COMUNE DI BRINDISI

REGIONE PUGLIA

AREA METROPOLITANA BRINDISI

PROGETTO PER LA REALIZZAZIONE ED ESERCIZIO DI UN IMPIANTO AGRIVOLTAICO DELLA POTENZA IN IMMISSIONE PARI A 36.52 MW E POTENZA MODULI PARI A 38.43 MWP CON RELATIVO COLLEGAMENTO ALLA RETE ELETTRICA - IMPIANTO AEPV20 UBICATO IN AGRO DEL COMUNE DI BRINDISI LOCALITA' MASSERIA AUTIGNO

ELABORATO:

PRODUZIONE DI ENERGIA

IDENTIFICAZIONE ELABORATO

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01	[...]	[...]	IVC	N/A	N/A

PROGETTAZIONE

MAYA Engineering

MAYA ENGINEERING SRLS
C.F./P.IVA 08365980724
Dott. Ing. Vito Caliò
Amministratore Unico
4, Via San Girolamo
70017 Putignano (BA)
M.: +39 328 4819015
E.: v.calio@maya-eng.com
PEC: vito.calio@ingpec.eu

Firmato digitalmente da: Vito Calio'
Limitazioni d'uso: Explicit Text: Certificate issued through Sistema Pubblico di Identità Digitale (SPID) digital identity, not usable to require other SPID digital identity
Data: 06/07/2022 11:28:39

MAYA ENGINEERING SRLS
4, Via San Girolamo
70017 Putignano (BA)
C.F./P.IVA 08365980724

(TIMBRO E FIRMA)

TECNICO SPECIALISTA

Dott. Ing. Vito Caliò
4, Via San Girolamo
70017 Putignano (BA)
M.: + 39 328 4819015
E.: v.calio@maya-eng.com

ORDINE DEGLI INGEGNERI PROVINCIA DI BARI
INGEGNERE VITO CALIO'
Sez. A - 6566
a) CIVILE AMBIENTALE b) INDUSTRIALE c) DELL'INFORMAZIONE

(TIMBRO E FIRMA)

SPAZIO RISERVATO AGLI ENTI

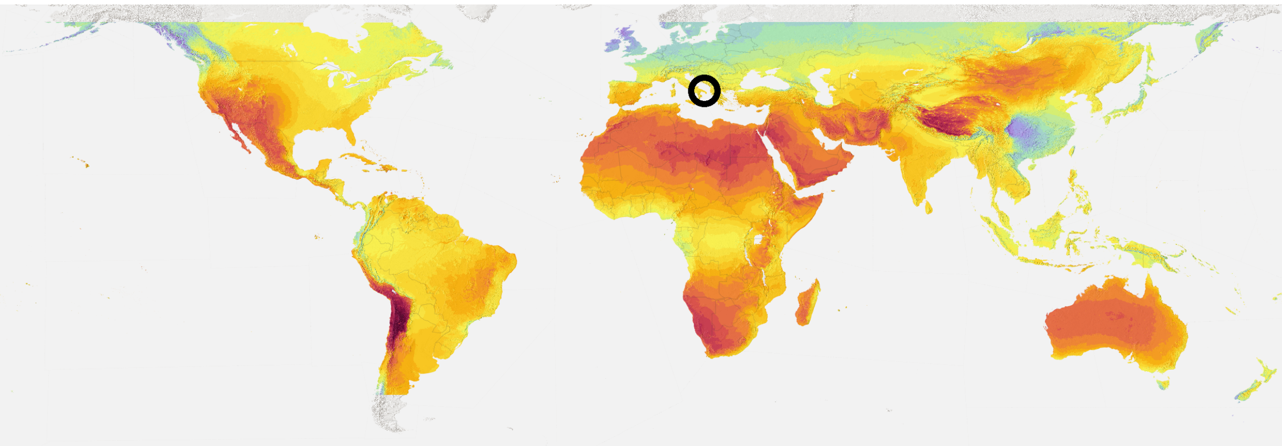
RICHIEDENTE

BRINDISI SOLAR ENERGY S.R.L.
C.F./P.IVA 10812770963
Piazza Generale Armando Diaz, 7
20123 Milano (MI)
E.: brindisisolarenergy@legalmail.it

DI PASCALE GIOVANNI
08.07.2022 11:00:00 GMT+01:00

(TIMBRO E FIRMA PER BENESTARE)

SOLARGIS PROSPECT



Preliminary assessment of the photovoltaic electricity production

Project: AEPV20 (36.5 MW, fixed 20deg) (Italy)

Geographical coordinates	40.636525, 17.758327 (40°38'11", 17°45'30")
Report number	P-sg2|16434-2020-09-14-0449
Report generated	2020-09-14
Generated by	Solargis
Customer	Maya Engineering SRLS (Italy)

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

Specific photovoltaic power output	PVOUT_specific	1503	kWh/kWp
Total photovoltaic power output	PVOUT_total	54.899	GWh
Global tilted irradiation	GTI	1840	kWh/m^2
Performance ratio	PR	81.7	%
Global horizontal irradiation	GHI	1631	kWh/m^2
Direct normal irradiation	DNI	1684	kWh/m^2
Diffuse horizontal irradiation	DIF	620	kWh/m^2
Air temperature	TEMP	17.2	°C

2 Project info

Project name	AEPV20 (36.5 MW, fixed 20deg)
Address	Strada Comunale 41, San Vito dei Normanni, Apulia, Italy
Geographical coordinates	40.636525, 17.758327 (40°38'11", 17°45'30")
Time zone	UTC+01
Elevation	65 m
Land cover	Mosaic cropland (>50%) / natural vegetation
Population density	277 inh./km^2
Terrain azimuth	flat
Terrain slope	0°
Location on the map	https://apps.solargis.com/prospect/map?c=40.636525,17.758327,10&s=40.636525,17.758327

Figure 2.1: Project location

Figure 2.2: Detailed map view

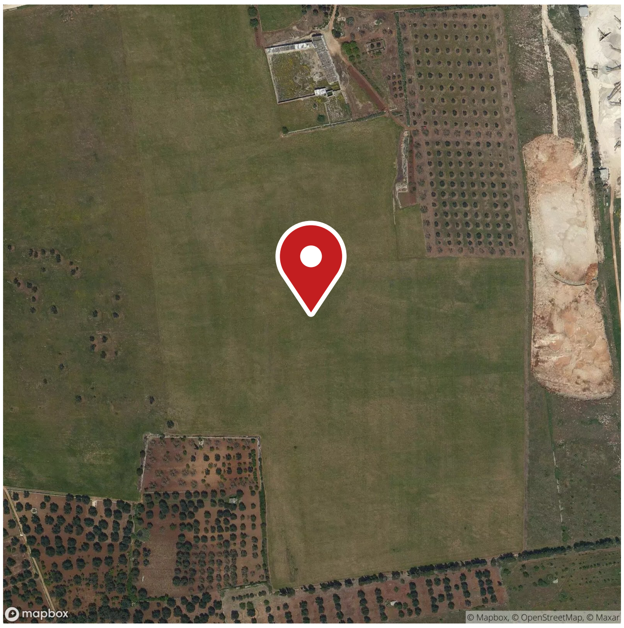


Figure 2.3: Project horizon and sunpath

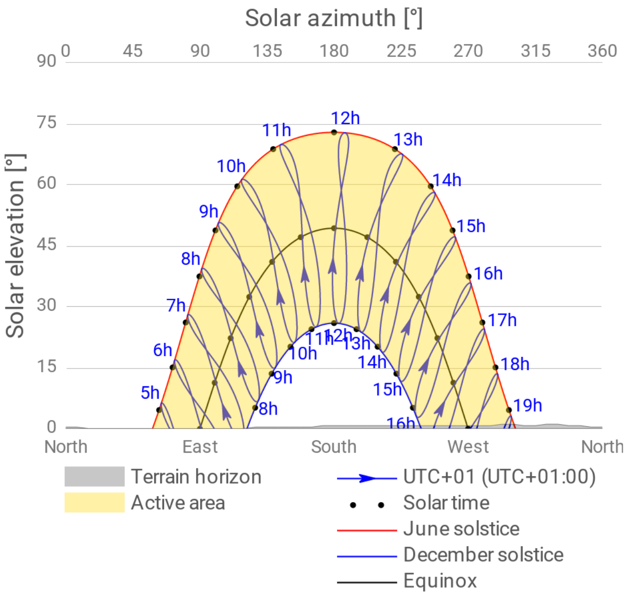
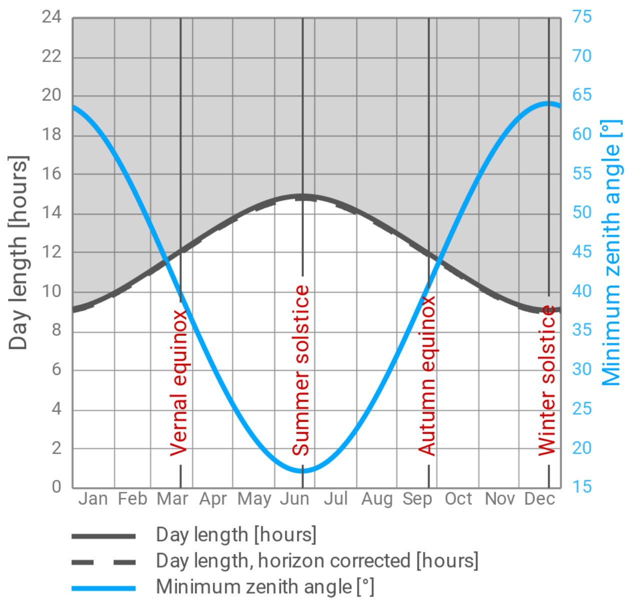
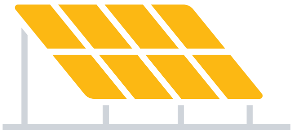


Figure 2.4: Day length and solar zenith angle



3 PV system configuration



Ground based fix-mounted

Large-scale commercial photovoltaic system mounted on leveled ground. Azimuth and tilt of PV modules are homogeneous, usually facing towards the Equator and inclined at the optimum tilt to maximize yearly energy yield. The modules are fix-mounted on tilted structures aligned in rows. During low-sun angles, they may be partially shaded by preceding rows. 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: 36.52MWp
PV module type	c-Si - crystalline silicon (mono or polycrystalline)
Geometry of PV modules	Azimuth: 180° • Tilt: 20°
Relative row 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 2.0 % • Monthly snow losses up to 0.0 %
Cabling losses	DC cabling 2 % • DC mismatch 0.3 % • AC cabling 1.5 %
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	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
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	87	28	0.47	9.8	5.3	0	269
Feb	76	92	35	0.46	10.0	5.5	0	229
Mar	126	131	52	0.41	11.8	5.4	0	191
Apr	156	140	65	0.42	14.5	4.9	3	103
May	201	180	75	0.37	18.9	4.3	55	23
Jun	220	205	73	0.33	23.3	4.1	166	0
Jul	233	233	68	0.29	26.0	4.4	239	0
Aug	203	204	65	0.32	26.0	4.1	243	0
Sep	141	139	57	0.41	22.1	4.1	121	1
Oct	101	112	46	0.45	18.2	4.4	27	27
Nov	63	80	31	0.50	14.3	5.1	0	119
Dec	52	81	25	0.48	10.9	5.3	0	236
Yearly	**1631**	**1684**	**620**	**0.38**	**17.2**	**4.8**	**855**	**1196**

Table 4.2: Other meteorological parameters

Month	ALB	RH %	PWAT kg/m^2	PREC mm
Jan	0.15	80	14	68
Feb	0.16	79	13	62
Mar	0.17	76	14	66
Apr	0.17	71	17	40
May	0.18	65	21	30
Jun	0.19	56	26	20
Jul	0.19	50	27	17
Aug	0.19	52	29	26
Sep	0.16	62	27	45
Oct	0.16	73	23	72
Nov	0.14	78	19	81
Dec	0.14	80	15	72
Yearly	**0.16**	**69**	**20**	**599**

Figure 4.1: Global + diffuse horizontal irradiation

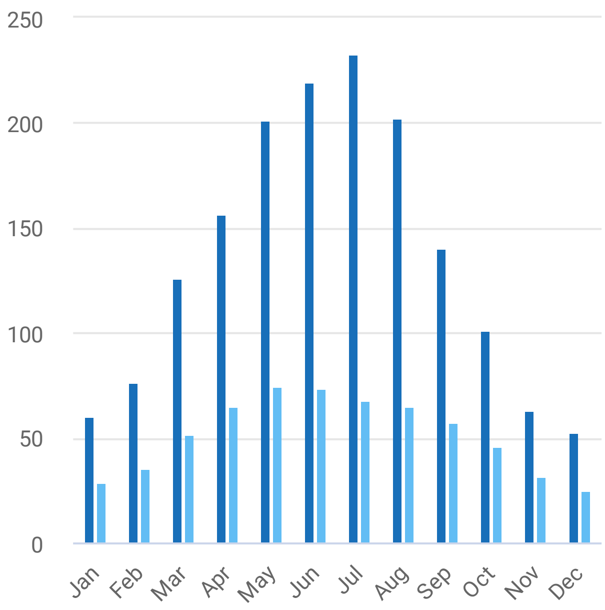


Figure 4.2: Direct normal irradiation

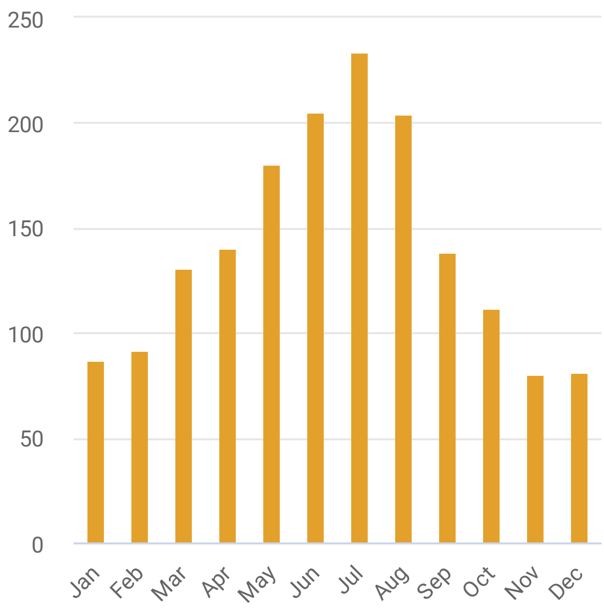


Figure 4.3: Ratio of diffuse to global irradiation

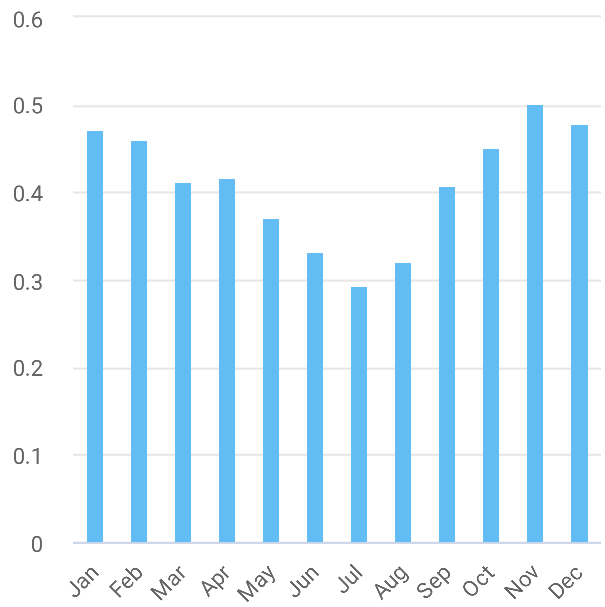


Figure 4.4: Air temperature

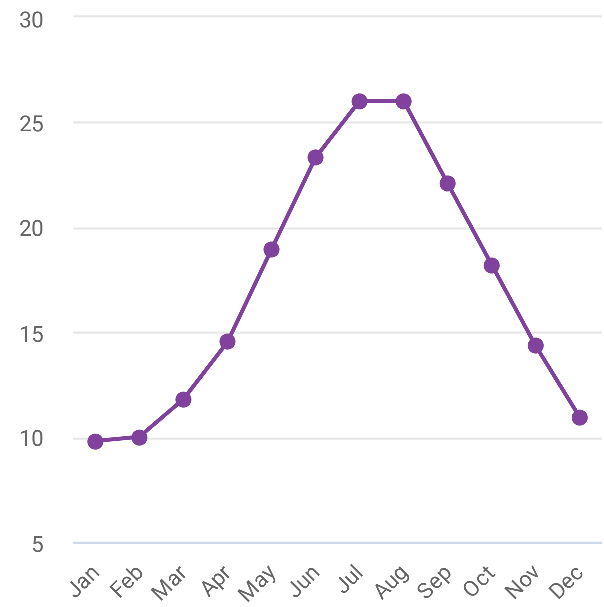


Figure 4.5: Surface albedo

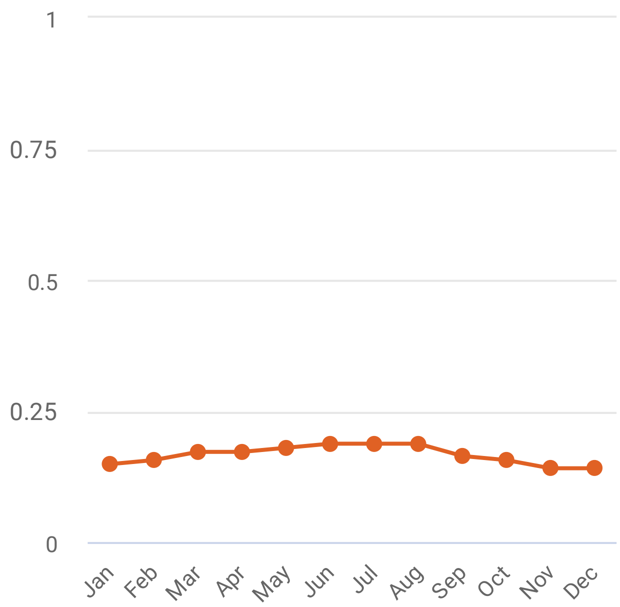


Figure 4.6: Wind speed

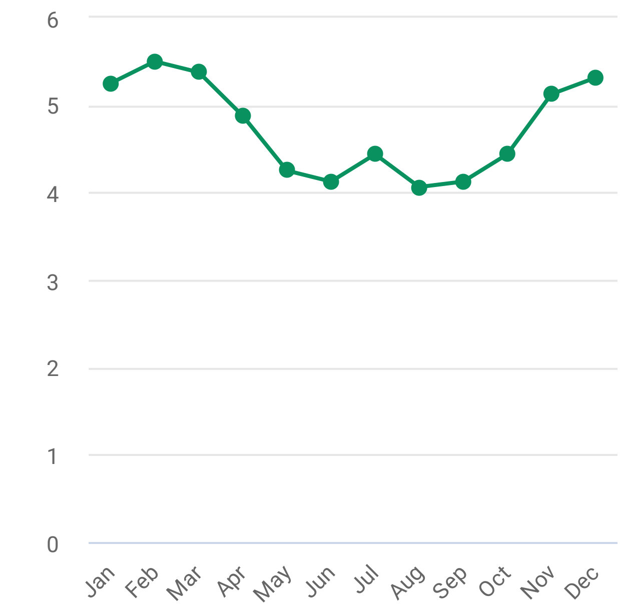


Figure 4.7: Relative humidity

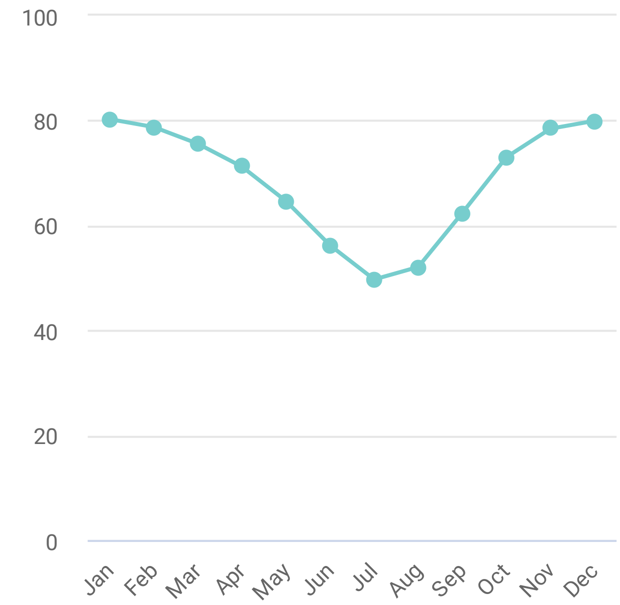


Figure 4.8: Precipitation (rainfall)

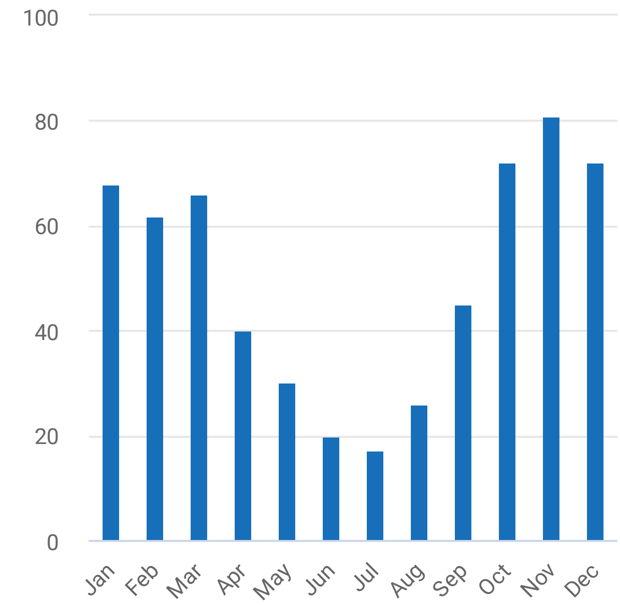


Figure 4.9: Precipitable water

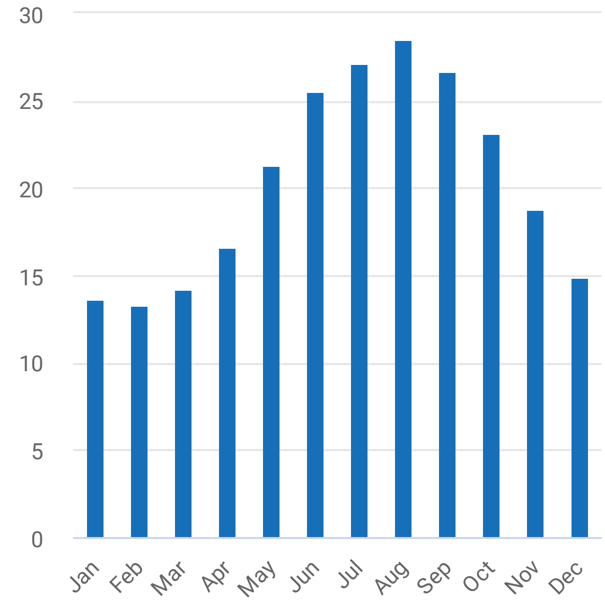


Figure 4.10: Snow days

Figure 4.11: Cooling degree days

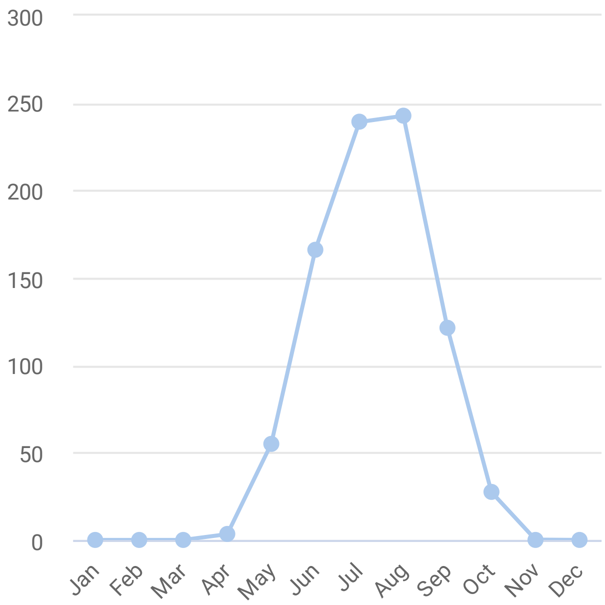
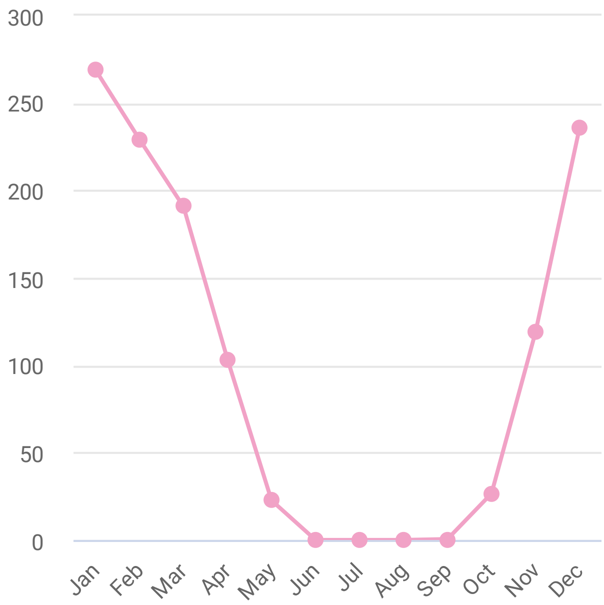


Figure 4.12: Heating degree days



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	86	2763	75	2414	2.733	88.166	87.4
Feb	100	3557	86	3079	3.149	112.447	86.6
Mar	150	4831	127	4083	4.623	149.122	84.5
Apr	171	5694	141	4706	5.156	171.864	82.7
May	207	6689	167	5393	6.106	196.967	80.6
Jun	220	7332	174	5788	6.341	211.368	78.9
Jul	237	7651	185	5958	6.745	217.594	77.9
Aug	218	7040	171	5514	6.243	201.388	78.3
Sep	162	5405	131	4378	4.797	159.895	81.0
Oct	127	4100	106	3428	3.881	125.206	83.6
Nov	85	2848	73	2447	2.681	89.378	85.9
Dec	77	2479	67	2158	2.443	78.820	87.1
Yearly	**1840**	**5032**	**1503**	**4112**	**54.899**	**150.185**	**81.7**

Figure 5.1: Specific photovoltaic power output

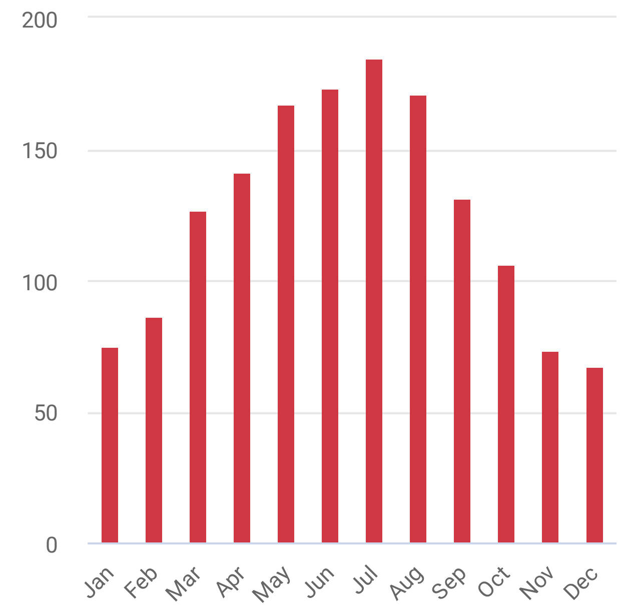


Figure 5.2: Global tilted irradiation

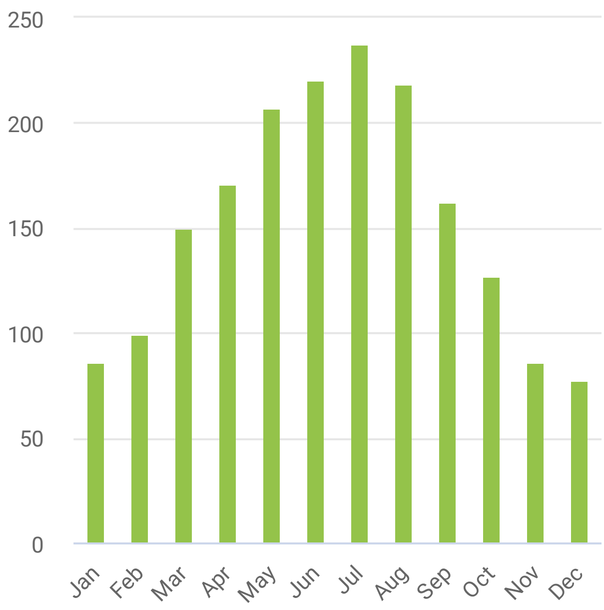
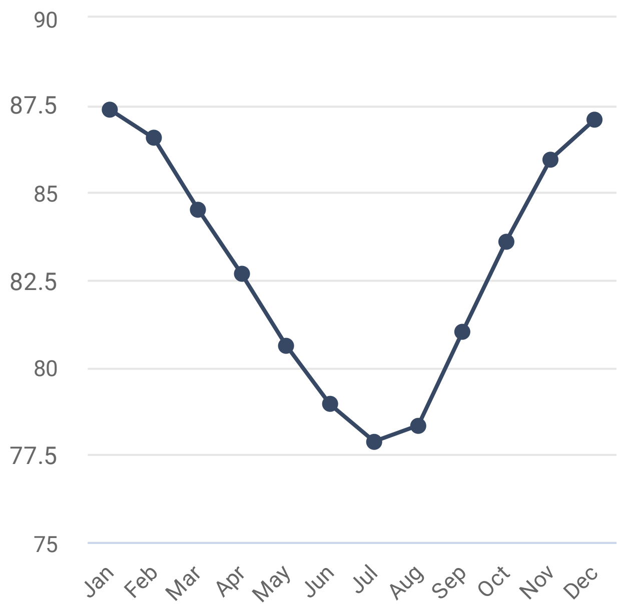


Figure 5.3: Performance ratio



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

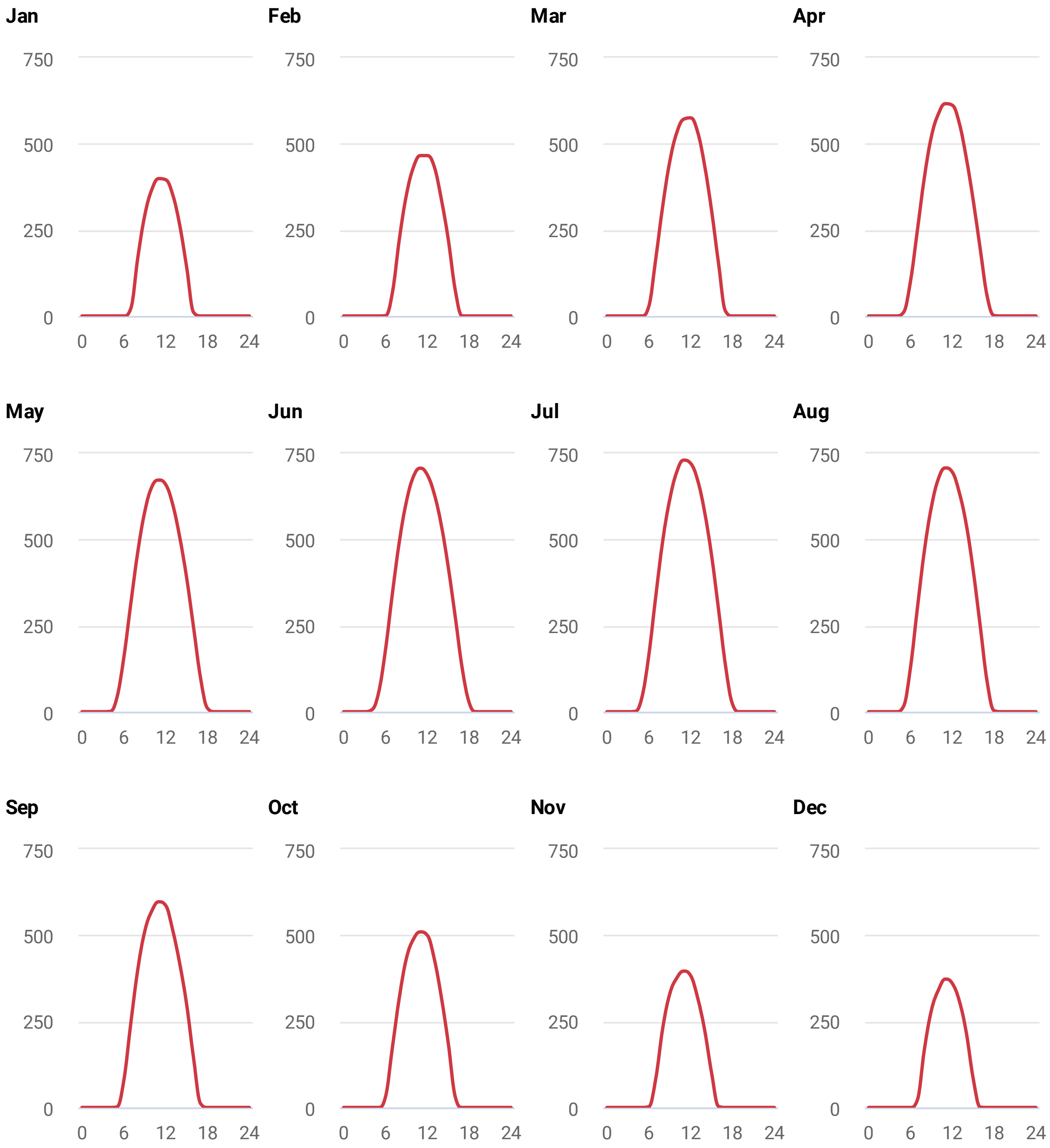


Table 6.1: Specific photovoltaic power output – hourly averages [Wh/kWp]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1	-	-	-	-	-	-	-	-	-	-	-	-
1 - 2	-	-	-	-	-	-	-	-	-	-	-	-
2 - 3	-	-	-	-	-	-	-	-	-	-	-	-
3 - 4	-	-	-	-	-	-	-	-	-	-	-	-
4 - 5	-	-	-	-	1	5	1	-	-	-	-	-
5 - 6	-	-	0	10	40	54	40	15	1	-	-	-
6 - 7	-	1	28	100	158	180	164	127	79	31	2	-
7 - 8	22	69	166	249	314	345	335	301	245	176	84	22
8 - 9	169	225	320	402	464	496	496	467	401	321	231	169
9 - 10	292	351	448	520	581	610	616	594	512	433	329	282
10 - 11	367	432	532	586	653	683	696	676	570	488	376	341
11 - 12	399	466	571	617	673	707	731	708	597	510	396	373
12 - 13	396	466	575	612	660	688	721	696	587	500	383	360
13 - 14	353	433	534	560	602	632	672	637	515	431	319	310
14 - 15	265	340	437	460	508	542	580	544	419	321	225	218
15 - 16	142	222	306	336	389	419	454	410	299	187	100	84
16 - 17	10	75	152	195	244	276	296	250	142	31	3	1
17 - 18	-	0	14	57	97	126	133	86	11	-	-	-
18 - 19	-	-	-	1	10	26	22	3	-	-	-	-
19 - 20	-	-	-	-	-	0	-	-	-	-	-	-
20 - 21	-	-	-	-	-	-	-	-	-	-	-	-
21 - 22	-	-	-	-	-	-	-	-	-	-	-	-
22 - 23	-	-	-	-	-	-	-	-	-	-	-	-
23 - 24	-	-	-	-	-	-	-	-	-	-	-	-
Sum	**2414**	**3079**	**4083**	**4706**	**5393**	**5788**	**5958**	**5514**	**4378**	**3428**	**2447**	**2158**

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	**1631**	-			-	
Horizon shading (terrain + horizon objects)	1631	0			0.0	
Global horizontal irradiation site specific	**1631**	**0**			**0.0**	
Conversion to surface of PV modules	1840	209			12.8	
Global tilted irradiation (GTI)	**1840**					**100.0**
Dirt, dust and soiling	1803	-37			-2.0	98.0
Angular reflectivity	1758	-46			-2.5	95.5
GTI effective	**1758**	**-83**			**-4.5**	**95.5**
Spectral correction			1765	7	0.4	95.9
Conversion of solar radiation to DC in the modules			1653	-111	-6.3	89.8
Electrical losses due to inter-row shading			1640	-13	-0.8	89.1
Power tolerance of PV modules			1640	0	0.0	89.1
Mismatch and cabling in DC section			1602	-38	-2.3	87.1
Inverters (DC/AC) conversion			1556	-46	-2.9	84.5
Transformer and AC cabling losses			1518	-37	-2.4	82.5
Total system performance (at system startup)			**1518**	**-239**	**-13.6**	**82.5**
Losses due to snow			1518	0	0.0	82.5
Technical availability			1503	-15	-1.0	81.7
Total system performance considering technical availability and losses due to snow			**1503**	**-15**	**-1.0**	**81.7**
Capacity factor			**17.2%**			

Table 7.2: Loss diagram

0.0% / 81.7% / 100.0%		
Global tilted irradiation (GTI): 1840 kWh/m^2		**Solar losses**
	-2.0%	Dirt, dust and soiling
	-2.5%	Angular reflectivity
GTI effective: 1758 kWh/m^2		**Electric system losses**
	0.4%	Spectral correction
	-6.3%	Conversion of solar radiation to DC in the modules
	-0.8%	Electrical losses due to inter-row shading
	0.0%	Power tolerance of PV modules
	-2.3%	Mismatch and cabling in DC section
	-2.9%	Inverters (DC/AC) conversion
	-2.4%	Transformer and AC cabling losses
Total system performance (at system startup): 1518 kWh/kWp		
	0.0%	Losses due to snow
	-1.0%	Technical availability
Total system performance considering technical availability and losses due to snow: 1503 kWh/kWp		

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 MWh	PR %
Theoretical	-	**1503**	**54,898.8**	**81.7**
1	0.8	1491	54,459.6	81.0
2	0.5	1484	54,187.3	80.6
3	0.5	1476	53,916.4	80.2
4	0.5	1469	53,646.8	79.8
5	0.5	1462	53,378.6	79.4
6	0.5	1454	53,111.7	79.0
7	0.5	1447	52,846.1	78.6
8	0.5	1440	52,581.9	78.2
9	0.5	1433	52,319.0	77.9
10	0.5	1425	52,057.4	77.5
11	0.5	1418	51,797.1	77.1
12	0.5	1411	51,538.1	76.7
13	0.5	1404	51,280.4	76.3
14	0.5	1397	51,024.0	75.9
15	0.5	1390	50,768.9	75.5
16	0.5	1383	50,515.1	75.2
17	0.5	1376	50,262.5	74.8
18	0.5	1369	50,011.2	74.4
19	0.5	1363	49,761.1	74.0
20	0.5	1356	49,512.3	73.7
21	0.5	1349	49,264.8	73.3
22	0.5	1342	49,018.4	72.9
23	0.5	1336	48,773.3	72.6
24	0.5	1329	48,529.5	72.2
25	0.5	1322	48,286.8	71.9
Average	**0.5**	**1405**	**51,313.9**	**76.4**
Cumulative	**12.8**	-	**1,282,848.4**	-

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	MWh	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..

Service provider

Solargis s.r.o., Mýtna 48, 811 07 Bratislava, Slovakia
Registration ID: 45 354 766
VAT ID: SK2022962766
Telephone: +421 2 4319 1708
Email: contact@solargis.com
URL: solargis.com