SolPEG
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Yield Analysis
Agersted
30,827.20 kWp, Denmark

Evaluation of the power generation of a sun tracking bifacial photovoltaic system near Agersted in Denmark

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Datasheet Yield Analysis, Agersted, 30,827.20 kWp

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Yield Analysis Report – Agersted, 30,827.20 kWp, Denmark

1 Task and summary of results

This report aims to estimate the energy production of a 30,827.20 kWp sun tracking photovoltaic (PV) installation with a total fenced area of about 44.4 ha. The site of the planned power plant is located in the Frederikshavn commune in Denmark. The yield is predicted referring to planning documents and information provided by the customer European Energy A/S. The place has not been visited by SolPEG.

As a result, the **initial annual electricity production** is assessed to be **1,358 kWh per installed kWp** module power. This leads to a **total annual production** of **41,870 MWh** for the whole 30,827.20 kWp system. These figures imply a **performance ratio** (**PR**) of the system of **95.6 %** and a fictive **technical availability of 100 %**.
Assuming an annual degradation of 0.25 % the average specific annual yield over 20 years is 1,326 kWh/kWp with a corresponding PR of 93.4 %.

The standard deviation of the calculation which includes the uncertainty of the performance ratio and the uncertainty of the irradiation in module plane that is decisive for the electrical production is estimated to be 5.1 %. The results are only valid under the assumptions that are described in this report.

2 Location

The simulated tracking PV plant is planned to be built on an area in agriculturally used region approx. 2 km southeast of Agersted in the Frederikshavn commune in Denmark. The total fenced area of the PV system is about 44.4 ha. The area consists of an almost flat terrain structure. At the surrounding borders mainly individual trees and small forests are located. The place has not been visited by SolPEG. All information is provided by the customer. The following table and picture give more information about the site.

Table 1: Data of the site

General description of location	ca. 2 km southeast of Agersted, ca. 31 km south of Frederikshavn and ca. 35 km northeast of Aalborg
Coordinates	57.1789 °N, 10.3993 °E, 9 m a.s.l.
Area size	Approx. 44.4 ha
Accessibility	Access via the country road Agerstedvej, dirt roads at the field borders
Ground	Almost even terrain structure
Wind exposition	Mostly free
Shading situation	Very low Horizon line, single trees and small forests at the borders

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Figure 1: Google Earth aerial view of the site with outlined occupied area

3 System

The PV system that is to be simulated is based on planning documents provided by the customer. Overall 52,608 bifacial monocrystalline (PERC) photovoltaic modules with half-cut cells and a nominal power of 585 Wp and 590 Wp each by the manufacturer Risen Energy are installed on single north-south axis trackers. On each tracker one module is installed in portrait format and 32 or 64 next to each other in north-south direction. The axis distance in east-west direction is 4.8 m (Ground cover ratio GCR: 45.3 %) and the tracking axis is arranged to the south. The trackers are rotating within the tracking range of -55 ° to +55 ° including backtracking to avoid self shading of the modules.
With a series connection of 32 modules the system is planned as a 1,500 V DC system. The following tables describe the main features of the system. The technical specifications of the used inverter type listed in the subsequent table are taken from the manufacturer's data sheet.

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Table 2: Main design parameters of the simulated system. Source: provided planning documents

Module manufacturer	Risen Energy
Module type	RSM120-8-585BMDG, RSM120-8-590BMDG
Total number of modules	52,608 42,304 x RSM120-8-585BMDG 10,304 x RSM120-8-590BMDG
Total module power	30,827.20 kWp
Installation type	Single axis tracking system (north-south axis) Tracking range: ±55 ° (incl. backtracking) Axis distance (east-west): 4.8 m Module alignment: 1 x portrait (GCR: 45.3 %)
Orientation	Axis tilt: 0°, south
Total module area	Approx. 148,887 m²
Inverter manufacturer	Sungrow
Number and type of inverter	112 x SG250HX
Number of modules per string	32
Number of strings	1,644
Transformer types	5 x 3.000 kVA, 10 kV/0.8 kV, 50 Hz 4 x 3.250 kVA, 10 kV/0.8 kV, 50 Hz

Table 3: Technical specifications of the inverters relevant for the simulation
Source: data sheet, PVsyst model provided by the customer

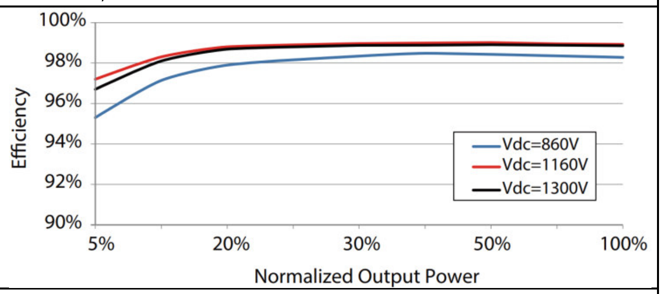
Inverter type	Sungrow SG250HX
Technology	Transformerless 3 phased inverter
MPPT voltage range (DC)	600 V – 1,500 V
Maximal input voltage (DC)	1,500 V
Maximal input current (DC) per MPPT	26 A (I_{MPP}), 50 A (I_{SC})
Number of MPP tracker	12
Nominal output power (AC)	225 kVA @ 40 °C, 200 kVA @ 50 °C
Maximal output power (AC)	250 kVA @ 30 °C
Rated output voltage (AC)	800 V (range: 680 V to 880 V)
Euro efficiency / Maximal efficiency	98.8 % / 99.0 %
Efficiency curves	
Operating ambient temperature	-30 °C … +60 °C

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Table 4: Technical specifications of the pv modules,
Source: data sheet, PVsyst model provided by the customer

Module type	RSM120-8-585BMDG	RSM120-8-590BMDG
Nominal power (P_{mp}) (STC: 1000 W/m² irradiance @ AM 1.5, 20°C ambience @ 0 m/s)	585 Wp	590 Wp
Power tolerance	+3 %	
Nominal short circuit current (I_{sc})	18.11 A	18.16 A
Nominal open circuit voltage (V_{oc})	41.10 V	41.30 V
Nominal maximum power current (I_{mp})	17.10 A	17.15 V
Nominal maximum power voltage (V_{mp})	34.22 V	34.42 V
Nominal efficiency	20.7 %	20.8 %
Bifaciality	70 ± 5 %	
Relative efficiency at 800 W/m²	100.5 %	
Relative efficiency at 600 W/m²	100.7 %	
Relative efficiency at 400 W/m²	100.4 %	
Relative efficiency at 200 W/m²	98.8 %	
NMOT (Nominal module operation temperature) (800 W/m² irradiance @ AM 1.5, 20°C ambience @ 1 m/s)	44 °C ± 2 °C	
NMOT power (P_{mp})	447.0 Wp	450.7 Wp
NMOT short circuit current (I_{sc})	14.89 A	14.93 A
NMOT open circuit voltage (V_{oc})	38.41 V	38.60 V
NMOT maximum power current (I_{mp})	13.99 A	14.04 A
NMOT maximum power voltage (V_{mp})	31.94 V	32.11 V
Maximum system voltage	1,500 V	
Temperature coefficient for I_{sc}	+0.04 %/°C	
Temperature coefficient for V_{oc}	-0.25 %/°C	
Temperature coefficient for P_{mp}	-0.34 %/°C	
Technology	Monocrystalline, bifacial, 120 cells (2 x 6 x 10)	
Dimensions	2,172 mm x 1,303 mm x 35 mm	

The provided module layout is displayed in the following picture.

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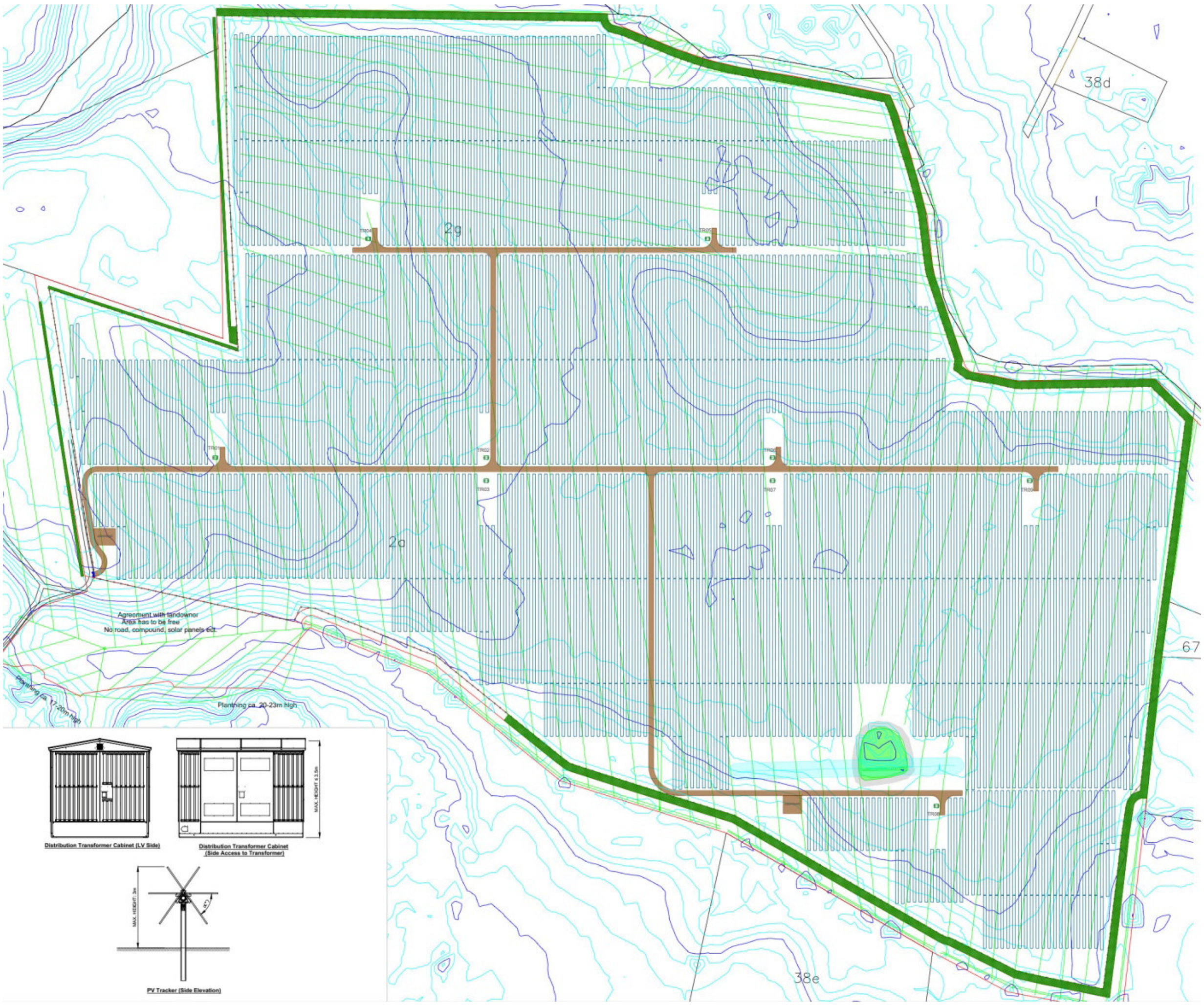

Figure 2: Provided module layout of the pv system (top view)

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4 Meteorological input data

For the simulation an hourly weather data file is generated according to an evaluation of diverse data sources. The following sections introduce the different data sources.

MeteoNorm 8[1] (V8.0.3.15910) is a well known and established software for generating irradiation data worldwide. It offers a global weather database and an interpolation algorithm with a pre-calculated irradiation map based on satellite and ground data to calculate data for any desired site. In the considered region the density of the MeteoNorm database is good. From the surrounding stations used for the interpolation the nearest station "Tylstrup" (2001-2010) is in a distance of 27 km. The irradiation data stems 44 % from satellite data.
Since MeteoNorm version 7.3. also historical time series[2] of irradiation and temperature for the single years 2008 – 2020 are available and the corresponding monthly values are considered for the yield analysis. Thereby the satellite-based irradiation values are compiled from Meteosat Second Generation (MSG) satellite data developed by the EUMETSAT[3]. The spatial resolution is 2.5 km x 2.5 km. The temperature data is derived from measured T_{min} and T_{max} daily data.

SolarGIS[4] covers the years from 1994 onwards and has a spatial resolution of 90 m. It provides different services like time series in maximal 15 minute steps and Typical Meteorological Years (TMY) in hourly resolution. According to an independent study by the University of Geneva[5] SolarGIS shows the best match with measured irradiation patterns in comparison with other satellite derived data products. Since it is likely that the meteorological stations used in the study are also used as calibration points for satellite derived data, it is hard to transfer the results of the study to other places, especially if a site is far away from ground measurement stations.
In this yield report long-term monthly average values of the period 1994-2018 are considered.

3TIER by Vaisala[6] offers data products for diverse renewable energy applications. The contemplated "Solar Prospecting Tool" provides monthly means of global irradiation, diffuse irradiation and direct irradiation. The data-background is based on half hourly long-term satellite data (July 1998 to 2010) with a spatial resolution of approx. 3 km.

HelioClim[7] is a chargeable online service that provides satellite derived irradiation data from 1985 onwards. But only the new construction method (HelioClim-3v5) with its high spatial resolution (approx. 5 km) and data from 2004 forward does provide coherent values for the considered site. Hence, the monthly time series from February 2004 to January 2021[8] is considered for the yield analysis.

[1] http://www.meteonorm.com
[2] https://meteonorm.com/en/meteonorm-timeseries
[3] https://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Meteosat/MeteosatDesign/index.html
[4] https://apps.solargis.com/prospect/map Documentation: https://solargis.com/docs/methodology/solar-radiation-modeling
[5] http://www.cuepe.ch/html/biblio/pdf/ineichen_2011_Five_satellite_products_deriving%28iea%29.pdf and http://www.cuepe.ch/archives/annexes-iae/ineichen-2013_long-term-validation.pdf
[6] http://www.3tier.com/en/ Documentation : https://www.vaisala.com/sites/default/files/documents/3TIER%20Solar%20Dataset%20Methodology%20and%20Validation.pdf
[7] http://www.soda-pro.com/web-services/radiation/helioclim-3-archives-for-pay
Documentation: http://www.soda-pro.com/help/helioclim/helioclim-3-overview
[8] The downloaded monthly values show an error in the irradiation data of December. In this case an average of the other sources has been used for this missing month.

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PVGIS[9] is an online service provided by the Joint Research Centre (JRC) of the European Commission in Ispra, Italy. For the current version “PVGIS 5” different irradiation databases for a large part of the world are available. In this analysis the “CMSAF” and the “SARAH” methods are used.
The PVGIS CMSAF[10] method provides monthly long-term averages of irradiation data derived from satellite images of the years 2007-2016. The spatial resolution is about 1.5 minutes of arc. CMSAF is a European project under the leadership of the German weather service DWD.
The PVGIS SARAH method which is available by “PVGIS 5” is considered for the years 2005-2016. Since 2017 the satellite derived irradiation data method SARAH is available, which has been developed in collaboration by PVGIS and CMSAF. The spatial resolution is about 3 minutes of arc.

The Danish meteorological institute of the Denmark (DMI) provides monthly data for 25 stations across the country including measurements of global irradiation[11]. In addition the DMI also offers monthly data for the years 2001 to 2020 that have been calculated as interpolated values on a grid level with a resolution of 20 km x 20 km.
The considered site is located within the corresponding grid cell “20100”. An additional analysis of the irradiation data of SolarGIS at different positions inside the considered grid cell shows an almost homogeneous distribution.

The following table lists the global horizontal irradiation data for the considered site provided by the different data sources. The irradiation used in the simulation is obtained by weighting the different sources due to generation method, time period and up-to-dateness. This procedure respects several data generation methods as well as a long and up-to-date averaging period.

Table 5: Global horizontal irradiation sums in kWh/m² for the site according to different sources

	MeteoNorm 8	MeteoNorm TimeSeries	SolarGIS Prospect	3TIER	HelioClim 3v5	PVGIS 5 CMSAF	PVGIS 5 SARAH	DMI 20100	Result
Jan	12	12	14	16	17	9	11	13	13
Feb	29	27	29	33	31	28	23	30	30
Mar	78	73	75	74	78	81	70	79	78
Apr	121	127	119	116	129	136	120	128	128
May	166	171	163	161	170	174	157	173	172
Jun	179	183	169	173	179	181	169	183	182
Jul	168	180	168	166	170	169	164	174	173
Aug	132	141	132	133	134	133	126	137	136
Sep	89	95	83	87	89	92	85	89	90
Oct	46	49	43	47	45	46	41	46	46
Nov	16	19	17	22	18	12	15	17	17
Dec	9	9	9	12	9	6	8	9	9
Year	1045	1085	1021	1040	1069	1067	989	1078	1073

The diffuse fraction of the global irradiation is calculated with help of the used simulation software PVsyst as follows[12].

[9] https://re.jrc.ec.europa.eu/pvgis.html
Dokumentation: https://ec.europa.eu/jrc/en/PVGIS/docs/usermanual
[10] http://www.cmsaf.eu/EN/Home/home_node.html
[11] https://www.dmi.dk/friedata/observationer/
[12] https://www.pvsyst.com/help/models_meteo_diffuse_irradiance.htm

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Table 6: Diffuse fraction of the horizontal irradiation in %

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
68.2	63.8	46.1	44.2	42.6	40.6	45.0	51.6	49.5	56.4	66.7	76.2	47.0

The solar irradiation has the biggest influence on the energy production of a photovoltaic system. Nevertheless also other meteorological parameters influence the yield.
The wind velocity and the ambient temperature influence the solar cell's temperature that reduces the energy production when it rises. Wind velocity is usually measured in a height of 10 meters. Due to the environmental conditions the wind velocity at a certain site can vary significantly from the measurements of a nearby weather station.

Precipitation usually cleans the modules from soiling. Longer periods without precipitation can lead to soiling losses. Besides rain can also be a source of soiling itself when it carries dust and other particles e.g. industry exhausts.

Temperature data for the site is used from MeteoNorm, SolarGIS Prospect and PVGIS 5 SARAH. The temperature data is available for the averaging periods 2000-2019 (MeteoNorm), 1994 -2018 (SolarGIS), as well as 2007-2016 (PVGIS 5). The relative humidity is used by models that assess snow cover and the solar spectrum.
For wind velocity, precipitation and relative humidity MeteoNorm is the only considered data source. The following table shows the values of the secondary meteorological parameters.

Table 7: Secondary meteorological values for the site considered for the yield assessment

	Ambient temperature /°C				Wind vel./m/s	Precipitation/mm	Rel. Humidity/%
	Meteo-Norm 8	SolarGIS Prospect	PVGIS 5 SARAH	Result	Meteo-Norm 8	Meteo-Norm 8	Meteo-Norm 8
Jan	0.7	1.4	2.0	1.4	4.2	60	87.0
Feb	0.4	1.1	1.6	1.1	4.1	39	88.0
Mar	2.7	3.4	3.1	3.1	4.0	39	82.9
Apr	7.3	7.7	6.8	7.3	3.7	35	73.7
May	11.5	11.8	11.0	11.5	3.3	53	74.6
Jun	14.5	14.9	14.3	14.6	3.3	67	75.8
Jul	17.7	17.4	17.0	17.3	3.0	89	74.0
Aug	17.4	16.5	17.1	17.0	3.1	82	74.8
Sep	13.2	13.8	14.1	13.7	3.4	57	82.8
Oct	8.5	9.7	10.1	9.5	3.6	76	87.8
Nov	4.8	6.0	6.3	5.7	3.8	72	89.9
Dec	1.5	3.2	1.6	2.1	4.1	58	88.3
Year	8.4	8.9	8.9	8.7	3.6	728	81.6

The monthly values are translated to hourly resolution by the software PVSYST in a current version[13]. All presented meteorological input data represent long-term average values. Single years may vary significantly from this means. E.g. the irradiation may vary by about ± 10 % in single years.

[13] http://www.PVsyst.com

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5 Transformation of irradiation

For the yield simulation of the system with the described input parameters (2, 3 and 4) the software PVsyst is used in a current version. PVsyst is a highly sophisticated simulation tool developed since 1993.
By default, PVsyst uses the physical model of Perez[14] for the transformation of the irradiation from horizontal to an orientated module plane. The calculation results presented in the following table refer to a ground reflection (albedo) value of 20 %. The transposition factor (TF) is the ratio between the irradiation in module plane and the horizontal irradiation.

Table 8: Rounded irradiation sums in module plane in kWh/m² according to Perez

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Perez	16.3	37.6	104.6	170.9	231.0	243.0	230.0	174.1	119.7	61.4	20.9	10.7	1420
TF	124%	126%	134%	134%	135%	134%	133%	128%	133%	133%	126%	120%	132%

6 System losses, performance ratio

The performance ratio (PR) is the relation between the real energy the system feeds into the grid and the theoretical production that is obtained when the nominal module efficiency is multiplied with the solar irradiation sum in the module plane. If the PV modules would always work with their nominal efficiency under all conditions and their energy could be injected into the grid without any losses a PR of 100 % would be reached. In reality long-term PR values between 75 % and 85 % are typical. The following sections describe the losses in the considered system.

6.1 Analysis of shadings and losses of irradiation

Horizon shading
Whenever the sun is behind the horizon line no direct sun light reaches the modules. To evaluate the influence of the site's horizon line on the yield, horizon pictures are created by the software MeteoNorm and the online service SolarGIS Prospect. The following graphs show a very low horizon line. This impression is also confirmed by Google Earth views. Thus, no system losses due to horizon shading are taken into account.

[14] R. Perez, P.Ineichen, R. Seals, J. Michalsky, R. Stewart. Modeling Daylight Availability and Irradiance Component from Direct and Global Irradiance. Solar Energy 44, no 5, pp 271-289, 1990.

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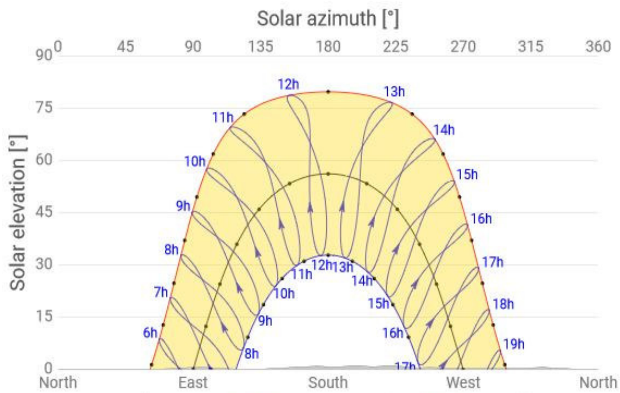

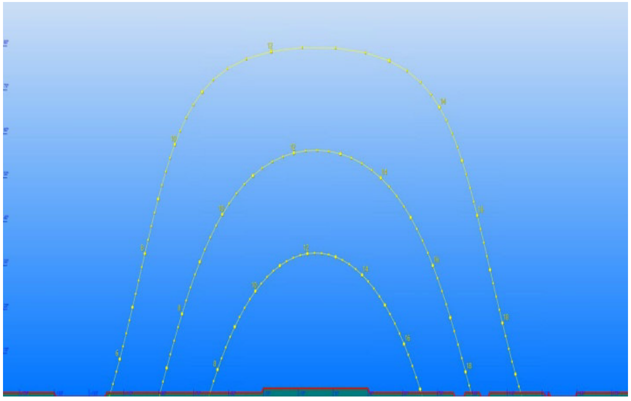

Figures 3 and 4: Horizon line graphs (sources: SolarGIS, MeteoNorm)

Near shading

Due to the back-tracking behavior of the tracking system the self-shading effect of module rows is limited to diffuse fraction of irradiation: Whenever the sun's height is that low that the module rows would be shaded the tracker turns the modules to a flatter position. This reduces the front side irradiation in the module plane by approx. 14 % compared with the irradiation that could be harvested if no shadings would occur and if the modules would always be at the optimal position towards the sun that the tracker is able to adjust.

The near shading losses by other objects as the transformer stations and trees are calculated in PVsyst by means of a three-dimensional model. The effect of the surrounding fence is respected by a small increase of the table width (inactive area 2 cm) in consideration of the present circumstances. The calculations consider the electrical effect of one respectively two strings installed on one tracker as well as portrait installation of the modules with half cut cells. The resulting near shading losses are simulated with 2.7 % irradiance losses plus 0.1 % electrical shading losses (mismatch of shaded and unshaded parts that are connected in series), of which 2.5 % plus 0.0 % are due to diffuse light self-shading.

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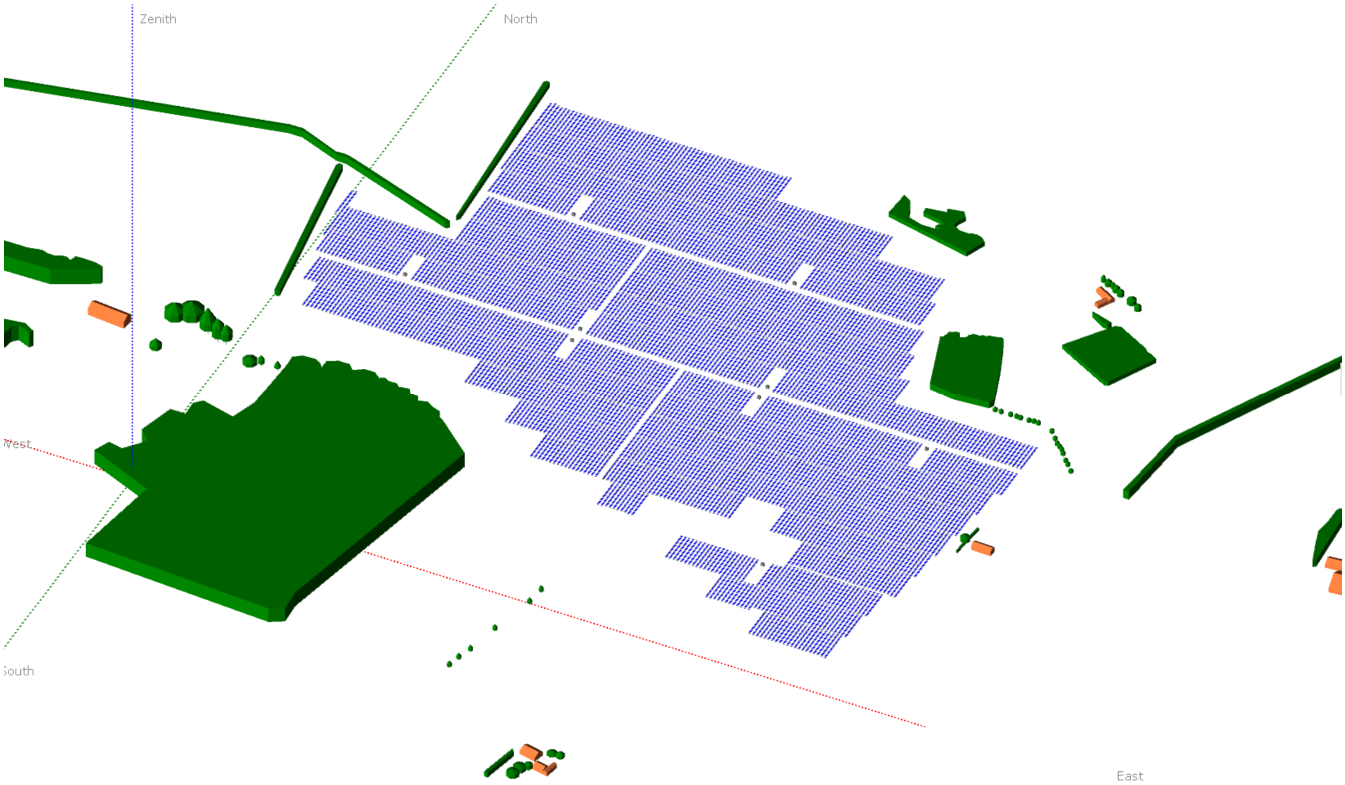

Figure 5: Three-dimensional near shading model of the planned PV system

Ground reflection front-side
PVsyst calculates a gain of 0.3 % due to ground reflections hitting the module front sides.

Soiling losses
Snowfall is rare but possible at the considered site. Snowfalls in winter can lead to yield losses. Snow covered modules behave similar like under permanent total shading. The losses due to snow are assessed on basis of the model by Townsend et al. (a.k.a. BEW model)[15] with the plant geometry described in chapter 3 and meteorological data by MeteoNorm 8. As a result the monthly average snow losses are estimated to be 6.4 % in January, 2.0 % in February, 0.4 % in March, 0.1 % in April as well as 0.9 % in November and 5.1 % in December. Regarding the whole year the losses due to snow are approx. 0.2%.
The influence of soiling depends on several factors. Besides the tracker arrangement, module rotation and meteorological effects like rain and wind the conditions on and nearby the site are important to estimate the factor of soiling. The customer states that regular cleaning of all module surfaces is not planned.
According to long-term meteorological data sufficient rainfall amounts occur over the whole year to realize a self-cleaning effect. It is assumed that the module surfaces will be cleaned if important soiling like e.g. by bird droppings is detected during plant inspections. In addition an independent soiling analysis of two individual photovoltaic systems in Denmark has been provided by the customer. The result shows that soiling losses can be considered negligible during the whole year.
Taking all information together an annual reduction of 0.5 % for soiling is taken into account in this report (plus 0.2 % snow losses).

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[15] Townsend, T.; Powers, L.: Photovoltaics and snow: An update from two winters of measurements in the SIERRA; 37th IEEE Photovoltaic Specialist Conference (PVSC); 19-24 June 2011, Seattle, WA / USA; DOI: 10.1109/PVSC.2011.6186627.
Remark: Due to expected snow melting in between snow fall events the ground interference term is not considered for this project.

Effective rear side irradiation

Based on the row distance, the ground albedo (see chapter 5), the site-specific sun positions as well as the orientation and position of the module rear sides towards ground PVsyst calculates the potential irradiation available at the module rear sides. For a tracking structure optimized for bifacial yield, SolPEG assumes 2 % rear side shading with corresponding 4 % rear side mismatch. Because the cell gaps of the modules are transparent due to the use of dual glass the module transparency is set to 7 %. Overall PVsyst simulates an effective radiation gain of 6.4 % due to sunlight entering the solar cells at the rear side. The relative efficiency of the rear side is 70 % of the front side. A corresponding bifacial efficiency loss is respected as module loss (1.8 % electrical loss).

6.2 Module losses

The PVsyst simulation models of the used RSM120-8-590BMDG and RSM120-8-585BMDG modules are provided by the customer. The simulations models have been created by DEKRA[16] according to independent laboratory testing.
In some cases the PVsyst simulation model produces a MPP power, which is slightly higher than the nominal power stated in the module data sheet. This is respected in the module quality factor (see below).

Reflection losses

Reflection losses at perpendicular incidence (incidence angle 0°) are already included in the nominal module efficiency. At higher incidence angles additional reflection losses occur.
For the considered module types specific information about the additional reflectance behavior at different angles of incidence is available in the PVsyst models by DEKRA. According to the test report the measurements have been performed with a small sample module. It is hence the responsibility of the independent laboratory to rate the test results as representative for the full-size module. The IAM factors in the following table indicate the weakening of irradiation due to incidence angle in addition to perpendicular reflection.
The overall annual losses due to incidence angle depending reflections are simulated with 0.2 % in total.

Table 9: Reflections at certain incident angles (module specific)

Incident angle /°	0	40	50	60	70	75	80	85	90
Fraction	1.000	1.000	1.000	1.000	0.992	0.978	0.946	0.850	0.000

Degradation and module quality

In this report a power reduction of half of the guaranteed value in year 1 is respected to consider the typical initial degradation as well as shipping and mounting effects (e.g. micro cracks). Thereby it is assumed that the modules are handled carefully. Furthermore it is assumed that the modules do not tend to special degradation effects like PID (Potential Induced Degradation) or LeTID (light and elevated temperature induced degradation reported for some PERC modules).
The power tolerance of the used module type stated in the data sheets is solely positive.
In addition, flash protocols of approx. 635 MWp flashed crystalline solar modules are considered in order to get a representative impression about the initial average module power.
These flash protocols show an average power which is approx. 3.2 W over nominal power. This performance gain can be considered as contrary effect to the initial degradation. If the delivered modules have a differing power the results of this report have to be corrected accordingly.

[16] DEKRA Testing and Certification (Shanghai) Ltd., Report number: 6097631B.51, Date of issue: 2021-04-08

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The used module quality factor further respects possible deviations of the modeled module power to the nameplate power.
After the initial degradation that occurs during the first days the modules are exposed to sunlight the solar cell power usually stays stable. But other parts of the modules and system components may suffer degradation e.g. due to corrosion of conducting elements, module glass and EVA sheet (EVA browning). Such effects are depending on the environmental conditions (e.g. rain periods, temperature cycles, humidity, salinity).
According to scientific publications only low annual degradation rates can be concluded under moderate climatic conditions[17].
This report assumes an annual degradation of 0.25 % provided that all components are suited for operations at the site conditions.

Irradiation level losses
Crystalline silicon modules normally lose efficiency with decreasing light intensity. The efficiency given in the data sheet is based on an irradiation of 1,000 W/m² (STC). At real conditions the irradiance differs heavily and leads to changed module efficiencies, which can be clearly lower at weak irradiations. The PVsyst simulation models of the used RSM120-8-590BMDG and RSM120-8-585BMDG modules show irradiation level losses of 0.1 % at the site's conditions.

Spectral correction
Additionally to the irradiance level, the deviation of the real varying solar spectrum from the test spectrum AM 1.5 may influence the module efficiency because solar cells are only sensitive within a certain spectral range. Crystalline modules show higher efficiencies under clear sky with low sun heights. But under cloudy conditions the blueshift of the spectrum may cause efficiency reductions. PVsyst offers a cell technology sensitive spectral correction according to the model by Lee and Panchulla[18]. The atmospheric water damp content above saturation (precipitable water) is derived from the relative humidity (MeteoNorm). With this approach 1.1 % spectral gains are simulated. The model by Huld and Gracia Amillo[19], that is implemented in the online service PVGIS, usually prognoses even higher spectral gains.

Temperature losses
With increasing cell temperature the solar cells show a decrease in power (usually about -0.4 % per °C for crystalline silicon modules). Modules are rated at 25 °C cell temperature, under normal operating conditions average cell temperatures around 50 °C are common. For the determination of the cell temperature PVsyst uses an equation with two thermal parameters Uc and Uv. Uc is multiplied just with the irradiation and the ambient temperature and Uv in addition also with the wind velocity. PVsyst recommends a parameter set of Uc= 29 and Uv= 0 for free mounted modules in order to deal with uncertainties of the wind velocity. The simulated average losses due to cell temperature are 0.8 %.

[17] K. Kiefer et. al. Degradation in PV Power Plants: Theory and Practice. 36th European Photovoltaic Solar Energy Conference and Exhibition, Proceedings p. 1331 - 1335. 2019 / D. Stellbogen, P. Lechner. A Determination of Degradation Rates for PV Modules and PV Generators Applying Various Methods. 33rd European Photovoltaic Solar Energy Conference and Exhibition, Proceedings p. 1805 - 1808. 2017 / G. Belluardo et. al. Medium-Term Degradation of Different Photovoltaic Technologies under Outdoor Conditions in Alpine Area. 28th European Photovoltaic Solar Energy Conference and Exhibition, Proceedings p. 4318 - 4321
[18] Lee, Mitchell, and Panchulla, Alex. "Spectral Correction for Photovoltaic Module Performance Based on Air Mass and Precipitable Water". IEEE Photovoltaic Specialists Conference, Portland, 2016.
[19] Huld T. and Gracia Amillo A. M. "Estimating PV Module Performance over Large Geographical Regions: The Role of Irradiance, Air Temperature, Wind Speed and Solar Spectrum". Energies. 2015 8, 5159-5181.

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6.3 DC and AC system losses

Mismatch losses

Not only the power but also the electrical factors that lead to the power underlie certain tolerances. This means that two modules with an identical measured maximum power may have different pairs of voltage and current. Nevertheless the inverter can adjust only one voltage which is an optimal compromise for all modules connected to it. Within a module string the module with the lowest current limits the whole string current. The current limitation could also be caused by different module orientations within the module string. The difference of the summation of all module power with each single module at its optimal working point and the actual power tapped by the inverter is described with mismatch loss. Additionally a heterogeneous cable dimensioning can lead to different voltage drops and further mismatch losses.

The mismatch losses have been evaluated with random module combinations based on the assumed average module power and tolerances determined from the mentioned flasher reports. Additional mismatch losses (besides the already described shading and rear side mismatch) do not apply for the considered system, because the string connection is mostly horizontal and because there are no orientation variances within one string on one table. Overall, the resulting mismatch losses have been determined with 0.3 % (plus 0.1 % mismatch losses due to shading and 0.2 % rear side mismatch).

DC wiring loss

The Ohmic losses on the DC cables are specified by the customer with an average annual loss of approx. 1.12 % at STC. This leads to an average annual loss of 0.6 %.

Inverter losses

For the technology used for the Sungrow SG250HX inverters the efficiency is optimal at the input voltage of around 1,160 V. Differing, especially lower, input voltages lead to lower efficiencies. In the considered system 32 modules are connected in series. This leads to average MPP voltages of approx. 1,095 V and 1,101 V at STC and approx. 1,016 V and 1,022 V at NMOT for the used module type.

For the simulation efficiency profiles at three different input voltage levels (860 V, 1,160 V and 1,300 V) are taken into account in the PVsyst model provided by the manufacturer.

PVsyst assumes that the maximal power point (MPP) can be adjusted exactly under all conditions. Especially in dynamic operation (cloud movements) this assumption is too optimistic. Based on manufacturer statements and divers studies the inverter efficiency is corrected by -0.5 % in PVsyst in order to care for losses due to the MPP tracking efficiency.

The simulation model in PVSYST interpolates the efficiency for each hour in the year according to the actual power and voltage level.

As a result the overall conversion losses of the inverters are simulated with 1.9 %.

Regarding the maximum active power of 250 kW of the inverters the AC/DC design ratio of the inverters is averagely approx. 90.8 % at maximal load (89.0 % to 95.4 %). PVsyst originally simulates no power limitation.

Hourly based simulation tools like PVsyst may not determine possible power limitations losses with sufficient accuracy. Especially during periods with changing irradiation conditions (e.g. cloud-enhancement effect) hourly mean values do not display the reality. Therefore additional analyses with minute data[20] have been performed. The results show that no relevant power limitation losses have to be taken into account.

[20] Based on the weather data created by SolPEG and convert into minute values with the help of the Software MeteoNorm

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For the yield analysis it is assumed that the inverters will be protected against direct sun light if power cuts due to excess temperature are detected during operation. Thus, no losses due to excess temperature are taken into account.

AC wiring and transformer losses

The produced energy is reimbursed after it is transformed to medium voltage (20 kV).
The customer states that the Ohmic losses on low voltage level between the inverters and transformer stations are 0.58 % at STC. Between the medium voltage transformers and the grid connection point the Ohmic losses are specified with 0.82 % at STC. The resulting annual loss for the total AC wiring is simulated with 0.9 %.
Because PVsyst refers the percentages for AC cable to a fictive AC power (which is close to the DC power) and not to the real AC power, usually it is necessary to enter different percentages to simulate the correct physical behaviour.
The relative no load and on load losses of the medium voltage transformers are respected according to the Ecodesign values stated in the European Committee specified minimum standard[21] for transformer losses. The resulting overall average transformer losses are simulated with 0.7 % (without night consumption).

Own consumption

It is assumed that the operational power is sourced from a separate power supply with own meter in order not to reduce the metered system production. Hence, the stated yield in this report is not reduced for own consumption (e.g. inverter station ventilation, night mode of the medium voltage transformers, lights, surveillance, tracking motor) but the related costs should to be respected in economical calculations.

Availability and failures

It is highly recommended to monitor the system carefully. Otherwise failures of e.g. single strings may rest undiscovered. Break-downs can also occur on the AC grid. This report is based on a fictive availability of the whole system of 100 %. As in each technical system it can be assumed, that the actual factor is lower. For economic calculation this aspect has to be respected.

[21] https://assets.new.siemens.com/siemens/assets/public.1541967638.157efbaae47f22215c73dc4e21fd37289700c9ff.eu-richtlinien-fuer-transformatoren-ecodesign-directive-de.pdf

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7 Summary and assessment of uncertainties

Table 10: Summary of results and assessment of uncertainties

Step	Gross loss	Net loss	PR	Annual yield		Uncertainty (±)
Global horizontal irradiation	-	-	-	1073	Irradiation (kWh/m²)	3.0%
Irradiation in module plane	-	-32.4%	100.0%	1420		2.6%
Horizon shading	0.0%	0.0%	100.0%	1420		+0.1%
Row and near shading	2.7%	2.7%	97.3%	1382		1.0%
Ground reflection front side	-0.3%	-0.3%	97.6%	1386		0.5%
Snow and soiling losses	0.7%	0.7%	97.0%	1377		1.0%
Reflection losses	0.2%	0.2%	96.8%	1374		-0.2%/+0.7%
Effective rear side irradiation	-6.2%	-6.4%	102.9%	1462		1.5%
Bifacial efficiency loss	1.8%	1.8%	101.1%	1436	Electricity (kWh/kWp)	0.5%
Module quality	-0.1%	-0.1%	101.2%	1438		1.0%
Initial degradation	1.0%	1.0%	100.2%	1423		1.0%
Irradiation level losses	0.1%	0.1%	100.1%	1422		0.7%
Spectral correction	-1.1%	-1.1%	101.2%	1437		0.5%
Temperature losses	0.8%	0.8%	100.3%	1425		1.0%
Shading mismatch	0.1%	0.1%	100.3%	1424		0.5%
Frontside mismatch	0.3%	0.3%	100.0%	1420		0.1%
Rearside mismatch	0.2%	0.2%	99.7%	1416		-0.2%/+0.3%
DC wiring loss	0.6%	0.6%	99.1%	1407		0.1%
Inverter losses	1.9%	1.9%	97.2%	1380		0.5%
AC wiring losses (LV)	0.4%	0.4%	96.8%	1375		0.1%
MV transformer losses	0.6%	0.7%	96.2%	1366		0.2%
AC wiring losses (MV)	0.5%	0.5%	95.6%	1358		0.1%
Result			**95.6%**	**1358**		**5.1%**

Assuming 100 % technical availability the initial yield of the considered PV system is assessed to be 1,358 kWh/kWp/year. This corresponds to a total annual production of 41,870 MWh for the 30,827.20 kWp system. The corresponding performance ratio found in this yield analysis is 95.6 %.

The standard deviation of the calculation which includes the uncertainty of the performance ratio and the uncertainty of the irradiation in module plane is calculated with the help of error propagation and is ± 5.1 %.

Due to weather fluctuations the yield in single years may differ from the stated average values. The variability is higher on monthly level. Thus, the monthly results in the following table should only be understood as an indication

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Table 11: Monthly results (100 % technical availability, grid-injection)

	GHI (kWh/m²)	GTI (kWh/m²)	Ta (°C)	Tm (°C)	Initial electrical production MWh	kWh/kWp	PR	Deviation PR/PR_{Year}	Monthly correction factor
Jan	13	16	1.4	4.3	474	15	94.1%	-1.6%	0.984
Feb	30	38	1.1	5.9	1181	38	101.8%	6.4%	1.064
Mar	78	105	3.1	11.7	3229	105	100.2%	4.8%	1.048
Apr	128	171	7.3	18.5	5138	167	97.5%	2.0%	1.020
May	172	231	11.5	24.1	6759	219	94.9%	-0.8%	0.992
Jun	182	243	14.6	27.1	7004	227	93.5%	-2.2%	0.978
Jul	173	230	17.4	29.4	6586	214	92.9%	-2.9%	0.971
Aug	136	174	17.0	27.6	5087	165	94.8%	-0.9%	0.991
Sep	90	120	13.7	22.8	3582	116	97.1%	1.5%	1.015
Oct	46	61	9.5	15.7	1888	61	99.8%	4.4%	1.044
Nov	17	21	5.7	9.1	636	21	98.8%	3.3%	1.033
Dec	9	11	2.1	4.8	306	10	92.5%	-3.3%	0.967
Year	1073	1420	8.7	19.7	41870	1358	95.6%		

(GHI = Global horizontal irradiation, GTI = Irradiation in module plane, Tm = Average module temperature during running, Ta = Ambient temperature, 24 h average).

Including an annual degradation of 0.25 % the average specific annual yield over 20 years is 1,326 kWh/kWp with a corresponding PR of 93.4 %.

Table 12: Summary Specific yield in kWh/kWp and PR in %, annual degradation 0.25 %

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Ø**
Yield	1358	1355	1351	1348	1345	1341	1338	1335	1331	1328	1326 kWh/kWp
PR	95.6	95.4	95.2	94.9	94.7	94.4	94.2	94.0	93.7	93.5	
Year	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
Yield	1325	1321	1318	1315	1311	1308	1305	1302	1298	1295	PR 93.4 %
PR	93.3	93.0	92.8	92.6	92.3	92.1	91.9	91.7	91.4	91.2	

Probabilities of exceedance

For the risk analysis of PV projects so called probabilities of exceedance are common. This consideration is based on a normal distribution of the expected yields. The p90 value for example means the yield exceeded with a probability of 90 % (analogous: p75 with 75 % etc.).
The predicted yield represents the p50 value.
The standard deviation of 5.1 % is determined with means of error propagation of the single uncertainties. Thereby annual irradiation fluctuations and deviations from the annual degradation factor are not considered.
The values presented in the following table result directly from the standard deviation, the predicted yield and the particular probability of exceedance.

Table 13: Exceedance probabilities and corresponding yields (standard deviation 5.1 %)

	p50	p55	p60	p65	p70	**p75**	p80	p85	**p90**	p95
Initial kWh/kWp	**1358**	1350	1341	1332	1322	**1312**	1300	1287	**1270**	1245
Average kWh/kWp	**1326**	1318	1309	1301	1291	**1281**	1270	1257	**1240**	1216
Difference to p50 /%	**0.0%**	-0.6%	-1.3%	-1.9%	-2.7%	**-3.4%**	-4.3%	-5.2%	**-6.5%**	-8.3%

All presented results refer to a system availability of 100 % and average meteorological conditions. Due to weather fluctuations the yield in single years may differ from the stated average values.

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8 Advises for optimisation

There are several possibilities to keep the PV system in a good operating condition and to optimize the yield.
Possible vegetation under and next to the modules, the inverters and transformer stations should be cut regularly to avoid extra shadings and overgrowing of fans etc.
The soiling state of the modules should be monitored and the cleaned regime should be adjusted if required.
All components have to be suited for operation at the site conditions.
The string inverters have to be protected against direct sunlight to avoid power cuts due to excess temperature.
Only by a professional system monitoring also minor yield reductions, e.g. due to breakdowns that only affect parts of the system, can be detected.

9 Disclaimer and legal notice

The results presented in this report were created in all conscience by means of state-of-the-art sources, methods and tools. The outcomes of this yield analysis are only valid under the assumptions described in detail. Therefore we do not guarantee that the realized PV system will provide the predicted yield. This report was created for European Energy A/S and is only determined for this customer and its project partners. It is not allowed to quote the content and results of this report in a disaffected or incoherent way. The originator of this report has always to be mentioned when citing this analysis or its results. The formulations in this report are copyrighted by SolPEG. It is prohibited to take text modules from this report to create other yield reports that are not generated by SolPEG. A possible third party review of this report has to be provided to SolPEG for comments.

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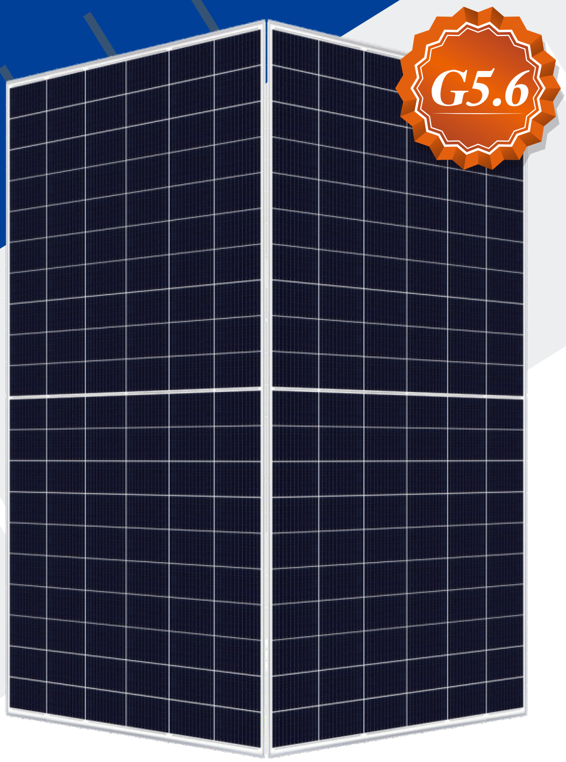
10 Appendix

TITAN

HIGH PERFORMANCE
BIFACIAL PERC MONOCRYSTALLINE MODULE



RSM120-8-585BMDG-605BMDG

120 CELL
Mono PERC Module

585-605Wp
Power Output Range

1500VDC
Maximum System Voltage

21.4%
Maximum Efficiency

ISO9001
ISO14001
OHSAS18001
IEC TS 62941

KEY SALIENT FEATURES

- Global, Tier 1 bankable brand, with independently certified state-of-the-art automated manufacturing
- Bifacial technology enables additional energy harvesting from rear side (up to 30%)
- Industry leading lowest thermal co-efficient of power
- Industry leading 12 years product warranty
- Excellent low irradiance performance
- Excellent PID resistance
- Positive tight power tolerance
- Dual stage 100% EL Inspection warranting defect-free product
- Module Imp binning radically reduces string mismatch losses
- Warranted reliability and stringent quality assurances well beyond certified requirements
- Certified to withstand severe environmental conditions
  - Anti-reflective & anti-soiling surface minimise power loss from dirt and dust
  - Severe salt mist, ammonia & blown sand resistance, for seaside, farm and desert environments
  - Excellent mechanical resistance: wind load 2400Pa & snow load 5400Pa

RISEN ENERGY CO., LTD.

Risen Energy is a leading, global tier 1 manufacturer of high-performance solar photovoltaic products and provider of total business solutions for residential, commercial and utility-scale power generation. The company, founded in 1986, and publicly listed in 2010, compels value generation for its chosen global customers. Techno-commercial innovation, underpinned by consummate quality and support, encircle Risen Energy's total Solar PV business solutions which are among the most powerful and cost-effective in the industry. With local market presence and strong financial bankability status, we are committed, and able, to building strategic, mutually beneficial collaborations with our partners, as together we capitalise on the rising value of green energy.

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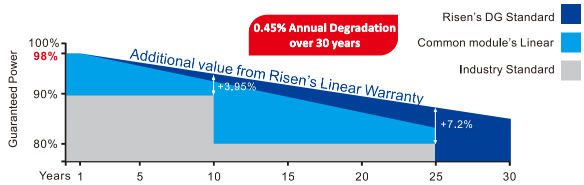
LINEAR PERFORMANCE WARRANTY

12 year Product Warranty / 30 year Linear Power Warranty



★ Please check the valid version of Limited Product Warranty which is officially released by Risen Energy Co., Ltd

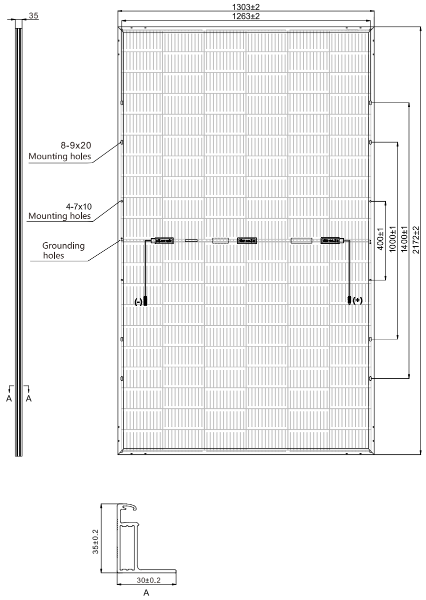
risen solar technology

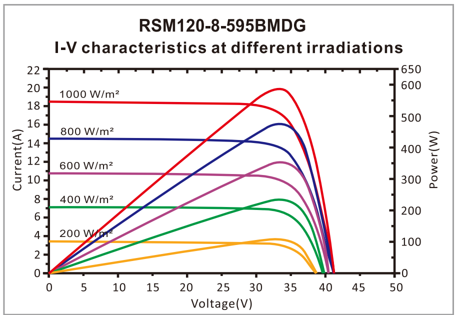
Preliminary
For Global Market

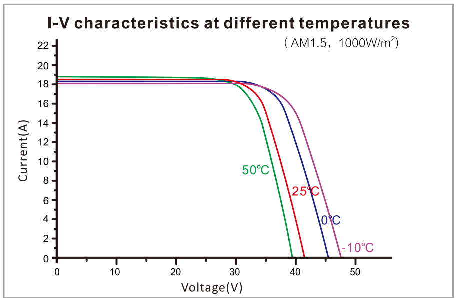
THE POWER OF RISING VALUE

Dimensions of PV Module

Unit: mm







Our Partners:

ELECTRICAL DATA (STC)

Model Number	RSM120-8-585BMDG	RSM120-8-590BMDG	RSM120-8-595BMDG	RSM120-8-600BMDG	RSM120-8-605BMDG
Rated Power in Watts-Pmax(Wp)	**585**	**590**	**595**	**600**	**605**
Open Circuit Voltage-Voc(V)	41.10	41.30	41.50	41.70	41.90
Short Circuit Current-Isc(A)	18.11	18.16	18.21	18.26	18.32
Maximum Power Voltage-Vmpp(V)	34.22	34.42	34.60	34.80	34.98
Maximum Power Current-Impp(A)	17.10	17.15	17.20	17.25	17.30
Module Efficiency (%) ★	20.7	20.8	21.0	21.2	21.4

STC: Irradiance 1000 W/m², Cell Temperature 25°C, Air Mass AM1.5 according to EN 60904-3.
Bifacial factor: 70%±5 ★Module Efficiency (%): Round-off to the nearest number

Electrical characteristics with 10% rear side power gain

Total Equivalent power -Pmax (Wp)	644	649	655	660	665
Open Circuit Voltage-Voc(V)	41.10	41.30	41.50	41.70	41.90
Short Circuit Current-Isc(A)	19.92	19.98	20.03	20.09	20.15
Maximum Power Voltage-Vmpp(V)	34.22	34.42	34.60	34.80	34.98
Maximum Power Current-Impp(A)	18.81	18.87	18.92	18.98	19.03

Rear side power gain: The additional gain from the rear side compared to the power of the front side at the standard test condition. It depends on mounting (structure, height, tilt angle etc.) and albedo of the ground.

ELECTRICAL DATA (NMOT)

Model Number	RSM120-8-585BMDG	RSM120-8-590BMDG	RSM120-8-595BMDG	RSM120-8-600BMDG	RSM120-8-605BMDG
Maximum Power-Pmax (Wp)	443.1	447.0	450.7	454.6	458.3
Open Circuit Voltage-Voc (V)	38.22	38.41	38.60	38.78	38.97
Short Circuit Current-Isc (A)	14.85	14.89	14.93	14.97	15.02
Maximum Power Voltage-Vmpp (V)	31.76	31.94	32.11	32.29	32.46
Maximum Power Current-Impp (A)	13.95	13.99	14.04	14.08	14.12

NMOT: Irradiance at 800 W/m², Ambient Temperature 20°C, Wind Speed 1 m/s.

MECHANICAL DATA

Solar cells	Monocrystalline
Cell configuration	120 cells (6×10+6×10)
Module dimensions	2172×1303×35mm
Weight	35kg
Superstrate	High Transmission, Low Iron, Tempered ARC Glass
Substrate	Tempered Glass
Frame	Anodized Aluminium Alloy type 6005-2T6, Silver Color
J-Box	Potted, IP68, 1500VDC, 3 Schottky bypass diodes
Cables	4.0mm² (12AWG), Positive(+)350mm, Negative(-)350mm (Connector Included)
Connector	Risen Twinsel PV-SY02, IP68

TEMPERATURE & MAXIMUM RATINGS

Nominal Module Operating Temperature (NMOT)	44°C±2°C
Temperature Coefficient of Voc	-0.25%/°C
Temperature Coefficient of Isc	0.04%/°C
Temperature Coefficient of Pmax	-0.34%/°C
Operational Temperature	-40°C~+85°C
Maximum System Voltage	1500VDC
Max Series Fuse Rating	35A
Limiting Reverse Current	35A

PACKAGING CONFIGURATION

	40ft(HQ)
Number of modules per container	527
Number of modules per pallet	31
Number of pallets per container	17
Box gross weight[kg]	1100

CAUTION: READ SAFETY AND INSTALLATION INSTRUCTIONS BEFORE USING THE PRODUCT.

THE POWER OF RISING VALUE

REM120-BMDG-12BB-EN-H2-6-2020

PV module - RSM120-8-585BMDG

Manufacturer	Risen Energy Co., Ltd	**Commercial data**	
Model	RSM120-8-585BMDG	Availability :	Prod. Since 2020
		Data source :	Manufacturer 2021
Pnom STC power (manufacturer)	585 Wp	Technology	Si-mono
Module size (W x L)	1.303 x 2.172 m²	Rough module area (Amodule)	2.83 m²
Number of cells	2 x 60	Sensitive area (cells) (Acells)	2.65 m²

Specifications for the model (manufacturer or measurement data)

Reference temperature (TRef)	25 °C	Reference irradiance (GRef)	1000 W/m²
Open circuit voltage (Voc)	41.1 V	Short-circuit current (Isc)	18.11 A
Max. power point voltage (Vmpp)	34.2 V	Max. power point current (Impp)	17.10 A
=> maximum power (Pmpp)	585.2 W	Isc temperature coefficient (muIsc)	7.2 mA/°C

One-diode model parameters

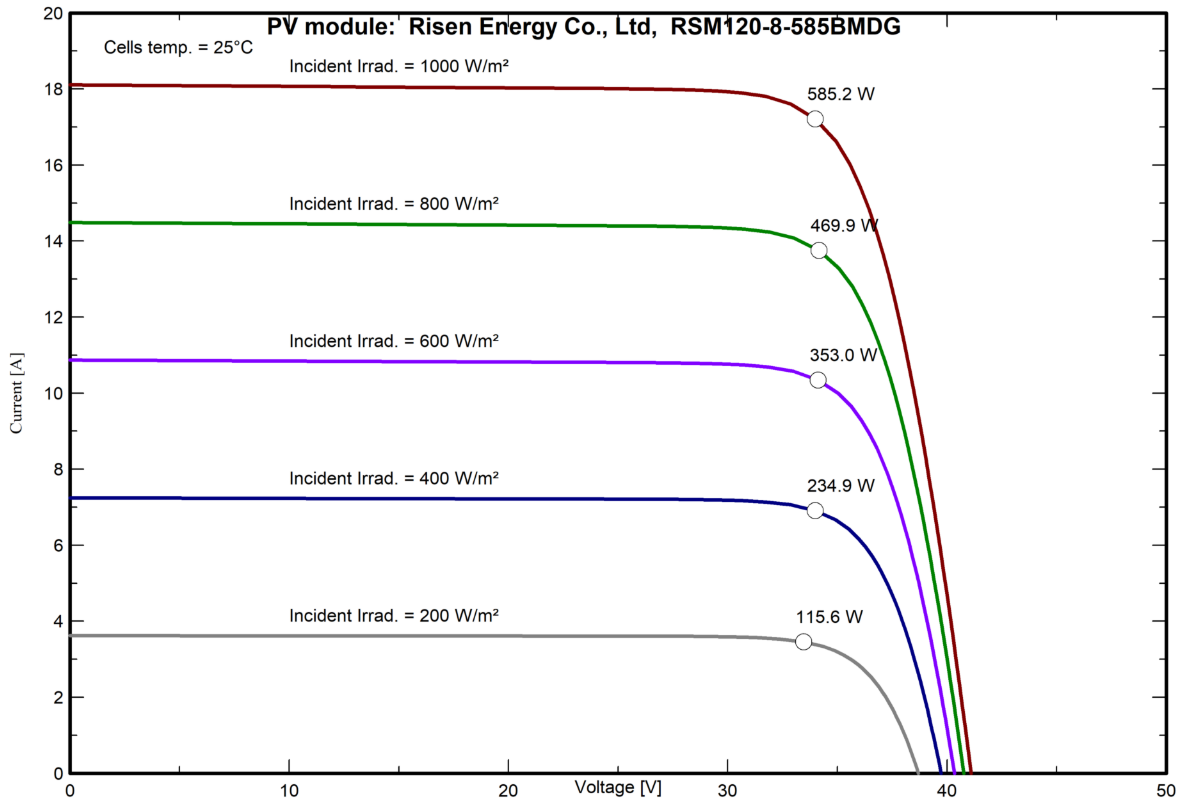
Shunt resistance (Rshunt)	250 Ω	Diode saturation current (IoRef)	0.021 nA
Serie resistance (Rserie)	0.14 Ω	Voc temp. coefficient (MuVoc)	-114 mV/°C
Specified Pmax temper. coeff. (muPMaxR)	-0.34 %/°C	Diode quality factor (Gamma)	0.97
		Diode factor temper. coeff. (muGamma)	0.000 1/°C

Reverse Bias Parameters, for use in behaviour of PV arrays under partial shadings or mismatch

Reverse characteristics (dark) (BRev)	3.20 mA/V²	(quadratic factor (per cell))	
Number of by-pass diodes per module	3	Direct voltage of by-pass diodes	-0.7 V

Model results for standard conditions (STC: T=25 °C, G=1000 W/m², AM=1.5)

Max. power point voltage (Vmpp)	34.0 V	Max. power point current (Impp)	17.23 A
Maximum power (Pmpp)	585.2 Wp	Power temper. coefficient (muPmpp)	-0.34 %/°C
Efficiency(/ Module area) (Eff_mod)	20.7 %	Fill factor (FF)	0.786
Efficiency(/ Cells area) (Eff_cells)	22.1 %		



PV module - RSM120-8-590BMDG

Manufacturer	Risen Energy Co., Ltd	**Commercial data**	
Model	RSM120-8-590BMDG	Availability :	Prod. Since 2020
	Manufacturer 2021	Data source:	DEKRA Testing and Certification (Shanghai) Ltd.
Pnom STC power (manufacturer)	590 Wp	Technology	Si-mono
Module size (W x L)	1.303 x 2.172 m²	Rough module area (Amodule)	2.83 m²
Number of cells	2 x 60	Sensitive area (cells) (Acells)	2.65 m²

Specifications for the model (manufacturer or measurement data)

Reference temperature (TRef)	25 °C	Reference irradiance (GRef)	1000 W/m²
Open circuit voltage (Voc)	41.3 V	Short-circuit current (Isc)	18.16 A
Max. power point voltage (Vmpp)	34.4 V	Max. power point current (Impp)	17.15 A
=> maximum power (Pmpp)	590.3 W	Isc temperature coefficient (muIsc)	7.3 mA/°C

One-diode model parameters

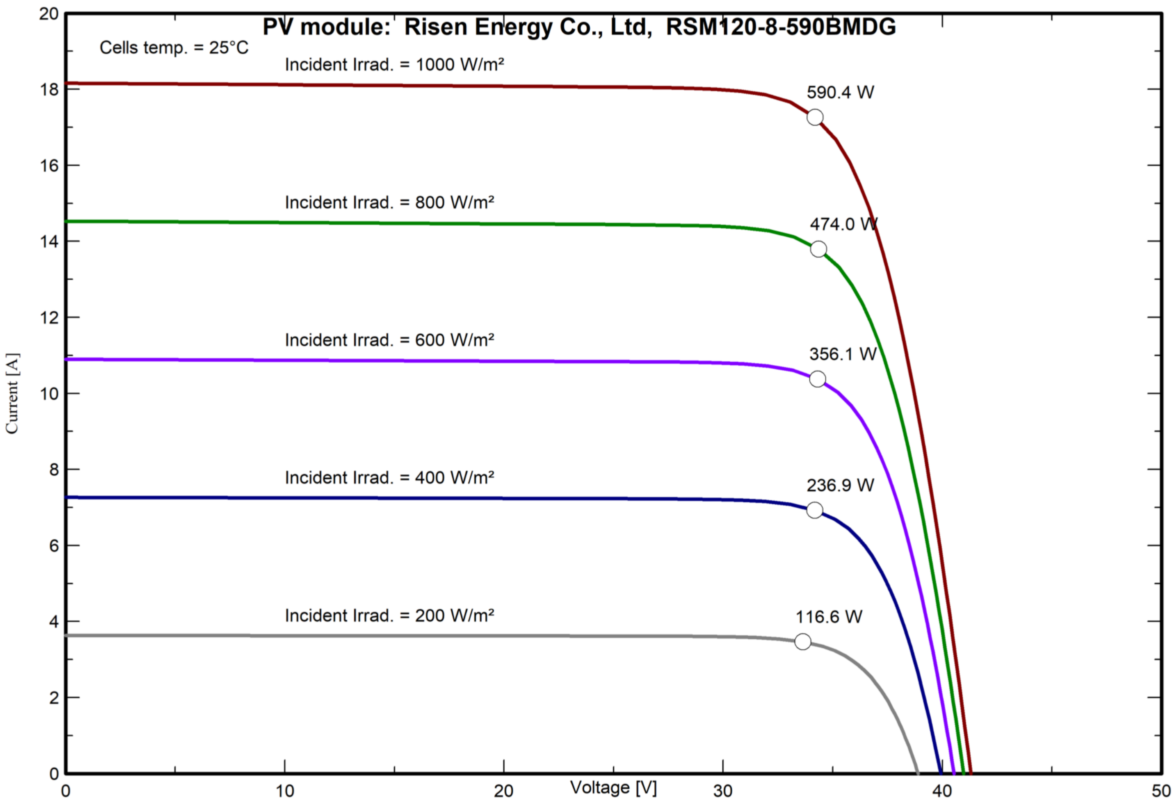
Shunt resistance (Rshunt)	250 Ω	Diode saturation current (IoRef)	0.019 nA
Serie resistance (Rserie)	0.14 Ω	Voc temp. coefficient (MuVoc)	-115 mV/°C
Specified Pmax temper. coeff. (muPMaxR)	-0.34 %/°C	Diode quality factor (Gamma)	0.97
		Diode factor temper. coeff. (muGamma)	0.000 1/°C

Reverse Bias Parameters, for use in behaviour of PV arrays under partial shadings or mismatch

Reverse characteristics (dark) (BRev)	3.20 mA/V²	(quadratic factor (per cell))	
Number of by-pass diodes per module	3	Direct voltage of by-pass diodes	-0.7 V

Model results for standard conditions (STC: T=25 °C, G=1000 W/m², AM=1.5)

Max. power point voltage (Vmpp)	34.2 V	Max. power point current (Impp)	17.29 A
Maximum power (Pmpp)	590.4 Wp	Power temper. coefficient (muPmpp)	-0.34 %/°C
Efficiency(/ Module area) (Eff_mod)	20.9 %	Fill factor (FF)	0.787
Efficiency(/ Cells area) (Eff_cells)	22.3 %		



SG250HX New

Multi-MPPT String Inverter for 1500 Vdc System

SUNGROW
Clean power for all

HIGH YIELD

- 12 MPPTs with max. efficiency 99%
- Compatible with bifacial module
- Built-in Anti-PID and PID recovery function

SMART O&M

- Touch free commissioning and remote firmware upgrade
- Online IV curve scan and diagnosis*
- Fuse free design with smart string current monitoring

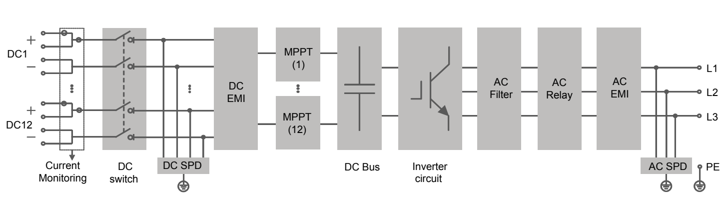
LOW COST

- Compatible with Al and Cu AC cables
- DC 2 in 1 connection enabled
- Power line communication (PLC)
- Q at night function

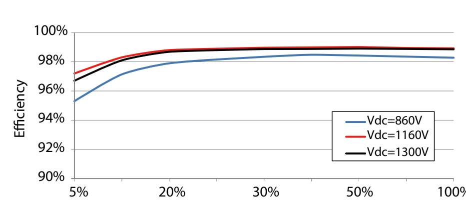
PROVEN SAFETY

- IP66 and C5 protection
- Type II SPD for both DC and AC
- Compliant with global safety and grid code

CIRCUIT DIAGRAM



EFFICIENCY CURVE



Type designation	SG250HX
Input (DC)	
Max. PV input voltage	1500 V
Min. PV input voltage / Startup input voltage	600 V / 600 V
Nominal PV input voltage	1160 V
MPP voltage range	600 V – 1500 V
MPP voltage range for nominal power	860 V – 1300 V
No. of independent MPP inputs	12
Max. number of input connectors per MPPT	2
Max. PV input current	26 A * 12
Max. current for input connector	30 A
Max. DC short-circuit current	50 A * 12
Output (AC)	
AC output power	250 kVA @ 30 ℃ / 225 kVA @40 ℃ / 200 KVA @ 50 ℃
Max. AC output current	180.5 A
Nominal AC voltage	3 / PE, 800 V
AC voltage range	680 – 880V
Nominal grid frequency / Grid frequency range	50 Hz / 45 – 55 Hz, 60 Hz / 55 – 65 Hz
THD	< 3 % (at nominal power)
DC current injection	< 0.5 % In
Power factor at nominal power / Adjustable power factor	> 0.99 / 0.8 leading – 0.8 lagging
Feed-in phases / connection phases	3 / 3
Efficiency	
Max. efficiency	99.0 %
European efficiency	98.8 %
Protection	
DC reverse connection protection	Yes
AC short circuit protection	Yes
Leakage current protection	Yes
Grid monitoring	Yes
Ground fault monitoring	Yes
DC switch	Yes
AC switch	No
PV String current monitoring	Yes
Q at night function	Yes
PID protection	Anti-PID or PID recovery
Overvoltage protection	DC Type II / AC Type II
General Data	
Dimensions (W*H*D)	1051 * 660 * 363 mm
Weight	95kg
Isolation method	Transformerless
Ingress protection rating	IP66
Night power consumption	< 2 W
Operating ambient temperature range	-30 to 60 ℃
Allowable relative humidity range (non-condensing)	0 – 100 %
Cooling method	Smart forced air cooling
Max. operating altitude	4000 m (> 3000 m derating)
Display	LED, Bluetooth+APP
Communication	RS485 / PLC
DC connection type	Amphenol UTX (Max. 6 mm²)
AC connection type	OT terminal (Max. 300 mm²)
Compliance	IEC 62109, IEC 61727, IEC 62116, IEC 60068, IEC 61683, VDE-AR-N 4110:2018, VDE-AR-N 4120:2018, IEC 61000-6-3, EN 50549, UNE 206007-1:2013, P.O.12.3, UTE C15-712-1:2013
Grid Support	Q at night function, LVRT, HVRT,active & reactive power control and power ramp rate control

*: Only compatible with Sungrow logger and iSolarCloud

Agersted
Location name

57.185
Latitude [°N]

10.407
Longitude [°E]

8
Altitude [m a.s.l.]

III, 3
Climate region

Standard
Radiation model

Standard
Temperature model

Perez
Tilt radiation model

Contemporary
Temperature period

Contemporary
Radiation period

Additional information

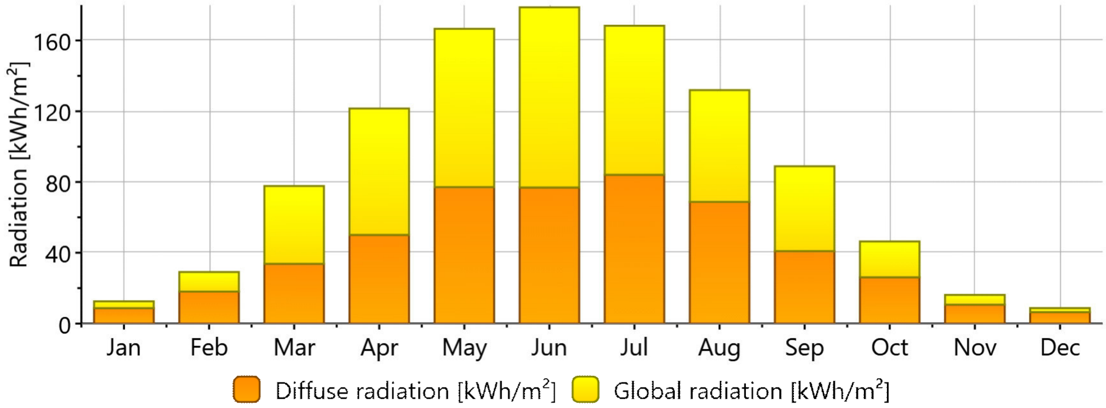
Uncertainty of yearly values: Gh = 5%, Bn = 11%, Ta = 0.8 °C
Trend of Gh / decade: 0.4%
Variability of Gh / year: 5.0%
Radiation interpolation locations: Tylstrup (2001-2010, 27 km), Skagen Fyr (62 km), Ars Syd (72 km), Anholt Havn (85 km), Silstrup (110 km), Foulum (92 km) (Share of satellite data: 44%)
Temperature interpolation locations: Tylstrup (27 km), Alborg Airp. (35 km), Skagen Fyr (62 km), Ars Syd (72 km), Nidingen (LGT-H) (91 km), Anholt Havn (85 km)
P90 and P10 of yearly Gh, referenced to average: 93.8%, 107.2%

Month	H_Gh	H_Dh	Ta	H_Gk	RH	Ts
	[kWh/m2]	[kWh/m2]	[°C]	[kWh/m2]	[%]	[°C]
January	13	9	0.7	13	86	-0.7
February	29	18	0.5	29	87	-1.0
March	78	34	2.7	78	82	2.3
April	122	50	7.6	122	71	7.6
May	167	77	11.6	167	72	12.4
June	179	77	14.7	179	73	15.8
July	168	84	17.3	168	74	18.6
August	132	69	17.1	132	74	17.9
September	89	41	13.5	89	80	13.2
October	46	26	8.7	46	86	7.7
November	16	11	5.1	16	88	3.5
December	9	6	1.5	9	88	-0.2
Year	1043	502	8.4	1043	80	8.1

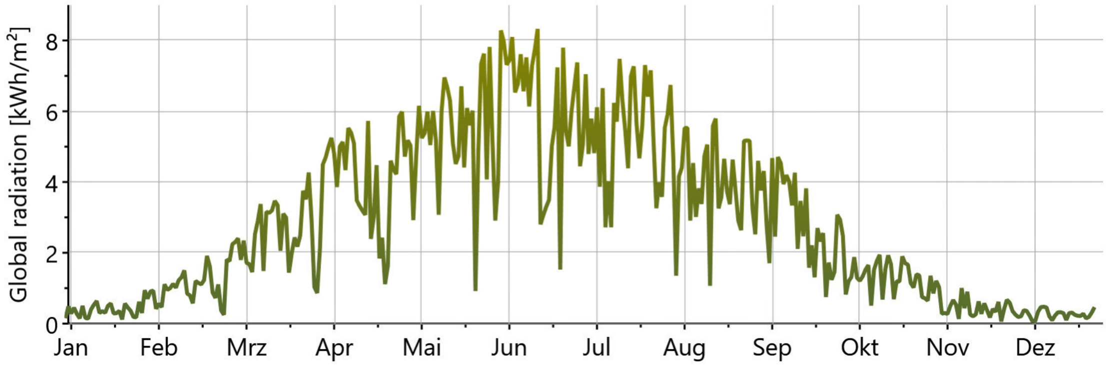
Month	FF	RR	Snd
	[m/s]	[mm]	[mm]
January	4.2	60.0	44.9
February	4.1	39.0	33.4
March	4.0	39.0	0.9
April	3.7	36.0	0.0
May	3.3	53.0	0.0
June	3.3	67.0	0.0
July	3.0	89.0	0.0
August	3.1	83.0	0.0
September	3.4	57.0	0.0
October	3.6	77.0	0.0
November	3.8	72.0	0.6
December	4.1	58.0	9.6
Year	3.6	730.0	7.5

H_Gh: Irradiation of global radiation horizontal
H_Dh: Irradiation of diffuse radiation horizontal
Ta: Air temperature
H_Gk: Irradiation of global rad., tilted plane
RH: Relative humidity
Ts: Surface temperature
FF: Wind speed
RR: Precipitation
Snd: Snow depth

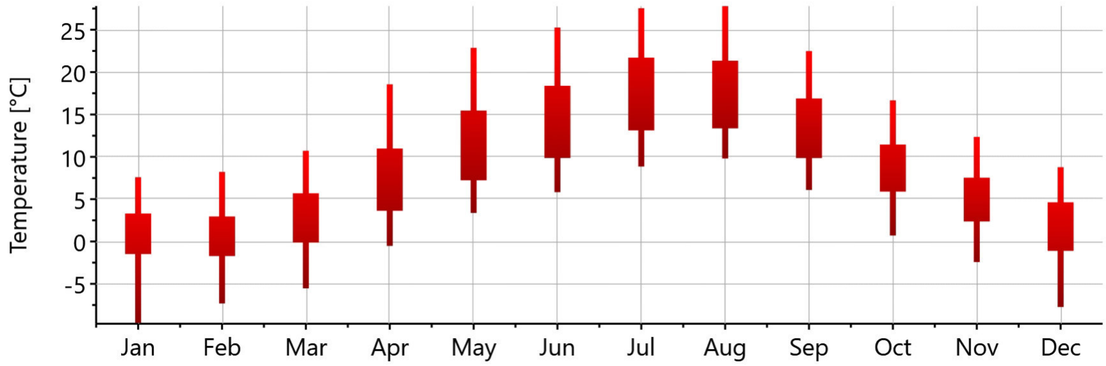
Monthly radiation



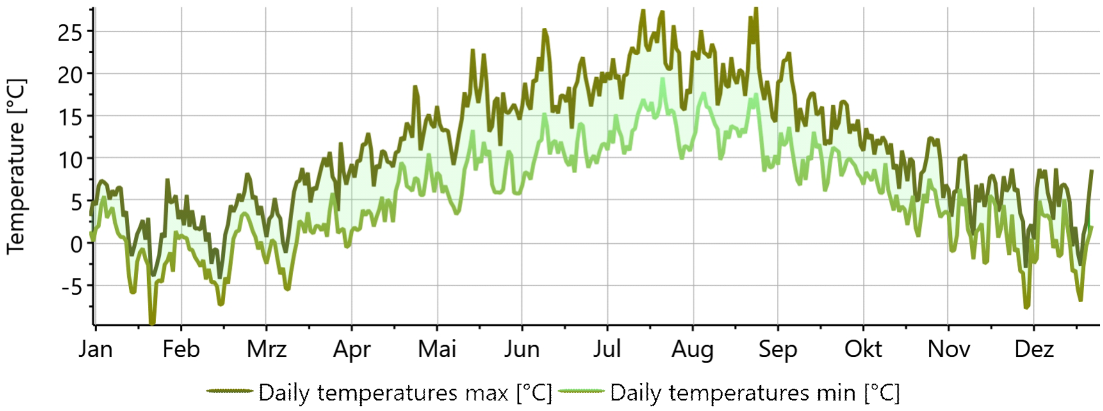
Daily global radiation



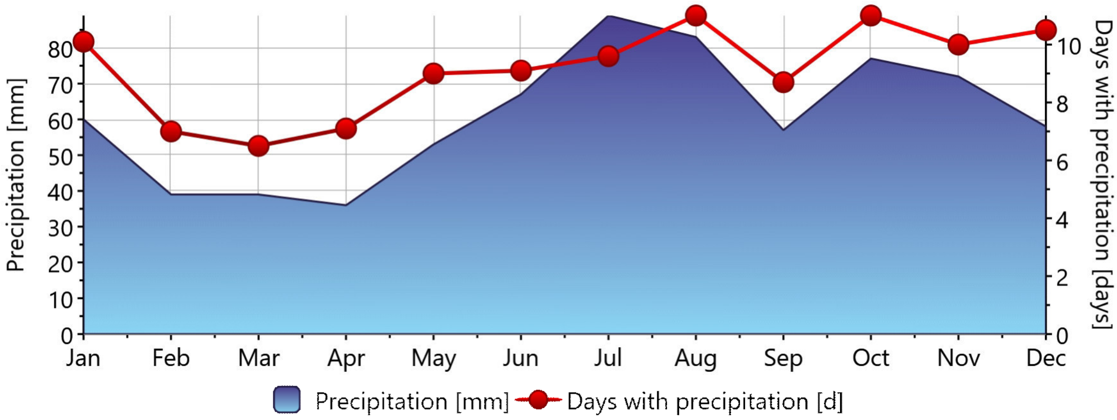
Monthly temperature



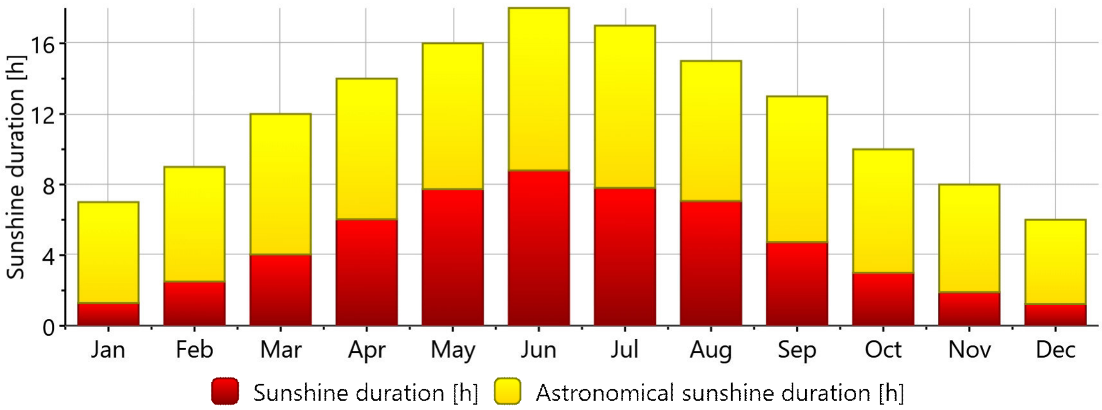
Daily temperature



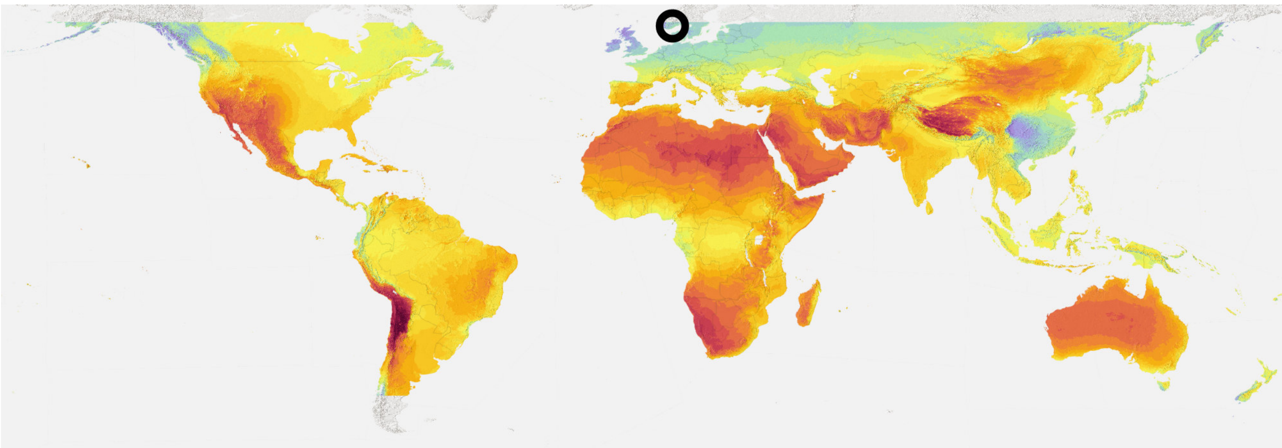
Precipitation



Sunshine duration



SOLARGIS **PROSPECT**



Preliminary assessment of site solar irradiance

Project: Agersted (Denmark)

Geographical coordinates	57.1853, 10.4072 (57°11'07", 10°24'26")
Report number	P-11637-2021-03-02-1025
Report generated	2021-03-02
Generated by	Solargis
Customer	SolPEG GmbH (Germany)

Solargis s.r.o., Mytna 48, 811 07 Bratislava, Slovakia
solargis.com • contact@solargis.com • tel.: +421 2 4319 1708

Contents

1 Overview

Table 1.1: Yearly average

Global horizontal irradiation	GHI	1021	kWh/m^2
Direct normal irradiation	DNI	1069	kWh/m^2
Diffuse horizontal irradiation	DIF	501	kWh/m^2
Air temperature	TEMP	8.9	°C

2 Project info

Project name	Agersted
Address	Søråvej, Agersted, North Denmark Region, Denmark
Geographical coordinates	57.1853, 10.4072 (57°11'07", 10°24'26")
Time zone	UTC+01, Europe/Copenhagen [CET], Daylight saving time not considered
Elevation	8 m
Land cover	Cropland, rainfed
Population density	42 inh./km^2
Terrain azimuth	flat
Terrain slope	0°
Location on the map	https://apps.solargis.com/prospect/map?c=57.1853,10.4072,10&s=57.1853,10.4072

Figure 2.1: Project location

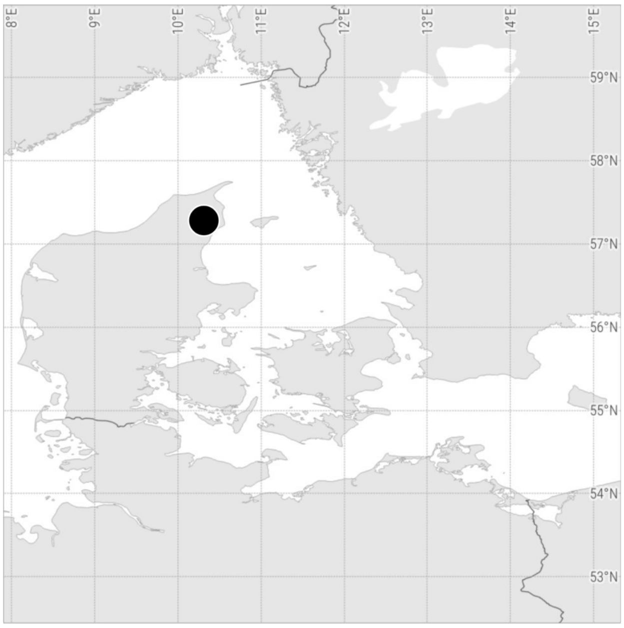


Figure 2.2: Detailed map view

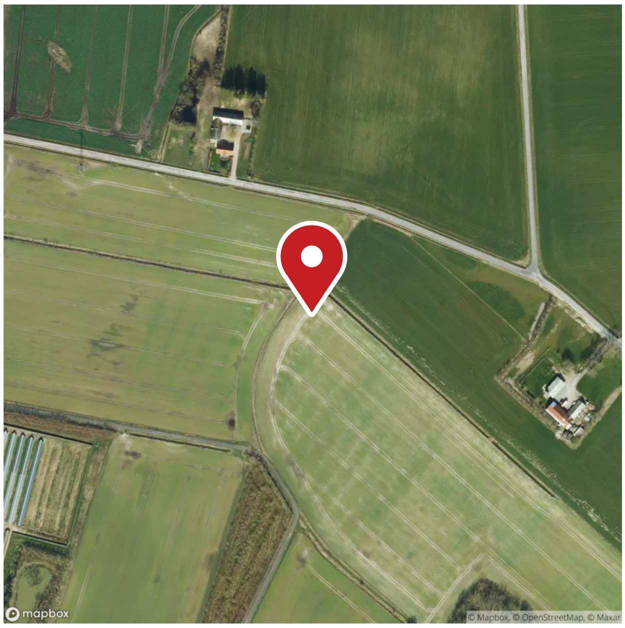


Figure 2.3: Project horizon and sunpath

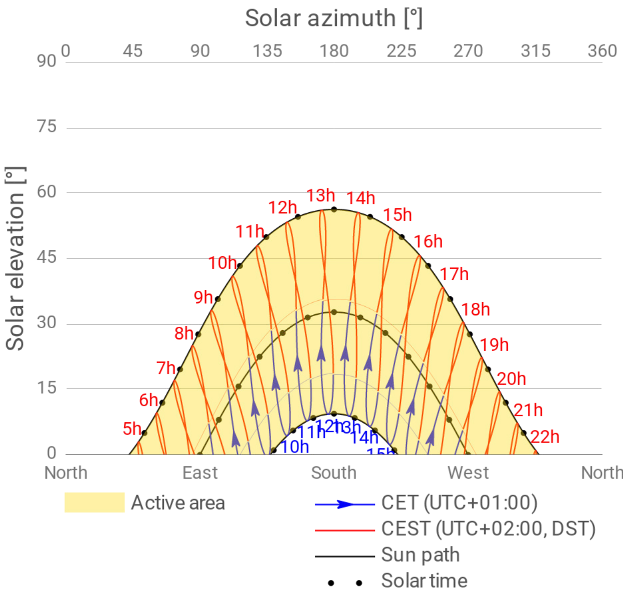
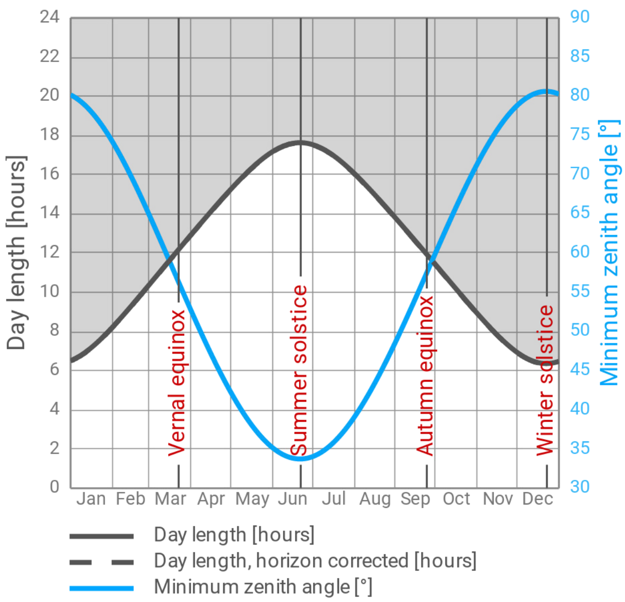


Figure 2.4: Day length and solar zenith angle



3 Solar and meteo: Monthly statistics

The most important project-specific meteorological parameter that determines solar electricity production is solar radiation, which fuels a PV power system. Power production is also influenced by air temperature. Other meteorological parameters also affect the performance, availability and ageing of a PV system.

Table 3.1: Solar radiation and meteorological parameters

Month	GHI kWh/m^2	DNI kWh/m^2	DIF kWh/m^2	D2G	GTI opta kWh/m^2	TEMP °C	WS m/s	CDD degree days	HDD degree days
Jan	14	26	9	0.68	31	2.0	7.5	0	503
Feb	29	45	17	0.60	54	1.6	7.3	0	458
Mar	75	94	38	0.51	112	3.1	6.6	0	443
Apr	119	124	57	0.47	147	6.8	5.6	0	323
May	163	158	71	0.44	175	11.0	5.4	0	204
Jun	169	154	76	0.45	170	14.3	5.7	0	107
Jul	168	150	79	0.47	174	17.0	5.1	14	40
Aug	132	123	66	0.50	152	17.1	5.6	11	36
Sep	83	88	45	0.54	112	14.1	6.4	0	115
Oct	43	57	25	0.58	72	10.1	7.1	0	243
Nov	17	29	11	0.66	34	6.3	7.4	0	351
Dec	9	21	6	0.70	24	3.4	7.1	0	454
Yearly	**1021**	**1069**	**501**	**0.49**	**1258**	**8.9**	**6.4**	**25**	**3275**

Optimum tilt/azimuth for GTI_opta 41° / 180°

Figure 3.1: Global + diffuse horizontal irradiation

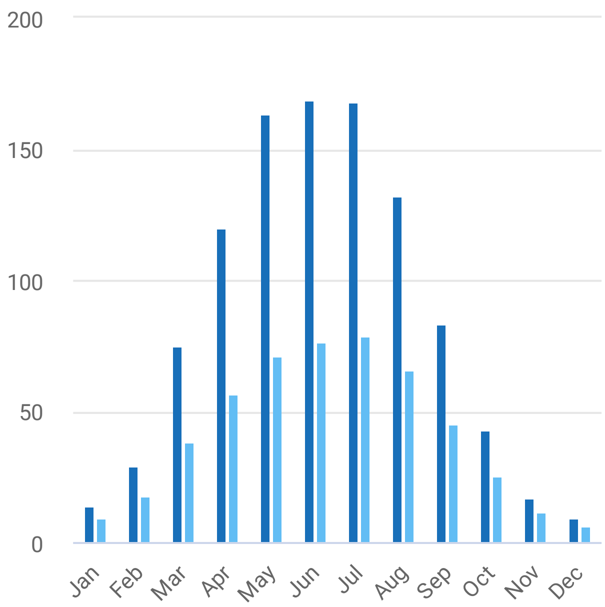


Figure 3.2: Direct normal irradiation

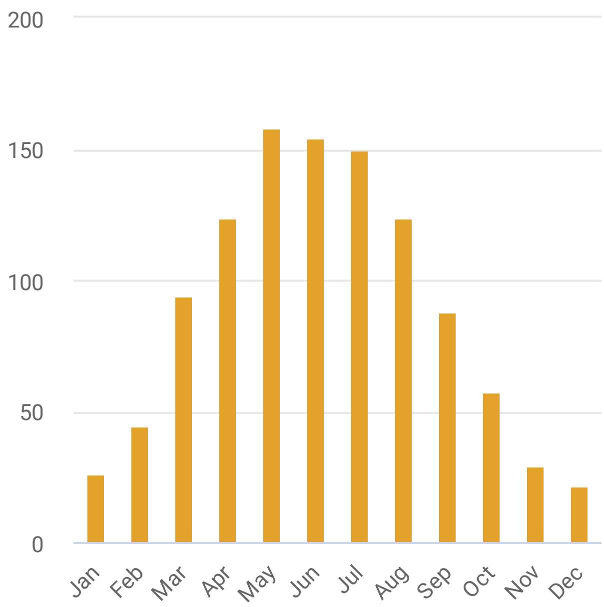


Figure 3.3: Ratio of diffuse to global irradiation

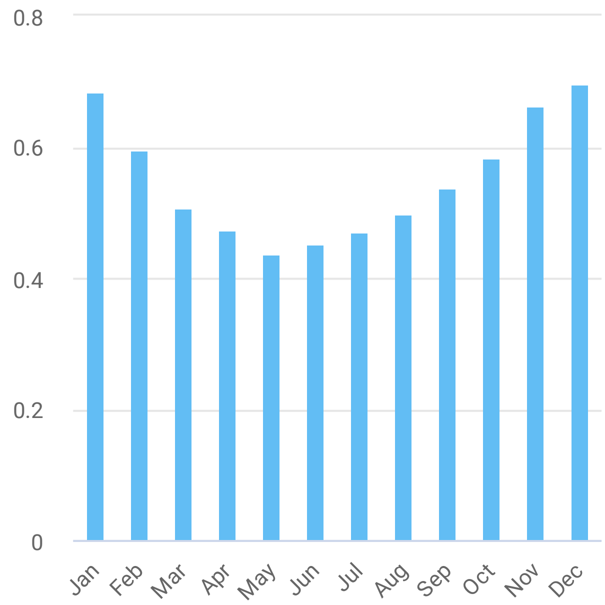


Figure 3.4: Global tilted irradiation at optimum angle

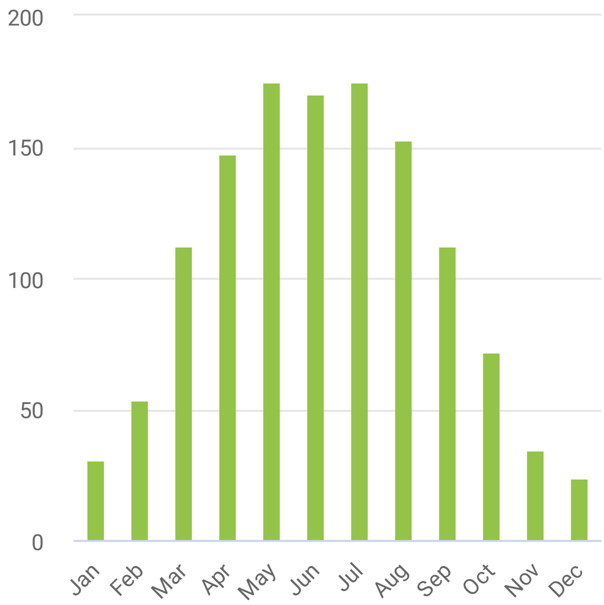


Figure 3.5: Air temperature

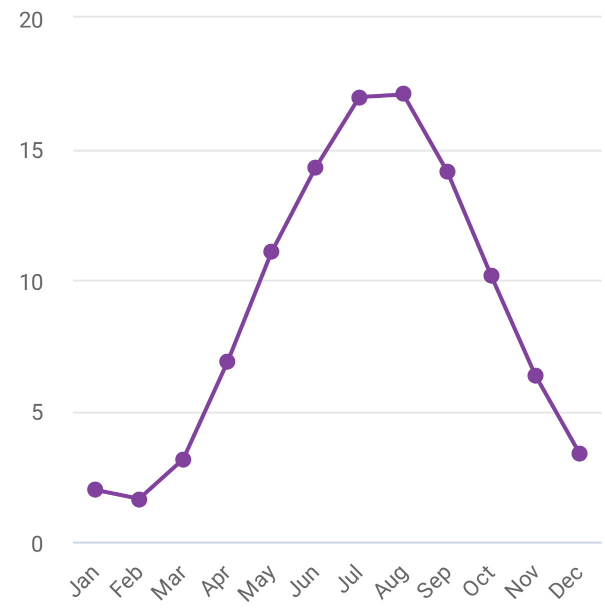


Figure 3.6: Wind speed

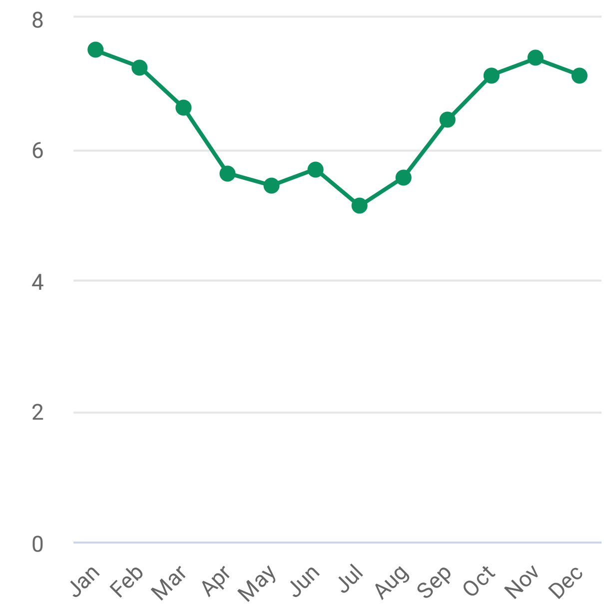


Figure 3.7: Cooling degree days

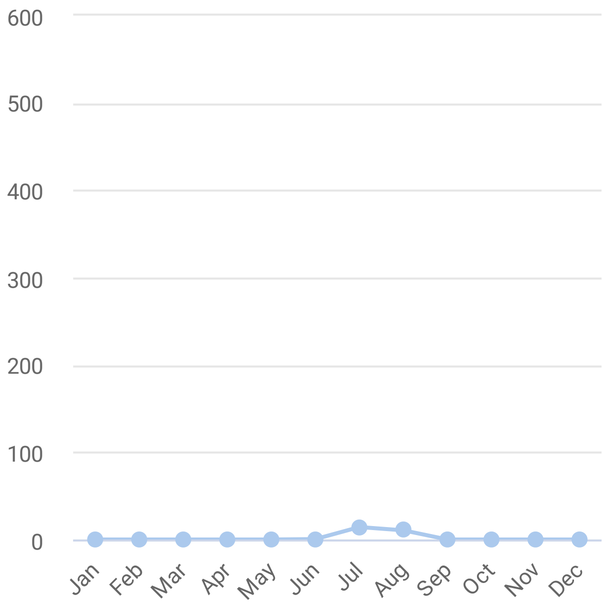
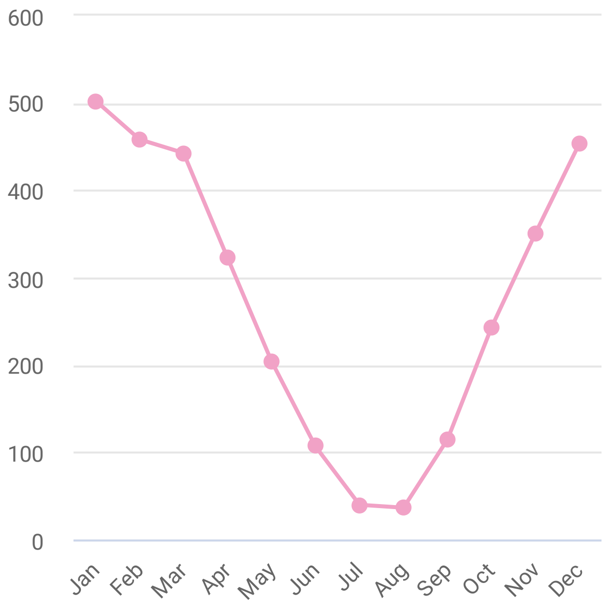


Figure 3.8: Heating degree days



4 Solar and meteo: Daily statistics

Solar radiation profiles below are calculated as an average of all hourly data for each month. The profiles give an indication of changing patterns of GHI per day, separately for each month. These patterns are driven by local geography, astronomy and climate of the site.

Figure 4.1: GHI, DNI, DIF - daily averages

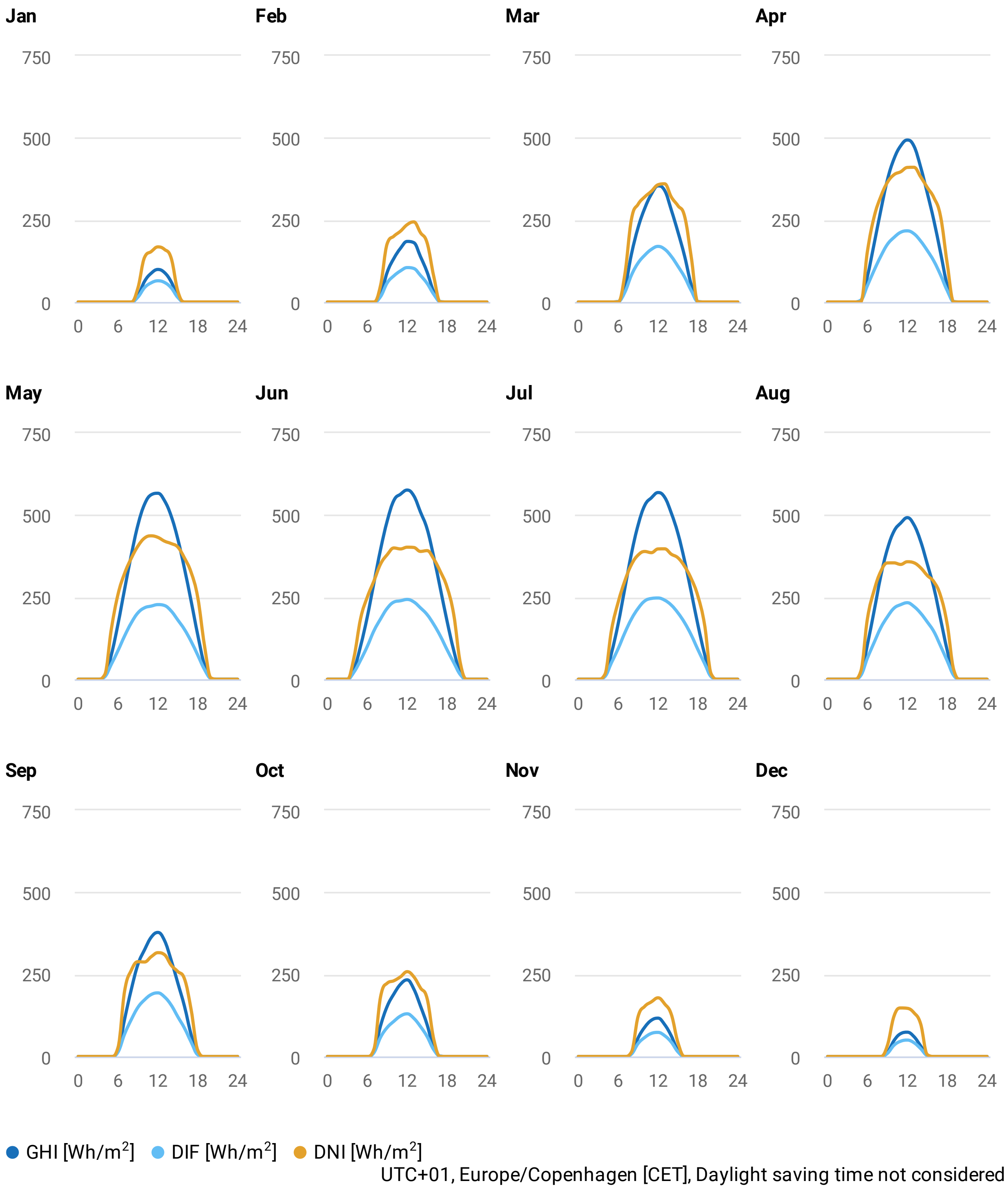


Table 4.1: Global horizontal irradiation - hourly averages [Wh/m^2]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1	-	-	-	-	-	-	-	-	-	-	-	-
1 - 2	-	-	-	-	-	-	-	-	-	-	-	-
2 - 3	-	-	-	-	-	-	-	-	-	-	-	-
3 - 4	-	-	-	-	-	0	-	-	-	-	-	-
4 - 5	-	-	-	-	8	30	9	-	-	-	-	-
5 - 6	-	-	-	5	75	102	80	14	-	-	-	-
6 - 7	-	-	1	78	168	190	169	106	17	-	-	-
7 - 8	-	-	42	176	275	293	276	207	114	14	-	-
8 - 9	-	22	146	278	378	396	383	313	204	94	8	-
9 - 10	19	91	227	372	470	482	470	396	281	153	56	12
10 - 11	63	133	285	436	533	545	530	451	325	190	89	49
11 - 12	88	164	329	476	562	564	553	476	363	220	110	70
12 - 13	99	184	354	493	567	576	569	492	378	233	117	74
13 - 14	90	181	340	475	544	559	554	471	353	206	97	61
14 - 15	61	138	280	411	497	509	506	421	293	154	62	32
15 - 16	16	91	213	332	427	458	444	351	224	97	17	3
16 - 17	0	31	139	248	337	372	360	278	153	26	0	-
17 - 18	-	1	52	150	238	275	265	183	67	1	-	-
18 - 19	-	-	1	51	135	177	165	88	6	-	-	-
19 - 20	-	-	-	1	44	88	77	13	-	-	-	-
20 - 21	-	-	-	-	2	19	9	-	-	-	-	-
21 - 22	-	-	-	-	-	-	-	-	-	-	-	-
22 - 23	-	-	-	-	-	-	-	-	-	-	-	-
23 - 24	-	-	-	-	-	-	-	-	-	-	-	-
Sum	**436**	**1035**	**2408**	**3983**	**5261**	**5636**	**5417**	**4261**	**2778**	**1388**	**558**	**300**

Table 4.2: Direct normal irradiation - hourly averages [Wh/m^2]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1	-	-	-	-	-	-	-	-	-	-	-	-
1 - 2	-	-	-	-	-	-	-	-	-	-	-	-
2 - 3	-	-	-	-	-	-	-	-	-	-	-	-
3 - 4	-	-	-	-	-	-	-	-	-	-	-	-
4 - 5	-	-	-	-	14	66	15	-	-	-	-	-
5 - 6	-	-	-	0	153	185	150	24	-	-	-	-
6 - 7	-	-	-	155	258	250	234	185	27	-	-	-
7 - 8	-	-	83	259	323	299	299	270	200	22	-	-
8 - 9	-	51	252	321	369	351	349	328	263	182	14	-
9 - 10	43	178	298	364	406	380	378	354	289	223	122	33
10 - 11	136	200	320	388	430	400	389	354	288	231	153	123
11 - 12	154	216	337	397	437	397	386	350	304	243	166	148
12 - 13	168	236	357	410	432	402	397	358	316	258	179	147
13 - 14	160	244	360	410	421	401	397	355	310	243	160	133
14 - 15	134	211	320	381	413	389	381	340	278	209	128	100
15 - 16	33	180	293	349	403	392	370	316	259	177	42	6
16 - 17	-	78	261	317	369	366	344	297	236	53	-	-
17 - 18	-	-	136	261	326	328	306	254	143	-	-	-
18 - 19	-	-	-	118	249	281	253	168	19	-	-	-
19 - 20	-	-	-	-	104	198	166	27	-	-	-	-
20 - 21	-	-	-	-	4	49	16	-	-	-	-	-
21 - 22	-	-	-	-	-	-	-	-	-	-	-	-
22 - 23	-	-	-	-	-	-	-	-	-	-	-	-
23 - 24	-	-	-	-	-	-	-	-	-	-	-	-
Sum	**827**	**1594**	**3017**	**4129**	**5109**	**5135**	**4830**	**3980**	**2932**	**1840**	**963**	**690**

5 Acronyms and glossary

Table 5.1: Acronyms and glossary

Acronym	Full name	Unit	Explanation
GHI	Global horizontal irradiation	kWh/m^2	Average annual, monthly or daily sum of global horizontal irradiation
DNI	Direct normal irradiation	kWh/m^2	Average yearly, monthly or daily sum of direct normal irradiation
DIF	Diffuse horizontal irradiation	kWh/m^2	Average yearly, monthly or daily sum of diffuse horizontal irradiation
D2G	Ratio of diffuse to global irradiation		Ratio of diffuse horizontal irradiation and global horizontal irradiation (DIF/GHI)
GTI opta	Global tilted irradiation at optimum angle	kWh/m^2	Average annual, monthly or daily sum of global tilted irradiation for PV modules fix-mounted at optimum angle
OPTA	Optimum tilt of PV modules	°	Optimum tilt of fix-mounted PV modules facing towards Equator set for maximizing GTI input
GHI season	GHI seasonality		Ratio of maximum and minimum monthly averages of global horizontal irradiation (GHI_month_max/GHI_month_min)
DNI season	DNI seasonality		Ratio of maximum and minimum monthly averages of direct normal irradiation (DNI_month_max/DNI_month_min)
GTI theoretical	Global tilted irradiation (theoretical)	kWh/m^2	Average annual, monthly or daily sum of global tilted irradiation without consideration of terrain shading
TEMP	Air temperature	°C	Average yearly, monthly and daily air temperature at 2 m above ground
WS	Wind speed	m/s	Average yearly, monthly and daily wind speed at 10 m above ground
CDD	Cooling degree days	degree days	Quantifies energy demand needed to cool a building. "Cooling degree days" are a measure of how much (in degrees), and for how long (in days), outside air temperature was higher than a specific base daily average temperature (18°C). Yearly and monthly values are aggregated from daily values
HDD	Heating degree days	degree days	Quantifies energy demand needed to heat a building. "Heating degree days" are a measure of how much (in degrees), and for how long (in days), outside air temperature was lower than a specific base daily average temperature (18°C). Yearly and monthly values are aggregated from daily values

6 Metadata

This report is based on high-resolution solar and meteorological database developed and operated by Solargis. The data parameters presented in this report are computed by Solargis models and algorithms. The data used as inputs to the models come from different sources. The data characteristics are explained below.

Time representation: 1994 to 2018 (25 calendar years)
Time step: Monthly and yearly long-term statistics
The estimations assume a year having 365 days
Solargis database version 2.5.0

Group of data	Source of data inputs	Organization	Solargis method
GHI, DNI, DIF, GTI, D2G	Meteosat MFG and MSG satellites (PRIME) Aerosols from MERRA-2 and MACC-II/CAMS models Water vapour from CSFR and GFS models ELE	EUMETSAT NASA, ECMWF NOAA CGIAR CSI	Solar model
TEMP	ERA-5 model	ECMWF	Data processing
RH, WS, WD	MERRA-2 and CDFv2 models	NASA, NOAA	Data processing
SNOWD	CFSR and CFSv2 models	NOAA	Data processing
PREC	GPCC database	DWD	Data processing
PWAT	CFSR and CFSv2 models	NOAA	Data processing
ALB	MODIS and ERA-5 databases	NASA, ECMWF	Data merging, cleaning, processing
LANDC	Land Cover CCI, v2.0.7	ESA CCI	Post-processing
POPUL	Gridded Population of the World, Version 4 (GPWv4)	CIESIN	Data processing
ELE, SLO, AZI	SRTM	CGIAR CSI	Data merging, cleaning, processing
PVOUT, OPTA	GTI, TEMP, ELE	Solargis	PV simulation model
HDD, CDD	TEMP	Solargis	Data processing

Documentation

Data uncertainty https://solargis.com/docs/accuracy-and-comparisons/combined-uncertainty/
Methodology https://solargis.com/docs/methodology/solar-radiation-modeling/
PV energy simulation https://solargis.com/docs/methodology/pv-energy-modeling/

7 Disclaimer and legal information

Considering the uncertainty of data and calculations, Solargis s.r.o. does not guarantee the accuracy of estimates. The maximum possible has been done for the assessment of weather parameters and preliminary assessment of the photovoltaic electricity production based on the best available data, software and knowledge. Solargis s.r.o. shall not be liable for any direct, incidental, consequential, indirect or punitive damages arising or alleged to have arisen out of use of the provided report.

This report shows solar power estimation in the start-up phase and over the entire lifetime of a PV system. The estimates are accurate enough for preliminary project assessment. For large projects planning and financing, more information is needed: 1. Statistical distribution and uncertainty of solar radiation 2. Detailed specification of a PV system 3. Inter-annual variability and P90 uncertainty of PV production 4. Lifetime energy production considering performance degradation of PV components.

More information about full PV yield assessment can be found at:
https://solargis.com/products/pv-yield-assessment-study/overview/

See full text of GENERAL CONTRACTUAL TERMS TO THE PAID SERVICES at:
https://solargis.com/legal/general-contractual-terms/

Validation of authenticity

This PDF report is electronically signed by Solargis s.r.o..

Service provider

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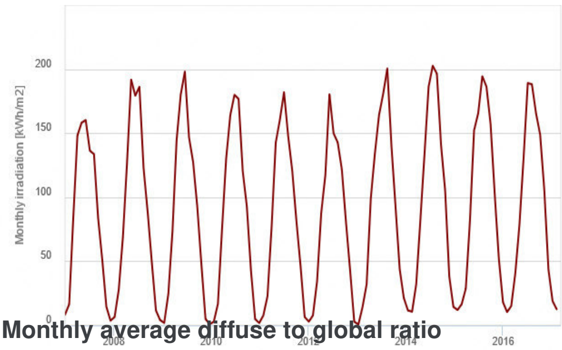
Report generated on

PVGIS-5 geo-temporal irradiation database

Provided inputs

Latitude/Longitude:	57.185, 10.407
Horizon:	None
Database used	PVGIS-CMSAF
Start year:	2007
End year:	2016
Variables included in this report:	
Global horizontal irradiation:	Yes
Direct Normal Irradiation:	No
Global irradiation optimum angle:	No
Global irradiation at angle °	No
Diffuse/global ratio	Yes
Average temperature	Yes

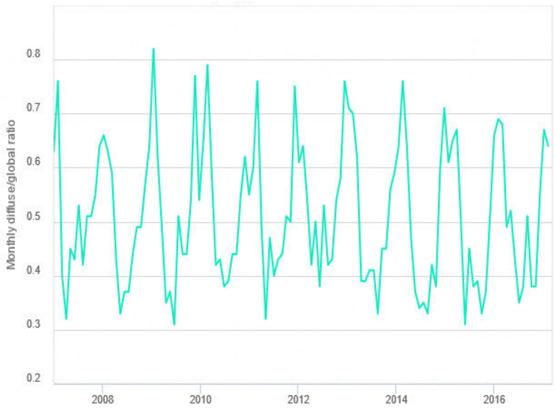
Monthly solar irradiation estimates



Global horizontal irradiation

Month	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
January	8.41	6.51	1.89	2.75	7.74	7.7	14.16	10.67	16.45	15.08
February	16.41	27.88	24.54	16.81	22.76	34.37	32.15	32.16	28.73	41.13
March	84.58	68.85	73.35	75.39	77.07	87.49	98.79	81.92	81.47	79.15
April	148.29	126.66	144.49	130.29	142.64	117.04	134.29	133.38	152.11	131.37
May	158.09	191.78	180.1	164.1	160.51	180.27	164.13	186.27	165.5	189.05
June	160.2	179.23	198.03	179.84	181.96	149.8	180.63	202.51	194.34	188.1
July	136.34	186.14	146.84	176.74	147.86	142.69	200.39	196.39	186.29	165.43
August	133.58	122.77	127.32	120.5	120.41	121.51	140.43	141.15	157.06	148.76
September	83.82	88.36	92.74	92.78	81.38	80.46	92.14	105.15	102.4	105.62
October	51.37	49.16	47.62	42.7	46.31	42.72	43.81	38.13	51.93	43.71
November	14.52	11.6	4.95	4.92	6.48	2.81	21.32	14.39	17.98	18.96
December	3.68	4.12	0.98	1.84	2.9	0.65	11.58	11.99	10.37	12.55

Monthly average diffuse to global ratio



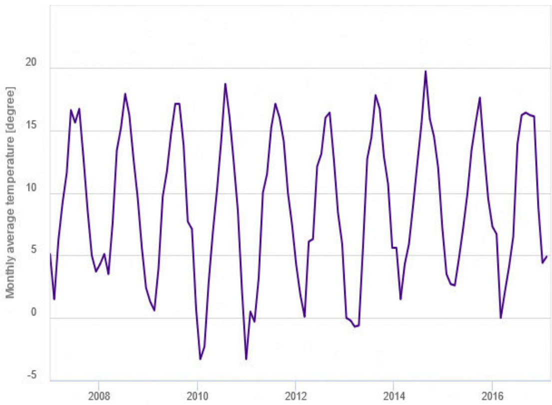
Diffuse/global ratio

Month	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
January	0.63	0.66	0.82	0.65	0.6	0.64	0.7	0.76	0.65	0.68
February	0.76	0.63	0.62	0.79	0.76	0.54	0.62	0.64	0.67	0.49
March	0.4	0.59	0.49	0.59	0.49	0.42	0.39	0.47	0.5	0.52
April	0.32	0.43	0.35	0.42	0.32	0.5	0.39	0.37	0.31	0.43
May	0.45	0.33	0.37	0.43	0.47	0.38	0.41	0.34	0.45	0.35
June	0.43	0.37	0.31	0.38	0.4	0.53	0.41	0.35	0.38	0.38
July	0.53	0.37	0.51	0.39	0.43	0.42	0.33	0.33	0.39	0.51
August	0.42	0.44	0.44	0.44	0.44	0.43	0.45	0.42	0.33	0.38
September	0.51	0.49	0.44	0.44	0.51	0.54	0.45	0.38	0.37	0.38
October	0.51	0.49	0.54	0.55	0.5	0.58	0.56	0.6	0.51	0.55
November	0.55	0.57	0.77	0.62	0.75	0.76	0.59	0.71	0.66	0.67
December	0.64	0.64	0.54	0.55	0.61	0.71	0.64	0.61	0.69	0.64

Report generated on 2021/03/02

European Commission

Monthly average temperature



Monthly average temperature

Month	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
January	5.1	4.3	1.3	-3.3	0.5	1.8	-0.2	1.5	2.7	0
February	1.5	5.1	0.6	-2.3	-0.3	0.1	-0.7	4.3	2.6	2.1
March	6.2	3.5	4	2.8	3.2	6.1	-0.6	5.9	4.8	4.1
April	9.2	7.6	9.7	6.8	10	6.3	5.7	9	7.2	6.5
May	11.6	13.4	11.7	10.2	11.5	12.1	12.7	12.3	9.9	13.9
June	16.6	15.2	14.7	14.1	15.2	13.1	14.4	15.5	13.4	16.2
July	15.6	17.9	17.1	18.7	17.1	16	17.8	19.7	15.6	16.4
August	16.7	16.2	17.1	16.1	16	16.4	16.7	15.9	17.6	16.2
September	12.8	12.7	13.8	12.5	14.1	12.7	12.9	14.5	13.3	16.1
October	8.6	9.6	7.7	8.6	10	8.4	10.7	12	9.5	8.9
November	5	5.6	7.1	2.1	7.4	5.9	5.6	7.2	7.3	4.4
December	3.7	2.4	0.7	-3.3	4.2	0	5.6	3.5	6.7	4.9

Report generated on 2021/03/02

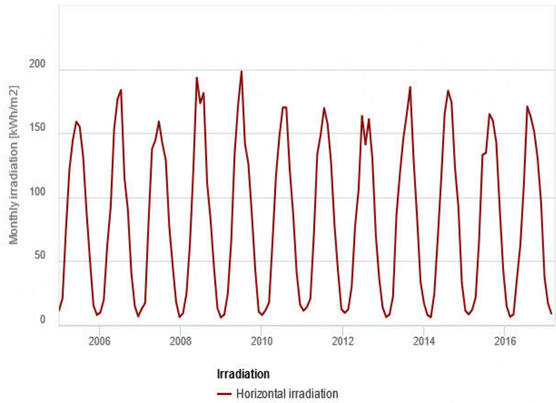
Report generated on

PVGIS-5 geo-temporal irradiation database

Provided inputs

Latitude/Longitude:	57.185, 10.407
Horizon:	None
Database used	PVGIS-SARAH
Start year:	2005
End year:	2016
Variables included in this report:	
Global horizontal irradiation:	Yes
Direct Normal Irradiation:	No
Global irradiation optimum angle:	No
Global irradiation at angle °	No
Diffuse/global ratio	Yes
Average temperature	Yes

Monthly solar irradiation estimates



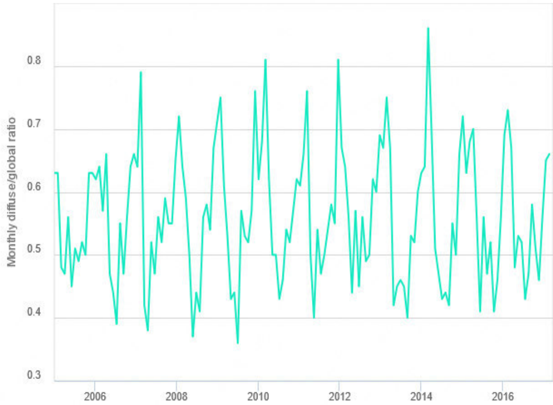
Global horizontal irradiation

Month	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
January	11.57	10.07	12.88	9.23	8.45	11.9	14.27	12.45	8.45	6.25	12.18	8.44
February	21.06	19.95	17.28	24.52	24.54	17.81	20.9	30.14	22.56	24.77	21.67	36.47
March	74.47	62.4	80.73	62.59	65.01	65	69.89	77.94	86.18	68.18	66.35	63.27
April	121.24	92.36	137.54	120.91	134.12	116.6	133.52	105.66	118.24	114.1	133.03	109.43
May	144.74	153	144.65	193.28	171.81	147.6	148.99	163.49	145.79	165.06	134.6	170.86
June	158.83	176.74	159.13	173.34	198.23	170.02	169.59	141.07	164.84	183.14	164.97	162.71
July	155.07	183.71	141.99	181.33	141.59	170.09	157.11	160.97	185.98	173.95	159.88	151.13
August	131.55	115.15	129.04	111.26	125.97	121.75	127.56	130.39	128.33	123.34	142.67	130.53
September	87.94	89.78	77.72	82.9	86.48	86.83	78.3	70.91	83.97	92.08	91.27	96.12
October	50.27	40.75	46.72	45.28	42.69	41.63	43.2	36.14	34	32.81	43.55	37.83
November	15.38	14.99	18.25	13.52	10.53	16.1	12.72	13.89	17.19	11.48	15.02	17.23
December	8.13	6.92	6.51	6.12	8.03	11.45	9.68	6.49	8.07	8.56	6.64	9.07

Report generated on 2021/03/02

European Commission

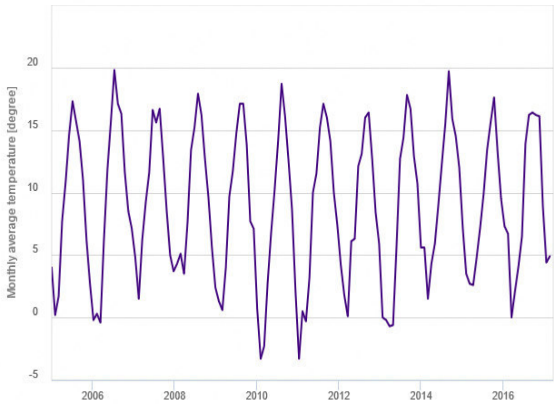
Monthly average diffuse to global ratio



Diffuse/global ratio

Month	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
January	0.63	0.62	0.64	0.72	0.75	0.68	0.66	0.64	0.75	0.86	0.68	0.67
February	0.63	0.64	0.79	0.64	0.61	0.81	0.76	0.56	0.67	0.69	0.7	0.48
March	0.48	0.57	0.42	0.59	0.53	0.62	0.5	0.44	0.42	0.51	0.56	0.53
April	0.47	0.66	0.38	0.5	0.43	0.5	0.4	0.57	0.45	0.47	0.41	0.52
May	0.56	0.47	0.52	0.37	0.44	0.5	0.54	0.45	0.46	0.43	0.56	0.43
June	0.45	0.44	0.47	0.44	0.36	0.43	0.47	0.56	0.45	0.44	0.47	0.47
July	0.51	0.39	0.56	0.41	0.57	0.46	0.5	0.49	0.4	0.42	0.52	0.58
August	0.49	0.55	0.52	0.56	0.53	0.54	0.54	0.5	0.53	0.55	0.41	0.51
September	0.52	0.47	0.59	0.58	0.52	0.52	0.58	0.62	0.52	0.5	0.46	0.46
October	0.5	0.56	0.55	0.54	0.57	0.57	0.55	0.6	0.6	0.66	0.56	0.56
November	0.63	0.64	0.55	0.67	0.76	0.62	0.81	0.69	0.63	0.72	0.69	0.65
December	0.63	0.66	0.65	0.71	0.62	0.61	0.67	0.67	0.64	0.63	0.73	0.66

Monthly average temperature



Monthly average temperature

Month	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
January	4	-0.2	4.8	4.3	1.3	-3.3	0.5	1.8	-0.2	1.5	2.7	0
February	0.2	0.3	1.5	5.1	0.6	-2.3	-0.3	0.1	-0.7	4.3	2.6	2.1
March	1.7	-0.4	6.2	3.5	4	2.8	3.2	6.1	-0.6	5.9	4.8	4.1
April	7.7	6.2	9.2	7.6	9.7	6.8	10	6.3	5.7	9	7.2	6.5
May	10.8	11.8	11.6	13.4	11.7	10.2	11.5	12.1	12.7	12.3	9.9	13.9
June	14.6	15.7	16.6	15.2	14.7	14.1	15.2	13.1	14.4	15.5	13.4	16.2
July	17.3	19.8	15.6	17.9	17.1	18.7	17.1	16	17.8	19.7	15.6	16.4
August	15.7	17.1	16.7	16.2	17.1	16.1	16	16.4	16.7	15.9	17.6	16.2
September	14.1	16.3	12.8	12.7	13.8	12.5	14.1	12.7	12.9	14.5	13.3	16.1
October	11	11.6	8.6	9.6	7.7	8.6	10	8.4	10.7	12	9.5	8.9
November	6.2	8.5	5	5.6	7.1	2.1	7.4	5.9	5.6	7.2	7.3	4.4
December	2.7	7.1	3.7	2.4	0.7	-3.3	4.2	0	5.6	3.5	6.7	4.9

Joint Research Centre

Report generated on 2021/03/02

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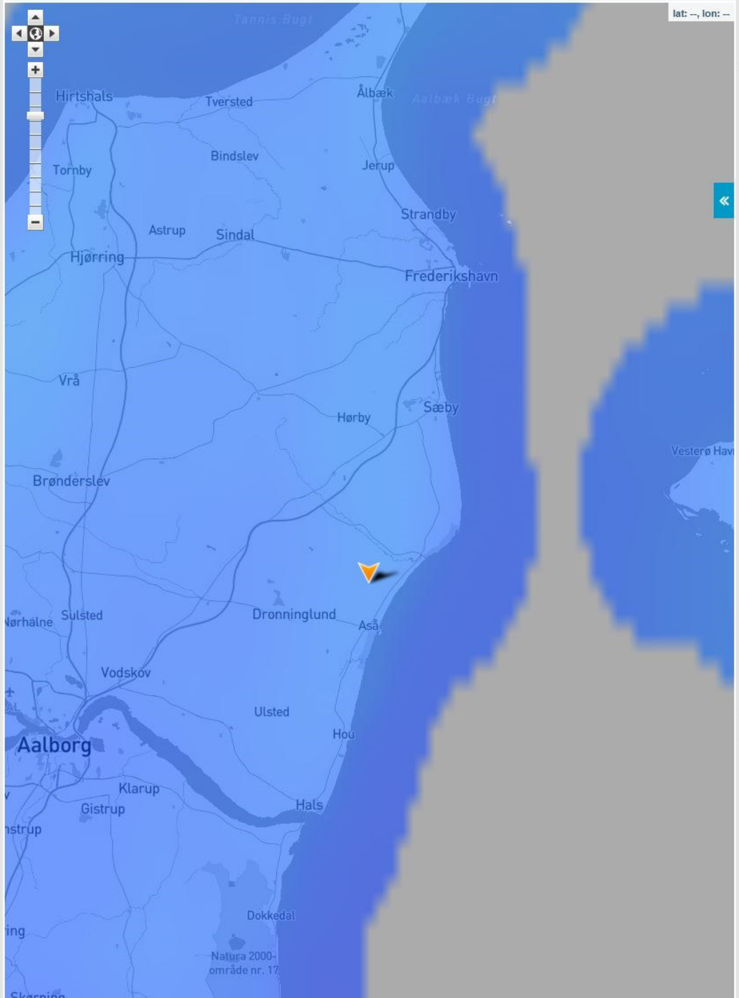
My Dashboard ▾   3TIER SUBSCRIPTIONS :: Solar Prospecting Tools

Map Controller

57.1853, 10.4072   Locate



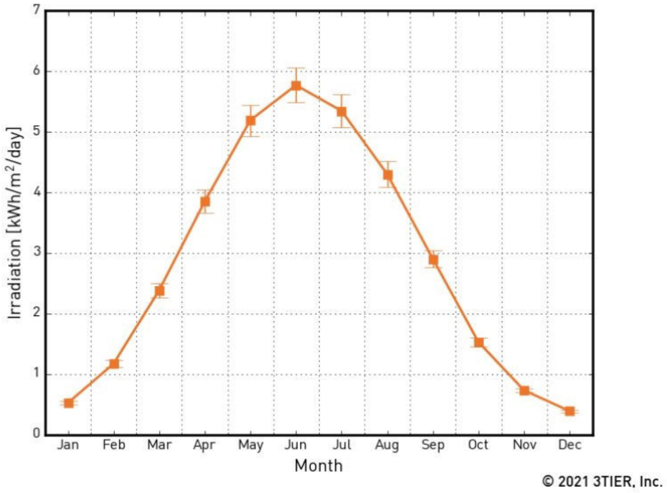
Annual Mean GHI Range: Solar Prospecting Tools

- Latitude: **57.185°** Longitude: **10.407°**

2.9 ± 0.1 kWh/m²/day

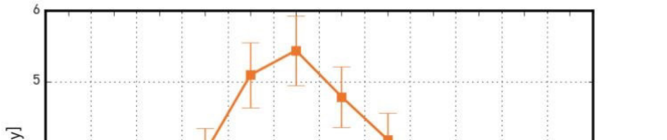
Monthly Mean GHI: Solar Prospecting Tools

- Latitude: **57.185°** Longitude: **10.407°**
- Your highest GHI month is: **June**
- Your lowest GHI month is: **December**



Monthly Mean DNI: Solar Prospecting Tools

- Latitude: **57.185°** Longitude: **10.407°**
- Your highest DNI month is: **June**
- Your lowest DNI month is: **December**



Annual Mean Diffuse Range: Solar Prospecting Tools

- Latitude: **57.185°** Longitude: **10.407°**

1.4 ± 0.2 kWh/m²/day

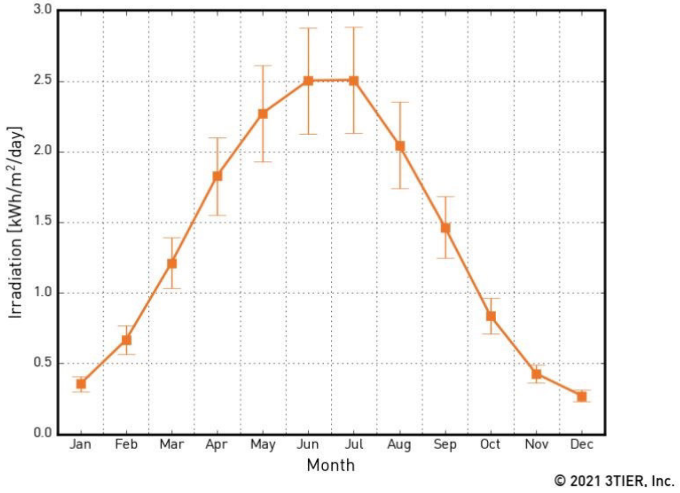
Annual Mean DNI Range: Solar Prospecting Tools

- Latitude: **57.185°** Longitude: **10.407°**

3.1 ± 0.3 kWh/m²/day

Monthly Mean Diffuse: Solar Prospecting Tools

- Latitude: **57.185°** Longitude: **10.407°**
- Your highest Diffuse month is: **July**
- Your lowest Diffuse month is: **December**



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Statement

For the sources **MeteoNorm time series**, **HelioClim** and **DMI** no printable reports exist.

MeteoNorm time series covers the single years 2008 – 2020. HelioClim-3 provides monthly irradiation sums of the period February 2004 to January 2021. The DMI offers monthly values of the irradiation from 2001 to 2020.

Version 7.1.8

PVsyst - Simulation report

Grid-Connected System

Project: Agersted

Variant: Agersted

Tracking system with backtracking

System power: 30.83 MWp

Agersted - Denmark

Autor

SolPEG GmbH (Germany)

Project summary

Geographical Site	Situation		Project settings	
Agersted	Latitude	57.19 °N	Albedo	0.20
Denmark	Longitude	10.41 °E		
	Altitude	8 m		
	Time zone	UTC+1		

Meteo data
Agersted
SolPEG 2021 - Synthetic

System summary

Grid-Connected System — **Tracking system with backtracking**

PV Field Orientation		Near Shadings		User's needs
Tracking plane, horizontal N-S axis		According to strings		Unlimited load (grid)
Axis azimuth	0 °	Electrical effect	100 %	

System information

PV Array		Inverters	
Nb. of modules	52608 units	Nb. of units	112 units
Pnom total	30.83 MWp	Pnom total	25.20 MWac
		Pnom ratio	1.223

Results summary

Produced Energy	41870 MWh/year	Specific production	1358 kWh/kWp/year	Perf. Ratio PR	95.63 %

Table of contents

General parameters

Grid-Connected System — **Tracking system with backtracking**

PV Field Orientation

Orientation

Tracking plane, horizontal N-S axis	
Axis azimuth	0 °

Backtracking strategy

Nb. of trackers	1026 units
Sizes	
Tracker Spacing	4.80 m
Collector width	2.17 m
Ground Cov. Ratio (GCR)	45.2 %
Phi min / max	-/+ 55.0 °
Backtracking limit angle	
Phi limits	+/- 62.9 °

Models used

Transposition	Perez
Diffuse	Perez, Meteonorm
Circumsolar	separate

Horizon

Free Horizon

Near Shadings

According to strings	
Electrical effect	100 %

User's needs

Unlimited load (grid)

Bifacial system

Model	2D Calculation unlimited trackers

Bifacial model geometry

Tracker Spacing	4.80 m
Tracker width	2.21 m
Backtracking limit angle	62.4 °
GCR	46.1 %
Axis height above ground	1.50 m

Bifacial model definitions

Ground albedo	0.20
Bifaciality factor	70 %
Rear shading factor	2.0 %
Rear mismatch loss	4.0 %
Module transparency	7.0 %

PV Array Characteristics

Array #1 - 590 Wp 14 S/INV

PV module

Manufacturer	Risen Energy Co., Ltd
Model	RSM120-8-590BMDG
(Custom parameters definition)	
Unit Nom. Power	590 Wp
Number of PV modules	10304 units
Nominal (STC)	6079 kWp
Modules	322 Strings x 32 In series
At operating cond. (50°C)	
Pmpp	5565 kWp
U mpp	1000 V
I mpp	5564 A

Inverter

Manufacturer	Sungrow
Model	SG250HX incl. MPPT effic.
(Custom parameters definition)	
Unit Nom. Power	225 kWac
Number of inverters	23 units
Total power	5175 kWac
Operating voltage	600-1500 V
Max. power (=>30°C)	250 kWac
Pnom ratio (DC:AC)	1.17

PV module

Manufacturer	Risen Energy Co., Ltd
Model	RSM120-8-585BMDG
(Custom parameters definition)	
Unit Nom. Power	585 Wp
Number of PV modules	42304 units
Nominal (STC)	24.75 MWp

Inverter

Manufacturer	Sungrow
Model	SG250HX incl. MPPT effic.
(Custom parameters definition)	
Unit Nom. Power	225 kWac
Number of inverters	89 units
Total power	20025 kWac

PV Array Characteristics

Array #2 - 585 Wp 15 S/INV

Number of PV modules	36480 units	Number of inverters	76 units
Nominal (STC)	21.34 MWp	Total power	17100 kWac
Modules	1140 Strings x 32 In series		
At operating cond. (50°C)		Operating voltage	600-1500 V
Pmpp	19.53 MWp	Max. power (=>30°C)	250 kWac
U mpp	995 V	Pnom ratio (DC:AC)	1.25
I mpp	19635 A		

Array #3 - 585 Wp 14 S/INV

Number of PV modules	5824 units	Number of inverters	13 units
Nominal (STC)	3407 kWp	Total power	2925 kWac
Modules	182 Strings x 32 In series		
At operating cond. (50°C)		Operating voltage	600-1500 V
Pmpp	3118 kWp	Max. power (=>30°C)	250 kWac
U mpp	995 V	Pnom ratio (DC:AC)	1.16
I mpp	3135 A		

Total PV power		**Total inverter power**	
Nominal (STC)	30827 kWp	Total power	25200 kWac
Total	52608 modules	Nb. of inverters	112 units
Module area	148887 m²	Pnom ratio	1.22
Cell area	139201 m²		

Array losses

Array Soiling Losses

Average loss Fraction 1.6 %

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
6.5%	2.0%	1.0%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	1.5%	5.0%

Thermal Loss factor

Module temperature according to irradiance
Uc (const) 29.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

LID - Light Induced Degradation

Loss Fraction 1.0 %

Module Quality Loss

Loss Fraction -0.1 %

Module mismatch losses

Loss Fraction 0.3 % at MPP

IAM loss factor

Incidence effect (IAM): User defined profile

0°	20°	40°	60°	70°	75°	80°	85°	90°
1.000	1.000	1.000	1.000	0.992	0.978	0.946	0.850	0.000

Spectral correction

FirstSolar model
Precipitable water estimated from relative humidity

Coefficient Set	C0	C1	C2	C3	C4	C5
Monocrystalline Si	0.85914	-0.02088	-0.0058853	0.12029	0.026814	-0.001781

DC wiring losses

Global wiring resistance 0.43 mΩ
Loss Fraction 1.1 % at STC

Array #1 - 590 Wp 14 S/INV

Global array res. 2.2 mΩ
Loss Fraction 1.1 % at STC

Array #2 - 585 Wp 15 S/INV

Global array res. 0.62 mΩ
Loss Fraction 1.1 % at STC

Array #3 - 585 Wp 14 S/INV

Global array res. 3.9 mΩ
Loss Fraction 1.1 % at STC

AC wiring losses

Inv. output line up to MV transfo

Inverter voltage 800 Vac tri
Loss Fraction 0.7 % at STC

Inverter: SG250HX incl. MPPT effic.

Wire section (112 Inv.) Copper 112 x 3 x 95 mm²
Average wires length 83 m

MV line up to Injection

MV Voltage 20 kV
Wires Copper 3 x 700 mm²
Length 4829 m
Loss Fraction 1.0 % at STC

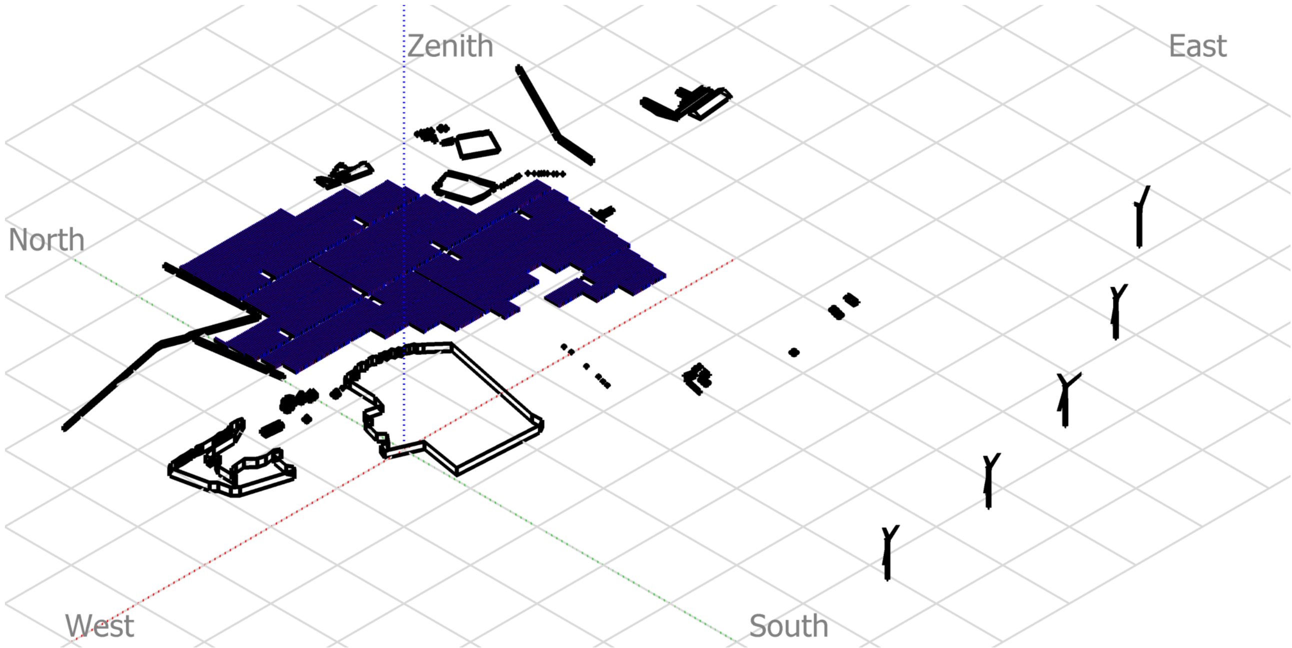
AC losses in transformers

MV transfo

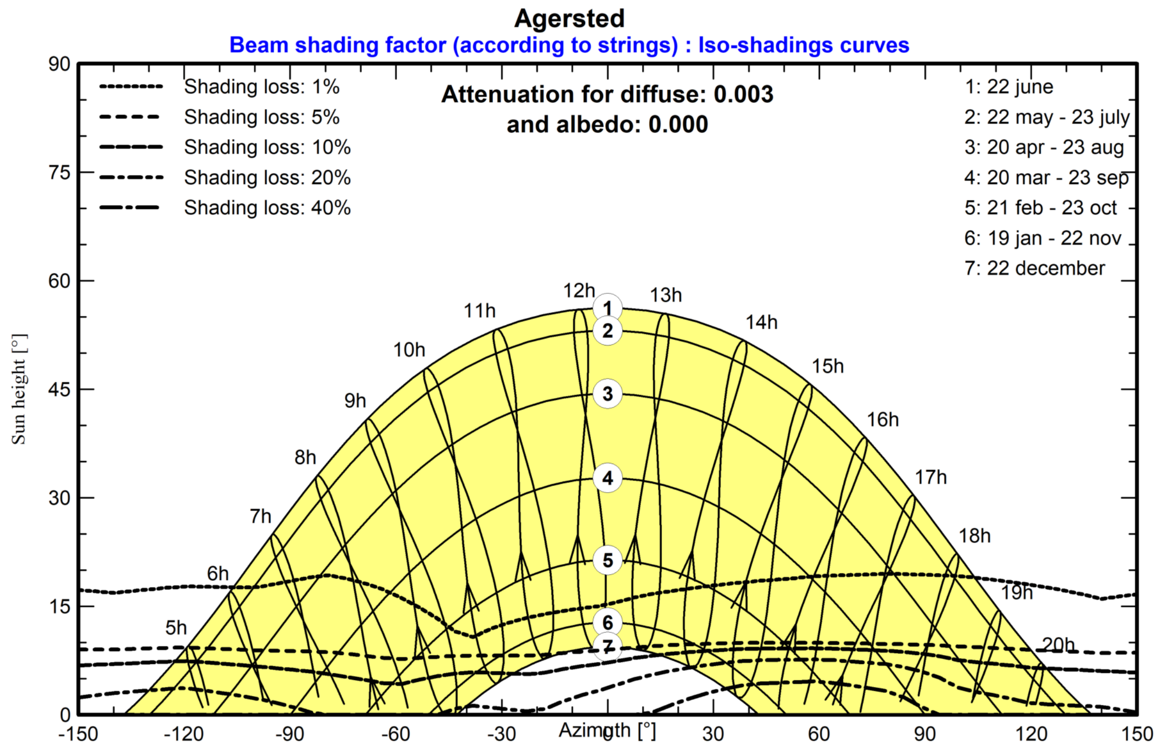
Grid Voltage	20 kV		
Transformer from Datasheets		**Operating losses at STC**	
Nominal power	28000 kVA	Nominal power at STC (PNomac)	30225 kVA
Iron loss	20.0 kVA	Iron loss (night disconnect)	20.00 kW
Loss Fraction	0.1 % of PNom	Loss Fraction	0.1 % at STC
Copper loss	224.0 kVA	Coils equivalent resistance	3 x 0.18 mΩ
Loss Fraction	0.8 % of PNom	Loss Fraction	0.9 % at STC

Near shadings parameter

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram



Main results

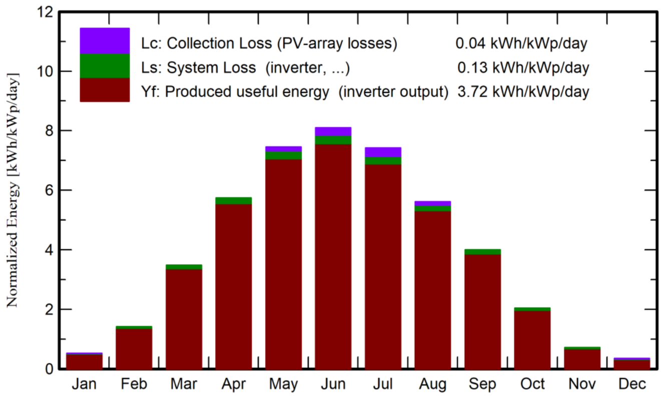
System Production

Produced Energy 41870 MWh/year

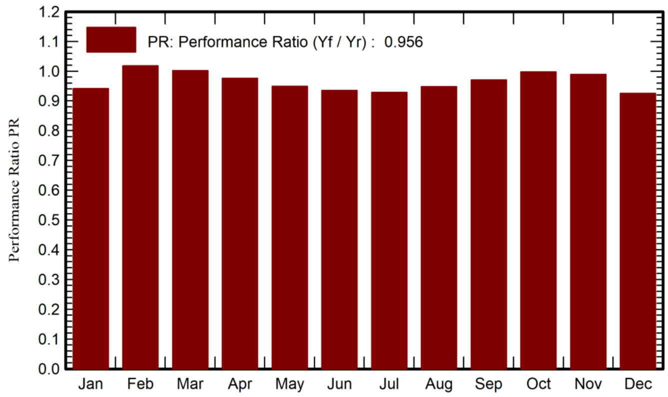
Specific production 1358 kWh/kWp/year

Performance Ratio PR 95.63 %

Normalized productions (per installed kWp)



Performance Ratio PR



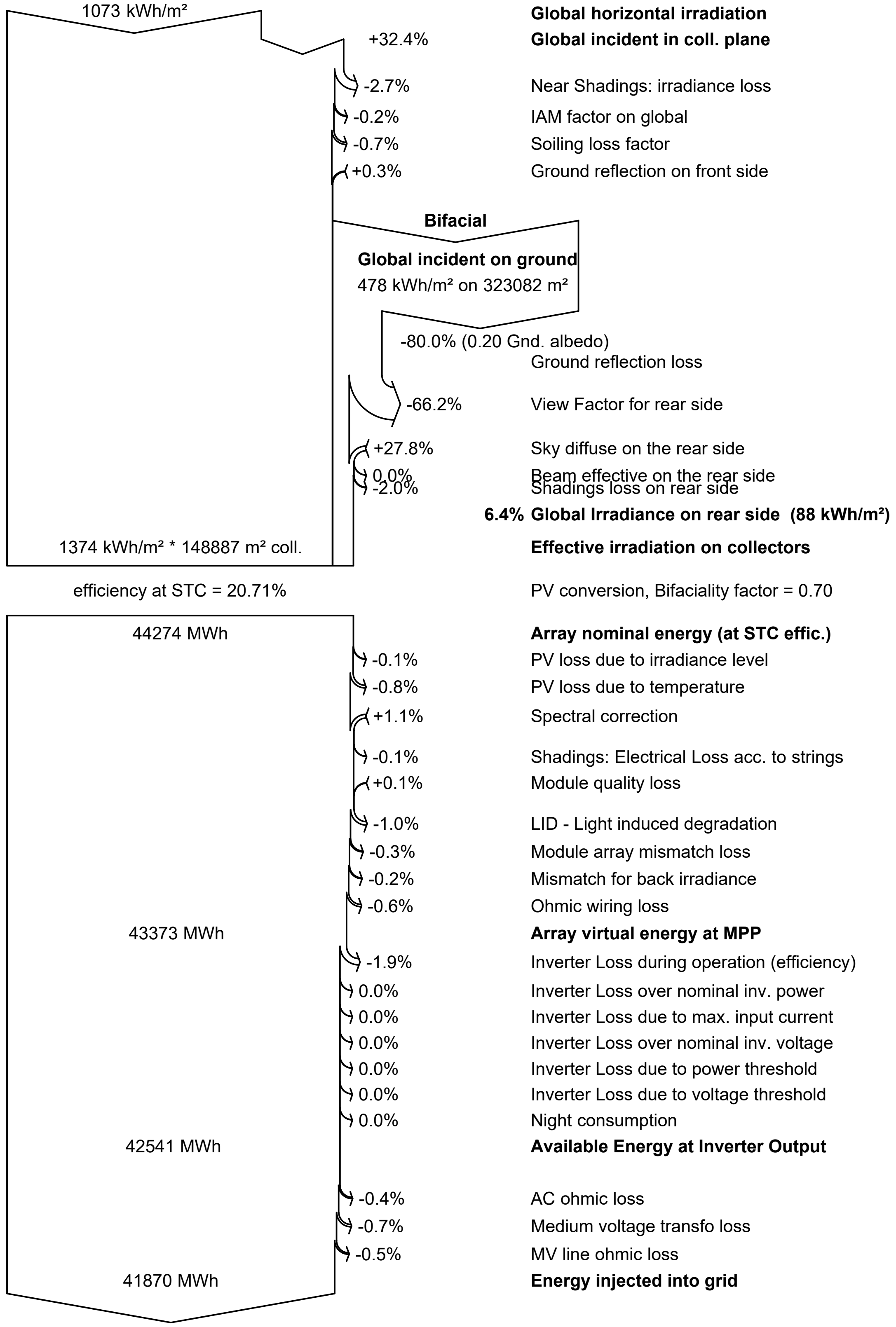
Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	13.1	8.94	1.36	16.3	14.5	496	474	0.941
February	29.9	19.08	1.06	37.6	35.5	1218	1181	1.018
March	78.2	36.04	3.08	104.6	100.8	3332	3229	1.002
April	128.0	56.57	7.28	170.9	166.0	5314	5138	0.975
May	171.6	73.12	11.46	231.0	224.7	7007	6759	0.949
June	181.6	73.74	14.56	243.0	236.5	7271	7004	0.935
July	173.0	77.78	17.35	230.0	223.4	6831	6586	0.929
August	136.1	70.25	16.99	174.1	168.6	5263	5087	0.948
September	89.9	44.46	13.72	119.7	115.9	3700	3582	0.971
October	46.0	25.93	9.46	61.4	59.1	1948	1888	0.998
November	16.6	11.08	5.71	20.9	19.5	661	636	0.988
December	8.9	6.78	2.11	10.7	9.5	324	306	0.925
Year	1072.9	503.78	8.72	1420.2	1374.1	43366	41870	0.956

Legends

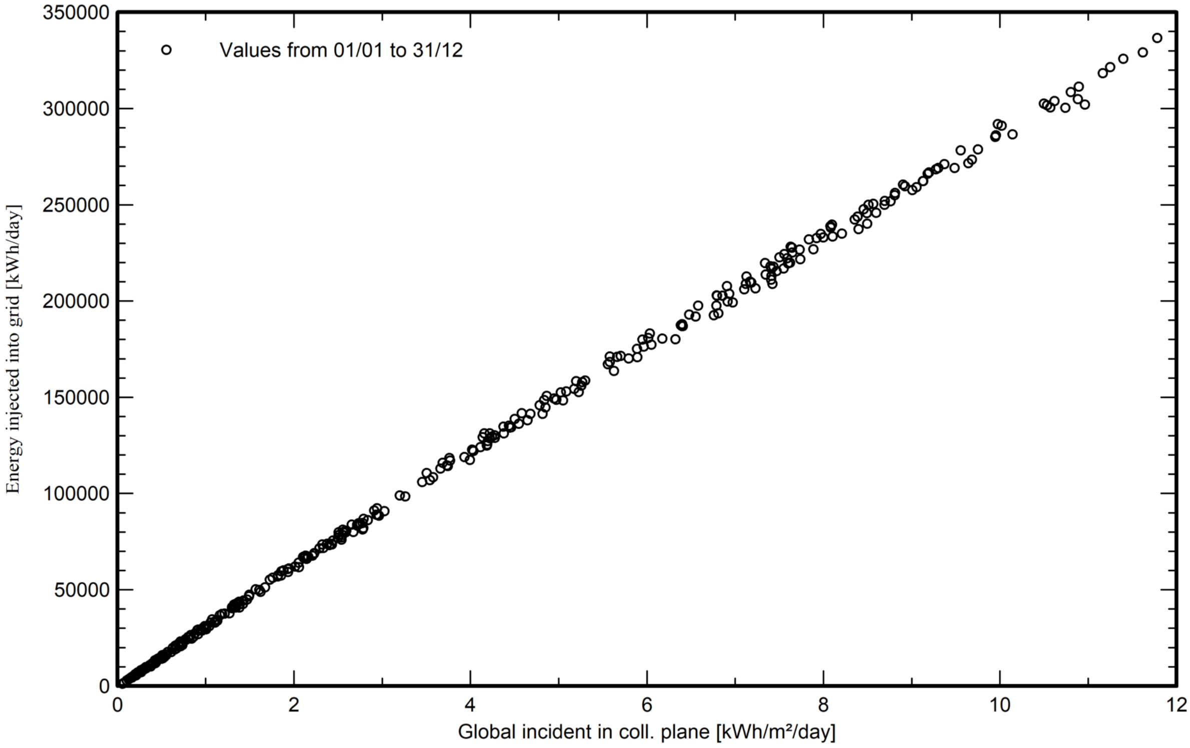
GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

Loss diagram



Special graphs

Daily Input/Output diagram



System Output Power Distribution