COMUNE DI BRINDISI

REGIONE PUGLIA

AREA METROPOLITANA BRINDISI

PROGETTO RELATIVO ALLA COSTRUZIONE ED ESERCIZIO DI UN IMPIANTO AGROVOLTAICO AVENTE POTENZA IN IMMISSIONE PARI A 11,22 MW E POTENZA MODULI PARI A 12,14 MWP CON RELATIVO COLLEGAMENTO ALLA RETE ELETTRICA - IMPIANTO AEPV12 UBICATO IN AGRO DEL COMUNE DI BRINDISI LOCALITÀ C.DA LA MACCHIA

ELABORATO:

PRODUZIONE DI ENERGIA

IDENTIFICAZIONE ELABORATO								
Livello Prog.	Codice Rintracciabilità	Tipo Doc.	Sez. Elaborato	N° Foglio	Tot. Fogli	N° Elaborato	DATA	SCALA
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REV	DATA	DESCRIZIONE	ESEGUITO	VERIFICATO	APPROVATO
01	[...]	[...]	IVC	N/A	N/A

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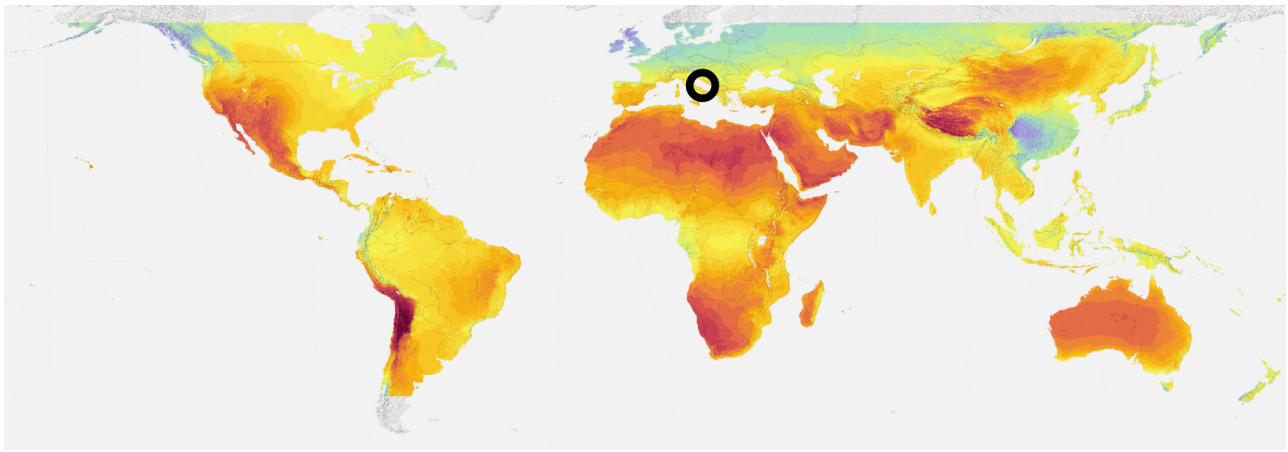
SOLARGIS PROSPECT



Preliminary assessment of the photovoltaic electricity production

Project: AEPV12 (Italy)

Geographical coordinates	40.600313°,017.935947° (40°36'01", 017°56'09")
Report number	P-sg2|16434-2021-06-21-1421
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Contents

1 Overview

Table 1.1: Yearly average

Specific photovoltaic power output	PVOUT_specific	1742.3	kWh/kWp
Total photovoltaic power output	PVOUT_total	21.151	GWh
Global tilted irradiation	GTI	2114.0	kWh/m^2
Performance ratio	PR	82.4	%
Global horizontal irradiation	GHI	1647.9	kWh/m^2
Direct normal irradiation	DNI	1706.0	kWh/m^2
Diffuse horizontal irradiation	DIF	619.9	kWh/m^2
Air temperature	TEMP	17.6	°C

2 Project info

Project name	AEPV12
Address	Strada Fra' Vito, Brindisi, Apulia, Italy
Geographical coordinates	40.600313°,017.935947° (40°36'01", 017°56'09")
Time zone	UTC+01, Europe/Rome [CET], Daylight saving time not considered
Elevation	32 m
Land cover	Cropland, rainfed
Population density	269 inh./km^2
Terrain azimuth	flat
Terrain slope	0°
Location on the map	https://apps.solargis.com/prospect/map?c=40.600313,17.935947,10&s=40.600313,17.935947

Figure 2.1: Project location

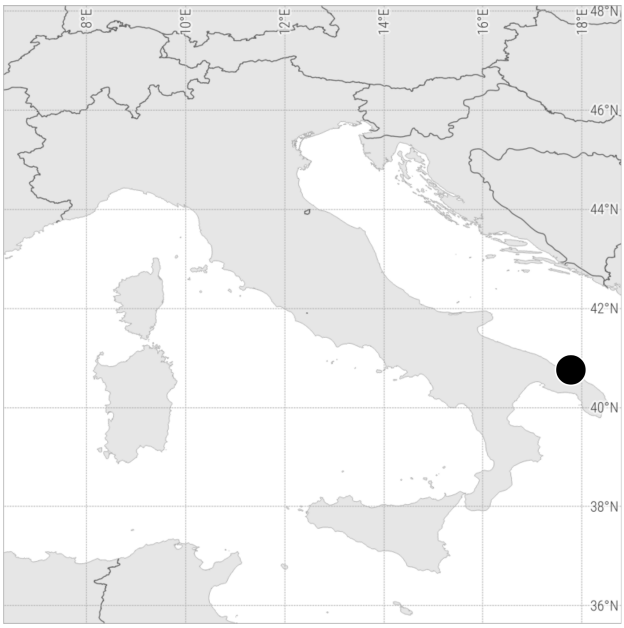


Figure 2.2: Detailed map view

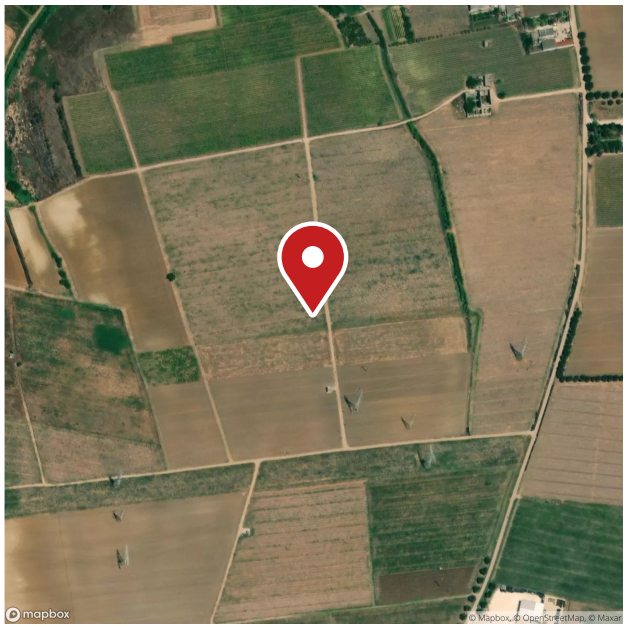


Figure 2.3: Project horizon and sunpath

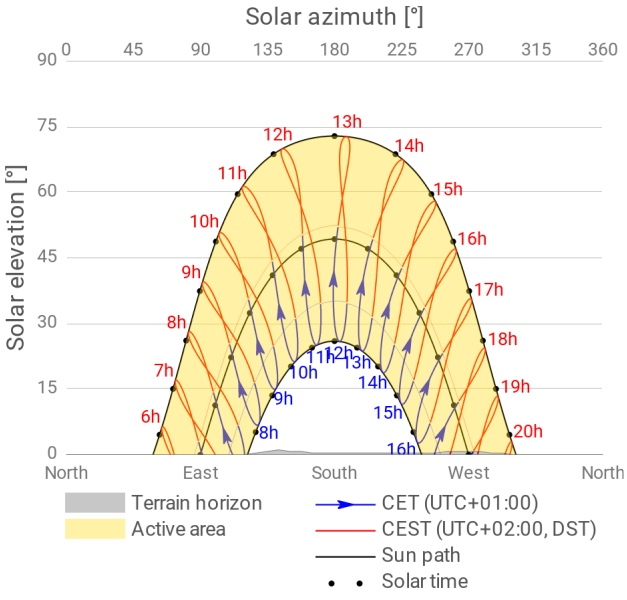
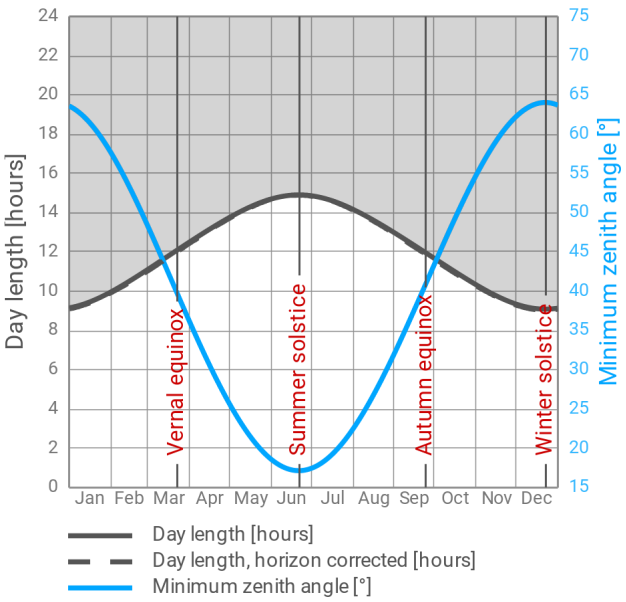


Figure 2.4: Day length and solar zenith angle



3 PV system configuration

Tracker with 1 horizontal axis

Large-scale commercial photovoltaic system mounted on leveled ground. PV modules are mounted on trackers with one horizontal axis North-South bound. Rotation limits for tracker are given for both East and West directions. Backtracking algorithm is used for reduction of shading loses between rows during low sun angles. The modules are well ventilated. This type of PV system is connected to a medium- or high-voltage grid through an inverter and distribution transformer, and an additional transformer may also be used. No electricity storage is considered.

System size	Installed capacity: 12.14MWp
PV module type	c-Si - crystalline silicon (mono or polycrystalline)
Backtracking	Enabled
Rotation limits	-60° East , 60° West
Relative column spacing	2.5
Inverter type	Centralized high-efficiency inverter [97.8% Euro efficiency]
Transformer type	High efficiency transformer [0.9% loss]
Snow and soiling losses at PV modules	Monthly soiling losses up to 1.0 % • Monthly snow losses up to 0.0 %
Cabling losses	DC cabling 2 % • DC mismatch 0.3 % • AC cabling 1 %
System availability	99 %

Table 3.1: Snow and soiling losses at PV modules

	Jan %	Feb %	Mar %	Apr %	May %	Jun %	Jul %	Aug %	Sep %	Oct %	Nov %	Dec %
Soiling losses	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Snow losses	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4 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 4.1: Solar radiation and meteorological parameters

Month	GHI kWh/m^2	DNI kWh/m^2	DIF kWh/m^2	D2G	TEMP °C	WS m/s	CDD degree days	HDD degree days
Jan	60.5	87.6	28.3	0.468	10.3	5.8	0	240
Feb	77.4	93.9	34.9	0.451	10.5	5.9	0	205
Mar	127.9	134.4	52.1	0.407	12.3	5.7	0	169
Apr	158.9	142.5	65.2	0.410	15.1	5.1	3	87
May	203.3	182.9	74.0	0.364	19.5	4.3	56	14
Jun	222.1	208.6	72.9	0.328	23.8	4.3	170	0
Jul	234.6	235.7	67.6	0.288	26.5	4.6	243	0
Aug	203.5	205.6	64.7	0.318	26.4	4.2	252	0
Sep	142.4	141.1	57.5	0.404	22.5	4.4	138	0
Oct	101.9	112.4	45.9	0.451	18.6	4.8	35	13
Nov	63.0	80.6	31.6	0.501	14.8	5.6	1	96
Dec	52.4	80.5	25.3	0.482	11.4	5.8	0	209
Yearly	**1647.9**	**1706.0**	**619.9**	**0.376**	**17.6**	**5.0**	**898**	**1032**

Table 4.2: Other meteorological parameters

Month	ALB	RH %	PWAT kg/m^2	PREC mm
Jan	0.17	77	14	68
Feb	0.17	76	13	62
Mar	0.17	74	14	66
Apr	0.17	73	17	40
May	0.17	69	21	30
Jun	0.17	63	26	20
Jul	0.17	59	27	17
Aug	0.17	60	29	26
Sep	0.17	65	27	45
Oct	0.16	73	23	72
Nov	0.16	76	19	81
Dec	0.16	76	15	72
Yearly	**0.17**	**70**	**20**	**599**

Figure 4.1: Global + diffuse horizontal irradiation

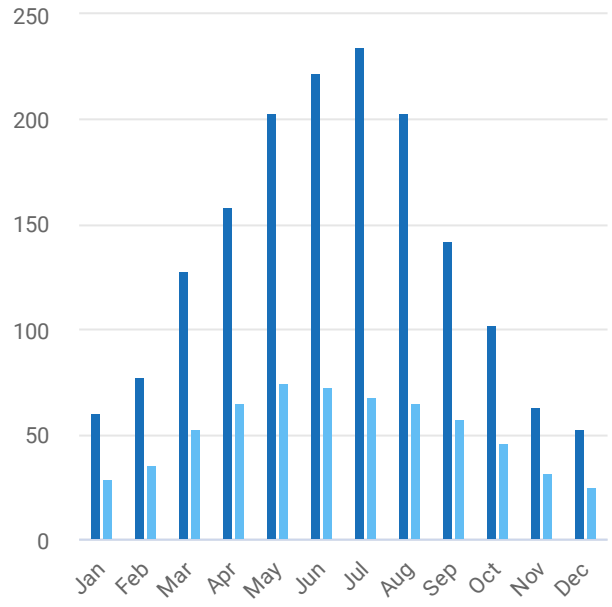


Figure 4.2: Direct normal irradiation

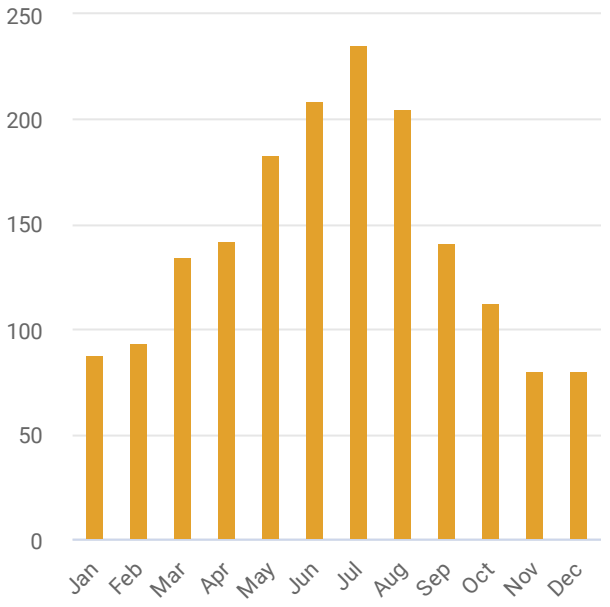


Figure 4.3: Ratio of diffuse to global irradiation

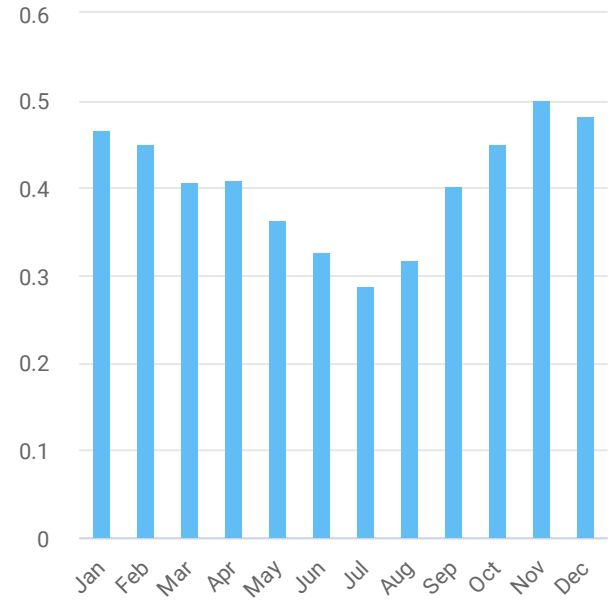


Figure 4.4: Air temperature

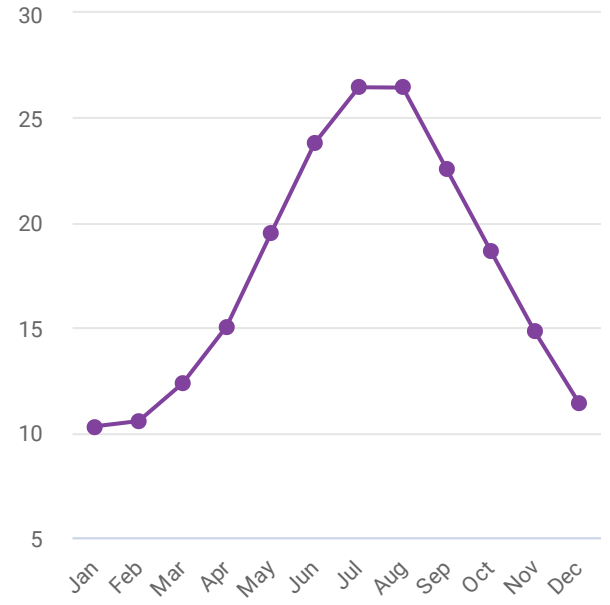


Figure 4.5: Surface albedo

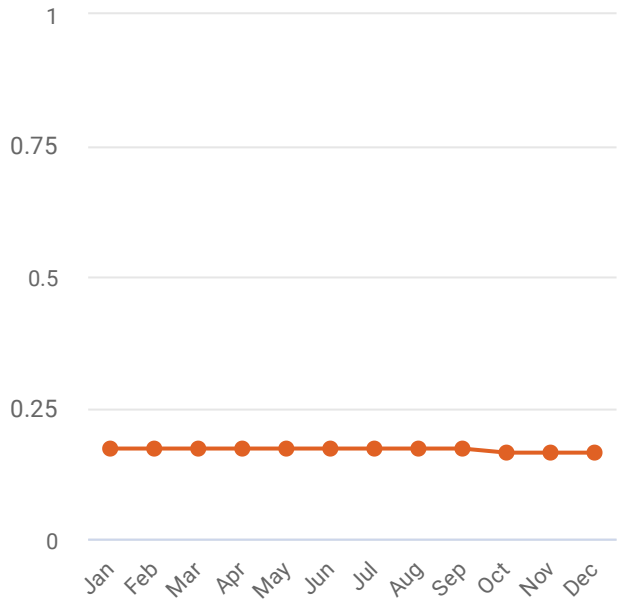


Figure 4.6: Wind speed

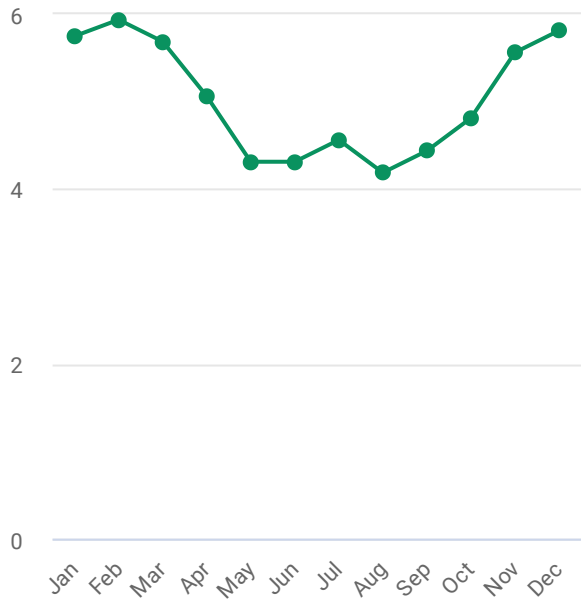


Figure 4.7: Relative humidity

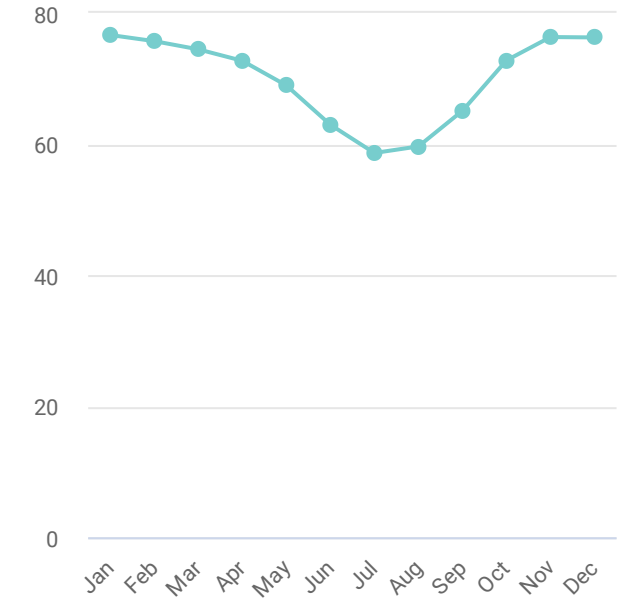


Figure 4.8: Precipitation (rainfall)

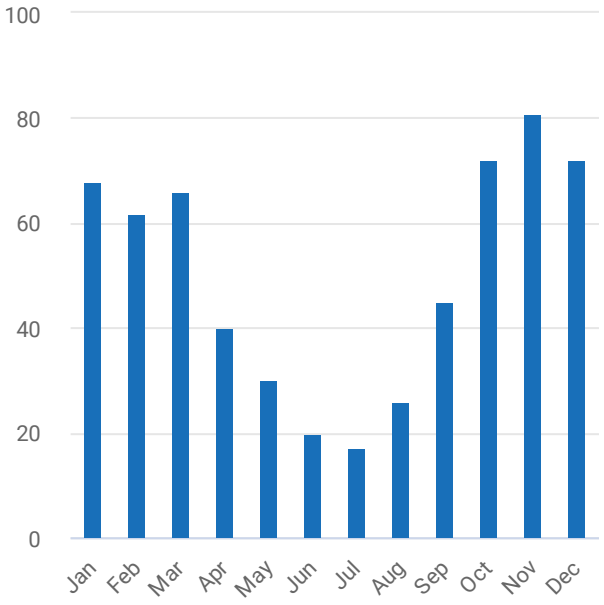


Figure 4.9: Precipitable water

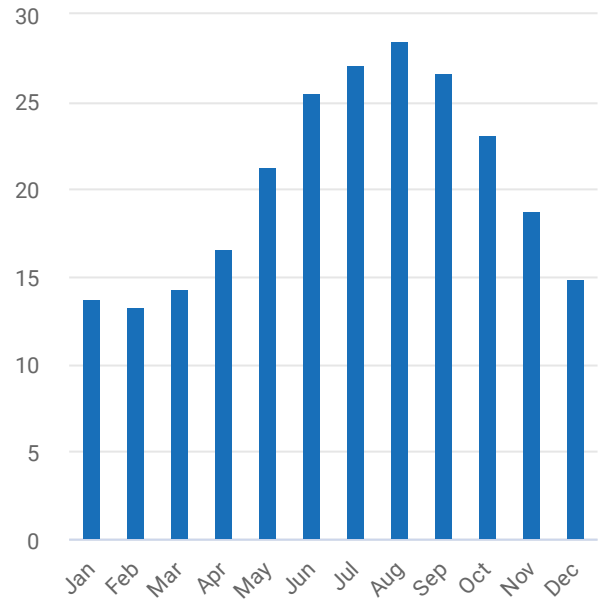


Figure 4.10: Snow days

Figure 4.11: Cooling degree days

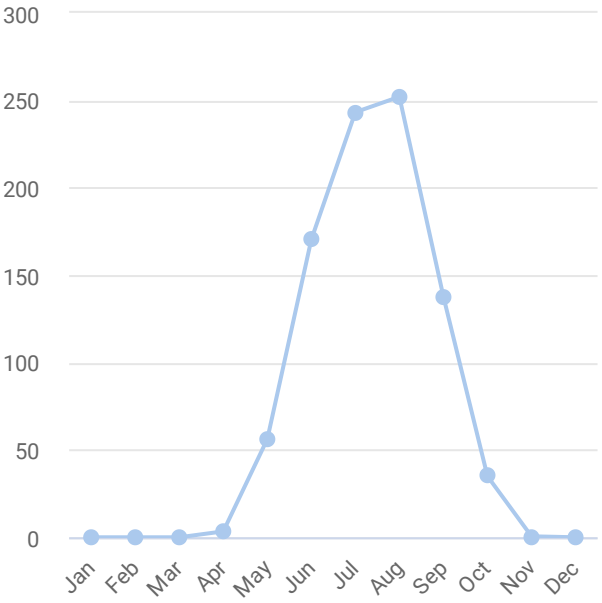
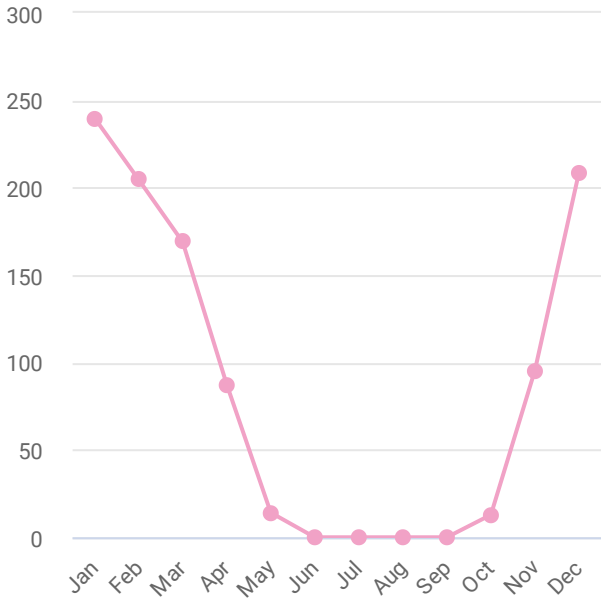


Figure 4.12: Heating degree days



5 PV electricity: Monthly statistics

Theoretical estimate of solar electricity production by a photovoltaic system without considering the long-term ageing and performance degradation of PV modules and other system components.

Table 5.1: PV power output – long-term averages

Month	GTI Monthly sum kWh/m^2	GTI Daily average Wh/m^2	PVOUT specific Monthly sum kWh/kWp	PVOUT specific Daily average Wh/kWp	PVOUT total Monthly sum GWh	PVOUT total Daily average MWh	PR %
Jan	78.9	2545	69.2	2232.7	0.840	27.105	87.7
Feb	100.2	3578	87.6	3127.6	1.063	37.969	87.4
Mar	164.5	5307	141.0	4547.9	1.712	55.211	85.7
Apr	199.9	6665	167.4	5580.0	2.032	67.741	83.7
May	256.4	8270	209.4	6756.4	2.543	82.022	81.7
Jun	282.5	9416	226.1	7537.1	2.745	91.501	80.0
Jul	303.8	9801	240.2	7749.5	2.916	94.079	79.1
Aug	264.5	8532	210.5	6790.1	2.555	82.432	79.6
Sep	183.6	6120	150.9	5029.5	1.832	61.058	82.2
Oct	130.5	4210	110.6	3566.2	1.342	43.294	84.7
Nov	80.9	2696	69.9	2329.3	0.848	28.278	86.4
Dec	68.2	2201	59.5	1919.7	0.722	23.305	87.2
Yearly	**2114.0**	**5778**	**1742.3**	**4763.8**	**21.151**	**57.833**	**82.4**

Figure 5.1: Specific photovoltaic power output

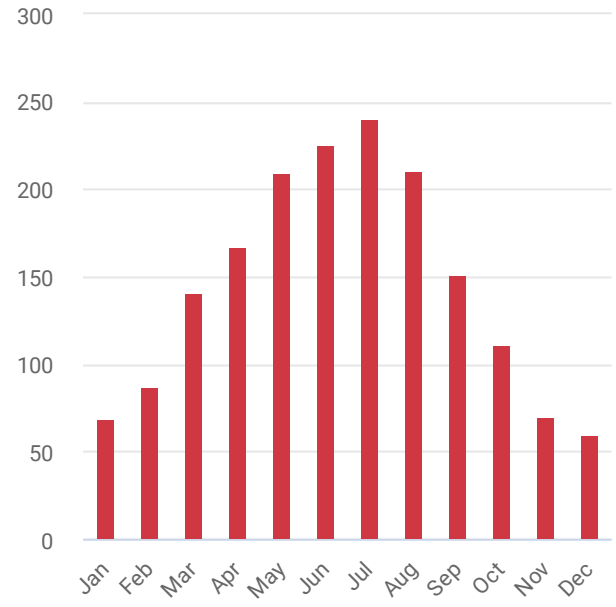


Figure 5.2: Global tilted irradiation

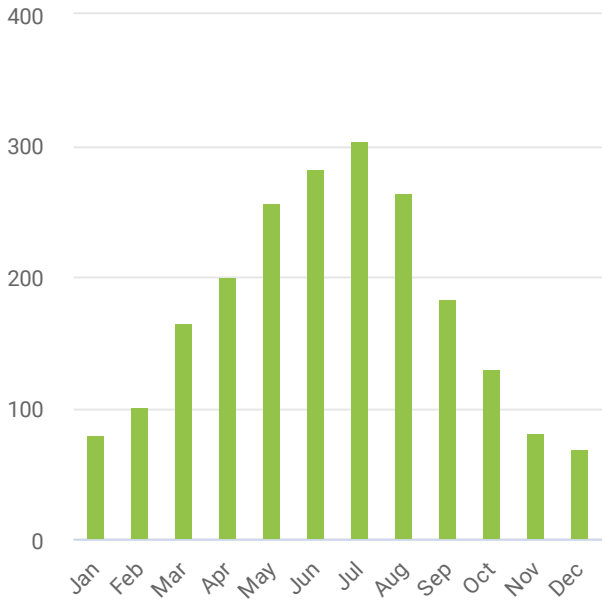
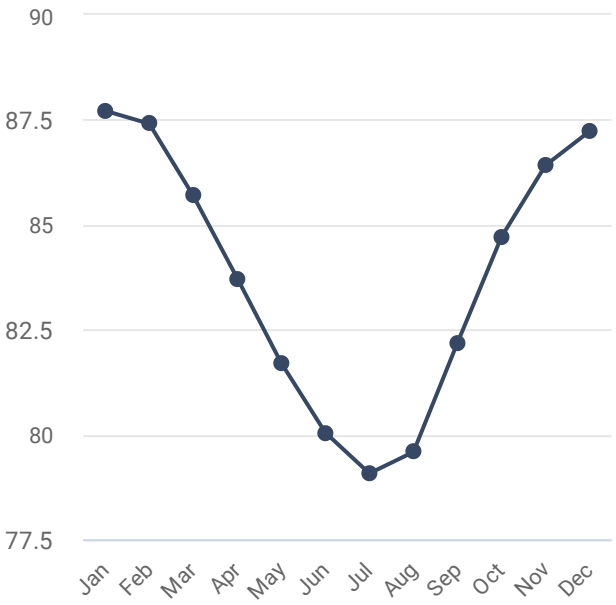


Figure 5.3: Performance ratio



6 PV electricity: Hourly profiles

PV power production profiles, shown below, are calculated as an average of all hourly data for each month. The profiles give an indication of changing power production patterns due to weather and the selected configuration of a PV system in the course of a day. It should be noted that the “average daily profile” is a theoretical concept, as in the majority of cases a profile is specific for each individual day of the year due to weather variability.

Figure 6.1: Specific photovoltaic power output – hourly averages

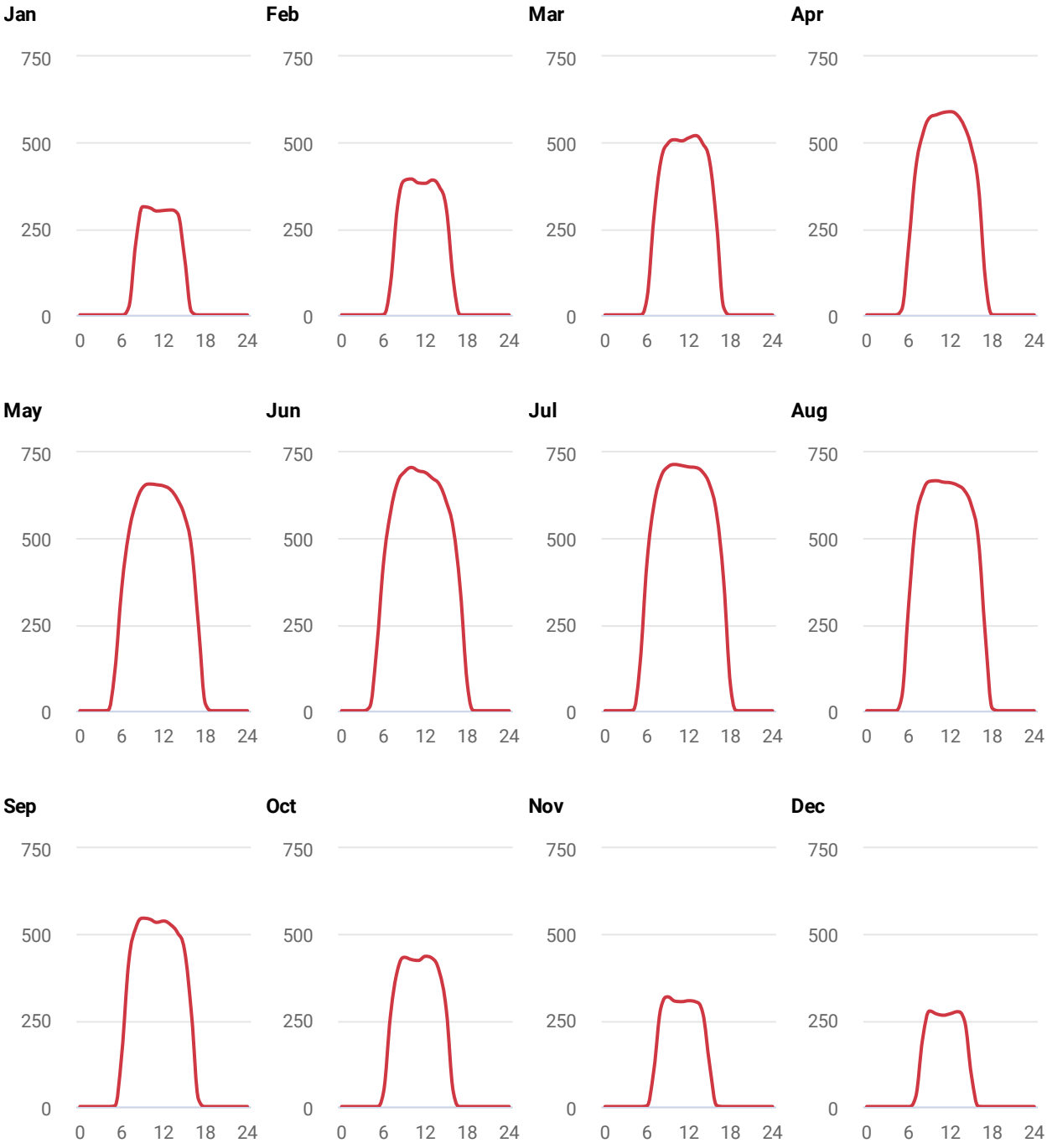


Table 6.1: Specific photovoltaic power output – hourly averages [Wh/kWp]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1	-	-	-	-	-	-	-	-	-	-	-	-
1 - 2	-	-	-	-	-	-	-	-	-	-	-	-
2 - 3	-	-	-	-	-	-	-	-	-	-	-	-
3 - 4	-	-	-	-	-	-	-	-	-	-	-	-
4 - 5	-	-	-	-	0.9	10.2	1.3	-	-	-	-	-
5 - 6	-	-	0.3	15.1	113.6	174.8	132.3	38.0	1.9	-	-	-
6 - 7	-	0.9	47.0	200.6	357.6	428.7	428.1	306.5	152.9	41.6	2.0	-
7 - 8	22.5	89.5	282.9	422.2	514.6	574.6	596.4	545.0	421.0	264.5	106.5	26.9
8 - 9	207.8	314.0	447.1	522.8	601.3	662.4	678.6	634.4	518.2	395.3	286.1	195.8
9 - 10	314.0	390.2	497.5	572.3	647.9	693.2	707.7	666.0	547.0	433.3	318.5	277.4
10 - 11	310.9	394.6	508.5	581.0	658.2	706.3	715.0	667.8	544.1	426.7	306.1	268.9
11 - 12	301.5	383.1	505.2	587.7	656.1	696.5	711.9	663.6	534.8	424.2	304.6	265.2
12 - 13	303.2	382.0	514.2	589.9	652.5	691.5	707.9	661.8	538.7	436.2	307.3	269.6
13 - 14	304.6	391.5	520.6	579.5	641.5	675.0	706.0	654.7	528.0	430.0	304.1	275.4
14 - 15	294.1	372.0	497.2	546.1	612.7	657.1	692.4	639.2	504.3	391.2	272.0	249.6
15 - 16	165.0	308.8	444.2	485.7	565.1	606.3	655.4	595.8	452.6	280.3	118.9	90.3
16 - 17	9.1	100.9	261.6	373.9	471.6	528.8	570.5	494.8	265.6	42.7	3.2	0.6
17 - 18	-	0.2	21.5	102.8	243.9	352.0	377.2	216.1	20.3	-	-	-
18 - 19	-	-	-	0.3	19.0	79.6	68.9	6.4	-	-	-	-
19 - 20	-	-	-	-	-	0.1	-	-	-	-	-	-
20 - 21	-	-	-	-	-	-	-	-	-	-	-	-
21 - 22	-	-	-	-	-	-	-	-	-	-	-	-
22 - 23	-	-	-	-	-	-	-	-	-	-	-	-
23 - 24	-	-	-	-	-	-	-	-	-	-	-	-
Sum	**2232.7**	**3127.6**	**4547.9**	**5580.0**	**6756.4**	**7537.1**	**7749.5**	**6790.1**	**5029.5**	**3566.2**	**2329.3**	**1919.7**

7 PV performance: Energy conversion and system losses

Theoretical yearly specific estimate of solar electricity production by a photovoltaic system without considering the long-term ageing and performance degradation of PV modules and other system components. Long-term average performance ratio (PR) is calculated for a start-up production of a PV system.

Table 7.1: Energy conversion and related losses

	Energy input kWh/m^2	Energy loss/gain kWh/m^2	Energy PVOUT specific kWh/kWp	Energy loss/gain kWh/kWp	Energy loss %	PR %
Global horizontal irradiation (GHI) theoretical	**1647.9**	-			-	
Horizon shading (terrain + horizon objects)	1647.9	0.0			0.0	
Global horizontal irradiation site specific	**1647.9**	**0.0**			**0.0**	
Conversion to surface of PV modules	2114.0	466.1			28.3	
Global tilted irradiation (GTI)	**2114.0**					**100.0**
Dirt, dust and soiling	2092.8	-21.1			-1.0	99.0
Angular reflectivity	2061.4	-31.4			-1.5	97.5
GTI effective	**2061.4**	**-52.6**			**-2.5**	**97.5**
Spectral correction			2074.4	13.0	0.6	98.1
Conversion of solar radiation to DC in the modules			1924.8	-149.6	-7.2	91.1
Electrical losses due to inter-row shading			1890.9	-33.9	-1.8	89.4
Power tolerance of PV modules			1890.9	0.0	0.0	89.4
Mismatch and cabling in DC section			1847.5	-43.4	-2.3	87.4
Inverters (DC/AC) conversion			1793.8	-53.7	-2.9	84.9
Transformer and AC cabling losses			1759.9	-33.9	-1.9	83.3
Total system performance (at system startup)			**1759.9**	**-301.5**	**-14.6**	**83.3**
Losses due to snow			1759.9	0.0	0.0	83.3
Technical availability			1742.3	-17.6	-1.0	82.4
Total system performance considering technical availability and losses due to snow			**1742.3**	**-17.6**	**-1.0**	**82.4**
Capacity factor			**19.9%**			

Table 7.2: Loss diagram

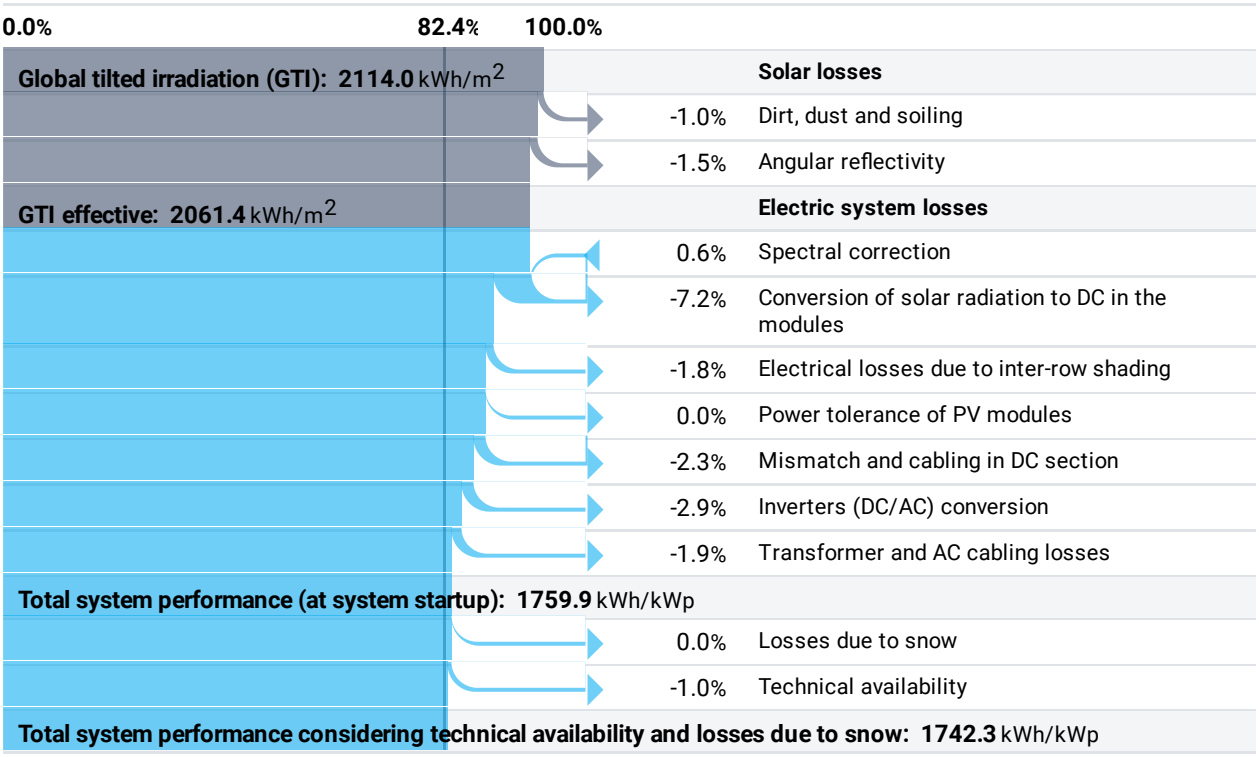


Diagram shows theoretical losses due to energy conversion in the PV power system

8 PV performance: Lifetime performance

Yearly average estimate of solar electricity production by a photovoltaic system. This value considers the PV system configuration and also takes into account the decline of system performance due to ageing and the performance degradation of PV modules and other components. The concept of specific PV power output is useful for comparing different projects or PV system configurations. Performance ratio (PR) shows the average efficiency over the lifetime of a PV system, taking into account the reduction in system performance.

Table 8.1: PV electricity production over lifetime

End of year	Degradation rate %	PVOUT specific kWh/kWp	PVOUT total kWh	PR %
Theoretical	**-**	**1742.3**	**21,151,368.8**	**82.4**
1	0.8	1728.3	20,982,157.8	81.8
2	0.5	1719.7	20,877,247.0	81.3
3	0.5	1711.1	20,772,860.8	80.9
4	0.5	1702.6	20,668,996.5	80.5
5	0.5	1694.0	20,565,651.5	80.1
6	0.5	1685.6	20,462,823.3	79.7
7	0.5	1677.1	20,360,509.1	79.3
8	0.5	1668.8	20,258,706.6	78.9
9	0.5	1660.4	20,157,413.1	78.5
10	0.5	1652.1	20,056,626.0	78.2
11	0.5	1643.9	19,956,342.9	77.8
12	0.5	1635.6	19,856,561.2	77.4
13	0.5	1627.5	19,757,278.4	77.0
14	0.5	1619.3	19,658,492.0	76.6
15	0.5	1611.2	19,560,199.5	76.2
16	0.5	1603.2	19,462,398.5	75.8
17	0.5	1595.1	19,365,086.5	75.5
18	0.5	1587.2	19,268,261.1	75.1
19	0.5	1579.2	19,171,919.8	74.7
20	0.5	1571.3	19,076,060.2	74.3
21	0.5	1563.5	18,980,679.9	74.0
22	0.5	1555.7	18,885,776.5	73.6
23	0.5	1547.9	18,791,347.6	73.2
24	0.5	1540.1	18,697,390.9	72.9
25	0.5	1532.4	18,603,903.9	72.5
Average	**0.5**	**1628.5**	**19,770,187.6**	**77.0**
Cumulative	**12.8**	**-**	**494,254,690.4**	**-**

9 Acronyms and glossary

Table 9.1: 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)
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)
ALB	Surface albedo		Fraction of solar irradiance reflected by surface. Ratio of upwelling to downwelling (GHI) radiative fluxes at the surface
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
RH	Relative humidity	%	Average yearly or monthly relative humidity at 2 m above ground
PWAT	Precipitable water	kg/m^2	Precipitable water is the depth of water vapour in a column of the atmosphere, if all the water in that column were precipitated as rain. It indicates the amount of moisture above ground
PREC	Precipitation (rainfall)	mm	Average yearly and monthly sums of precipitation
SNOWD	Snow days	days	Snow days are calculated as days with snow water depth equivalent to or higher than 5 mm
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

Acronym	Full name	Unit	Explanation
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
PVOUT specific	Specific photovoltaic power output	kWh/kWp	Yearly and monthly average values of photovoltaic electricity (AC) delivered by a PV system and normalized to 1 kWp of installed capacity
PVOUT total	Total photovoltaic power output	kWh	Yearly and monthly average values of photovoltaic electricity (AC) delivered by the total installed capacity of a PV system
PR	Performance ratio	%	Ratio between specific AC electricity output of a PV system and global tilted irradiation received by the surface of a PV array (PVOUTspecific/GTI)
GTI	Global tilted irradiation	kWh/m^2	Average annual, monthly or daily sum of global tilted irradiation
CF	Capacity factor	%	The ratio of an actual electrical energy output over a year to the maximum possible electrical energy output over a year expressed in %. The maximum possible power production is the AC installed capacity times the number of hours in a year, while the actual production is the amount of electricity delivered annually from the project.

10 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/

11 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..

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