

# YIELD ASSESSMENT OF THE PHOTOVOLTAIC POWER PLANT

Report number: PV-8-1512-180  
 Issued: 12 December 2015 06:56 (UTC)

## 1. Site info

Site name: Zhangye, People's Republic of China

Coordinates: **38° 49' 6.82" N, 100° 12' 30.09" E**  
 Elevation a.s.l.: 1682 m  
 Slope inclination: 0°  
 Slope azimuth: 270° west

Annual global in-plane irradiation: **1745 kWh/m<sup>2</sup>**  
 Annual air temperature at 2 m: **6.4 °C**

## 2. PV system info

Installed power: **50.0 kWp**  
 Type of modules: **crystalline silicon (c-Si)**  
 Mounting system: **fixed mounting, roof installed**  
 Azimuth/inclination: **160° (south) / 12°**  
 Inverter Euro eff.: 97.5%  
 DC / AC losses: 5.5% / 1.5%  
 Availability: 99.0%

Annual average electricity production: **71.3 MWh**  
 Average performance ratio: **81.2%**

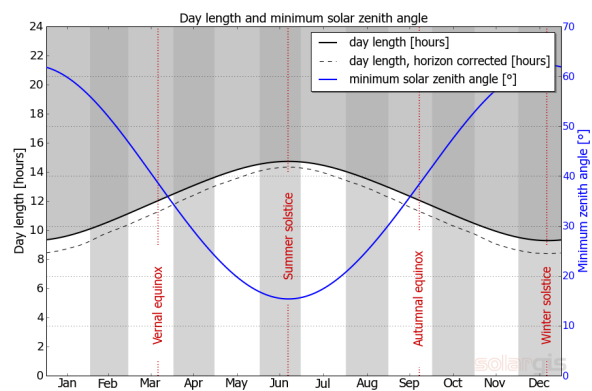
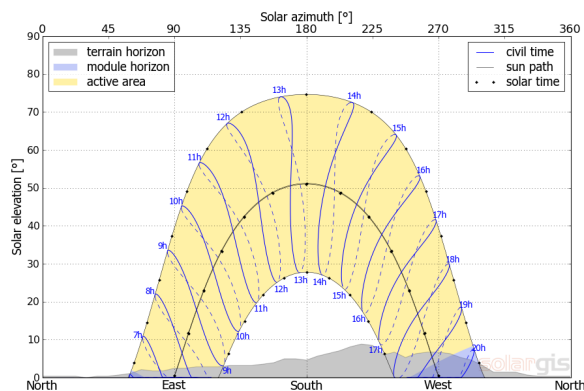
Location on the map: <http://solargis.info/imaps/#tl=Google:satellite&loc=38.8185619505,100.208358765&z=17>

## 3. Geographic position



Google Maps © 2015 Google

## 4. Terrain horizon and day length



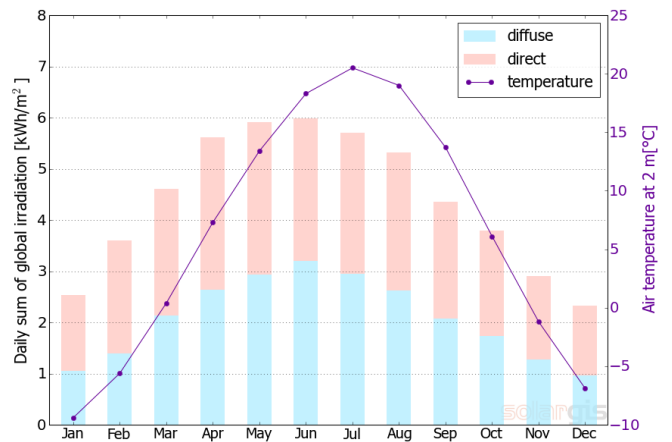
Left: Path of the Sun over a year. Terrain horizon (drawn by grey filling) and module horizon (blue filling) may have shading effect on solar radiation. Black dots show True Solar Time. Blue labels show Local Clock Time.

Right: Change of the day length and solar zenith angle during a year. The local day length (time when the Sun is above the horizon) is shorter compared to the astronomical day length, if obstructed by higher terrain horizon.

Site: Zhangye, People's Republic of China, lat/lon: 38.8186°/100.2084°  
 PV system: 50.0 kWp, crystalline silicon, fixed roof, azim. 160° (south), inclination 12°

### 5. Global horizontal irradiation and air temperature - climate reference

Month	Gh <sub>m</sub>	Gh <sub>d</sub>	Dh <sub>d</sub>	T <sub>24</sub>
Jan	78	2.53	1.05	-9.4
Feb	101	3.60	1.40	-5.6
Mar	143	4.61	2.13	0.4
Apr	169	5.62	2.63	7.3
May	183	5.91	2.94	13.4
Jun	180	5.99	3.20	18.3
Jul	177	5.71	2.95	20.5
Aug	165	5.32	2.62	19.0
Sep	131	4.36	2.08	13.7
Oct	118	3.80	1.74	6.1
Nov	87	2.90	1.27	-1.2
Dec	72	2.32	0.96	-6.9
<b>Year</b>	<b>1603</b>	<b>4.39</b>	<b>2.08</b>	<b>6.4</b>



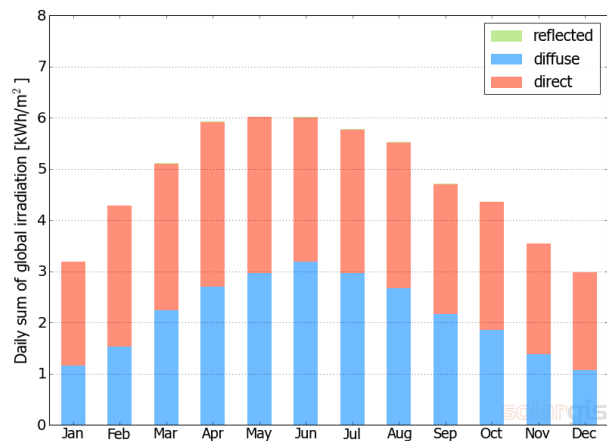
Long-term monthly averages:

- Gh<sub>m</sub> Monthly sum of global irradiation [kWh/m<sup>2</sup>]
- Gh<sub>d</sub> Daily sum of global irradiation [kWh/m<sup>2</sup>]
- Dh<sub>d</sub> Daily sum of diffuse irradiation [kWh/m<sup>2</sup>]
- T<sub>24</sub> Daily (diurnal) air temperature [°C]

### 6. Global in-plane irradiation

Fixed surface, azimuth 160° (south), inclination. 12°

Month	Gi <sub>m</sub>	Gi <sub>d</sub>	Di <sub>d</sub>	Ri <sub>d</sub>	Sh <sub>loss</sub>
Jan	99	3.18	1.15	0.00	0.6
Feb	120	4.28	1.52	0.00	0.5
Mar	158	5.11	2.24	0.01	0.5
Apr	178	5.92	2.70	0.01	0.4
May	187	6.02	2.96	0.01	0.5
Jun	180	6.01	3.19	0.01	0.5
Jul	179	5.78	2.96	0.01	0.5
Aug	171	5.52	2.67	0.01	0.5
Sep	141	4.71	2.16	0.01	0.5
Oct	135	4.36	1.85	0.01	0.5
Nov	106	3.54	1.38	0.00	0.5
Dec	93	2.98	1.06	0.00	0.8
<b>Year</b>	<b>1745</b>	<b>4.79</b>	<b>2.16</b>	<b>0.01</b>	<b>0.5</b>



Long-term monthly averages:

- Gi<sub>m</sub> Monthly sum of global irradiation [kWh/m<sup>2</sup>]
- Gi<sub>d</sub> Daily sum of global irradiation [kWh/m<sup>2</sup>]
- Di<sub>d</sub> Daily sum of diffuse irradiation [kWh/m<sup>2</sup>]
- Ri<sub>d</sub> Daily sum of reflected irradiation [kWh/m<sup>2</sup>]

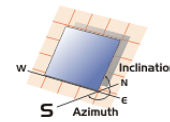
Sh<sub>loss</sub> Losses of global irradiation by terrain shading [%]

Average yearly sum of global irradiation for different types of surface:

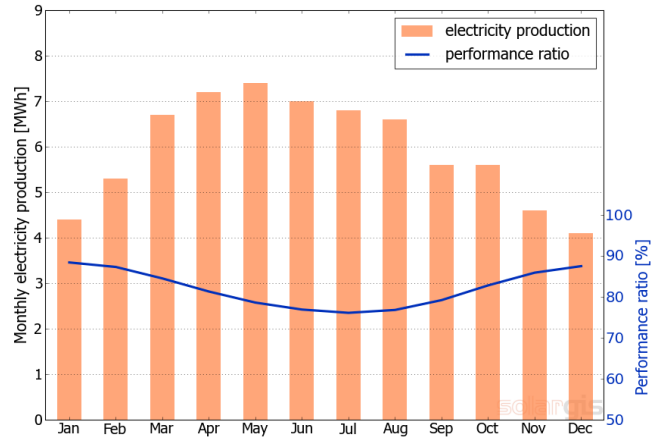
	kWh/m <sup>2</sup>	relative to optimally inclined
Horizontal	1603	86.8%
Optimally inclined (35°)	1847	100.0%
2-axis tracking	2302	124.6%
<b>Your option</b>	<b>1745</b>	<b>94.5%</b>

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**7. PV electricity production in the start-up**



Month	$E_{s_m}$	$E_{s_d}$	$E_{t_m}$	$E_{share}$	PR
Jan	88	2.83	4.4	6.2	88.4
Feb	105	3.76	5.3	7.4	87.3
Mar	134	4.33	6.7	9.4	84.5
Apr	145	4.83	7.2	10.2	81.3
May	147	4.75	7.4	10.3	78.6
Jun	139	4.65	7.0	9.8	76.9
Jul	137	4.41	6.8	9.6	76.1
Aug	132	4.26	6.6	9.3	76.8
Sep	112	3.75	5.6	7.9	79.2
Oct	112	3.62	5.6	7.9	82.8
Nov	92	3.06	4.6	6.4	85.9
Dec	82	2.63	4.1	5.7	87.5
<b>Year</b>	<b>1425</b>	<b>3.90</b>	<b>71.3</b>	<b>100.0</b>	<b>81.2</b>



Long-term monthly averages:

- $E_{s_m}$  Monthly sum of specific electricity prod. [kWh/kWp]
- $E_{s_d}$  Daily sum of specific electricity prod. [kWh/kWp]
- $E_{t_m}$  Monthly sum of total electricity prod. [MWh]
- $E_{share}$  Percentual share of monthly electricity prod. [%]
- PR Performance ratio [%]

**8. System losses and performance ratio**

Energy conversion step	Energy output [kWh/kWp]	Energy loss [kWh/kWp]	Energy loss [%]	Performance ratio	
				[partial %]	[cumul. %]
1. Global in-plane irradiation (input)	1754	-	-	100.0	100.0
2. Global irradiation reduced by terrain shading	1745	-9	-0.5	99.5	99.5
3. Global irradiation reduced by reflectivity	1688	-58	-3.3	96.7	96.2
4. Conversion to DC in the modules	1586	-102	-6.0	94.0	90.4
5. Other DC losses	1499	-87	-5.5	94.5	85.5
6. Inverters (DC/AC conversion)	1461	-38	-2.5	97.5	83.3
7. Transformer and AC cabling losses	1440	-22	-1.5	98.5	82.1
8. Reduced availability	1425	-14	-1.0	99.0	81.2
<b>Total system performance</b>	<b>1425</b>	<b>-329</b>	<b>-18.8</b>	<b>-</b>	<b>81.2</b>

Energy conversion steps and losses:

1. Initial production at Standard Test Conditions (STC) is assumed,
2. Reduction of global in-plane irradiation due to obstruction of terrain horizon and PV modules,
3. Proportion of global irradiation that is reflected by surface of PV modules (typically glass),
4. Losses in PV modules due to conversion of solar radiation to DC electricity; deviation of module efficiency from STC,
5. DC losses: this step assumes integrated effect of mismatch between PV modules, heat losses in interconnections and cables, losses due to dirt, snow, icing and soiling, and self-shading of PV modules,
6. This step considers euro efficiency to approximate average losses in the inverter,
7. Losses in AC section and transformer (where applicable) depend on the system architecture,
8. Availability parameter assumes losses due to downtime caused by maintenance or failures.

Losses at steps 2 to 4 are numerically modeled by pvPlanner. Losses at steps 5 to 8 are to be assessed by a user. The simulation models have inherent uncertainties that are not discussed in this report. Read more about simulation methods and related uncertainties to evaluate possible risks at <http://solargis.info/doc/pvplanner/>.

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## 9. SolarGIS - description of the database

SolarGIS is high-resolution climate database operated by GeoModel Solar. Primary data layers include solar radiation, air temperature and terrain (elevation, horizon).

**Air temperature at 2 m:** developed from the CFSR data (© NOAA NCEP, USA); years: 1994 - 2011; recalculated to 15-minute values. The data are spatially enhanced to 1 km resolution to reflect variability induced by high resolution terrain.

**Solar radiation:** calculated from the satellite and atmospheric data:

- Meteosat PRIME satellite (© EUMETSAT, Germany) 1994 - 2010, 15-minute or 30-minute values for Europe, Africa and Middle East,
- Meteosat IODC satellite (© EUMETSAT, Germany) 1999 - 2011, 30-minute values for Asia,
- GOES EAST satellite (© NOAA, USA) 1999 - 2014, 30-minute, partially 3-hourly values for Americas,
- MTSAT satellite (© JMA, Japan) 2007 - 2014, 30-minute values for Pacific,
- MACC-II (© ECMWF, UK) 2003 - 2014, atmospheric data,
- GFS, CFSR (© NOAA, USA), 1994 - 2014, atmospheric data.

This estimation assumes year having 365 days. Occasional deviations in calculations may occur as a result of mathematical rounding and cannot be considered as a defect of algorithms. More information about the applied data, algorithms and uncertainty can be found at: <http://solargis.info/doc/pvplanner/>.

## 10. Service provider

GeoModel Solar s.r.o. , Milana Marečka 3, 84107 Bratislava, Slovakia; Registration ID: 45 354 766, VAT Number: SK2022962766; Registration: Business register, District Court Bratislava I, Section Sro, File 62765/B

## 11. Mode of use

This report shows solar power estimation in the start-up phase of a PV system. The estimates are accurate enough for small and medium-size PV systems. For suntracking simulations, only theoretical options are shown without considering backtracking and shading. 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. Interannual 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: <http://solargis.info/doc/8>.

## 12. Disclaimer and legal information

Considering the nature of climate fluctuations, interannual and long-term changes, as well as the uncertainty of measurements and calculations, GeoModel Solar cannot take full guarantee of the accuracy of estimates. The maximum possible has been done for the assessment of climate conditions based on the best available data, software and knowledge. GeoModel Solar 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.

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## 13. Contact information

This report has been generated for Mr. Juraj Betak, Pionierska 15, 84545, Bratislava, Slovakia.

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