,409	5,1
1 NNE	6,90	6,13	2,553	6,1	7,17	2,556	6,1
2 ENE	7,01	6,25	2,854	7,5	7,44	2,846	7,5
3 E	7,28	6,48	2,736	7,2	8,00	2,719	7,3
4 ESE	6,36	5,67	2,889	5,1	7,48	2,842	5,3
5 SSE	6,71	5,96	2,561	4,9	7,58	2,593	4,8
6 S	8,23	7,30	2,451	7,8	8,90	2,428	7,5
7 SSW	9,20	8,16	2,432	13,4	10,02	2,417	12,9
8 WSW	9,74	8,63	2,393	16,7	10,28	2,395	16,8
9 W	8,69	7,70	2,275	12,1	9,15	2,282	12,3
10 WNW	7,66	6,79	2,123	8,1	8,05	2,137	8,2
11 NNW	7,26	6,43	2,236	6,0	7,60	2,239	6,1
All	8,10	7,18	2,248	100,0	8,67	2,284	100,0









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PARK - Park power curve

Calculation: PARK_CLUSTER2_V0_MCP_GOG_MERRA

Wind speed [m/s]	Power Free WTGs [kW]	Park WTGs [kW]	N [kW]	NNE [kW]	ENE [kW]	E [kW]	ESE [kW]	SSE [kW]	S [kW]	SSW [kW]	WSW [kW]	W [kW]	WNW [kW]	NNW [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	1.398	1.089	1.218	1.175	1.122	1.165	1.121	550	1.218	1.177	1.120	1.160	1.124	536
4,5	3.473	2.967	3.199	3.132	3.034	3.094	3.028	1.937	3.199	3.135	3.039	3.099	3.039	1.913
5,5	6.641	5.763	6.154	6.039	5.873	5.970	5.846	4.066	6.154	6.045	5.879	5.976	5.870	4.035
6,5	11.153	9.748	10.373	10.193	9.923	10.084	9.888	7.028	10.374	10.201	9.928	10.088	9.926	6.982
7,5	17.210	15.150	16.072	15.809	15.417	15.656	15.373	11.104	16.073	15.822	15.417	15.653	15.427	11.033
8,5	24.469	21.879	23.073	22.739	22.230	22.548	22.232	16.506	23.074	22.754	22.234	22.548	22.296	16.407
9,5	30.737	28.650	29.739	29.459	28.981	29.276	29.165	23.353	29.738	29.468	29.019	29.323	29.206	23.232
10,5	33.683	32.866	33.392	33.279	33.026	33.131	33.197	30.034	33.390	33.282	33.107	33.238	33.220	29.989
11,5	34.305	34.183	34.284	34.267	34.175	34.170	34.233	33.678	34.283	34.267	34.245	34.264	34.247	33.664
12,5	34.388	34.376	34.388	34.388	34.351	34.338	34.369	34.362	34.388	34.388	34.388	34.388	34.376	34.343
13,5	34.425	34.421	34.425	34.425	34.410	34.404	34.418	34.421	34.425	34.425	34.425	34.425	34.420	34.414
14,5	34.442	34.440	34.442	34.442	34.437	34.435	34.439	34.440	34.442	34.442	34.442	34.442	34.440	34.438
15,5	34.448	34.447	34.448	34.448	34.447	34.446	34.447	34.447	34.448	34.448	34.448	34.448	34.447	34.447
16,5	34.450	34.449	34.450	34.450	34.449	34.449	34.449	34.449	34.450	34.450	34.450	34.450	34.449	34.449
17,5	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450
18,5	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450
19,5	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450
20,5	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450
21,5	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450
22,5	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450	34.450
23,5	850	850	850	850	850	850	850	850	850	850	850	850	850	850
24,5	850	850	850	850	850	850	850	850	850	850	850	850	850	850
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.

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PARK - WTG distances

Calculation: PARK_CLUSTER2_V0_MCP_GOG_MERRA

WTG distances

	Z [m]	Nearest WTG	Z [m]	Horizontal distance [m]	Distance in rotor diameters (max)	Distance in rotor diameters (min)
1	0,0	5	0,0	200	3,8	1,3
2	0,0	4	0,0	431	2,9	2,9
3	0,0	4	0,0	420	2,8	2,8
4	0,0	3	0,0	420	2,8	2,8
5	0,0	1	0,0	200	3,8	1,3
6	0,0	5	0,0	423	2,8	2,8
7	0,0	8	0,0	450	3,0	3,0
8	0,0	7	0,0	450	3,0	3,0
9	0,0	8	0,0	495	3,3	3,3
Min	**0,0**		**0,0**	**200**	**2,8**	**1,3**
Max	**0,0**		**0,0**	**495**	**3,8**	**3,3**

Scale 1:40.000
New WTG Existing WTG

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PARK - Wind statistics info

Calculation: PARK_CLUSTER2_V0_MCP_GOG_MERRA

Main data for wind statistic

File	\\BVR_NAS\NAS Data\GIS bestanden\2016\16095 - A16 MER PIP Vergunningen\AEP\NL MCP - MCP - [Regression].wws
Name	MCP - MCP session (1) - [Regression]
Country	Netherlands
Source	USER
Mast coordinates	Dutch Stereo-RD/NAP 2008 East: 100.863 North: 403.831
Created	16-8-2018
Edited	16-8-2018
Sectors	12
WAsP version	WAsP 11 Version 11.06.0028
Displacement height	None

Comments
From MCP

Additional info for wind statistic

Based on measurement height	98,0 m
Base elevation for measurement mast	0,0 m
Long term correction information	
Method	Regression
Source data	MERRA_basic_E04.668_N51.500 (3)
Distance to source data	14,1 km
Long term period from	1-1-1988
Long term period to	1-3-2016
Concurrent period from	30-11-2012
Concurrent period to	1-7-2015
Concurrent data records	22521
Concurrent record interval	60 minutes
Concurrent data recovery	99,8 %
Number of years with long term data	28,2 years
Number of months with concurrent data	30,8 Months
Correlation test based on Concurrent monthly windindices	
Power curve used for index	Simple power curve truncated at: 13,0 m/s
Data availability demand for inclusion of month	60 %
Number of months	0
r^2 - wind index	0,0000
r - wind index	0,0000
s - wind index	0,0000

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.

Resultaten cluster zuid:

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PARK - Main Result

Calculation: PARK_V0_MCP_GOG_MERRA

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 31
At the site centre the difference between grid north and true north is: 1,3°

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: GILZE-RIJEN
Base temperature: 9,9 °C at 11,0 m
Base pressure: 1013,3 hPa at 0,0 m
Air density for Site center in key hub height: 10,0 m + 135,0 m = 1,229 kg/m³ -> 100,3 % 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 NL MCP - MCP - [Regression].wws

WAsP version WAsP 11 Version 11.06.0028

Scale 1:200.000
New WTG Existing WTG Site Data

Key results for height 135,0 m above ground level

Terrain Dutch Stereo-RD/NAP 2008

	X (east)	Y (north)	Name of wind distribution	Type	Wind energy [kWh/m²]	Mean wind speed [m/s]	Equivalent roughness
A	108.802	388.938	Site data: WAsP_MCP_GOG_MERRA	WAsP (WAsP 11 Version 11.06.0028)	3.355	7,1	1,8

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	Result-10,0% [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	299.345,8	269.411,2	329.962,2	9,3	34,1	9.978,2	2.991	7,0
New WTGs only	152.051,3	136.846,2	165.879,7	8,3	36,9	12.440,6	3.234	7,0
Existing park WTGs only	147.294,5	132.565,0	164.082,5	10,2	31,7	8.285,3	2.776	7,0
Existing park WTGs without new WTGs	153.379,4	138.041,5	164.082,5	0,0		8.627,6		
Reduction for existing park WTGs caused by new	6.084,9	5.476,4						

=) Based on Result-10,0%

Calculated Annual Energy for each of 11 new WTGs with total 42,3 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]	Result-10,0% [MWh/y]	Wake loss [%]	Free mean wind speed [m/s]
17	A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	15.555,0	13.999	6,4	7,07
18	A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	15.572,4	14.015	6,5	7,09
19	A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	15.854,3	14.269	5,1	7,09
20	A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	15.173,8	13.656	9,5	7,10
21	A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	15.158,2	13.642	10,1	7,13
22	A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	14.998,0	13.498	11,2	7,14
23	A	Yes	VESTAS	V110-2.0-2.000	2.000	110,0	110,0	EMD	Level 0 - - Mode 0 - 12-2013	7.143,4	6.429	7,4	6,68
24	A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	15.542,1	13.988	7,8	7,13
25	A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	16.014,2	14.413	5,7	7,16
26	A	Yes	VESTAS	V150-4.2-4.200	4.200	150,0	135,0	EMD	Level 0 - Calculated - Modes PO1 & PO1-0S - 27-07-2017	15.142,3	13.628	10,1	7,13
27	A	Yes	LAGERWEY	L100-2.5MW-2.520	2.520	100,0	100,0	EMD	Level 0 - - Standard mode - 04-2013	5.897,7	5.308	15,5	6,45

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PARK - Main Result

Calculation: PARK_V0_MCP_GOG_MERRA

Calculated Annual Energy for each of 16 existing park WTGs with total 47,8 MW rated power

	WTG type							Power curve		Annual Energy			
	Links	Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Creator	Name	Calculated prod. without new WTGs	After New WTGs	Decrease due to new WTGs	Wake loss
					[kW]	[m]	[m]			[MWh/y]	[MWh/y]	[MWh %]	[%]
1	A	Yes	LAGERWEY	L100-2.5MW-2.520	2.520	100,0	99,0	EMD	Level 0 - - Standard mode - 04-2013	6.606,4	5.863,2	743,3 11,3	16,5
2	A	Yes	LAGERWEY	L100-2.5MW-2.520	2.520	100,0	99,0	EMD	Level 0 - - Standard mode - 04-2013	6.717,4	6.360,2	357,2 5,3	9,2
3	A	Yes	LAGERWEY	L100-2.5MW-2.520	2.520	100,0	99,0	EMD	Level 0 - - Standard mode - 04-2013	6.659,6	6.471,0	188,6 2,8	7,7
4	A	Yes	SENVION	3.2M114-3.200	3.200	114,0	143,0	EMD	Level 0 - Calculated - Before trafo - open mode - 01-2014	10.539,1	9.893,7	645,4 6,1	11,8
5	A	Yes	SENVION	3.2M114-3.200	3.200	114,0	143,0	EMD	Level 0 - Calculated - Before trafo - open mode - 01-2014	10.398,5	10.050,8	347,7 3,3	10,7
6	A	Yes	SENVION	3.2M114-3.200	3.200	114,0	143,0	EMD	Level 0 - Calculated - Before trafo - open mode - 01-2014	10.642,1	10.496,8	145,3 1,4	6,7
7	A	No	Siemens	SWT-3.2-101-3.200	3.200	100,6	94,0	EMD	Level 0 - Calculated - Std. 107dB - 10-2014	7.180,8	6.868,1	312,7 4,4	12,2
8	A	No	Siemens	SWT-3.2-101-3.200	3.200	100,6	94,0	EMD	Level 0 - Calculated - Std. 107dB - 10-2014	7.137,3	6.699,2	438,0 6,1	14,7
9	A	No	Siemens	SWT-3.2-101-3.200	3.200	100,6	94,0	EMD	Level 0 - Calculated - Std. 107dB - 10-2014	7.291,4	6.843,5	447,9 6,1	12,9
10	A	Yes	VESTAS	V126-3.0-3.000	3.000	126,0	147,0	EMD	Level 0 - - Mode 0 - 06-2015	11.456,4	10.677,2	779,3 6,8	12,2
11	A	Yes	VESTAS	V126-3.0-3.000	3.000	126,0	147,0	EMD	Level 0 - - Mode 0 - 06-2015	11.570,2	10.893,5	676,7 5,8	10,7
12	A	Yes	VESTAS	V126-3.0-3.000	3.000	126,0	147,0	EMD	Level 0 - - Mode 0 - 06-2015	11.317,1	10.893,6	423,5 3,7	10,9
13	A	Yes	VESTAS	V126-3.0-3.000	3.000	126,0	147,0	EMD	Level 0 - - Mode 0 - 06-2015	11.231,6	10.968,3	263,3 2,3	10,5
14	A	Yes	VESTAS	V126-3.0-3.000	3.000	126,0	147,0	EMD	Level 0 - - Mode 0 - 06-2015	11.132,4	10.963,3	169,1 1,5	10,9
15	A	Yes	VESTAS	V126-3.0-3.000	3.000	126,0	147,0	EMD	Level 0 - - Mode 0 - 06-2015	11.472,1	11.371,5	100,6 0,9	7,6
16	A	Yes	VESTAS	V126-3.0-3.000	3.000	126,0	147,0	EMD	Level 0 - - Mode 0 - 06-2015	12.026,8	11.980,6	46,2 0,4	2,8

WTG siting

		Dutch Stereo-RD/NAP 2008 X (east)	Y (north)	Z [m]	Row data/Description
1	Exist	110.028	389.323	7,7	Lagerwey - L100-NL
2	Exist	110.383	390.346	8,8	Lagerwey - L100-NL
3	Exist	110.747	390.768	5,0	Lagerwey - L100-NL
4	Exist	108.551	387.094	10,0	Senvion - 3.2M114
5	Exist	108.586	386.723	10,0	Senvion - 3.2M114
6	Exist	108.531	386.311	10,0	Senvion - 3.2M114
7	Exist	110.596	388.964	9,9	Siemens - SWT-3.2-101
8	Exist	110.716	389.414	9,5	Siemens - SWT-3.2-101
9	Exist	110.856	389.965	9,4	Siemens - SWT-3.2-101
10	Exist	109.916	388.736	1,1	Vestas V126
11	Exist	109.720	388.255	10,0	Vestas V126
12	Exist	109.479	387.531	10,0	Vestas V126
13	Exist	109.372	387.115	10,0	Vestas V126
14	Exist	109.208	386.577	10,0	Vestas V126
15	Exist	109.126	386.232	10,0	Vestas V126
16	Exist	109.001	385.623	10,0	Vestas V126
17	New	111.026	393.467	10,0	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (70)
18	New	110.760	393.823	10,0	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (71)
19	New	110.554	393.462	9,2	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (72)
20	New	108.924	388.217	3,4	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (73)
21	New	109.217	388.740	3,0	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (74)
22	New	109.472	389.193	6,0	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (75)
23	New	111.294	390.375	10,0	VESTAS V110-2.0 2000 110.0 !O! hub: 110,0 m (TOT: 165,0 m) (76)
24	New	108.665	387.771	10,0	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (77)
25	New	108.085	386.886	10,0	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (78)
26	New	109.659	389.618	5,7	VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (79)
27	New	110.243	389.690	3,0	LAGERWEY L100-2.5MW 2520 100.0 !O! hub: 100,0 m (TOT: 150,0 m) (80)

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PARK - Reference WTGs

Calculation: PARK_V0_MCP_GOG_MERRA

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 31
At the site centre the difference between grid north and true north is: 1,3°

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: GILZE-RIJEN
Base temperature: 9,9 °C at 11,0 m
Base pressure: 1013,3 hPa at 0,0 m
Air density for Site center in key hub height: 10,0 m + 135,0 m = 1,229 kg/m³ -> 100,3 % of Std
Relative humidity: 0,0 %

Wake Model Parameters
Wake decay constant 0,075 DTU default onshore

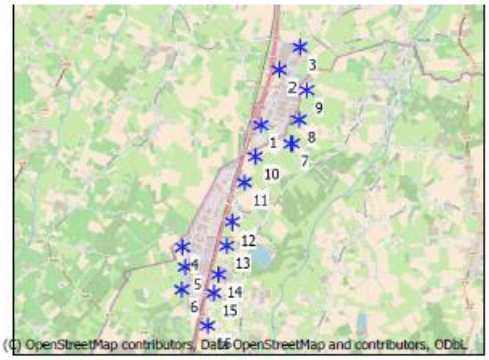
Omnidirectional displacement height from objects

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 NL MCP - MCP - [Regression].wws

WAsP version WAsP 11 Version 11.06.0028



Scale 1:100.000
New WTG Existing WTG

Key results for height 135,0 m above ground level

Terrain **Dutch Stereo-RD/NAP 2008**

	X (east)	Y (north)	Name of wind distribution	Type	Wind energy [kWh/m²]	Mean wind speed [m/s]	Equivalent roughness
A	108.802	388.938	Site data: WAsP_MCP_GOG_MERRA	WAsP (WAsP 11 Version 11.06.0028)	3.355	7,1	1,8

Calculated Annual Energy for reference WTGs

Calculated prod. without new WTGs	GROSS (no loss) Free WTGs	Wake loss	Specific results Capacity factor	Specific results Mean WTG result	Full load hours	Mean wind speed @hub height	Actual wind corrected energy	Goodness Factor
[MWh/y]	[MWh/y]	[%]	[%]	[MWh/y]	[Hours/year]	[m/s]	[MWh/y]	[%]
153.379,4	164.082,5	10,2	36,6	9.586,2	3.211	7,0	0,0	

Calculated Annual Energy for each of 16 reference WTGs with total 47,8 MW rated power

	Links	WTG type Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Power curve Creator	Name	Calculated prod. without new WTGs	Goodness Factor
					[kW]	[m]	[m]			[MWh/y]	[%]
1	A	Yes	LAGERWEY	L100-2.5MW-2.520	2.520	100,0	99,0	EMD	Level 0 - - Standard mode - 04-2013	6.606,4	0
2	A	Yes	LAGERWEY	L100-2.5MW-2.520	2.520	100,0	99,0	EMD	Level 0 - - Standard mode - 04-2013	6.717,4	0
3	A	Yes	LAGERWEY	L100-2.5MW-2.520	2.520	100,0	99,0	EMD	Level 0 - - Standard mode - 04-2013	6.659,6	0
4	A	Yes	SENVION	3.2M114-3.200	3.200	114,0	143,0	EMD	Level 0 - Calculated - Before trafo - open mode - 01-2014	10.539,1	0
5	A	Yes	SENVION	3.2M114-3.200	3.200	114,0	143,0	EMD	Level 0 - Calculated - Before trafo - open mode - 01-2014	10.398,5	0
6	A	Yes	SENVION	3.2M114-3.200	3.200	114,0	143,0	EMD	Level 0 - Calculated - Before trafo - open mode - 01-2014	10.642,1	0
7	A	No	Siemens	SWT-3.2-101-3.200	3.200	100,6	94,0	EMD	Level 0 - Calculated - Std. 107dB - 10-2014	7.180,8	0
8	A	No	Siemens	SWT-3.2-101-3.200	3.200	100,6	94,0	EMD	Level 0 - Calculated - Std. 107dB - 10-2014	7.137,3	0
9	A	No	Siemens	SWT-3.2-101-3.200	3.200	100,6	94,0	EMD	Level 0 - Calculated - Std. 107dB - 10-2014	7.291,4	0
10	A	Yes	VESTAS	V126-3.0-3.000	3.000	126,0	147,0	EMD	Level 0 - - Mode 0 - 06-2015	11.456,4	0
11	A	Yes	VESTAS	V126-3.0-3.000	3.000	126,0	147,0	EMD	Level 0 - - Mode 0 - 06-2015	11.570,2	0
12	A	Yes	VESTAS	V126-3.0-3.000	3.000	126,0	147,0	EMD	Level 0 - - Mode 0 - 06-2015	11.317,1	0
13	A	Yes	VESTAS	V126-3.0-3.000	3.000	126,0	147,0	EMD	Level 0 - - Mode 0 - 06-2015	11.231,6	0
14	A	Yes	VESTAS	V126-3.0-3.000	3.000	126,0	147,0	EMD	Level 0 - - Mode 0 - 06-2015	11.132,4	0
15	A	Yes	VESTAS	V126-3.0-3.000	3.000	126,0	147,0	EMD	Level 0 - - Mode 0 - 06-2015	11.472,1	0
16	A	Yes	VESTAS	V126-3.0-3.000	3.000	126,0	147,0	EMD	Level 0 - - Mode 0 - 06-2015	12.026,8	0

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PARK - Reference WTGs

Calculation: PARK_V0_MCP_GOG_MERRA

WTG siting

Dutch Stereo-RD/NAP 2008

	X (east)	Y (north)	Z [m]	Row data/Description	Production source	Statistical basis for normalized production: [Months]
1	110.028	389.323	7,7	Lagerwey - L100-NL		
2	110.383	390.346	8,8	Lagerwey - L100-NL		
3	110.747	390.768	5,0	Lagerwey - L100-NL		
4	108.551	387.094	10,0	Senvion - 3.2M114		
5	108.586	386.723	10,0	Senvion - 3.2M114		
6	108.531	386.311	10,0	Senvion - 3.2M114		
7	110.596	388.964	9,9	Siemens - SWT-3.2-101		
8	110.716	389.414	9,5	Siemens - SWT-3.2-101		
9	110.856	389.965	9,4	Siemens - SWT-3.2-101		
10	109.916	388.736	1,1	Vestas V126		
11	109.720	388.255	10,0	Vestas V126		
12	109.479	387.531	10,0	Vestas V126		
13	109.372	387.115	10,0	Vestas V126		
14	109.208	386.577	10,0	Vestas V126		
15	109.126	386.232	10,0	Vestas V126		
16	109.001	385.623	10,0	Vestas V126		

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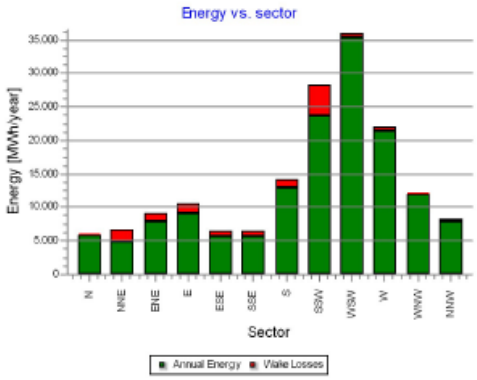
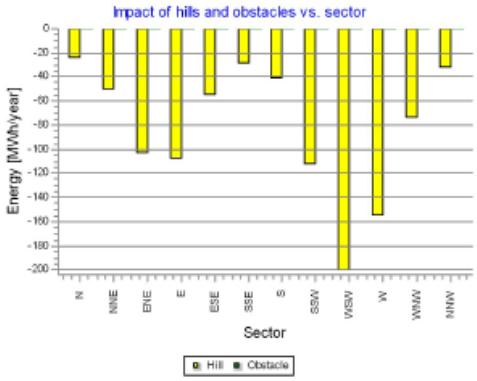
PARK - Production Analysis

Calculation: PARK_V0_MCP_GOG_MERRA**WTG:** All new WTGs, Air density varies with WTG position 1,228 kg/m³ - 1,234 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]	6.004,4	6.769,1	9.214,2	10.557,7	6.541,2	6.545,5	14.120,1	28.451,3	36.113,1	22.201,6	12.129,5	8.222,5	166.870,1
+Increase due to hills	[MWh]	-24,7	-51,2	-104,2	-107,9	-55,3	-29,2	-42,2	-112,5	-200,9	-155,9	-74,0	-32,3	-990,4
-Decrease due to wake losses	[MWh]	209,6	1.864,4	1.193,0	1.346,3	770,4	780,6	1.261,7	4.635,9	593,0	755,9	183,2	234,5	13.828,4
Resulting energy	**[MWh]**	**5.770,2**	**4.853,4**	**7.917,1**	**9.103,5**	**5.715,5**	**5.735,7**	**12.816,2**	**23.702,8**	**35.319,2**	**21.289,8**	**11.872,3**	**7.955,7**	**152.051,3**
Specific energy	[kWh/m²]													862
Specific energy	[kWh/kW]													3.593
Increase due to hills	[%]	-0,4	-0,8	-1,1	-1,0	-0,8	-0,4	-0,3	-0,4	-0,6	-0,7	-0,6	-0,4	-0,59
Decrease due to wake losses	[%]	3,5	27,8	13,1	12,9	11,9	12,0	9,0	16,4	1,7	3,4	1,5	2,9	8,34
Utilization	[%]	37,4	29,5	35,9	33,0	35,9	33,3	27,2	20,5	23,1	26,3	30,4	33,4	26,5
Operational	[Hours/year]	434	518	634	604	429	403	653	1.121	1.395	1.006	675	503	8.375
Full Load Equivalent	[Hours/year]	136	115	187	215	135	136	303	560	835	503	281	188	3.593





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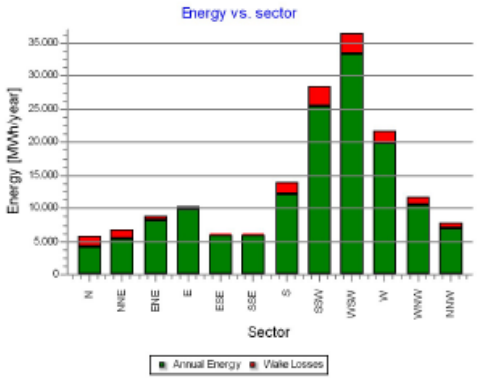
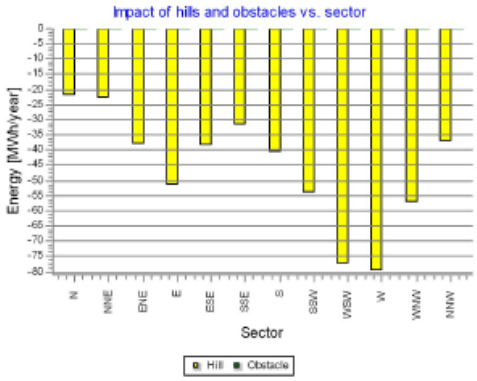
PARK - Production Analysis

Calculation: PARK_V0_MCP_GOG_MERRA**WTG:** All existing WTGs, Air density varies with WTG position 1,228 kg/m³ - 1,234 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]	5.746,6	6.696,8	8.941,4	10.342,1	6.211,2	6.212,1	14.036,3	28.529,1	36.518,1	21.826,7	11.741,4	7.832,6	164.634,5
+Increase due to hills	[MWh]	-22,1	-22,7	-38,0	-51,7	-38,6	-31,7	-40,9	-54,2	-77,7	-79,8	-57,3	-37,2	-552,0
-Decrease due to wake losses	[MWh]	1.558,9	1.358,3	638,5	486,2	324,0	239,6	1.965,7	3.064,5	3.090,3	1.879,6	1.278,9	903,4	16.788,0
Resulting energy	**[MWh]**	**4.165,6**	**5.315,8**	**8.264,8**	**9.804,2**	**5.848,6**	**5.940,8**	**12.029,8**	**25.410,4**	**33.350,0**	**19.867,4**	**10.405,2**	**6.892,0**	**147.294,5**
Specific energy	[kWh/m²]													891
Specific energy	[kWh/kW]													3.084
Increase due to hills	[%]	-0,4	-0,3	-0,4	-0,5	-0,6	-0,5	-0,3	-0,2	-0,2	-0,4	-0,5	-0,5	-0,34
Decrease due to wake losses	[%]	27,2	20,4	7,2	4,7	5,2	3,9	14,0	10,8	8,5	8,6	10,9	11,6	10,23
Utilization	[%]	28,6	32,4	38,3	36,5	38,8	37,2	26,8	23,7	23,3	26,8	28,9	31,6	27,4
Operational	[Hours/year]	432	517	636	606	429	402	649	1.124	1.398	1.005	672	500	8.371
Full Load Equivalent	[Hours/year]	87	111	173	205	122	124	252	532	698	416	218	144	3.084





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PARK - Power Curve Analysis

Calculation: PARK_V0_MCP_GOG_MERRA**WTG:** 17 - VESTAS V150-4.2 4200 150.0 !O!, Hub height: 135,0 m

Name: Level 0 - Calculated - Modes PO1 & PO1-OS - 27-07-2017
Source: Manufacturer

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
27-7-2017	EMD	10-8-2017	10-8-2017	22,5	Pitch	User defined	Variable	0,24

Document no.: DMS 0067-7067 V04.
IEC S (HH 105 & 155 m)
DiBT WZ2(S) (HH 123 & 166 m)

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	8.530	12.511	16.163	19.289	21.849	23.843
VESTAS V150-4.2 4200 150.0 !O! Level 0 - Calculated - Modes PO1 & PO1-OS - 27-07-2017	[MWh]	8.686	12.685	16.332	19.399	21.798	23.511
Check value	[%]	-2	-1	-1	-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 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

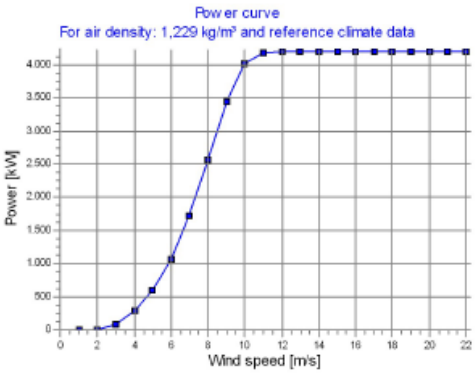
Original data, Air density: 1,225 kg/m³

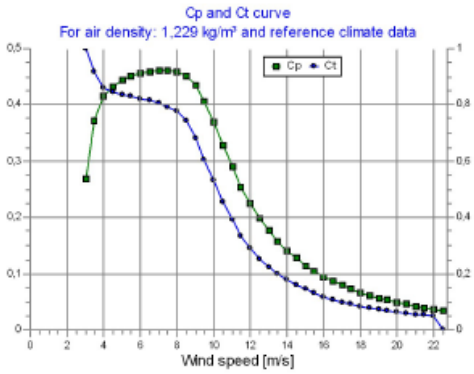
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
3,0	78,0	0,27	3,0	1,00
3,5	172,0	0,37	3,5	0,92
4,0	287,0	0,41	4,0	0,86
4,5	426,0	0,43	4,5	0,85
5,0	601,0	0,44	5,0	0,84
5,5	814,0	0,45	5,5	0,83
6,0	1.069,0	0,46	6,0	0,82
6,5	1.367,0	0,46	6,5	0,82
7,0	1.717,0	0,46	7,0	0,81
7,5	2.110,0	0,46	7,5	0,79
8,0	2.546,0	0,46	8,0	0,78
8,5	3.062,0	0,45	8,5	0,74
9,0	3.428,0	0,43	9,0	0,68
9,5	3.773,0	0,41	9,5	0,61
10,0	4.012,0	0,37	10,0	0,53
10,5	4.131,0	0,33	10,5	0,46
11,0	4.186,0	0,29	11,0	0,39
11,5	4.190,0	0,26	11,5	0,33
12,0	4.200,0	0,22	12,0	0,29
12,5	4.200,0	0,20	12,5	0,25
13,0	4.200,0	0,18	13,0	0,22
13,5	4.200,0	0,16	13,5	0,20
14,0	4.200,0	0,14	14,0	0,18
14,5	4.200,0	0,13	14,5	0,16
15,0	4.200,0	0,11	15,0	0,14
15,5	4.200,0	0,10	15,5	0,13
16,0	4.200,0	0,09	16,0	0,12
16,5	4.200,0	0,09	16,5	0,11
17,0	4.200,0	0,08	17,0	0,10
17,5	4.200,0	0,07	17,5	0,09
18,0	4.200,0	0,07	18,0	0,08
18,5	4.200,0	0,06	18,5	0,08
19,0	4.200,0	0,06	19,0	0,07
19,5	4.200,0	0,05	19,5	0,07
20,0	4.200,0	0,05	20,0	0,06
20,5	4.200,0	0,05	20,5	0,06
21,0	4.200,0	0,04	21,0	0,05
21,5	4.200,0	0,04	21,5	0,05
22,0	4.200,0	0,04	22,0	0,05
22,5	4.200,0	0,03	22,5	0,05

Power, Efficiency and energy vs. wind speed

Data used in calculation, Air density: 1,229 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	78,6	0,27	2,50- 3,50	61,4	61,4	0,4
4,0	288,2	0,41	3,50- 4,50	254,6	316,0	2,0
5,0	603,4	0,44	4,50- 5,50	605,6	921,6	5,9
6,0	1.073,0	0,46	5,50- 6,50	1.108,1	2.029,7	13,0
7,0	1.723,1	0,46	6,50- 7,50	1.677,6	3.707,3	23,8
8,0	2.554,1	0,46	7,50- 8,50	2.161,1	5.868,5	37,7
9,0	3.435,1	0,43	8,50- 9,50	2.350,1	8.218,6	52,8
10,0	4.014,8	0,37	9,50-10,50	2.135,1	10.353,7	66,6
11,0	4.186,2	0,29	10,50-11,50	1.674,7	12.028,4	77,3
12,0	4.200,0	0,22	11,50-12,50	1.211,3	13.239,7	85,1
13,0	4.200,0	0,18	12,50-13,50	843,1	14.082,9	90,5
14,0	4.200,0	0,14	13,50-14,50	568,8	14.651,7	94,2
15,0	4.200,0	0,11	14,50-15,50	370,4	15.022,2	96,6
16,0	4.200,0	0,09	15,50-16,50	231,7	15.253,9	98,1
17,0	4.200,0	0,08	16,50-17,50	138,7	15.392,6	99,0
18,0	4.200,0	0,07	17,50-18,50	79,2	15.471,8	99,5
19,0	4.200,0	0,06	18,50-19,50	43,1	15.514,9	99,7
20,0	4.200,0	0,05	19,50-20,50	22,3	15.537,3	99,9
21,0	4.200,0	0,04	20,50-21,50	11,0	15.548,2	100,0
22,0	4.200,0	0,04	21,50-22,50	5,1	15.553,4	100,0
23,0	0,0	0,00	22,50-23,50	1,6	15.555,0	100,0





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PARK - Terrain

Calculation: PARK_V0_MCP_GOG_MERRA**Site Data:** A - Site data: WAsP_MCP_GOG_MERRA

Obstacles:

0 Obstacles used

Roughness:

Terrain data files used in calculation:
\\BVR_NAS\NAS Data\GIS bestanden\2016\16095 - A16 MER PIP Vergunningen\AEP\ROUGHNESSLINE_ONLINEDATA_5.wpo
Min X: 572.504, Max X: 655.927, Min Y: 5.666.110, Max Y: 5.753.359, Width: 83.423 m, Height: 87.250 m

Orography:

Terrain data files used in calculation:
\\BVR_NAS\NAS Data\GIS bestanden\2016\16095 - A16 MER PIP Vergunningen\AEP\CONTOURLINE_ONLINEDATA_8.wpo
Min X: 575.120, Max X: 653.542, Min Y: 5.669.031, Max Y: 5.750.848, Width: 78.422 m, Height: 81.816 m

Project:
A16 AEP

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Aniel Balhari / aniel@boschenvanrijn.nl
Calculated:
20-8-2018 16:01/3.2.712

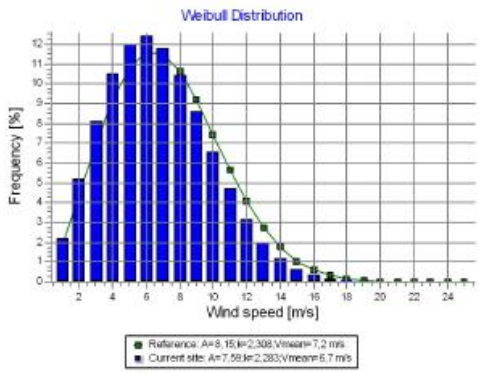
PARK - Wind Data Analysis

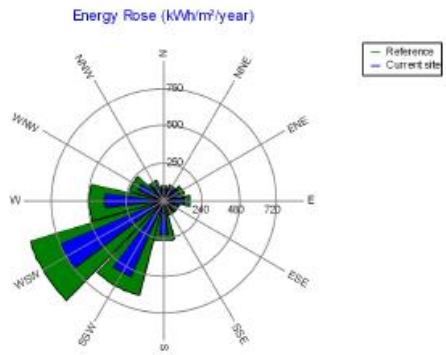
Calculation: PARK_V0_MCP_GOG_MERRA**Wind data:** A - Site data: WAsP_MCP_GOG_MERRA; Hub height: 110,0

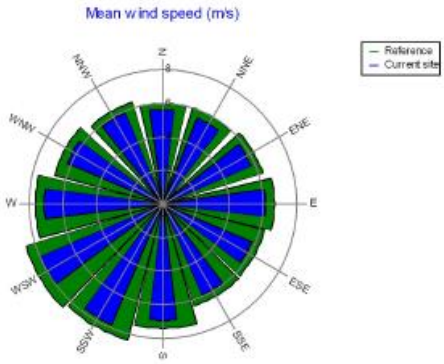
Site coordinates
Dutch Stereo-RD/NAP 2008
East: 108.802 North: 388.938
Wind statistics
NL MCP - MCP - [Regression].wws

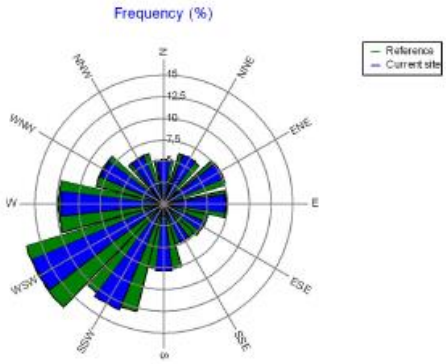
Weibull Data

	Current site				Reference: Roughness class 1		
Sector	A-parameter [m/s]	Wind speed [m/s]	k-parameter	Frequency [%]	A-parameter [m/s]	k-parameter	Frequency [%]
0 N	6,33	5,62	2,451	5,2	6,76	2,438	5,1
1 NNE	6,19	5,50	2,627	6,2	6,74	2,586	6,1
2 ENE	6,44	5,74	2,900	7,6	6,99	2,880	7,5
3 E	6,91	6,15	2,768	7,2	7,51	2,752	7,3
4 ESE	6,48	5,78	2,920	5,1	7,03	2,876	5,3
5 SSE	6,67	5,93	2,615	4,8	7,13	2,624	4,8
6 S	7,82	6,94	2,475	7,8	8,36	2,457	7,5
7 SSW	8,81	7,81	2,459	13,4	9,41	2,446	12,9
8 WSW	9,02	8,00	2,424	16,7	9,68	2,423	16,8
9 W	8,03	7,12	2,307	12,0	8,60	2,309	12,3
10 WNW	7,04	6,23	2,170	8,0	7,57	2,162	8,2
11 NNW	6,65	5,89	2,283	6,0	7,14	2,266	6,1
All	7,59	6,72	2,283	100,0	8,15	2,308	100,0









Project:
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Calculated:
20-8-2018 16:01/3.2.712

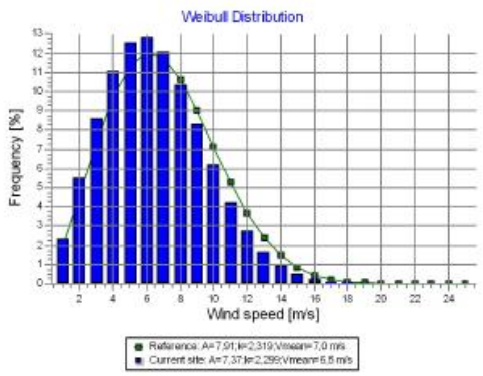
PARK - Wind Data Analysis

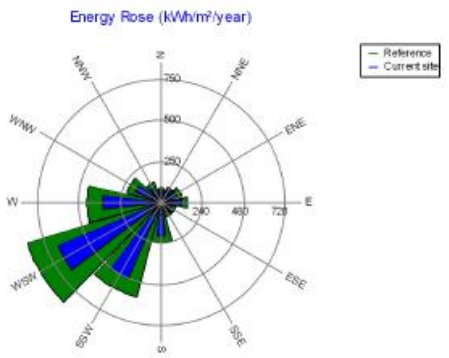
Calculation: PARK_V0_MCP_GOG_MERRA**Wind data:** A - Site data: WAsP_MCP_GOG_MERRA; Hub height: 100,0

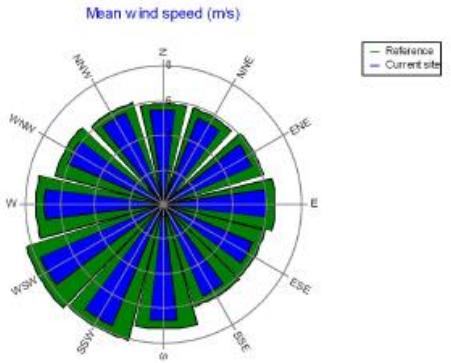
Site coordinates
Dutch Stereo-RD/NAP 2008
East: 108.802 North: 388.938
Wind statistics
NL MCP - MCP - [Regression].wws

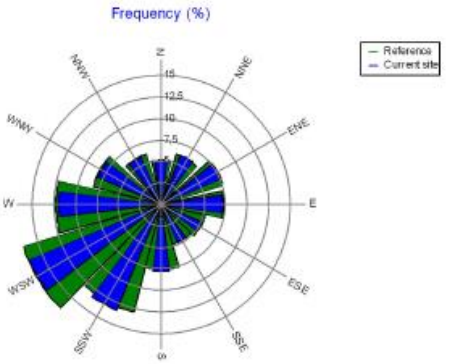
Weibull Data

	Current site				Reference: Roughness class 1		
Sector	A-parameter [m/s]	Wind speed [m/s]	k-parameter	Frequency [%]	A-parameter [m/s]	k-parameter	Frequency [%]
0 N	6,15	5,46	2,471	5,2	6,56	2,451	5,1
1 NNE	6,02	5,35	2,646	6,2	6,54	2,600	6,1
2 ENE	6,25	5,58	2,920	7,6	6,78	2,896	7,5
3 E	6,71	5,97	2,787	7,2	7,29	2,768	7,3
4 ESE	6,29	5,61	2,939	5,1	6,81	2,893	5,3
5 SSE	6,48	5,76	2,635	4,8	6,91	2,639	4,8
6 S	7,58	6,73	2,494	7,8	8,11	2,471	7,5
7 SSW	8,55	7,58	2,475	13,4	9,13	2,459	12,9
8 WSW	8,76	7,77	2,439	16,7	9,41	2,436	16,8
9 W	7,79	6,90	2,322	12,0	8,35	2,322	12,3
10 WNW	6,84	6,05	2,182	8,0	7,35	2,174	8,2
11 NNW	6,46	5,72	2,299	6,0	6,93	2,279	6,1
All	7,37	6,53	2,299	100,0	7,91	2,319	100,0









Project:
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Calculated:
20-8-2018 16:01/3.2.712

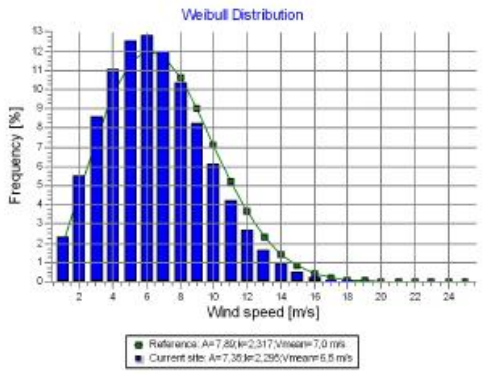
PARK - Wind Data Analysis

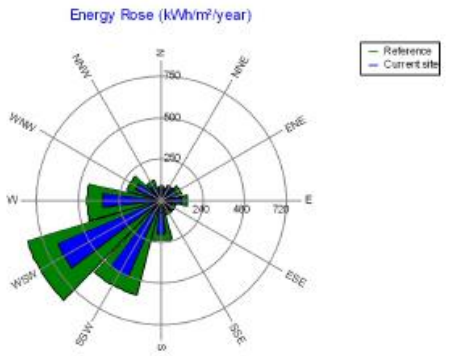
Calculation: PARK_V0_MCP_GOG_MERRA**Wind data:** A - Site data: WAsP_MCP_GOG_MERRA; Hub height: 99,0

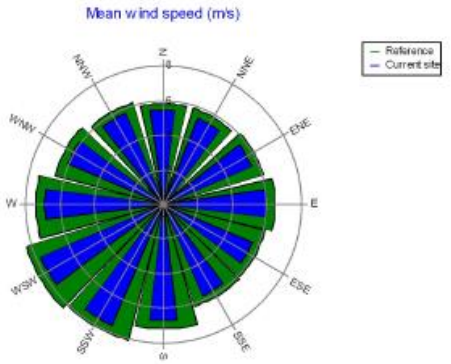
Site coordinates
Dutch Stereo-RD/NAP 2008
East: 108.802 North: 388.938
Wind statistics
NL MCP - MCP - [Regression].wws

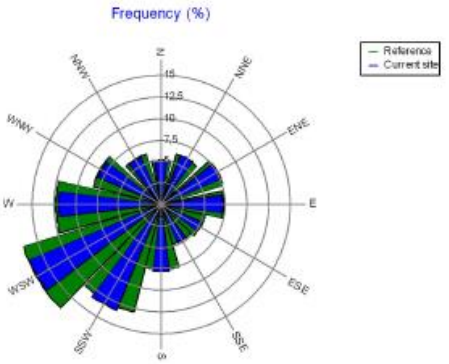
Weibull Data

	Current site				Reference: Roughness class 1		
Sector	A-parameter [m/s]	Wind speed [m/s]	k-parameter	Frequency [%]	A-parameter [m/s]	k-parameter	Frequency [%]
0 N	6,14	5,44	2,467	5,2	6,55	2,449	5,1
1 NNE	6,00	5,34	2,643	6,2	6,52	2,597	6,1
2 ENE	6,24	5,56	2,916	7,6	6,77	2,894	7,5
3 E	6,69	5,96	2,783	7,2	7,27	2,765	7,3
4 ESE	6,28	5,60	2,936	5,1	6,80	2,890	5,3
5 SSE	6,46	5,74	2,631	4,8	6,90	2,636	4,8
6 S	7,56	6,71	2,490	7,8	8,09	2,468	7,5
7 SSW	8,53	7,56	2,471	13,4	9,11	2,457	12,9
8 WSW	8,74	7,75	2,436	16,7	9,39	2,433	16,8
9 W	7,77	6,89	2,322	12,0	8,33	2,320	12,3
10 WNW	6,82	6,04	2,182	8,0	7,33	2,172	8,2
11 NNW	6,45	5,71	2,295	6,0	6,91	2,277	6,1
All	7,35	6,51	2,295	100,0	7,89	2,317	100,0









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Aniel Balhari / aniel@boschenvanrijn.nl
Calculated:
20-8-2018 16:01/3.2.712

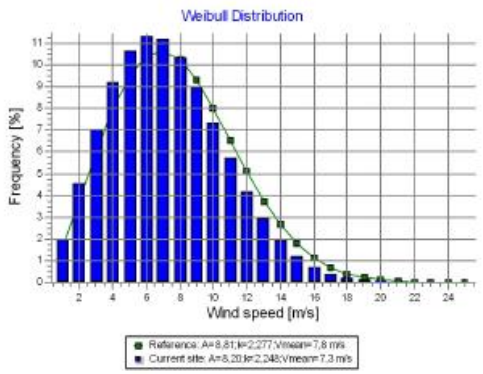
PARK - Wind Data Analysis

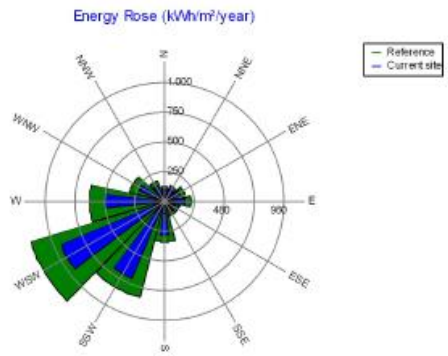
Calculation: PARK_V0_MCP_GOG_MERRA**Wind data:** A - Site data: WAsP_MCP_GOG_MERRA; Hub height: 143,0

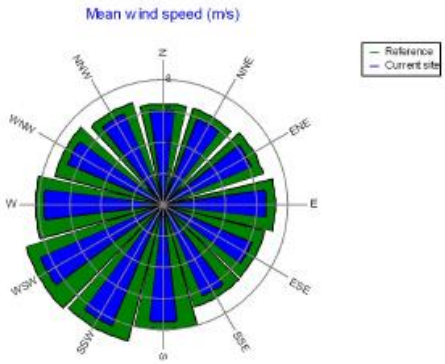
Site coordinates
Dutch Stereo-RD/NAP 2008
East: 108.802 North: 388.938
Wind statistics
NL MCP - MCP - [Regression].wws

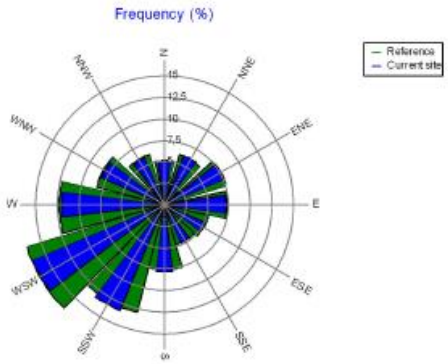
Weibull Data

Sector	Current site A-parameter [m/s]	Current site Wind speed [m/s]	Current site k-parameter	Current site Frequency [%]	Reference: Roughness class 1 A-parameter [m/s]	Reference: Roughness class 1 k-parameter	Reference: Roughness class 1 Frequency [%]
0 N	6,83	6,06	2,412	5,2	7,32	2,401	5,1
1 NNE	6,67	5,92	2,588	6,2	7,29	2,547	6,1
2 ENE	6,95	6,20	2,854	7,6	7,57	2,836	7,5
3 E	7,48	6,65	2,725	7,2	8,13	2,709	7,3
4 ESE	6,99	6,23	2,873	5,1	7,61	2,832	5,3
5 SSE	7,21	6,40	2,572	4,8	7,71	2,584	4,8
6 S	8,48	7,52	2,436	7,8	9,05	2,420	7,5
7 SSW	9,54	8,46	2,420	13,4	10,19	2,409	12,9
8 WSW	9,74	8,63	2,385	16,7	10,45	2,387	16,8
9 W	8,68	7,69	2,271	12,0	9,31	2,274	12,3
10 WNW	7,59	6,72	2,135	8,0	8,19	2,129	8,2
11 NNW	7,20	6,38	2,248	6,0	7,73	2,231	6,1
All	8,20	7,26	2,248	100,0	8,81	2,277	100,0









Project:
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Calculated:
20-8-2018 16:01/3.2.712

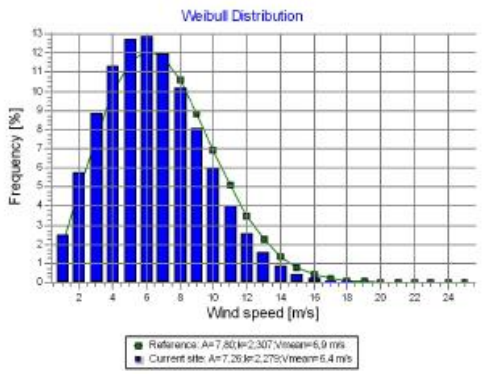
PARK - Wind Data Analysis

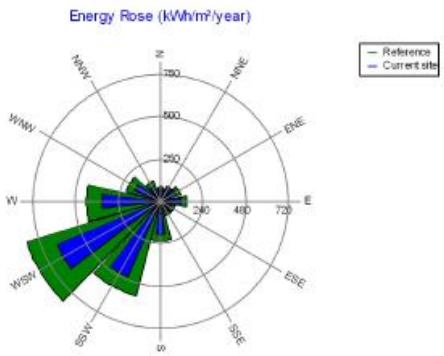
Calculation: PARK_V0_MCP_GOG_MERRA**Wind data:** A - Site data: WAsP_MCP_GOG_MERRA; Hub height: 94,0

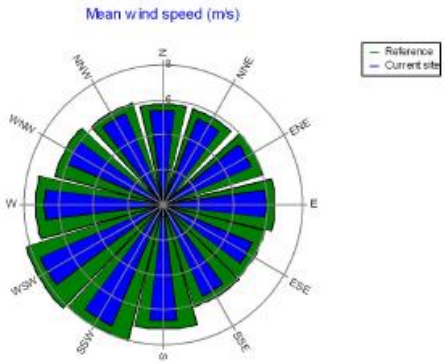
Site coordinates
Dutch Stereo-RD/NAP 2008
East: 108.802 North: 388.938
Wind statistics
NL MCP - MCP - [Regression].wws

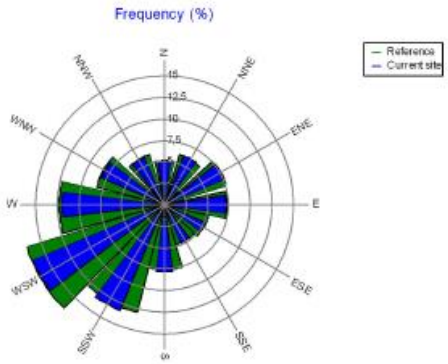
Weibull Data

	Current site				Reference: Roughness class 1		
Sector	A-parameter [m/s]	Wind speed [m/s]	k-parameter	Frequency [%]	A-parameter [m/s]	k-parameter	Frequency [%]
0 N	6,07	5,38	2,451	5,2	6,47	2,437	5,1
1 NNE	5,94	5,27	2,623	6,2	6,45	2,585	6,1
2 ENE	6,16	5,49	2,896	7,6	6,69	2,880	7,5
3 E	6,61	5,88	2,764	7,2	7,19	2,752	7,3
4 ESE	6,19	5,53	2,920	5,1	6,72	2,876	5,3
5 SSE	6,39	5,68	2,615	4,8	6,82	2,623	4,8
6 S	7,47	6,63	2,475	7,8	8,00	2,457	7,5
7 SSW	8,42	7,47	2,455	13,4	9,01	2,445	12,9
8 WSW	8,64	7,66	2,420	16,7	9,28	2,421	16,8
9 W	7,68	6,81	2,307	12,0	8,23	2,309	12,3
10 WNW	6,74	5,97	2,166	8,0	7,25	2,161	8,2
11 NNW	6,37	5,65	2,283	6,0	6,83	2,266	6,1
All	7,26	6,43	2,279	100,0	7,80	2,307	100,0









Project:
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Aniel Balhari / aniel@boschenvanrijn.nl
Calculated:
20-8-2018 16:01/3.2.712

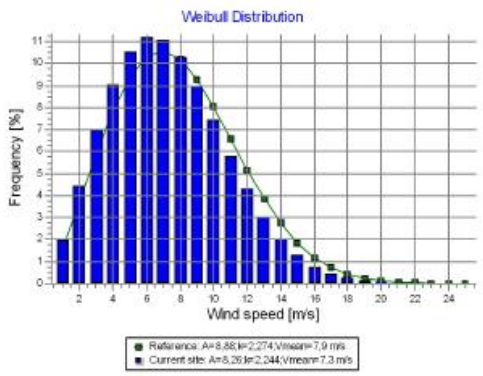
PARK - Wind Data Analysis

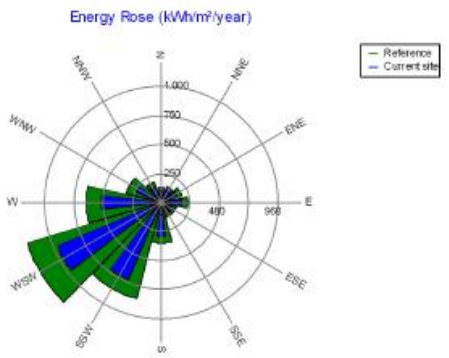
Calculation: PARK_V0_MCP_GOG_MERRA**Wind data:** A - Site data: WAsP_MCP_GOG_MERRA; Hub height: 147,0

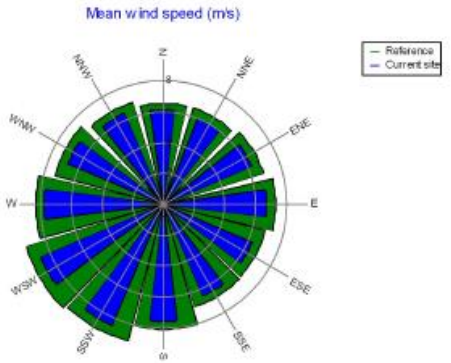
Site coordinates
Dutch Stereo-RD/NAP 2008
East: 108.802 North: 388.938
Wind statistics
NL MCP - MCP - [Regression].wws

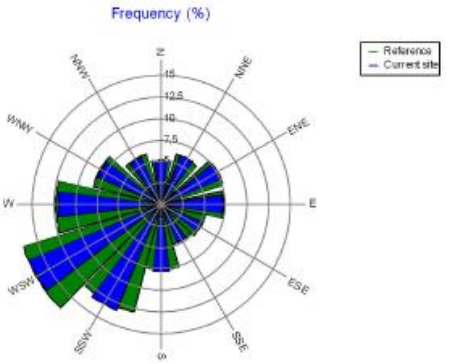
Weibull Data

Sector	Current site A-parameter [m/s]	Current site Wind speed [m/s]	Current site k-parameter	Current site Frequency [%]	Reference: Roughness class 1 A-parameter [m/s]	Reference: Roughness class 1 k-parameter	Reference: Roughness class 1 Frequency [%]
0 N	6,89	6,10	2,408	5,2	7,38	2,397	5,1
1 NNE	6,72	5,97	2,584	6,2	7,35	2,543	6,1
2 ENE	7,01	6,24	2,850	7,6	7,63	2,831	7,5
3 E	7,54	6,71	2,717	7,2	8,20	2,705	7,3
4 ESE	7,05	6,28	2,869	5,1	7,67	2,827	5,3
5 SSE	7,26	6,45	2,568	4,8	7,77	2,580	4,8
6 S	8,55	7,58	2,432	7,8	9,12	2,416	7,5
7 SSW	9,62	8,52	2,416	13,4	10,27	2,405	12,9
8 WSW	9,81	8,70	2,381	16,7	10,53	2,383	16,8
9 W	8,75	7,75	2,268	12,0	9,38	2,270	12,3
10 WNW	7,65	6,77	2,131	8,0	8,25	2,126	8,2
11 NNW	7,26	6,43	2,244	6,0	7,79	2,227	6,1
All	8,26	7,32	2,244	100,0	8,88	2,274	100,0









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Aniel Balhari / aniel@boschenvanrijn.nl
Calculated:
20-8-2018 16:01/3.2.712

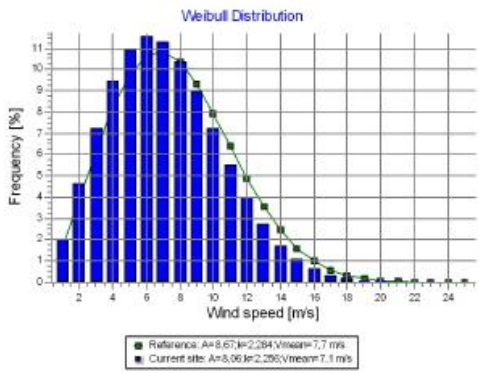
PARK - Wind Data Analysis

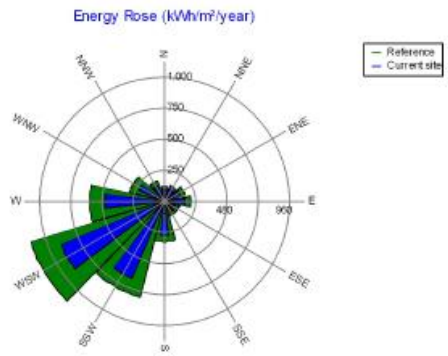
Calculation: PARK_V0_MCP_GOG_MERRA**Wind data:** A - Site data: WAsP_MCP_GOG_MERRA; Hub height: 135,0

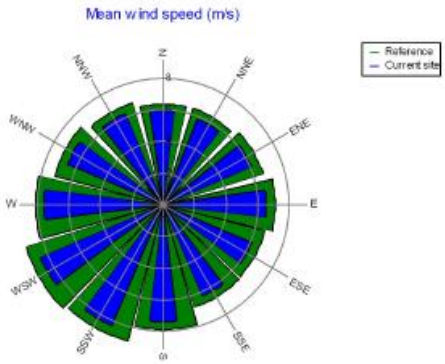
Site coordinates
Dutch Stereo-RD/NAP 2008
East: 108.802 North: 388.938
Wind statistics
NL MCP - MCP - [Regression].wws

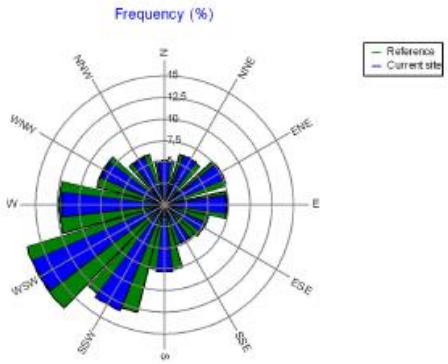
Weibull Data

Sector	Current site A-parameter [m/s]	Current site Wind speed [m/s]	Current site k-parameter	Current site Frequency [%]	Reference: Roughness class 1 A-parameter [m/s]	Reference: Roughness class 1 k-parameter	Reference: Roughness class 1 Frequency [%]
0 N	6,72	5,96	2,420	5,2	7,20	2,409	5,1
1 NNE	6,57	5,83	2,596	6,2	7,17	2,556	6,1
2 ENE	6,84	6,10	2,865	7,6	7,44	2,846	7,5
3 E	7,36	6,55	2,732	7,2	8,00	2,719	7,3
4 ESE	6,88	6,13	2,885	5,1	7,48	2,842	5,3
5 SSE	7,09	6,29	2,580	4,8	7,58	2,593	4,8
6 S	8,34	7,39	2,443	7,8	8,90	2,428	7,5
7 SSW	9,38	8,32	2,428	13,4	10,02	2,417	12,9
8 WSW	9,58	8,49	2,393	16,7	10,28	2,395	16,8
9 W	8,54	7,56	2,279	12,0	9,15	2,282	12,3
10 WNW	7,47	6,62	2,143	8,0	8,05	2,137	8,2
11 NNW	7,08	6,27	2,256	6,0	7,60	2,239	6,1
All	8,06	7,14	2,256	100,0	8,67	2,284	100,0









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Calculated:
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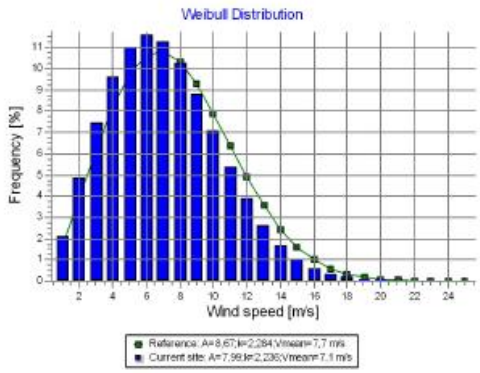
PARK - Wind Data Analysis

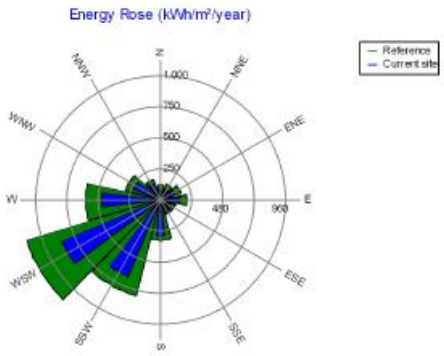
Calculation: PARK_V0_MCP_GOG_MERRA**Wind data:** A - Site data: WAsP_MCP_GOG_MERRA; Hub height: 135,0

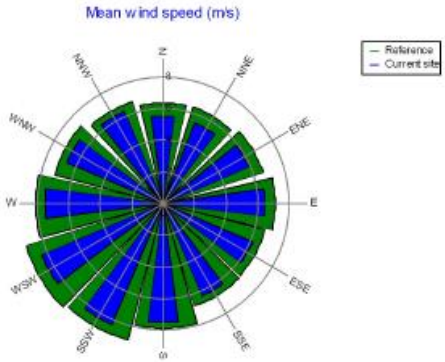
Site coordinates
Dutch Stereo-RD/NAP 2008
East: 111.026 North: 393.467
VESTAS V150-4.2 4200 150.0 !O! hub: 135,0 m (TOT: 210,0 m) (70)
Wind statistics
NL MCP - MCP - [Regression].wws

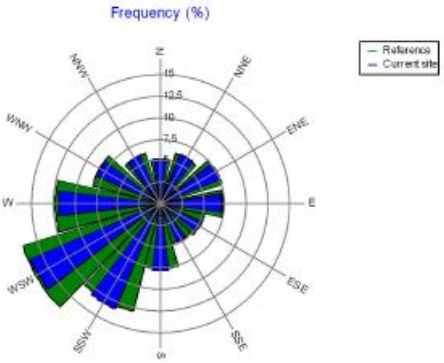
Weibull Data

	Current site				Reference: Roughness class 1			
Sector	A-parameter [m/s]	Wind speed [m/s]	k-parameter	Frequency [%]	A-parameter [m/s]	k-parameter		Frequency [%]
0 N	6,23	5,53	2,447	5,3	7,20	2,409		5,1
1 NNE	6,15	5,47	2,623	6,2	7,17	2,556		6,1
2 ENE	6,65	5,93	2,865	7,5	7,44	2,846		7,5
3 E	7,26	6,46	2,736	7,2	8,00	2,719		7,3
4 ESE	6,94	6,19	2,877	5,2	7,48	2,842		5,3
5 SSE	7,15	6,35	2,572	4,9	7,58	2,593		4,8
6 S	8,47	7,51	2,432	7,8	8,90	2,428		7,5
7 SSW	9,39	8,32	2,428	13,3	10,02	2,417		12,9
8 WSW	9,46	8,39	2,396	16,5	10,28	2,395		16,8
9 W	8,50	7,53	2,279	12,0	9,15	2,282		12,3
10 WNW	7,53	6,67	2,143	8,1	8,05	2,137		8,2
11 NNW	7,13	6,32	2,252	6,1	7,60	2,239		6,1
All	7,99	7,07	2,236	100,0	8,67	2,284		100,0









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PARK - Park power curve

Calculation: PARK_V0_MCP_GOG_MERRA

Wind speed [m/s]	Power Free WTGs [kW]	Park WTGs [kW]	N [kW]	NNE [kW]	ENE [kW]	E [kW]	ESE [kW]	SSE [kW]	S [kW]	SSW [kW]	WSW [kW]	W [kW]	WNW [kW]	NNW [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	79	45	42	52	70	79	79	79	71	35	12	31	26	53
3,5	3.182	2.286	2.209	1.662	2.458	2.447	2.526	2.527	2.117	1.650	2.480	2.479	2.567	2.524
4,5	8.221	6.651	6.364	5.382	7.034	7.020	7.157	7.138	6.262	5.407	7.063	7.030	7.184	7.136
5,5	15.741	13.125	12.692	11.089	13.688	13.664	13.905	13.865	12.490	11.108	13.816	13.753	14.014	13.948
6,5	26.453	22.273	21.582	19.047	23.144	23.120	23.515	23.467	21.269	19.088	23.365	23.269	23.676	23.573
7,5	40.817	34.647	33.612	29.832	35.935	35.913	36.520	36.457	33.133	29.899	36.289	36.139	36.714	36.569
8,5	58.291	50.249	48.725	43.796	52.037	52.018	52.807	52.710	48.129	43.821	52.473	52.277	53.047	52.815
9,5	75.109	67.303	65.228	60.352	69.506	69.560	70.138	70.205	64.739	60.228	69.621	69.570	70.248	70.227
10,5	84.594	80.214	78.017	75.470	81.970	82.150	82.090	82.480	77.962	75.149	81.706	82.062	82.206	82.759
11,5	88.441	86.886	85.413	85.524	87.701	87.833	87.474	87.845	85.590	85.023	87.344	87.741	87.581	88.059
12,5	89.742	89.465	89.164	89.392	89.660	89.688	89.558	89.695	89.194	89.124	89.514	89.590	89.512	89.679
13,5	89.996	89.955	89.926	89.948	89.985	89.992	89.979	89.991	89.929	89.917	89.947	89.964	89.947	89.981
14,5	90.067	90.061	90.054	90.059	90.066	90.067	90.065	90.067	90.055	90.055	90.060	90.063	90.060	90.065
15,5	90.079	90.078	90.077	90.078	90.079	90.079	90.079	90.079	90.077	90.078	90.078	90.078	90.078	90.078
16,5	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080
17,5	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080
18,5	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080
19,5	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080	90.080
20,5	88.080	88.080	88.080	88.080	88.080	88.080	88.080	88.080	88.080	88.080	88.080	88.080	88.080	88.080
21,5	88.080	88.080	88.080	88.080	88.080	88.080	88.080	88.080	88.080	88.080	88.080	88.080	88.080	88.080
22,5	78.480	78.480	78.480	78.480	78.480	78.480	78.480	78.480	78.480	78.480	78.480	78.480	78.480	78.480
23,5	19.680	19.680	19.680	19.680	19.680	19.680	19.680	19.680	19.680	19.680	19.680	19.680	19.680	19.680
24,5	19.680	19.680	19.680	19.680	19.680	19.680	19.680	19.680	19.680	19.680	19.680	19.680	19.680	19.680
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.

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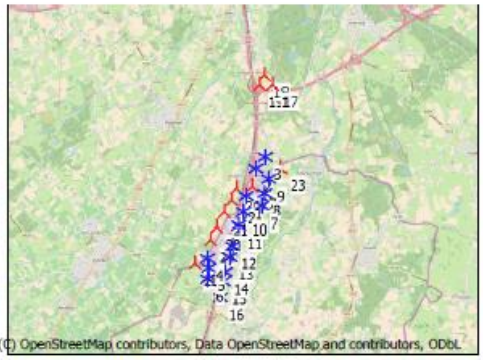
PARK - WTG distances

Calculation: PARK_V0_MCP_GOG_MERRA

WTG distances

	Z [m]	Nearest WTG	Z [m]	Horizontal distance [m]	Distance in rotor diameters (max)	Distance in rotor diameters (min)
1	7,7	27	3,0	426	4,3	4,3
2	8,8	3	5,0	557	5,6	5,6
3	5,0	2	8,8	557	5,6	5,6
4	10,0	5	10,0	373	3,3	3,3
5	10,0	4	10,0	373	3,3	3,3
6	10,0	5	10,0	415	3,6	3,6
7	9,9	8	9,5	466	4,6	4,6
8	9,5	7	9,9	466	4,6	4,6
9	9,4	8	9,5	568	5,6	5,6
10	1,1	11	10,0	519	4,1	4,1
11	10,0	10	1,1	519	4,1	4,1
12	10,0	13	10,0	429	3,4	3,4
13	10,0	12	10,0	429	3,4	3,4
14	10,0	15	10,0	355	2,8	2,8
15	10,0	14	10,0	355	2,8	2,8
16	10,0	15	10,0	622	4,9	4,9
17	10,0	18	10,0	445	3,0	3,0
18	10,0	19	9,2	416	2,8	2,8
19	9,2	18	10,0	416	2,8	2,8
20	3,4	24	10,0	516	3,4	3,4
21	3,0	22	6,0	520	3,5	3,5
22	6,0	26	5,7	464	3,1	3,1
23	10,0	9	9,4	600	6,0	5,5
24	10,0	20	3,4	516	3,4	3,4
25	10,0	4	10,0	510	4,5	3,4
26	5,7	22	6,0	464	3,1	3,1
27	3,0	1	7,7	426	4,3	4,3
Min	**1,1**		**1,1**	**355**	**2,8**	**2,8**
Max	**10,0**		**10,0**	**622**	**6,0**	**5,6**



Scale 1:200.000
New WTG
Existing WTG

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PARK - Wind statistics info

Calculation: PARK_V0_MCP_GOG_MERRA

Main data for wind statistic

File	\\BVR_NAS\NAS Data\GIS bestanden\2016\16095 - A16 MER PIP Vergunningen\AEP\NL MCP - MCP - [Regression].wws
Name	MCP - MCP session (1) - [Regression]
Country	Netherlands
Source	USER
Mast coordinates	Dutch Stereo-RD/NAP 2008 East: 100.863 North: 403.831
Created	16-8-2018
Edited	16-8-2018
Sectors	12
WAsP version	WAsP 11 Version 11.06.0028
Displacement height	None

Comments
From MCP

Additional info for wind statistic

Based on measurement height	98,0 m
Base elevation for measurement mast	0,0 m
Long term correction information	
Method	Regression
Source data	MERRA_basic_E04.668_N51.500 (3)
Distance to source data	14,1 km
Long term period from	1-1-1988
Long term period to	1-3-2016
Concurrent period from	30-11-2012
Concurrent period to	1-7-2015
Concurrent data records	22521
Concurrent record interval	60 minutes
Concurrent data recovery	99,8 %
Number of years with long term data	28,2 years
Number of months with concurrent data	30,8 Months
Correlation test based on Concurrent monthly windindices	
Power curve used for index	Simple power curve truncated at: 13,0 m/s
Data availability demand for inclusion of month	60 %
Number of months	0
r^2 - wind index	0,0000
r - wind index	0,0000
s - wind index	0,0000

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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