# TECHNICAL DUE DILIGENCE OF VANGPAN PROJECT, 40 MW

A PHOTOVOLTAIC PLANT SITED IN LEPHALALE MUNICIPALITY

IN LIMPOPO PROVINCE, SOUTH AFRICA

## SOLAR RESOURCE AND ENERGY PRODUCTION

**Draft version**

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## INDEX

# 1. SOLAR RESOURCE AND ENERGY PRODUCTION ESTIMATION

Enertis Solar has evaluated the solar resource at the Project site. Following the analysis included in this section, Enertis Solar has prepared the global horizontal irradiation value for this site.

## 1.1. SOLAR RESOURCE

Enertis Solar has reviewed several irradiation databases for this study, which are discussed hereinafter.

### 1.1.1. SolarGIS v1.8

SolarGIS v1.8 is a web-based system that includes maps, software for solar energy applications, and high-resolution climate databases, developed and maintained by GeoModel Solar. Specifically, the SolarGIS v1.8 database is derived from Meteosat and GOES satellite data, by means of EUMETSAT, and atmospheric data, from ECMWF, NOAA and NCEP, using in-house computing infrastructure and high performance algorithms. SolarGIS v1.8 database covers a period from 1994 up to the present in Europe, Africa and Middle East, and from 1999 up to the present for Asia, South America and some regions of North America. The time resolution of this database is between 15-minutes and 30-minutes and it displays a spatial resolution of approximately 4km, which can be increased using high resolution Digital Elevation Model SRTM-3.

SolarGIS v1.8 has provided Enertis Solar with average global horizontal irradiation hourly values for an 19-year period which includes the latest years passed. For the Project's location, the spatial resolution of the model is 250 m x 250 m for a period between January 1994 and June 2013. Accordingly, SolarGIS v1.8 estimates the average annual global horizontal irradiation at the Project's location to be 2,088 kWh/m$^2$.

Enertis Solar considers SolarGIS as a reliable database for the Project's location, with a remarkable spatial resolution. In addition, the Technical

Advisor was able to study and analyze 19-year period hourly data, which made possible establishing a long-term estimation. It is worth to be noted that SolarGIS v1.8 is the only database of this analysis which provides data for the latest years elapsed. Considering the previous, the Technical Advisor has used SolarGIS v1.8 model on this study.

#### 1.1.2. Meteonorm 7

Meteonorm 7 software estimates the irradiation level at any point in the world, through interpolation of data recorded from more than 8,300 ground weather stations. The irradiation database has been updated with more than 24 years of records, specifically from 1981 to 2005. In the case of the variable temperatures, the data has been collected for more than 40 years. It should be noted that if the desired geographical location is too far from the nearest Meteonorm weather station, the software uses satellite data for interpolation. The uncertainty of its estimations, according to the information provided by Meteonorm 7, is 5% for irradiation and 1.3°C for temperature; nevertheless, these values are also estimated and taken into account by the software for the selected location.

The annual global horizontal irradiation value for the Plant's location obtained through Meteonorm 7 was 2,117 kWh/m$^2$. It is worth noting that due to the low density of Meteonorm weather stations near the Project's site, Meteornorm 7 has estimated this value using a precalculated radiation map based on satellite and ground information.

The Technical Advisor found that the annual global horizontal irradiation value is within the expected range, but has not used the data from Meteonorm 7 due to there is a more accurate database with long-term data comprising recent years, considered in this study.

#### 1.1.3. SSE NASA

The surface meteorology and Solar Energy, SSE, version 6.0, database has been developed with the support of the National Aeronautics and Space

Administration, NASA. This database provides estimations of solar radiation and other meteorological parameters, which are derived from satellite data and other measurements recorded at weather stations. It should be noted that the satellite data was obtained by approximately 200 satellites for a 22-year period. Furthermore, the records of solar global radiation were collected at the World Radiation Data Centre (WRDC) using 1,195 weather stations for a 30-year period. In order to assess the accuracy of this database, estimation was made from a comparison with the data measured by the Baseline Surface Radiation Network (BSRN) and, concerning horizontal solar radiation, the difference was approximately 10%.

Enertis Solar has studied the global horizontal irradiation values in SSE NASA database for the Plant's location. This model gave an output of 2,460 kWh/m$^2$ for the Project's location. The spatial resolution of the model for the irradiation values is 1° x 1°, which represents a low grid resolution. The Project is located as shown in Figure 1.1 within the model's grid.

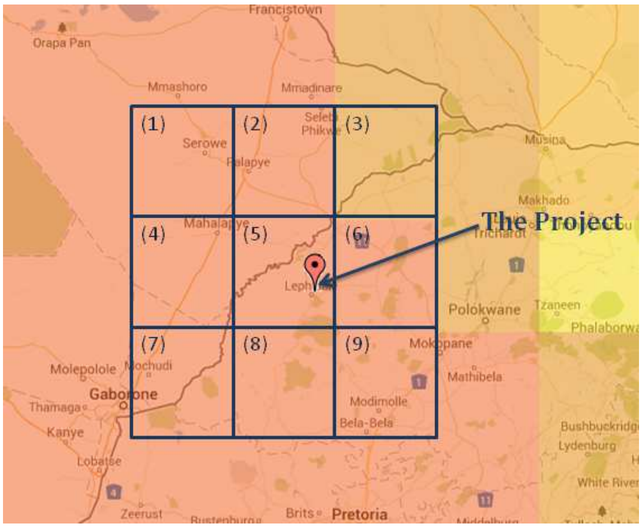

Figure 1.1. Project's location within SSE NASA grid.
Source: NREL maps.

Enertis Solar has reviewed the global horizontal irradiation values given by SSE NASA model for each cell of the grid highlighted in the previous figure, which are shown in the following table.

| | | |
|---|---|---|
| 2,456 | 2,376 | 2,332 |
| 2,475 | **2,460** | 2,427 |
| 2,486 | 2,519 | 2,413 |

Table 1.1. SSE NASA global horizontal irradiation values for the Project's cell of NASA's grid and for the adjacent cells (kWh/m$^2$).

With this database, significant variability is typically found between the values obtained for adjacent cells as a result of the large area covered by each cell and, especially in some cases, the presence of water (sea, lakes, etc.) in parts of cells. In this case, Enertis Solar observed that the variability of irradiation values was up to 4.34% in respect to the cell's average irradiation, which represents a significant variability.

Furthermore, the Technical Advisor notes that the value of global horizontal irradiation is significantly higher than the rest of databases reviewed. Accordingly, Enertis Solar has not considered SSE NASA database.

### 1.1.4. PVGIS

PVGIS (Photovoltaic Geographical Information System) is an instrument for geographical assessment of the solar energy resource developed by Joint Research Centre (JRC) of the European Commission. JRC has developed two databases: (i) the PVGIS HelioClim and (ii) CM-SAF PVGIS.

JRC has developed a database specifically for Africa named PVGIS-HelioClim. The database is considered as a starting point for the HelioClim-1 database, which is reviewed in Section 1.1.5, for the period from 1985 to 2004 with a spatial resolution of approximately 28 km x 28 km. PVGIS has processed Helio-Clim 1 data by with tools integrated within GRASS[1], mainly with a solar radiation model, r.sun, and spatial interpolation techniques, s.surf.rst and

[1] *GRASS, Geographic Resources Analysis Support System, is an image processing system and graphics production system.*

s.vol.rst. It shall be noted that JRC has not reported the accuracy of PVGIS-HelioClim database. The Technical Advisor obtained for the Plant's site using PVGIS-HelioClim an annual global horizontal irradiation equal to 2,128 kWh/m$^2$.

On the other hand, PVGIS has released CM-SAF PVGIS database after PVGIS-HelioClim, and, it is based on newer meteorological data sets for the period from 1998 to 2005 with a spatial resolution of approximately 3 km x 3 km. After testing the CM-SAF database against high-quality measurements on the ground, JRC considers that that the error is less than 5%. In addition, in opinion of JRC, CM-SAF PVGIS database is more accurate than the PVGIS-HelioClim. The Technical Advisor obtained for the Plant's site using CM-SAF PVGIS an annual global horizontal irradiation equal to 2,105 kWh/m$^2$.

Based on PVGIS statements, Enertis Solar considers that, even though both PVGIS databases indicates global irradiation values within the expected range, the spatial resolution is not the better of the available sources. Therefore, the Technical Advisor has not considered in this study the global horizontal irradiation values offered by PVGIS models.

1.1.5. Helio-Clim

Mines Paristech-Armines receives Meteosat data from Eumetsat and process them in real time, producing Helioclim solar irradiance database that can be accessed through SoDa Service. There are several versions of this database, and at the present the available one is Helio-Clim 1. The database provides irradiation values for horizontal plane, built from Meteosat images, with a spatial resolution of 20 km. It covers a time-period from January 1985 to December 2005.

For the Plant's location, Helioclim 1 estimates 2,127 kWh/m$^2$, which is in the expected range. However, Enertis Solar has not considered Helioclim 1 database's irradiation value since it is obtained through a low resolution satellite data.

**Global horizontal irradiation for the Project's location**

After the available database review, Enertis Solar has considered an annual global horizontal irradiation value for the Project's location of 2,088 kWh/m$^2$, obtained through SolarGIS v1.8. The high resolution and the availability of 19-year period hourly data, which made possible establishing a long-term estimation, makes SolarGIS v1.8 the most reliable source compared with the other databases studied in this report.

### 1.2. ENERGY PRODUCTION ESTIMATIONS

The estimation of the output energy (***E***) of a photovoltaic plant during a specific period of time is carried out through an independent evaluation of the following parameters: Peak Power ($\mathbf{P_p}$), Irradiation on the surface of the generator ($\mathbf{I_{GEN}}$), Performance Ratio (**PR**) and Availability (**A**).

$$E = P_P \cdot \left( I_{GEN} / I^* \right) \cdot PR \cdot A$$

$\mathbf{P_P}$ is a design parameter which indicates the peak power of all of the photovoltaic modules installed at the Plant, $\mathbf{I_{GEN}}$ is the irradiation which reaches the surface of the photovoltaic generator, $\mathbf{I^*}$ is a constant value which corresponds to the irradiance at Standard Test Conditions[2] (STC), **PR** is a parameter which shows the performance of photovoltaic systems and **A** is the percentage of time that the photovoltaic system is able to run at 100%.

[2] *1,000 W/m$^2$ irradiance, AM 1.5G and 25°C cell temperature.*

### 1.2.1. Peak Power

The peak power is the total output power of a photovoltaic module operating at Standard Test Conditions. Enertis Solar has considered, in this study, the overall DC power of the Plant, which is 45.996 $MW_{DC}$, according to the information submitted by the Sponsor, this represents a DC/AC ratio equal to 15% taking into account the nominal power to be installed in the Plant 40 $MW_{AC}$. Regarding the requirements established in the RFP, the Plant's DC/AC ratio will be less than or equal to 15.0%.

The photovoltaic modules being considered are poly-crystalline silicon technology, YL295P-35b model, 295W each, supplied by Yingli Solar. It is important to note that this module's technology is affected by a degradation which occurs in two different stages: (i) an initial degradation that takes place in the first hours of operation, due to the intrinsic characteristics of the silicon, and (ii) a long-term progressive degradation, usually with less severe degradation than the initial one, which is associated with intrinsic and extrinsic conditions to the technology of the photovoltaic modules.

The initial degradation of the photovoltaic modules is the result of the LID effect, or Light-Induced Degradation effect. During the production process of silicon ingots, where solar cells are obtained from, oxygen atoms are diffused into the silicon structure. At the time of first exposure of photovoltaic modules to sunlight, a recombination of oxygen atoms with boron, an element used for silicon doping, takes place. The result of this recombination is that the photovoltaic properties of silicon are slightly reduced.

D. Chianese *et al*, in their article *News on PV module testing at LEEE-TISO*, discussed the degradation caused by the LID effect. The data was gathered from tests performed in the LEEE-TISO laboratory since 1993. Most notably, the results came from a test on a 14 module-sample, 10 of which were crystalline silicon modules. The tests have been analyzed since 2003. The authors of this article reported an average power loss in crystalline silicon modules due to the initial degradation equal to 1.1%.

It is important to note that the initial degradation depends on the quality of the silicon used in the manufacturing of photovoltaic cells. Enertis Solar owns a photovoltaic testing laboratory where periodic measurements of photovoltaic module degradation are performed. The experience obtained through these measurements, performed during the last 6 years, concludes an average initial degradation of approximately 1%. The Technical Advisor has considered this value in this study.

Conversely, the long-term degradation experienced by the photovoltaic module is a process caused by several factors. M. A. Quintana *et al*, developed a study on this phenomenon, based on data sets gathered in the Sandia National Laboratories, National Renewable Energy Laboratory and LEEE-TISO CH-Testing Centre for Photovoltaic Modules. The results of this analysis were published by NREL in the article, *Commonly Observed Degradation in field-aged photovoltaic modules, presented in the IEEE Photovoltaic Specialist Conference of New Orleans, 2002*. The authors classified the observed degradation in photovoltaic modules in five categories: (i) degradation of packaging materials, (ii) loss of adhesion, (iii) degradation of cell/module interconnects, (iv) degradation caused by moisture intrusion, and (v) degradation of the semiconductor device.

C. R. Osterwald *et al*, in their article published by NREL, also *presented in the IEEE Photovoltaic Specialist Conference of New Orleans, 2002*, *Degradation analysis of weathered crystalline-silicon PV modules,* considered an annual average degradation of 0.71% for four types of crystalline silicon modules subjected to real-time and accelerated solar weathering programs at the National Renewable Energy Laboratory. M. A. Quintana *et al*, in their article developed at Sandia National Laboratories and presented at the 28$^{th}$ IEEE Photovoltaic Specialists Conference, *Diagnostic analysis of silicon photovoltaic modules after 20-year field exposure, published in the IEEE Photovoltaic*

*Specialists Conference of Anchorage, 2000*, expressed that the modules showed a power loss of 0.5% per year for crystalline silicon modules without any reliability issues.

Considering its own experience acquired through Enertis Solar's photovoltaic testing laboratory, as well as the studies about power degradation trends, the Technical Advisor estimates an annual average loss of 0.5% as an appropriate rate for the Project.

1.2.2. Irradiation on the surface of the photovoltaic modules

Enertis Solar reviewed the irradiation databases available for the Project's location in which the Technical Advisor has considered a global horizontal irradiation value equal to 2,088 kWh/m$^2$ for the Project's site.

The photovoltaic modules of the Plant will be installed on fixed tilted metallic structure with a tilt angle of 22°. Therefore, the irradiation which reaches the photovoltaic modules is higher than the irradiation in the horizontal plane. The ratio between the irradiation on the horizontal plane and the irradiation projected on the photovoltaic generator is called Gain.

Enertis Solar has used PVSyst simulation software, developed by the University of Geneve, to calculate the Gain. This parameter depends on the site location, the local weather and the lay-out of the photovoltaic plant. In this case, Enertis Solar has modeled the photovoltaic modules according to the design submitted by the Sponsor.

There are several mathematical models to calculate the transposition factor from horizontal to in-plane irradiation, widely discussed in several scientific articles. Specifically, in PVSyst software it is possible to choose between two different models: (i) Hay model, a robust model which gives accurate results even if the knowledge of the diffuse irradiation is not perfect and (ii) Pérez model, a more sophisticated model which requires a precise measurement of the horizontal data. Due to the Technical Advisor has obtained a good correlation between the database selected and ground measurements registered in the Plant's site and, also, that SolarGIS provided hourly data with a remarkable spatial resolution, Enertis Solar has considered the Pérez model to estimate the Gain.

The Gain obtained by the computer simulations and the resulting global irradiation incident in the modules plane are shown in the following table.

| Parametro | The Plant |
|---|---|
| Annual horizontal global irradiation (kWh/m2) | 2,088 |
| Gain (%) | 8.4% |
| Annual global irradiation on PV modules plane (kWh/m2) | 2,264 |

Table 1.2. Annual global irradiation incident on modules plane.

The data outlined in the table above has been used by the Technical Advisor for the estimation of the Plant's energy production.

### 1.2.3. Performance Ratio

The performance of a photovoltaic plant is commonly denominated as Performance Ratio, or PR. The PR represents the ratio between the expected energy, taking into account all the losses that occur, and the theoretical energy input in ideal conditions. Note that the PR was presented at the beginning of this section.

Enertis Solar have assessed each energy loss that will take place in the Project.

<u>Angular and spectral losses</u>

When the solar spectrum reaches the surface of the module with an incident angle different from 90°, *i.e*, not in a perpendicular way, part of the radiation is reflected and does not reach the photovoltaic cells, thus, angular losses occur.

Furthermore, depending on the atmospheric conditions, the solar spectrum reaching the solar cell is modified and, therefore, spectral losses occur.

Enertis Solar, based on the PVSyst simulation, has estimated the sum of these losses for three scenarios to be 2.9%.

Shading losses

Shadows projected over the modules reduce the incident radiation, and thus, the produced energy.

The near shadows were considered by Enertis Solar, which occur due to the adjacent photovoltaic modules, the structures, the inverters and transformer skids, the fence surrounding the Plant and other shading elements. In addition, any obstruction in the horizon can cause shadows over the photovoltaic modules.

Enertis Solar has simulated the lay-out of the Project using PVSyst software, as it is shown in the following figure.

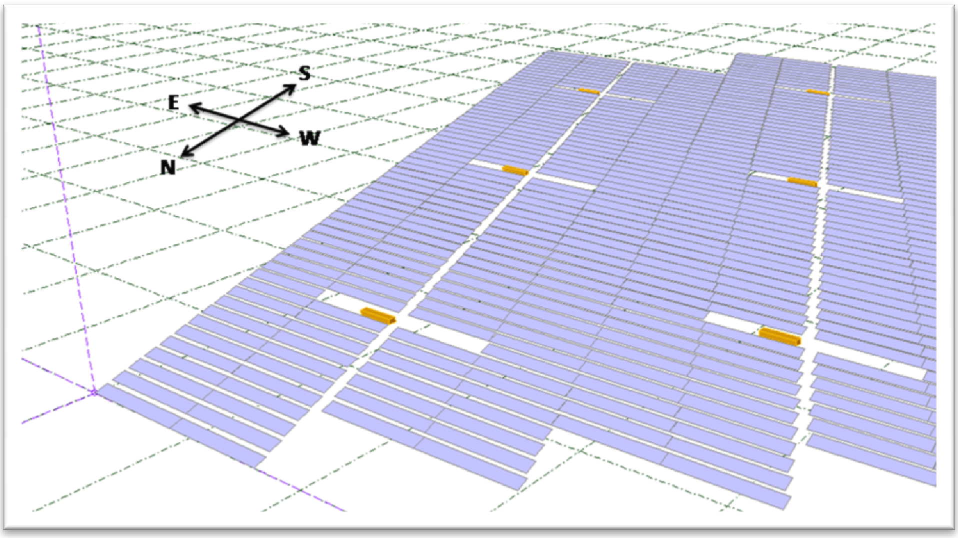


Figure 1.2. Project's lay-out used in the simulation made by Enertis Solar using PVSyst software.

Enertis Solar has considered a 2.3% loss due to the shading at the Plant.

Soiling losses

The soiling losses will depend on the characteristics of the location, the meteorological conditions, the type of structure in which the modules will be installed and the frequency of module cleanings stated in the maintenance planning.

Considering the modules will be installed on a fixed structure, the average rainfall for the project location is about 450 mm per year, and the module cleanings' frequency is not defined yet in the O&M contract. Enertis Solar has estimated a 2.5% soiling loss, which, in the opinion of the Technical Advisor, is within the usual range for this kind of photovoltaic plant.

Furthermore, Enertis Solar recommends that the O&M Contractor monitors the soiling losses existing at the Plant by comparing the irradiance given by one sensor frequently cleaned, and other only cleaned with the same frequency than the module cleaning.

For a further stage of the due diligence process, the Technical Advisor will review this value regarding the O&M strategy established for the Plant.

Temperature losses

The photovoltaic cells voltage, hence the module power, depends on the cell temperature. When operating at higher cell temperatures than the Standard Test Conditions, 25°C, the peak power of the module becomes lower than the peak power at STC.

This factor depends on the characteristics of the photovoltaic module itself, specifically, the temperature coefficient of maximum power. In this case, for the Yingli Solar YL295P-35b module this coefficient is equal to -0.45 %/°C.

Enertis Solar has evaluated the temperature losses though the studies shown in 2 papers: (i) Skoplaki *et al*, *Solar Energy Materials & Solar Cells* for the estimation of the cell temperature variability along a year and (ii) M. Alonso

Abella and F. Chenlo, *Estimación de la energía generada por un sistema fotovoltaico conectado a red*.

Enertis Solar has estimated this loss as equal to 10.2% for the Project.

Losses due to the irradiance level

Operating outside the Standard Test Conditions, specifically when the irradiation level is different from 1,000 W/m$^2$, the photovoltaic module efficiency is different, usually lower, from the efficiency given by the manufacturer in the technical specifications of the module. Thus, these losses are greater at sites where irradiation is lower. Likewise, these losses are greatest at dawn and at dusk compared to midday.

The Technical Advisor has evaluated these losses through the simulation made by PVSyst software. Enertis Solar has estimated this loss to be equal to 2.6%.

Mismatch losses

Due to the dispersion of the I-V curves of the photovoltaic modules, not all of the modules operate in the same conditions, and mismatch losses will occur. In general terms, the mismatch losses are the result of the limitation of the electrical parameters of every module connected in series to the electrical parameters of the module with the lowest peak power.

According to the experience of Enertis Solar, there are two hypothetical scenarios which could determine the origin of these losses:

(i) Modules provided with a negative and positive power tolerance.
It could occur that the DC power of several modules to be installed will be lower than their nameplate power. Connecting one of these lower power modules in series with other modules with higher output power would result in all of the modules in that series being limited and offering the same output power as the one with the lowest

power. Therefore, the mismatch losses can make the operating power of the Plant lower than the sum of the nominal DC power of every module installed on it.

(ii) Modules provided only with positive power tolerance.
It could occur that the DC power of all the modules to be installed will be equal or higher than their nameplate power. As explained before, the lower power module connected in a series will determine the output power of all the modules connected to it. Hence, in the worst case, the output power of the series will be equal to the DC nameplate power. For this reason, the Technical Advisor considers that mismatch losses will not be included.

Notwithstanding the foregoing, Enertis Solar suggests that if the energy production of the Plant is going to be estimated through the PR of this study, the peak power that should be considered is the sum of the nominal peak power of the modules of the Plant, which is different to the actual peak power that will be delivered, shown in manufacturer's flash-report[3], when the Project's modules are acquired.

As noted before, Enertis Solar has considered in this study 45.996 $MW_{DC}$, given by the sum of the nominal DC power of each photovoltaic module at the Plant. Considering the modules that will be installed in the Plant have positive tolerances, the Technical Advisor considered mismatch losses equal to 0.0% for all the cases analyzed.

[3] *A report prepared by the modules manufacturer which shows the peak power of each purchased module at Standard Test Conditions.*

Low Voltage ohmic losses

This loss appears as a consequence of the ohmic resistance in the Low Voltage cabling from the modules to the inverters.

According to the information submitted by the Sponsor, the Project is in an early stage of design, and it has not gone through detailed engineering yet. Taking into account its own experience in this kind of photovoltaic plants, Enertis Solar considers 1.5% electrical losses to be likely. It is noteworthy that this value could be modified in a further engineering stage.

Inverter losses

The conversion efficiency of the inverters depends on the power load. Generally, as load increases, the conversion efficiency rises too. A typical criterion to study the inverters efficiency curves is the CEC efficiency parameter, as it establishes a common parameter to compare different inverters using their technical data-sheet. According to the Sponsor's design, the inverters that will be used are PV750WD inverters. This inverter's CEC efficiency is 98.08%.

Nevertheless, it is necessary to study the inverters performance for the Plant's location and weather conditions. After simulating the operation of this equipment, Enertis Solar has estimated a loss equal to 2.6% for the whole Project.

In addition, the loss due to the accuracy of the maximum power point tracking system of the inverters must be considered. According to Enertis Solar's experience, this value is approximately 0.6% for this kind of location.

Medium and High Voltage wiring and transformation losses

The transformation from low voltage to medium voltage creates electric losses. Likewise, there are losses due to the electricity transportation through medium voltage wiring. Thus, it is necessary to consider the electrical losses that will occur in the transformers, each of them placed in the transformation centers along with the inverters. These transformers will raise the voltage to 20 kV.

In addition, attending to the Sponsor's guide-lines, Enertis Solar has considered Medium Voltage lines which shall transmit the produced electricity from the transformation centers to a substation, which will be located in the plot adjacent to the Plant's facilities.

Therefore, the Technical Advisor has considered 2.5% of losses regarding the transformers operation and Medium Voltage. As noted before, the Project is in an early stage of design and it has not gone through detailed engineering yet. Enertis Solar will reassess these losses in a further stage of this due diligence process.

Summary of system design losses

Taking into account the aforementioned losses, Enertis Solar has estimated the efficiency of the Plant which is represented as the design PR parameter. The following table shows a summary of the losses and design PR calculated for the Project.

| Loss factor | The Plant |
|---|---|
| Spectral | 2,9% |
| Angular | |
| Shading | 2,3% |
| Soiling | 2,5% |
| Temperature | 10,2% |
| Irradiance level | 2,6% |
| Mismatch | 0,0% |
| Low Voltage wiring | 1,5% |
| Inverter | 2,6% |
| MPP tracking | 1,0% |
| Transformation and Medium Voltage wiring | 2,5% |
| **Design PR** | **75,0%** |

Table 1.3. Loss factors and design PR.

### 1.2.4. Unavailability

Unavailability is defined as the periods of time in which the Plant is not producing energy at full capacity. It should be noted that losses of availability may occur within the photovoltaic plant facilities (hereinafter, the internal unavailability), which the operation and maintenance contractor is liable for, or outside the photovoltaic plant facilities (hereinafter, the external unavailability), *i.e*, in the transmission infrastructures.

Regarding the internal unavailability, at the time of this report, the operation and maintenance agreement is not defined yet. Nonetheless, the Technical Advisor has considered a typical availability value for this kind of plants, which is 99%. In Enertis Solar's view this availability could be achieved through proper operation and maintenance of the Plant, and, consequently, 1% unavailability has been considered in this study. Nonetheless it would be convenient to review this value in a further stage of the Project development, once the operation and maintenance agreement is fully defined.

### 1.2.5.Energy self-consumption

The Power Purchase Agreement to be signed after the tender, stated that the Plant shall not supply energy to the grid whilst it is importing energy from the electric system, unless the Plant uses such imported energy for safety systems, lighting or other loads no directly related to energy generation.

Enertis Solar considered several assumptions regarding this matter, specifically about the auxiliary systems energy. Therefore, from this information and its own experience in similar projects, Enertis Solar has estimated the Plant's self-consumption to be 583,716 kWh per year. In a further stage of the due diligence process, the Technical Advisor recommends a review of this value.

1.2.6. Estimated energy production

After analyzing each of the factors discussed above, the Technical Advisor has estimated the parameters for the first year of Plant operation. Specifically, the energy production estimate and the equivalent hours[4] for the Project are displayed in the table below.

| Parameter | The Plant |
|---|---|
| Annual global irradiation on PV modules plane (kWh/m$^2$) | 2.264 |
| Peak power (kW) | 45.996 |
| Design PR | 75,0% |
| **Design equivalent hours (kWh/kW)** | **1.698** |
| Unavailability | 1,0% |
| Initial power degradation | 1,0% |
| Long term degradation | 0,5% |
| **PR del año 1 de operación** | **73,3%** |
| **Equivalent hours for 1$^{st}$ year (kWh/kWp)** | **1.660** |
| Energy production estimation for 1$^{st}$ year (kWh) | 76.357.445 |
| Energy self-consumption (kWh) | 583.716 |
| Energy self-consumption (%) of the energy production for 1$^{st}$ year | 0,76% |
| **Equivalent hours for 1$^{st}$ year considering self-consumption (kWh/kWp)** | **1.647** |
| Energy production estimation for 1$^{st}$ year (kWh) considering energy self-consumption | 75.773.729 |

Table 1.4. Summary of annual parameters estimated for the Project.

To estimate the energy production of the Project, Enertis Solar has considered the annual power degradation of the photovoltaic modules as 0.5% for poly-crystalline technology modules. Thus, the amount of energy produced, as well as the equivalent hours, will decrease 0.5% from the first year value per year. It is also important to note that the Technical Advisor has considered the overall peak power of the Plant, 45,996 $kW_{DC}$ for the energy production estimation.

Enertis Solar has developed a monthly energy production study, as this is a requirement established in the RFP of the Third Bid. These results are

[4] *Parameter defined as the kWh produced for kWp installed in a photovoltaic plant.*

summarized in the following table as a monthly energy percentage distribution.

| Month | Monthly P50 energy production distribution (%) |
|---|---|
| January | 8,20% |
| February | 7,57% |
| March | 8,11% |
| April | 7,82% |
| May | 8,34% |
| June | 7,86% |
| July | 8,53% |
| August | 9,16% |
| September | 9,11% |
| October | 9,02% |
| November | 8,08% |
| December | 8,21% |

Table 1.5. Energy production monthly distribution.

### 1.2.7. Uncertainty analysis

Enertis Solar has studied the variables involved in the energy generation capacity of the Project, using Monte Carlo Simulation Method[5] for experimental iterations, in order to determine the probabilistic distribution of the annual energy production estimations for the Project. The distributions for each scenario can be approximated to a Gaussian distribution model defined by (i) the average equal to the equivalent hours for each year as detailed before and (ii) a standard deviation equal to 5.5%.

In the following tables, the equivalent hours and the annual energy production estimations, including the energy self-consumption, are shown in

[5] *This analytical technique works running a large number of simulations of random variables in order to solve integrals of several variables.*

P50, P60, P70, P80, P90 and P99 probabilistic scenarios for the first 20 years of operation, as indicated in the RFP established for Third Bid.

| Year | Design peak power percentage | Equivalent hours (kWh/kW) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Probability 50% | Probability 60% | Probability 70% | Probability 80% | Probability 90% | Probability 95% | Probability 99% |
| 1 | 98,75% | 1.647 | 1.625 | 1.600 | 1.572 | 1.532 | 1.499 | 1.438 |
| 2 | 98,25% | 1.639 | 1.616 | 1.592 | 1.564 | 1.524 | 1.492 | 1.431 |
| 3 | 97,75% | 1.631 | 1.608 | 1.584 | 1.556 | 1.516 | 1.484 | 1.423 |
| 4 | 97,25% | 1.622 | 1.600 | 1.576 | 1.548 | 1.509 | 1.476 | 1.416 |
| 5 | 96,75% | 1.614 | 1.592 | 1.568 | 1.540 | 1.501 | 1.469 | 1.409 |
| 6 | 96,25% | 1.606 | 1.583 | 1.560 | 1.532 | 1.493 | 1.461 | 1.401 |
| 7 | 95,75% | 1.597 | 1.575 | 1.552 | 1.524 | 1.485 | 1.454 | 1.394 |
| 8 | 95,25% | 1.589 | 1.567 | 1.543 | 1.516 | 1.478 | 1.446 | 1.387 |
| 9 | 94,75% | 1.581 | 1.559 | 1.535 | 1.508 | 1.470 | 1.439 | 1.380 |
| 10 | 94,25% | 1.572 | 1.551 | 1.527 | 1.500 | 1.462 | 1.431 | 1.372 |
| 11 | 93,75% | 1.564 | 1.542 | 1.519 | 1.492 | 1.454 | 1.423 | 1.365 |
| 12 | 93,25% | 1.556 | 1.534 | 1.511 | 1.484 | 1.447 | 1.416 | 1.358 |
| 13 | 92,75% | 1.547 | 1.526 | 1.503 | 1.476 | 1.439 | 1.408 | 1.351 |
| 14 | 92,25% | 1.539 | 1.518 | 1.495 | 1.468 | 1.431 | 1.401 | 1.343 |
| 15 | 91,75% | 1.531 | 1.509 | 1.487 | 1.460 | 1.423 | 1.393 | 1.336 |
| 16 | 91,25% | 1.522 | 1.501 | 1.479 | 1.452 | 1.416 | 1.385 | 1.329 |
| 17 | 90,75% | 1.514 | 1.493 | 1.471 | 1.444 | 1.408 | 1.378 | 1.321 |
| 18 | 90,25% | 1.506 | 1.485 | 1.462 | 1.436 | 1.400 | 1.370 | 1.314 |
| 19 | 89,75% | 1.497 | 1.477 | 1.454 | 1.428 | 1.392 | 1.363 | 1.307 |
| 20 | 89,25% | 1.489 | 1.468 | 1.446 | 1.420 | 1.385 | 1.355 | 1.300 |
| 21 | 88,75% | 1.481 | 1.460 | 1.438 | 1.412 | 1.377 | 1.347 | 1.292 |
| 22 | 88,25% | 1.472 | 1.452 | 1.430 | 1.404 | 1.369 | 1.340 | 1.285 |
| 23 | 87,75% | 1.464 | 1.444 | 1.422 | 1.397 | 1.361 | 1.332 | 1.278 |
| 24 | 87,25% | 1.456 | 1.435 | 1.414 | 1.389 | 1.354 | 1.325 | 1.270 |
| 25 | 86,75% | 1.447 | 1.427 | 1.406 | 1.381 | 1.346 | 1.317 | 1.263 |

Table 1.6. Equivalent hours.

| Year | Design peak power percentage | Net yield (kWh) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Probability 50% | Probability 60% | Probability 70% | Probability 80% | Probability 90% | Probability 95% | Probability 99% |
| 1 | 98,75% | 75.773.729 | 74.724.270 | 73.601.465 | 72.287.417 | 70.465.059 | 68.960.125 | 66.137.119 |
| 2 | 98,25% | 75.390.065 | 74.345.919 | 73.228.799 | 71.921.404 | 70.108.274 | 68.610.960 | 65.802.247 |
| 3 | 97,75% | 75.006.400 | 73.967.569 | 72.856.133 | 71.555.392 | 69.751.489 | 68.261.795 | 65.467.376 |
| 4 | 97,25% | 74.622.736 | 73.589.218 | 72.483.468 | 71.189.380 | 69.394.704 | 67.912.629 | 65.132.504 |
| 5 | 96,75% | 74.239.072 | 73.210.867 | 72.110.802 | 70.823.368 | 69.037.919 | 67.563.464 | 64.797.633 |
| 6 | 96,25% | 73.855.407 | 72.832.516 | 71.738.136 | 70.457.355 | 68.681.134 | 67.214.299 | 64.462.761 |
| 7 | 95,75% | 73.471.743 | 72.454.166 | 71.365.471 | 70.091.343 | 68.324.349 | 66.865.134 | 64.127.890 |
| 8 | 95,25% | 73.088.078 | 72.075.815 | 70.992.805 | 69.725.331 | 67.967.563 | 66.515.969 | 63.793.018 |
| 9 | 94,75% | 72.704.414 | 71.697.464 | 70.620.139 | 69.359.319 | 67.610.778 | 66.166.804 | 63.458.147 |
| 10 | 94,25% | 72.320.749 | 71.319.113 | 70.247.474 | 68.993.307 | 67.253.993 | 65.817.638 | 63.123.275 |
| 11 | 93,75% | 71.937.085 | 70.940.763 | 69.874.808 | 68.627.294 | 66.897.208 | 65.468.473 | 62.788.404 |
| 12 | 93,25% | 71.553.420 | 70.562.412 | 69.502.142 | 68.261.282 | 66.540.423 | 65.119.308 | 62.453.532 |
| 13 | 92,75% | 71.169.756 | 70.184.061 | 69.129.477 | 67.895.270 | 66.183.638 | 64.770.143 | 62.118.661 |
| 14 | 92,25% | 70.786.091 | 69.805.710 | 68.756.811 | 67.529.258 | 65.826.853 | 64.420.978 | 61.783.789 |
| 15 | 91,75% | 70.402.427 | 69.427.360 | 68.384.146 | 67.163.245 | 65.470.068 | 64.071.812 | 61.448.918 |
| 16 | 91,25% | 70.018.763 | 69.049.009 | 68.011.480 | 66.797.233 | 65.113.283 | 63.722.647 | 61.114.046 |
| 17 | 90,75% | 69.635.098 | 68.670.658 | 67.638.814 | 66.431.221 | 64.756.497 | 63.373.482 | 60.779.175 |
| 18 | 90,25% | 69.251.434 | 68.292.308 | 67.266.149 | 66.065.209 | 64.399.712 | 63.024.317 | 60.444.303 |
| 19 | 89,75% | 68.867.769 | 67.913.957 | 66.893.483 | 65.699.196 | 64.042.927 | 62.675.152 | 60.109.432 |
| 20 | 89,25% | 68.484.105 | 67.535.606 | 66.520.817 | 65.333.184 | 63.686.142 | 62.325.986 | 59.774.560 |
| 21 | 88,75% | 68.100.440 | 67.157.255 | 66.148.152 | 64.967.172 | 63.329.357 | 61.976.821 | 59.439.689 |
| 22 | 88,25% | 67.716.776 | 66.778.905 | 65.775.486 | 64.601.160 | 62.972.572 | 61.627.656 | 59.104.817 |
| 23 | 87,75% | 67.333.111 | 66.400.554 | 65.402.820 | 64.235.147 | 62.615.787 | 61.278.491 | 58.769.946 |
| 24 | 87,25% | 66.949.447 | 66.022.203 | 65.030.155 | 63.869.135 | 62.259.002 | 60.929.326 | 58.435.075 |
| 25 | 86,75% | 66.565.782 | 65.643.852 | 64.657.489 | 63.503.123 | 61.902.217 | 60.580.160 | 58.100.203 |

Table 1.7. Energy production.