# YIELD ASSESSMENT OF THE PHOTOVOLTAIC POWER PLANT

Report number: PV-0-1404-0
Issued: 08 April 2014 11:14 (UTC)

## 1. Site info

| | |
|---|---|
| Site name: | Arica, Čile |
| Coordinates: | **18° 29' 7.69" S, 70° 17' 33.31" W** |
| Elevation a.s.l.: | 58 m |
| Slope inclination: | 1° |
| Slope azimuth: | 348° north |

Annual global in-plane irradiation: **2893 kWh/m$^2$**
Annual air temperature at 2 m: **21.5 °C**

## 2. PV system info

| | |
|---|---|
| Installed power: | **0.75 kWp** |
| Type of modules: | crystalline silicon **(c-Si)** |
| Mounting system: | **2-axis tracking, astronomical** |
| Inverter Euro eff.: | 97.5% |
| DC / AC losses: | 5.5% / 1.5% |
| Availability: | 99.0% |

Annual average electricity production: **1685.0 kWh**
Average performance ratio: **77.5%**

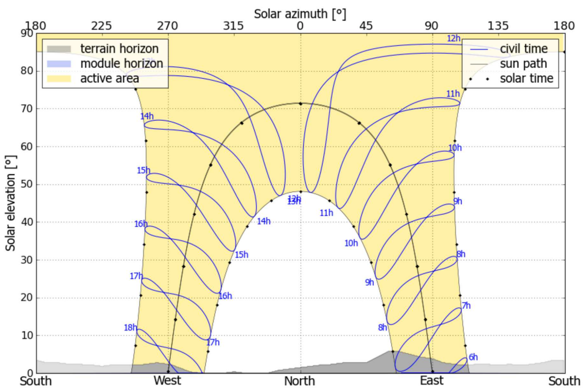
Location on the map: http://solargis.info/imaps/#loc=-18.48547,-70.292587&tl=Google:Satellite&z=12

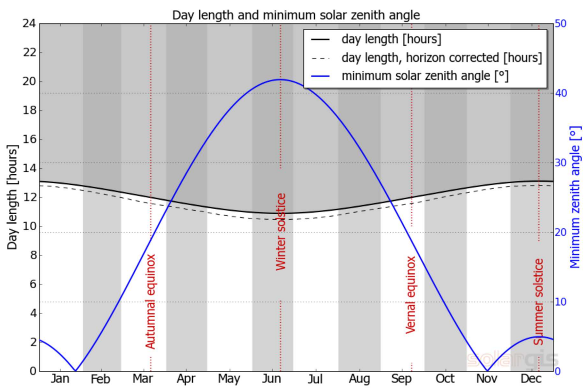
## 3. Geographic position



Google Maps © 2014 Google

## 4. Terrain horizon and day length



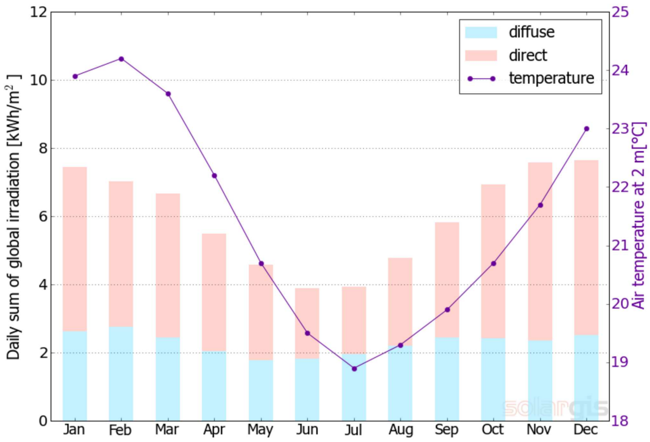




| | |
|---|---|
| Left: | Path of the Sun over a year. Terrain horizon (drawn by grey filling) and module horizon (blue filling) may have shading effect on solar radiation. Black dots show True Solar Time. Blue labels show Local Clock Time. |
| Right: | Change of the day length and solar zenith angle 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: Arica, Čile, lat/lon: -18.4855°/-70.2926°
PV system: 0.75 kWp, crystalline silicon, 2-axis

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

| Month | $Gh_m$ | $Gh_d$ | $Dh_d$ | $T_{24}$ |
|---|---|---|---|---|
| **Jan** | 231 | 7.45 | 2.63 | 23.9 |
| **Feb** | 197 | 7.02 | 2.75 | 24.2 |
| **Mar** | 207 | 6.67 | 2.45 | 23.6 |
| **Apr** | 165 | 5.49 | 2.04 | 22.2 |
| **May** | 142 | 4.58 | 1.77 | 20.7 |
| **Jun** | 117 | 3.90 | 1.82 | 19.5 |
| **Jul** | 122 | 3.93 | 1.96 | 18.9 |
| **Aug** | 148 | 4.77 | 2.21 | 19.3 |
| **Sep** | 175 | 5.82 | 2.44 | 19.9 |
| **Oct** | 215 | 6.94 | 2.43 | 20.7 |
| **Nov** | 227 | 7.58 | 2.36 | 21.7 |
| **Dec** | 237 | 7.65 | 2.52 | 23.0 |
| **Year** | **2183** | **5.98** | **2.28** | **21.5** |



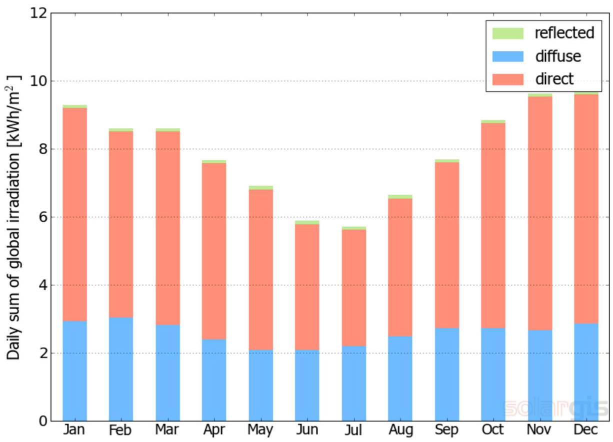

Long-term monthly averages:

| | |
|---|---|
| $Gh_m$ | Monthly sum of global irradiation [kWh/m²] |
| $Gh_d$ | Daily sum of global irradiation [kWh/m²] |
| $Dh_d$ | Daily sum of diffuse irradiation [kWh/m²] |
| $T_{24}$ | Daily (diurnal) air temperature [°C] |

## 6. Global in-plane irradiation

2-axis tracking surface

| Month | $Gi_m$ | $Gi_d$ | $Di_d$ | $Ri_d$ | $Sh_{loss}$ |
|---|---|---|---|---|---|
| **Jan** | 288 | 9.29 | 2.93 | 0.09 | 0.1 |
| **Feb** | 241 | 8.60 | 3.04 | 0.08 | 0.1 |
| **Mar** | 267 | 8.61 | 2.82 | 0.09 | 0.2 |
| **Apr** | 230 | 7.67 | 2.39 | 0.10 | 0.4 |
| **May** | 214 | 6.91 | 2.10 | 0.10 | 0.3 |
| **Jun** | 176 | 5.88 | 2.08 | 0.10 | 0.4 |
| **Jul** | 177 | 5.71 | 2.20 | 0.09 | 0.6 |
| **Aug** | 206 | 6.64 | 2.49 | 0.10 | 0.6 |
| **Sep** | 231 | 7.70 | 2.74 | 0.09 | 0.4 |
| **Oct** | 274 | 8.84 | 2.73 | 0.09 | 0.3 |
| **Nov** | 289 | 9.62 | 2.67 | 0.09 | 0.2 |
| **Dec** | 300 | 9.68 | 2.86 | 0.09 | 0.2 |
| **Year** | **2893** | **7.93** | **2.59** | **0.09** | **0.3** |



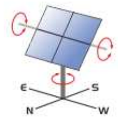

Long-term monthly averages:

| | |
|---|---|
| $Gi_m$ | Monthly sum of global irradiation [kWh/m²] |
| $Gi_d$ | Daily sum of global irradiation [kWh/m²] |
| $Di_d$ | Daily sum of diffuse irradiation [kWh/m²] |
| $Ri_d$ | Daily sum of reflected irradiation [kWh/m²] |
| $Sh_{loss}$ | Losses of global irradiation by terrain shading [%] |

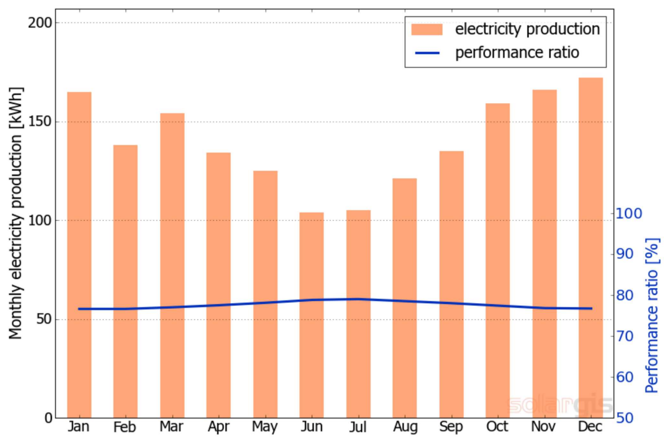
Average yearly sum of global irradiation for different types of surface:

| | kWh/m² | relative to optimally inclined |
|---|---|---|
| Horizontal | 2182 | 96.6% |
| Optimally inclined (17°) | 2258 | 100.0% |
| 2-axis tracking | 2893 | 128.1% |
| **Your option** | **2893** | **128.1%** |

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




| Month | $Es_m$ | $Es_d$ | $Et_m$ | $E_{share}$ | PR |
|---|---|---|---|---|---|
| **Jan** | 220 | 7.12 | 165.0 | 9.8 | 76.6 |
| **Feb** | 184 | 6.60 | 138.0 | 8.2 | 76.6 |
| **Mar** | 206 | 6.65 | 154.0 | 9.2 | 77.0 |
| **Apr** | 179 | 5.97 | 134.0 | 8.0 | 77.5 |
| **May** | 167 | 5.42 | 125.0 | 7.5 | 78.1 |
| **Jun** | 139 | 4.65 | 104.0 | 6.2 | 78.8 |
| **Jul** | 140 | 4.54 | 105.0 | 6.3 | 79.0 |
| **Aug** | 162 | 5.24 | 121.0 | 7.2 | 78.5 |
| **Sep** | 181 | 6.03 | 135.0 | 8.1 | 78.0 |
| **Oct** | 212 | 6.86 | 159.0 | 9.5 | 77.4 |
| **Nov** | 222 | 7.41 | 166.0 | 9.9 | 76.8 |
| **Dec** | 230 | 7.44 | 172.0 | 10.3 | 76.7 |
| **Year** | **2247** | **6.16** | **1685.0** | **100.0** | **77.5** |




Long-term monthly averages:

$Es_m$ Monthly sum of specific electricity prod. [kWh/kWp]
$Es_d$ Daily sum of specific electricity prod. [kWh/kWp]
$Et_m$ Monthly sum of total electricity prod. [kWh]
$E_{share}$ 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 %] | Performance ratio [cumul. %] |
|---|---|---|---|---|---|
| 1. Global in-plane irradiation (input) | 2902 | - | - | 100.0 | 100.0 |
| 2. Global irradiation reduced by terrain shading | 2893 | -9 | -0.3 | 99.7 | 99.7 |
| 3. Global irradiation reduced by reflectivity | 2847 | -46 | -1.6 | 98.4 | 98.1 |
| 4. Conversion to DC in the modules | 2501 | -346 | -12.2 | 87.8 | 86.2 |
| 5. Other DC losses | 2364 | -137 | -5.5 | 94.5 | 81.5 |
| 6. Inverters (DC/AC conversion) | 2305 | -59 | -2.5 | 97.5 | 79.4 |
| 7. Transformer and AC cabling losses | 2270 | -35 | -1.5 | 98.5 | 78.2 |
| 8. Reduced availability | 2248 | -22 | -1.0 | 99.0 | 77.5 |
| **Total system performance** | **2248** | **-654** | **-22.5** | **-** | **77.5** |

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/.

## 9. SolarGIS v1.8 - 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 and GFS 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 - 2012, 30-minute, partially 3-hourly values for Americas,
- MTSAT satellite (© JMA, Japan) 2007 - 2012, 30-minute values for Pacific,
- MACC (© ECMWF, UK) 1994 - 2012, atmospheric data,
- GFS, CFSR (© NOAA, USA), 1994 - 2012, 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.



## 13. Contact information

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