Attestazione n. 38253/10/00

FEASIBILITY STUDY MOZAMBIQUE

CLIENT: CONVIVIUM ENERGY MOZAMBIQUE LDA

BUSINESS IMPROVEMENT SRL

Summary

A. FOREWORD

A.1. ENGAGEMENT OBJECT AND PURPOSE OF WORK

Business Improvement has been mandated as Technical Advisor for the evaluation of the technical feasibility of a ground-mounted photovoltaic plants to be realized in Mozambique, in Boane district near the village of Comicho, by CONVIVIUM ENERGY MOZAMBIQUE Ltd. (the "Client").
The PV plant Maputo will have a total capacity of 150 MW and will be divided into 5 lots of 30 MW each and will be realized through silicon PV modules, the plants are called "Comicho 1, Comicho 2, Comicho 3, Comicho 4, Comicho 5, localizated in the same area, 2 km far from the high voltage substation of Maputo.
The present Report includes:

- The characterization of the area;
- The study of the layout;
- The study of the electrical design;
- The evaluation of the irradiation data;
- The evaluation of the achievable Performance Ratios;
- The predicted net energy production;

This document constitutes the preliminary technical feasibility study of the Maputo Solar park, developed under the project "MAPUTO PLANTS", by the company CONVIVIUM ENERGY MOZAMBIQUE. In addition to this introductory chapter, this document is divided into three more chapters. Chapter B is subdivided into a global analysis of the solar resource for Mozambique, where the model used is characterized, and in a second phase an analysis of the more specific resource for the study site. In chapter C the project is characterized by its location, possibility of network connection and environmental framework, and the production is estimated by describing the methods and parameters used. In chapter D we also will see the electric layout, the preliminary connection layout and the technical design choices.

A.2. PREMISE

The photovoltaic technology is, by its nature, characterized by a working power that changes - from time to time - on the basis of the irradiation incident on the PV surface and of the temperature of the PV cells.
In detail, the parameter known as "nominal power" is calculated as the sum of the power of each PV module, as measured in "standard weather conditions" (i.e. Irradiation = 1.000 W/m2; Temperature = 25 °C). Anyhow, such "nominal power" will never be totally delivered to the grid, since (i) the "standard weather conditions" will be hardly achieved because we must take into account the temperature derating of photovoltaic cells; (ii) between the PV generator and the delivery point some electrical losses will occur (please see yield assessment below for any detail).

A.3. DISCLAIMER

The technical study hereinafter reported is based on data and information provided by the Client, so assuming that they represent the current status of the project development. Business Improvement is not responsible for completeness, accuracy, truthfulness and updating of data herein treated, or of data used for the evaluations. In particular, Business Improvement worked on the basis of the documentation and the information made available by the Client.
Our activity has an advisory scope, the analysis has been developed giving support to the evaluation activity and verification of the project. Any document used or issued during the mandate execution is confidential.

A.4. ECONOMIC AND SOCIAL CONTEXT

Currently 9 million Mozambicans (representing approximately 20,20 percent of the population) have electricity in their homes. The data, is all the more positive as we take into account the fact that in 2004 there were only 1.7 million people (or about 7 percent of the population) to have access to 'electricity.
Despite the wide availability of energy resources and the enormous needs (70 percent of the local population has no access to electricity), Mozambique does not have a distribution network covering the whole territory.
The main project in this sense and 'the so-called "backbone", an electrical distribution line that should be built along the North-South trajectory and whose time and' in progress the Center-South phase ("Cesul Transmission Project").
Although the current state of public finances and the embryonic nature of the regulatory and energy infrastructure necessary for the development framework will make the effective implementation of complex investment projects, there are, in perspective, many opportunities' in the field of renewable sources and energy efficiency, especially in light of recent global agreement on climate change in Paris. It 'also being studied by the Government, the construction of a gas pipeline of 2,600 km long from the basin of the Rovuma should bring gas to South Africa and to all major cities of Mozambique and special economic zones, the generation of electricity and the industrialization of the country.
Peak electricity demand was 530 MW in 2010 (without Mozal) with an energy consumption of approximately 3,032 GWh. The increase in power consumption has been significant during recent years with average annual increases in the order of 6 to 8 % over the last 10 years. These figures reflect supply to domestic, commercial and industrial consumers in the national power network supplied by Electricidade de Moçambique (EdM) the national power company.
Approx. 136 MW (61 MW from hydro and 75 MW from diesel and gas) are supplied by EdM's own generation, mainly by ageing plants requiring refurbishment. The remaining demand is supplied through a purchase agreement with Cahora Bassa, a hydropower plant at the Zambezi River with an installed capacity of 2,075 MW. The number of consumers has grown with more than 10% annually since the year 2000 and was about 850,000 in 2010 (2,240 Medium & High Voltage clients). At present still only 16% of the population has access to electricity. Power demand forecasts indicate that with an average projected growth rate of 6% p.a. Mozambique will reach a maximum demand of 1,350 MW by 2030 and a projected consumption of 8,300 GWh.

From 2009 until 2013, it is foreseen that demand reach 560 MW by 2013. For meeting the country‘s electricity needs in a timely manner, it is imperative given that the Cahora Bassa‘s reserve for domestic market requirements of 400 MW is almost exhausted. Therefore it is important that the HEP sites Mavuzi, Chicamba, Corumana are rehabilitated and that the technical and economical feasb. HEP sites Tsate, Mueneze, Alto Malema, Massingir and Mavuzi II and III are errected and the retrofit of the MTC Maputo Gas Turbine. These investments would sum to approx. 415 MW Cap and approx. 300 MW additional firm power. Several large scale IPPs, mainly for export purposes, are planned (totalling ca. 3 to 5 GW).
Below we show the electricity production data from active power plants in the territory of Mozambique:

Hydroelectric Producer Park:

Central	Installed Power (MW)	Productive Power (MW)	Available Power (MW)	Production (MWh)	Load Factor (%)	Storage Quota	Storage Volume (Mm3)
Corumana	16.6	16	16	38.800	21	111	1200
Chicamba	38.4	38	38	48,000	21	624.5	2000
Mavuzi	52	36	36	232,000	73	345.6	2.0
Cuamba	1.09	0.9	0.9	5,600	60	1001	2.6
Lichinga	0.73	0.5	0.5	4,320	67	1280	0.66
TOTAL	**108.82**	**91.4**	**91.4**	**328,720**			

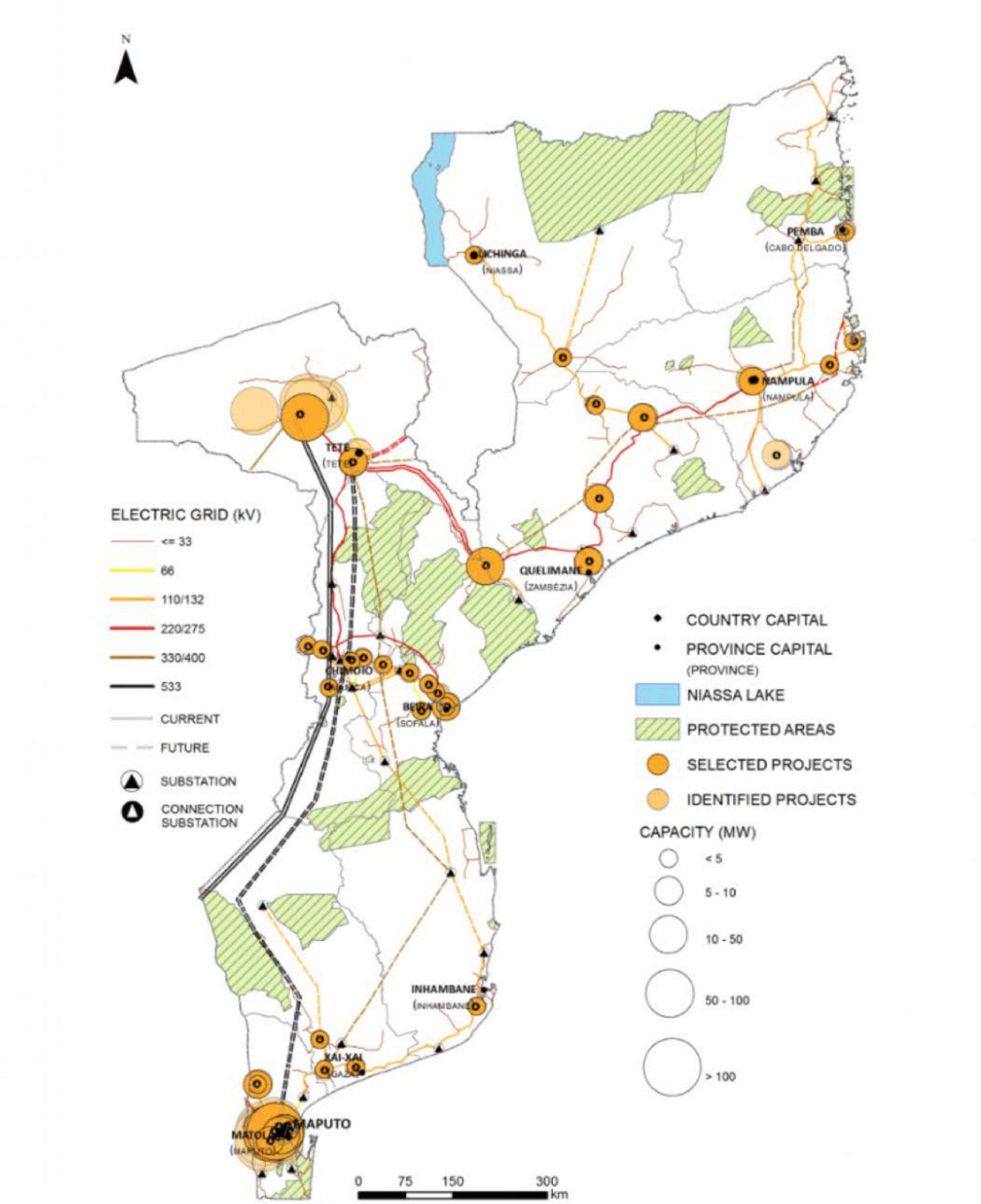
Thermoelectric Producer Park:

Central	Installed Power (MW)	Productive power (MW)	Power available (MW)	Type of plant	Fuel
GTG1 Maputo	17	12	0	OCGT	JET A1
GTG2 Maputo	36	32	0	OCGT	Diesel
GTG3 Maputo	24	22	0	OCGT	Diesel
GTG Beira	14	12	14	OCGT	Diesel
Térmica de Temane	11.2	11.2	11.2	Ciclo Otto	Gás Natural
TOTAL	**102.2**	**89.2**	**25.0**		

OCGT- Open cycle gas turbines

OCGS- Engine

Below we show the national electricity grid of Mozambique:



B. METEOROLOGICAL INPUT DATA

Maputo's area was chosen for obvious reasons:

1. proximity to the electricity transmission network in high voltage;
2. proximity to users of electricity produced by photovoltaic systems;
3. logistical issues;
4. possibility of further industrial development in the same area;

The capital Maputo is located in the far south, on the coast, the graphs relating to the rainfall and annual average temperatures refer to Motola (15 km far from Boane), and has an average temperature ranging from 26 degrees in January to 19.5 in July. Although the maximum in January and February are on average around 30 degrees.

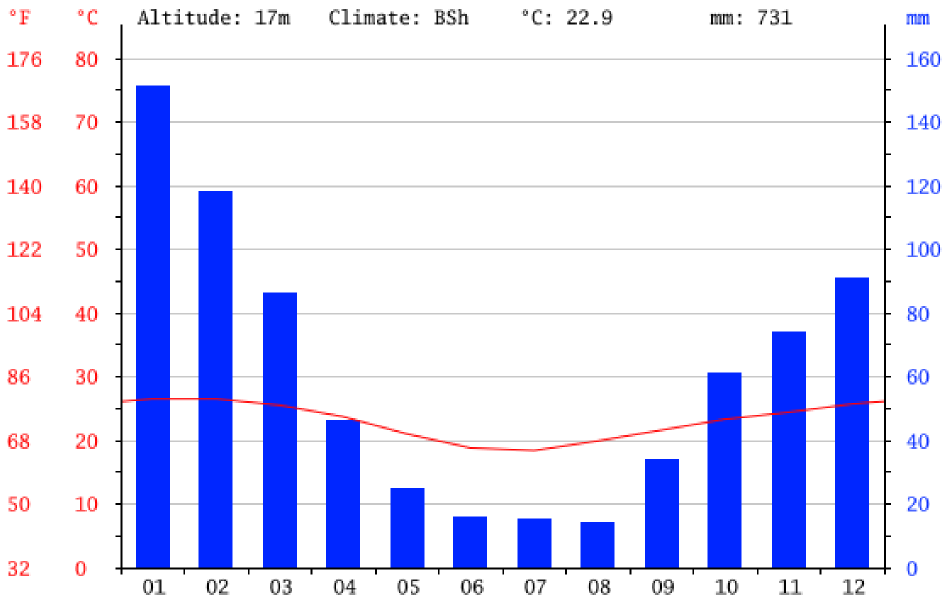


Figure 1 Rainfall graphic

In a year fall **731 mm** of rain, most of which from November to March. The wettest month is January with 151 mm. The rains have still an irregular pattern and may be more abundant in some years. Here the average rainfall.

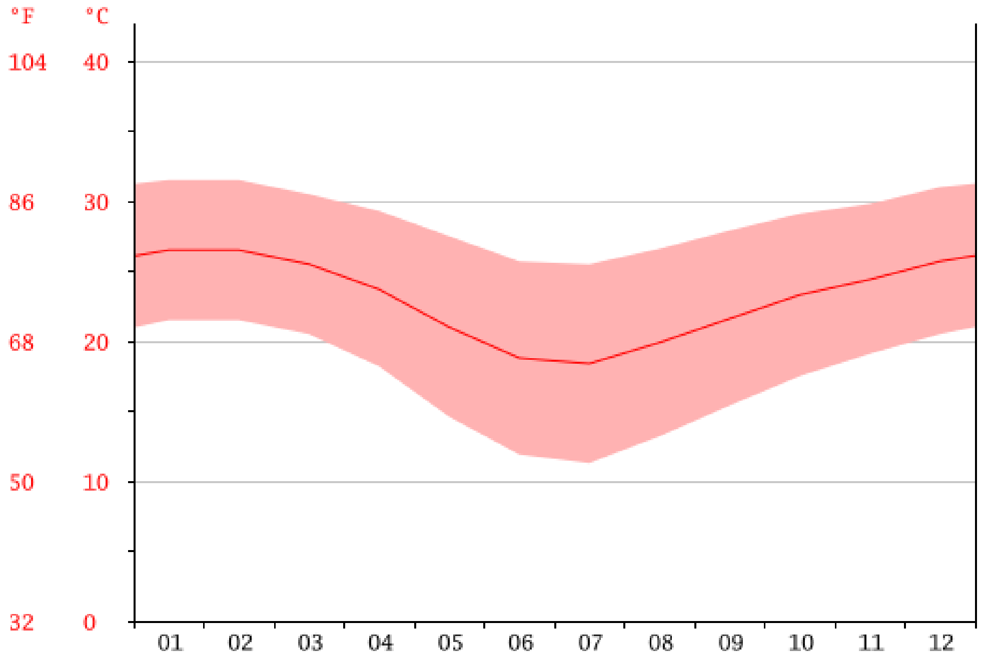


Figure 2 Temperature graph

Motola has an average temperature of 22.9 ° C.

month	1	2	3	4	5	6	7	8	9	10	11	12
mm	151	118	86	46	25	16	15	14	34	61	74	91
°C	26.5	26.5	25.5	23.7	21.0	18.8	18.4	19.9	21.6	23.3	24.4	25.7
°C (min)	21.5	21.5	20.5	18.2	14.6	11.9	11.3	13.2	15.4	17.5	19.1	20.5
°C (max)	31.5	31.5	30.5	29.3	27.5	25.7	25.5	26.6	27.9	29.1	29.8	31.0
°F	79.7	79.7	77.9	74.7	69.8	65.8	65.1	67.8	70.9	73.9	75.9	78.3
°F (min)	70.7	70.7	68.9	64.8	58.3	53.4	52.3	55.8	59.7	63.5	66.4	68.9
°F (max)	88.7	88.7	86.9	84.7	81.5	78.3	77.9	79.9	82.2	84.4	85.6	87.8

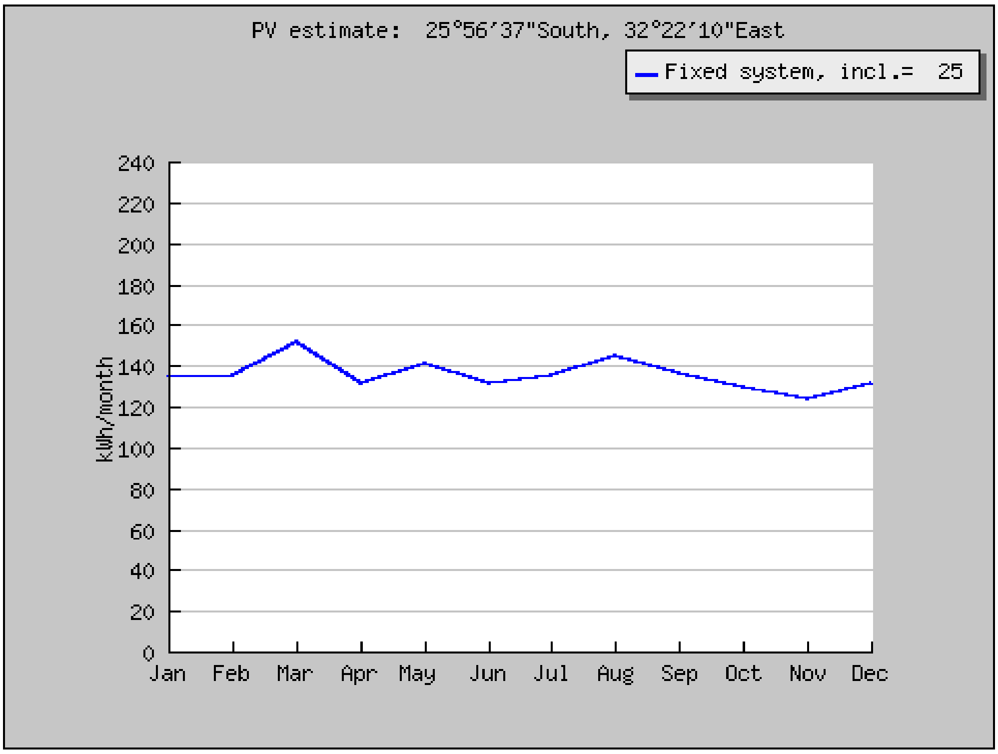
Solar insolation
Performance of Grid-connected PV
PVGIS estimates of solar electricity generation
Location: 25°56'37" South, 32°22'10" East, Elevation: 34 m a.s.l., in Boane district

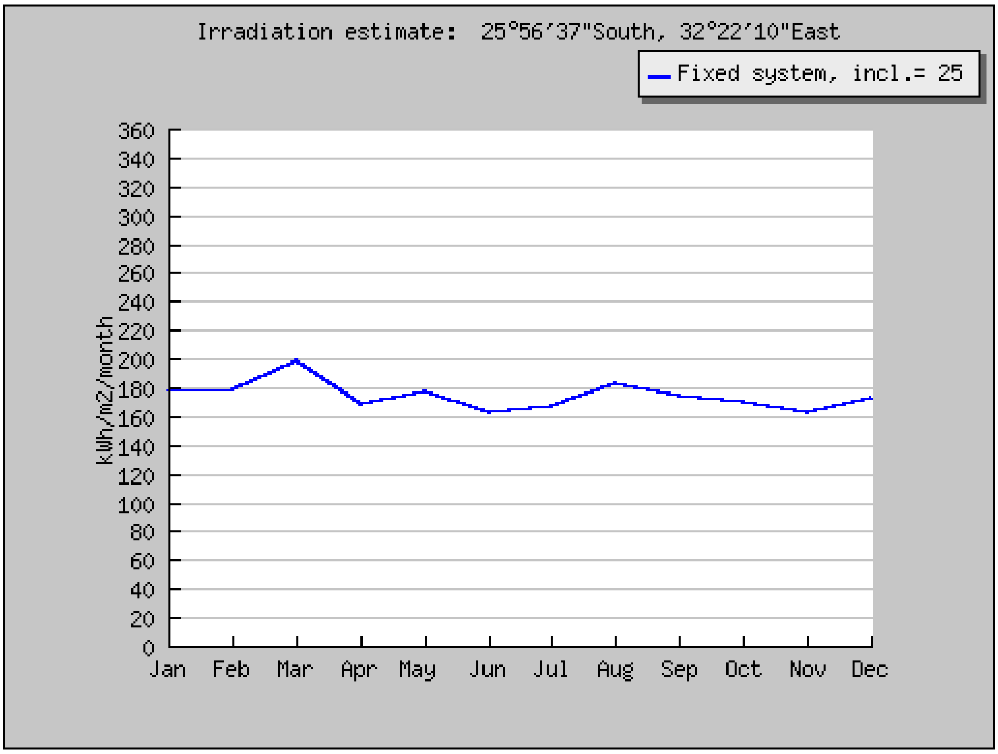
Solar radiation database used: PVGIS-CMSAF

Nominal power of the PV system: 1.0 kW (crystalline silicon)
Estimated losses due to temperature and low irradiance: 13.6% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 2.7%
Other losses (cables, inverter etc.): 7.0%
Combined PV system losses: 21.8%

Fixed system: inclination=25°, orientation= - 178° (optimum) - 180°				
Month	**E_d**	**E_m**	**H_d**	**H_m**
Jan	4.24	131	5.56	172
Feb	4.76	133	6.26	175
Mar	4.88	151	6.39	198
Apr	4.45	133	5.69	171
May	4.66	145	5.88	182
Jun	4.52	136	5.60	168
Jul	4.50	140	5.57	173
Aug	4.77	148	6.02	187
Sep	4.57	137	5.85	175
Oct	4.15	129	5.42	168
Nov	4.05	121	5.30	159
Dec	4.11	127	5.42	168
Yearly average	**4.47**	**136**	**5.74**	**175**
Total for year		**1630**		**2100**

Ed: Average daily electricity production from the given system (kWh)
Em: Average monthly electricity production from the given system (kWh)
Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2)
Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m2)


PV estimate: 25°56'37"South, 32°22'10"East
Fixed system, incl.= 25
kWh/month
0
20
40
60
80
100
120
140
160
180
200
220
240
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Irradiation estimate: 25°56'37"South, 32°22'10"East
Fixed system, incl.= 25
kWh/m2/month
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Monthly Solar Irradiation

Location: 25°56'37" South, 32°22'10" East, Elevation: 34 m a.s.l.,

Solar radiation database used: PVGIS-CMSAF

Optimal inclination angle is: 29 degrees-25 degrees
Annual irradiation deficit due to shadowing (horizontal): 0.0 %

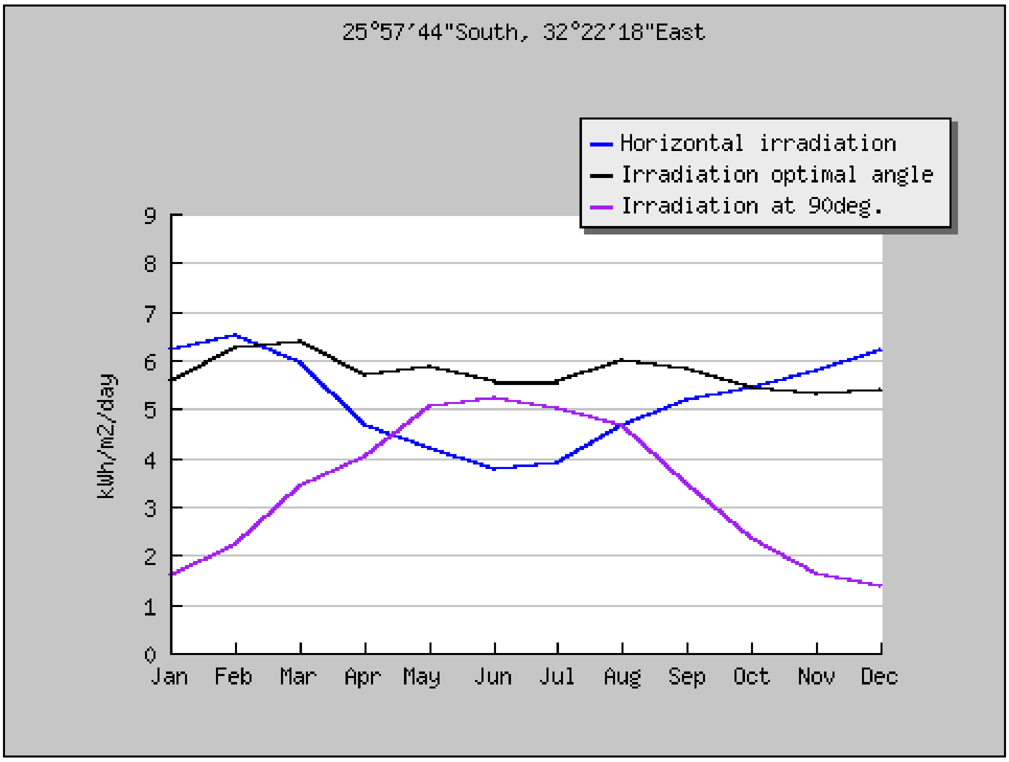
Month	H_h	H_{opt}	H(90)	I_{opt}
Jan	6140	5500	1590	-4
Feb	6400	6150	2240	8
Mar	5880	6280	3380	25
Apr	4660	5650	3990	40
May	4190	5810	5000	51
Jun	3760	5550	5160	56
Jul	3870	5510	4930	54
Aug	4620	5970	4620	46
Sep	5150	5790	3450	31
Oct	5410	5380	2370	14
Nov	5760	5260	1650	-1
Dec	6130	5360	1390	-8
Year	5160	5680	3320	29

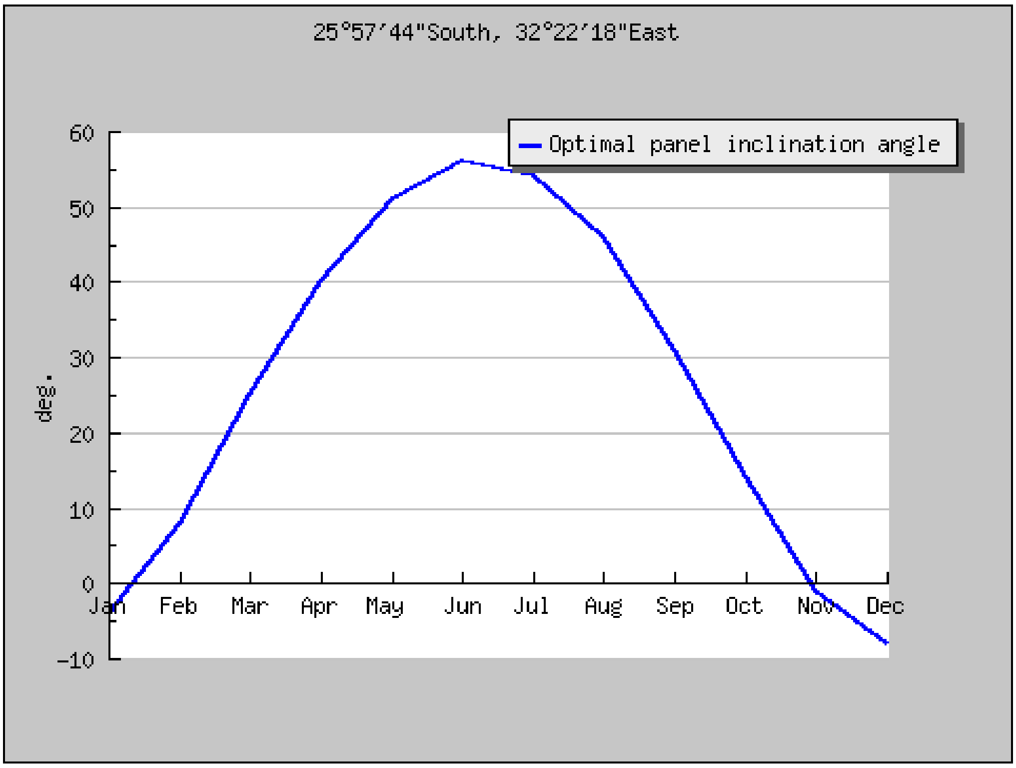
Hh: Irradiation on horizontal plane (Wh/m2/day)

Hopt: Irradiation on optimally inclined plane (Wh/m2/day)

H(90): Irradiation on plane at angle: 90deg. (Wh/m2/day)

Iopt: Optimal inclination (deg.)


25°57'44"South, 32°22'18"East
Horizontal irradiation
Irradiation optimal angle
Irradiation at 90deg.
kWh/m2/day
0
1
2
3
4
5
6
7
8
9
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


25°57'44"South, 32°22'18"East
Optimal panel inclination angle
deg.
-10
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

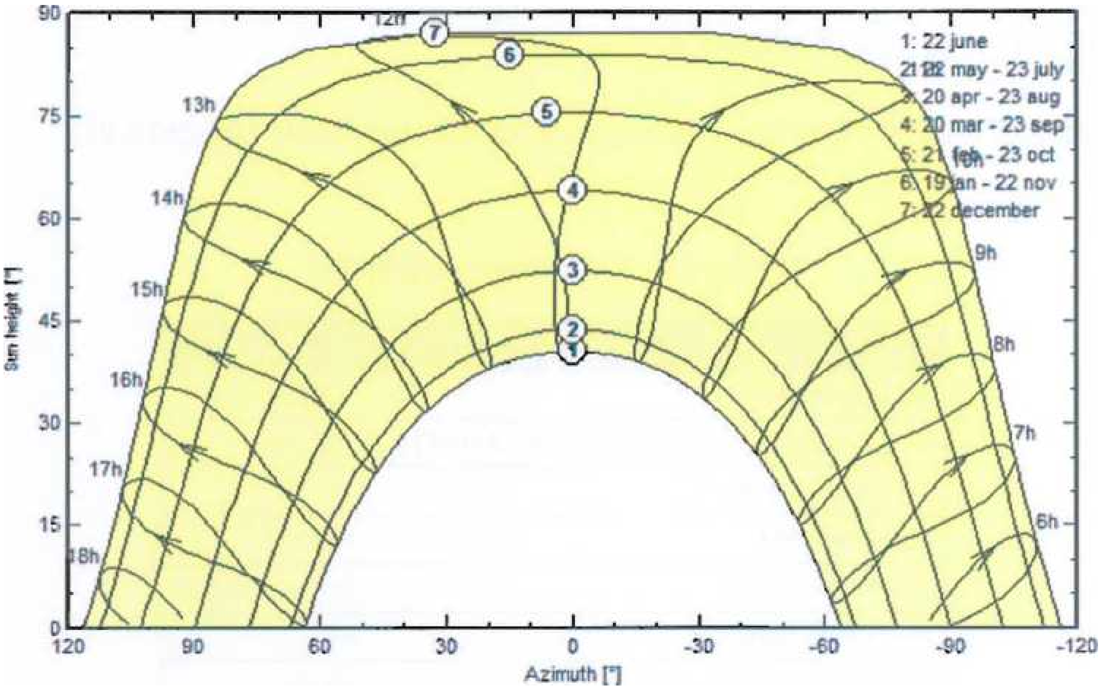


Figure 3.1 Solar Route in Southern Mozambique

C. PV FIELD LAYOUT

C.1. MAIN FEATURES OF THE AREA INTERVENTION

The project in question involves the construction of a photovoltaic plant 150 MWp to be built in Mozambique , in the Boane district. Below the map of the horizontal radiation with the site highlighted.

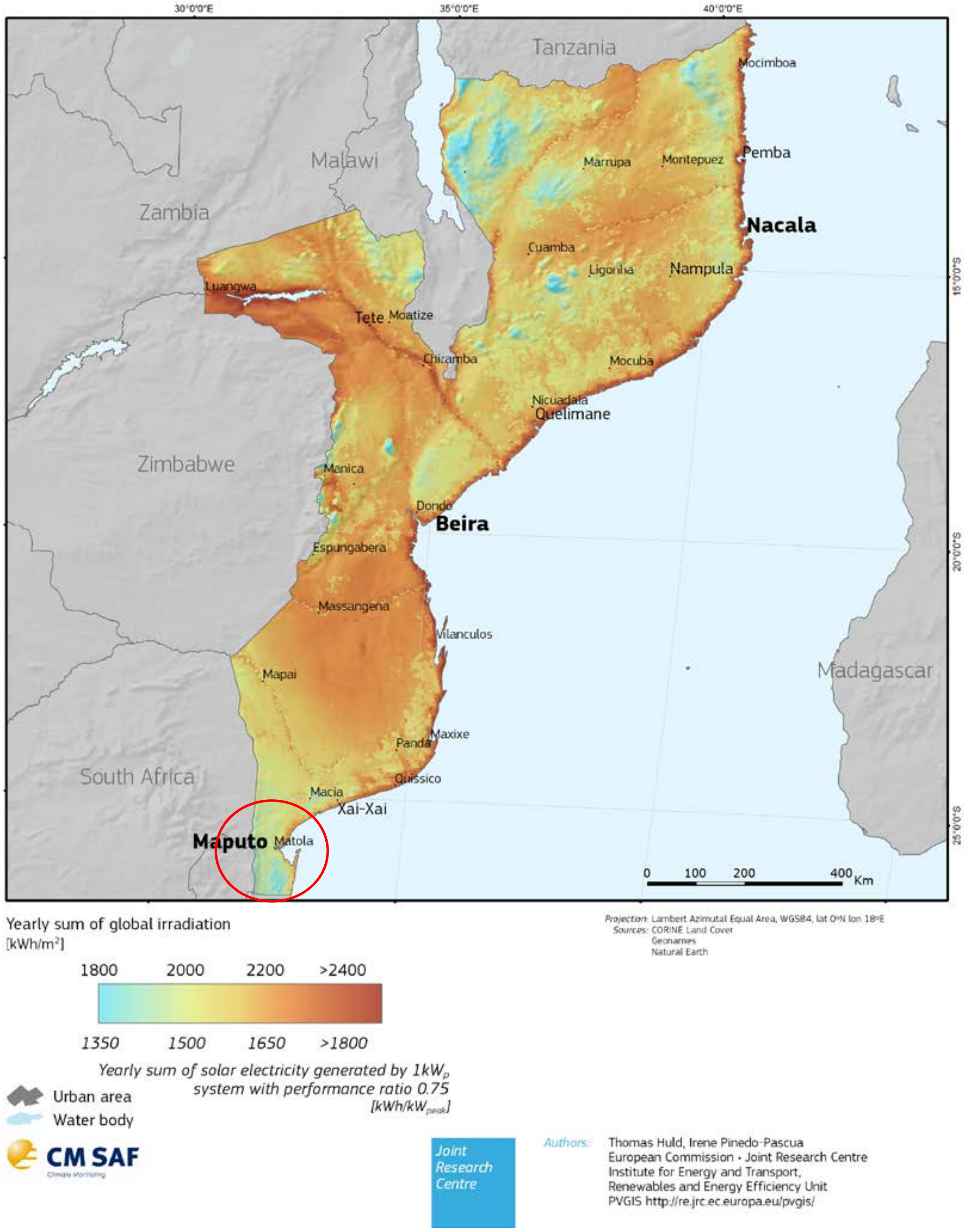


Figure 4 Position of the site in the Africa irradiation map

Figure 5 Satellite view of the site

C.2. OPTIMAL ORIENTATION

Given the photovoltaic technology, we must point out that the production delivered to the electrical grid will depend on the solar irradiation incident on the PV modules; such parameter, in turn, is related to the orientation of the panels themselves. In particular, the amount of solar power collected depends on:

- The Azimuth angle, which represents the orientation, angle in respect to the geographical South;
- The Tilt angle, which indicates the modules tilt in reference to the horizontal plane.

The optimal values of such angles depend on the geographical position of the site, and they have been identified through a dedicated software named PVGIS (please see section focused on the yield assessment for any further detail). In detail, PVGIS shows that the production of the PV plant can be maximized through the adoption of the following angles:

- Azimuth equal to -180°;
- Tilt included between 25° and 29°.

In light of such results, azimuth equal to -180° and tilt equal to 25° have been considered for designing the layout.
This type of technical choice leads the following benefits:

- reduce the distance between the photovoltaic modules file due to shading effects;
- reduce the areas for construction of the plant;
- guarantee the positive washing effect of the rainfall events;
- maximize the performance of photovoltaic modules exploiting the diffuse solar radiation.

In order to analyze the possibility of shadowing phenomenon, considering the schematic arrangement of the panels on an inclined plane (Figure 6), which may represent a layer of a roof as well as the profile of a hill, where the letters are attributed the following meanings:

- L is the length of the section of the test panel;
- d is the minimum distance of the next panel;
- β is the inclination angle of the panel to the horizontal;
- γ is the angle of inclination of the terrain relative to the horizontal;
- δ it is the declination angle at the winter solstice.

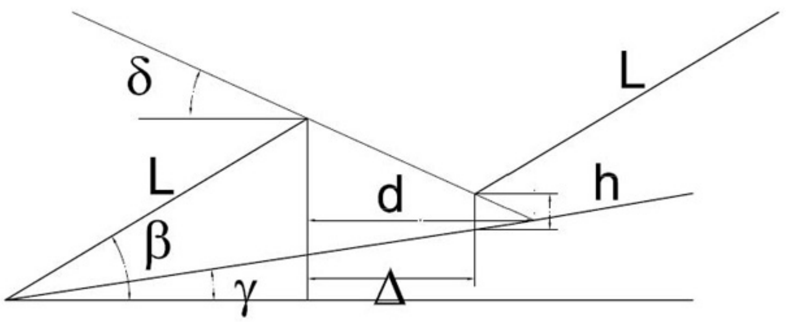


Figure 6 – geometric design

Applying the principles of trigonometry to the representation in Figure 6, you obtain the following equality:

$$d = [sen(\beta)-cos(\beta)\cdot tg(\gamma)]/[tg(\delta)+tg(\gamma)]\cdot L$$

In this case study is considered optimal for the distance between the photovoltaic modules files of **3 meters**

C.3. PV STRUCTURES

The PV generator will be installed on fixed structures driven into the ground and oriented with the optimal angles outlined in the previous section.
A preliminary layout of the structures has been designed, assuming the arrangement of four lines of panels per each row.
Picture below shows the sample drawings (section) of the structures:

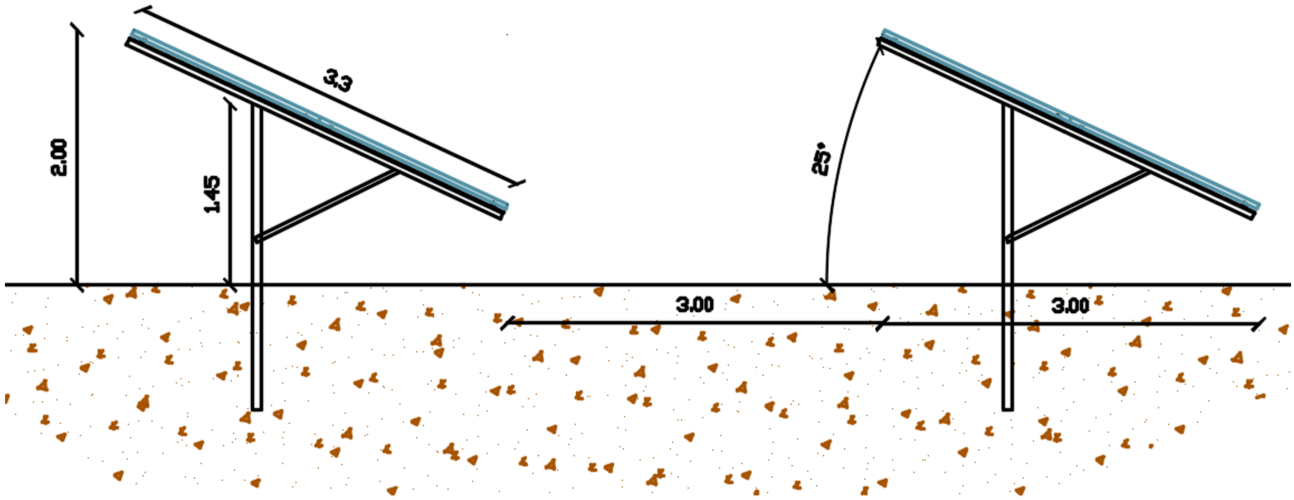


Figure 7 Section of the PV structures

C.4. DISTANCE BETWEEN THE PV ROWS

Once defined the optimal orientation, it is possible to proceed with the sizing of the distance between the PV rows. In detail, such parameter influences the natural events of mutual shadings between the PV panels and it depends:

- On the tilt angle chosen (i.e. 25° for the case in exam);
- On the wideness of each rows (i.e. 3,3 meters, see previous section);
- On the surface available for the arrangement of the PV generator.

For the Project in exam, a distance between the rows equal to 3 m has been selected, since it allows (i) to minimize the natural mutual-shading losses, (ii) to optimize the internal spaces of the layout for the maintenance of the PV field.

D. ELECTRICAL LAYOUT

D.1. KEY DESIGN

The PV plants Maputo was done with the purpose of achieving the following points:

- The system must be easy to maintain;
- Any damage to power lines or devices should create as little disruption as possible;
- Modular system so that during maintenance or failures there will be a reduced MTTR.

The PV plant consists of 5 sub-installation, called for simplicity: Comicho 1, Comicho 3, Comicho 3, Comicho 4, Comicho 5, each of the 30 MW power, each 30 MW plant unit inside the medium-voltage high-voltage transformer station will have its transformer.
From the transformer station will start the high-voltage power line (132 kV approximately 2.8 kilometers) that will connect PV systems to the national power line at the high-voltage substation of Maputo.
Each 30 MW plant unit is equipped with 9 electrical substations (Power Station) with inverters, low voltage-medium voltage transformer, medium voltage panels and cable arrivals from string low-voltage supply.

The choice of the inverter was made considering:

- inverter reliability;
- Performance;
- Previous use in a plant of the same type sites in similar environments;
- Degree of protection IP65;
- Multi MPPT - 4 independent per inverter that allow optimization of inverter performance;
- Very low MTTR (Mean Time To Restore).

The new integrated "plug & play" solution for a direct connection to the medium voltage grid and injection of the generated energy, the Power Station is equipped with an integrated communication platform that allows remote monitoring of the entire plant.

- Outdoor installation;
- 3 phases;
- MV transformer inside;
- MV switchboard;
- Communication system MODBUS / LAN / ADSL / GPRS;
- Trasportable by truck and sea shipping (RINA approved).

D.2. PRELIMINARY CONNECTION LAYOUT

The PV plant will be connected to the Mozambique electrical grid and, in detail, to the existing grid line, on the north-est side of the intervention site. On this point, it has to be reminded that the electricity produced by the PV generators is in low voltage and, thus, it will be elevated (i) by the LV/MV transformers present in the transformer cabins of each subfield; (ii) by the MV/HV transformers 30 MVA sized, which will process the electricity produced by the Plant. Further – based on the available information of the Mozambique electrical grid – the following position of the connection has been preliminary hypothesized:

Figure 9 Hypothesis of the connection point

D.3. ELECTRICAL DESIGN

SELECTED PV DEVICES
<u>PV panels</u>

The operating principle of a photovoltaic panel is to convert the solar energy incident on its surface to electricity in direct current. The main parameters that influence the performances of a PV module are the following:

- The nominal power represents the electrical size of the PV generator;
- The module's efficiency that measures the potentiality of the PV surface to convert the incoming solar energy. Such parameter determines the area occupied by the PV panels;
- The NOCT that indicates the PV cell temperature during the nominal operative conditions. This feature measures the module capacity to dissipate heath, in order to guarantee optimal performances, also during the warmest periods. More specifically, the lower the NOCT, the higher the productivity of the panels;
- The Fill Factor that measures the aptitude of the PV technology to work in situations that differ from test conditions. In fact, such parameter is equal to the ratio between the maximum operating power and the open circuit power;
- The power tolerance that indicates the device's uniformity and influences the possible losses related to the mismatching events;
- The temperature coefficient connected to the power that measures the potentiality of the modules to keep down the thermal losses during the warmest periods.

Regarding the Project in exam, PV devices from Q-CELL (Q.PLUS BFR-G4 280 Wp) model "Q-CELLS Multicrystalline" 280 Wp, have been selected.
Further, the selected panels are characterized by an efficiency parameter tuned with the best standard of the market and, so, this will allow an optimization of the layout and of the spaces foreseen between the rows. Pictures below show the data-sheet of Q-CELLS CELL Multicrystalline 280Wp panels from Q-CELL:

Q.PLUS BFR-G4.1 270-280

POLYCRYSTALLINE SOLAR MODULE

The new high-performance module Q.PLUS BFR-G4.1 is the ideal solution for all applications thanks to its innovative cell technology Q.ANTUM. The world-record cell design was developed to achieve the best performance under real conditions – even with low radiation intensity and on clear, hot summer days.

LOW ELECTRICITY GENERATION COSTS
Higher yield per surface area and lower BOS costs thanks to higher power classes and an efficiency rate of up to 17.1 %.

INNOVATIVE ALL-WEATHER TECHNOLOGY
Optimal yields, whatever the weather with excellent low-light and temperature behavior.

ENDURING HIGH PERFORMANCE
Long-term yield security with Anti-PID Technology[1], Hot-Spot-Protect and Traceable Quality Tra.Q™.

LIGHT-WEIGHT QUALITY FRAME
High-tech aluminum alloy frame, certified for high snow (5400 Pa) and wind loads (4000 Pa) regarding IEC.

MAXIMUM COST REDUCTIONS
Up to 10 % lower logistics costs due to higher module capacity per box.

A RELIABLE INVESTMENT
Inclusive 12-year product warranty and 25-year linear performance guarantee[2].

EUPD RESEARCH TOP BRAND PV MODULES EUROPE 2015

VDE Quality Tested ID. 40032587

THE IDEAL SOLUTION FOR:

Rooftop arrays on residential buildings

Rooftop arrays on commercial/industrial buildings

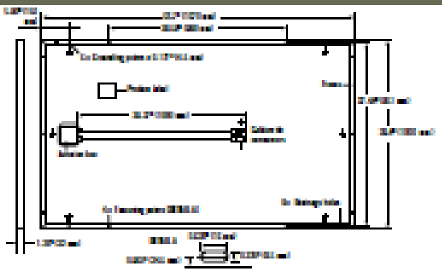
[1] APT test conditions: Cells at -1500V against grounded, with conductive metal foil covered module surface, 25 °C, 168 h
[2] See data sheet on rear for further information.

Engineered in **Germany**

Q CELLS

MECHANICAL SPECIFICATION

Format	65.7 in x 39.4 in x 1.26 in (including frame) (1670 mm x 1000 mm x 32 mm)
Weight	41.45 lb (18.8 kg)
Front Cover	0.13 in (3.2 mm) thermally pre-stressed glass with anti-reflection technology
Back Cover	Composite film
Frame	Black anodised aluminum
Cell	6 x 10 QANTUM solar cells
Junction box	3.03 in x 3.54 in x 0.62 in (77 mm x 90 mm x 15.8 mm), Protection class IP67, with bypass diodes
Cable	4 mm² Solar cable; (+) ≥ 39.37 in (1000 mm), (-) ≥ 39.37 in (1000 mm)
Connector	MC4, IP68

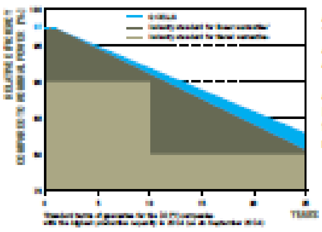


ELECTRICAL CHARACTERISTICS

POWER CLASS			270	275	280
MINIMUM PERFORMANCE AT STANDARD TESTING CONDITIONS, STC[1] (POWER TOLERANCE +5W / -0W)					
Minimum — Power at MPP[2]	P_{MPP}	[W]	270	275	280
Short Circuit Current[*]	I_{SC}	[A]	9.29	9.35	9.41
Open Circuit Voltage[*]	V_{OC}	[V]	38.46	38.72	38.97
Current at MPP[*]	I_{MPP}	[A]	8.70	8.77	8.84
Voltage at MPP[*]	V_{MPP}	[V]	31.04	31.36	31.67
Efficiency[2]	η	[%]	≥16.2	≥16.5	≥16.8
MINIMUM PERFORMANCE AT NORMAL OPERATING CONDITIONS, NOC[3]					
Minimum — Power at MPP[2]	P_{MPP}	[W]	199.6	203.3	207.0
Short Circuit Current[*]	I_{SC}	[A]	7.49	7.54	7.58
Open Circuit Voltage[*]	V_{OC}	[V]	35.89	36.13	36.37
Current at MPP[*]	I_{MPP}	[A]	6.81	6.87	6.93
Voltage at MPP[*]	V_{MPP}	[V]	29.30	29.59	29.87

[1] 1000 W/m², 25 °C, spectrum AM 1.5G [2] Measurement tolerances STC ±3 %; NOC ±5 % [3] 800 W/m², NOCT, spectrum AM 1.5G [*] typical values, actual values may differ

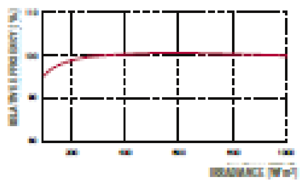
Q CELLS PERFORMANCE WARRANTY



At least 97% of nominal power during first year. Thereafter max. 0.6% degradation per year. At least 92% of nominal power after 10 years. At least 83% of nominal power after 25 years.

All data within measurement tolerances. Full warranties in accordance with the warranty terms of the Q CELLS sales organisation of your respective country.

PERFORMANCE AT LOW IRRADIANCE



Typical module performance under low irradiance conditions in comparison to STC conditions (25 °C, 1000 W/m²).

TEMPERATURE COEFFICIENTS

Temperature Coefficient of I_{SC}	α	[%/K]	+0.04	Temperature Coefficient of V_{OC}	β	[%/K]	−0.29
Temperature Coefficient of P_{MPP}	γ	[%/K]	−0.40	Normal Operating Cell Temperature	NOCT	[°F]	113 ± 5.4 (45 ± 3 °C)

PROPERTIES FOR SYSTEM DESIGN

Maximum System Voltage V_{SYS}	[V]	1000 (IEC) / 1000 (UL)	Safety Class	II
Maximum Series Fuse Rating	[A DC]	20	Fire Rating	C (IEC) / TYPE 1 (UL)
Max Load (UL)[2]	[lbs/ft²]	75 (3600 Pa)	Permitted module temperature on continuous duty	−40 °F up to +185 °F (−40 °C up to +85 °C)
Load Rating (UL)[2]	[lbs/ft²]	55.6 (2666 Pa)	[2] see installation manual	

QUALIFICATIONS AND CERTIFICATES

UL 1703; VDE Quality Tested; CE-compliant;
IEC 61215 (Ed.2); IEC 61730 (Ed.1) application class A

PACKAGING INFORMATION

Number of Modules per Pallet	32
Number of Pallets per 53' Container	32
Number of Pallets per 40' Container	26
Pallet Dimensions (L x W x H)	68.7 in x 45.3 in x 46.1 in (1745 x 1150 x 1170 mm)
Pallet Weight	1435 lb (651 kg)

NOTE: Installation instructions must be followed. See the installation and operating manual or contact our technical service department for further information on approved installation and use of this product.

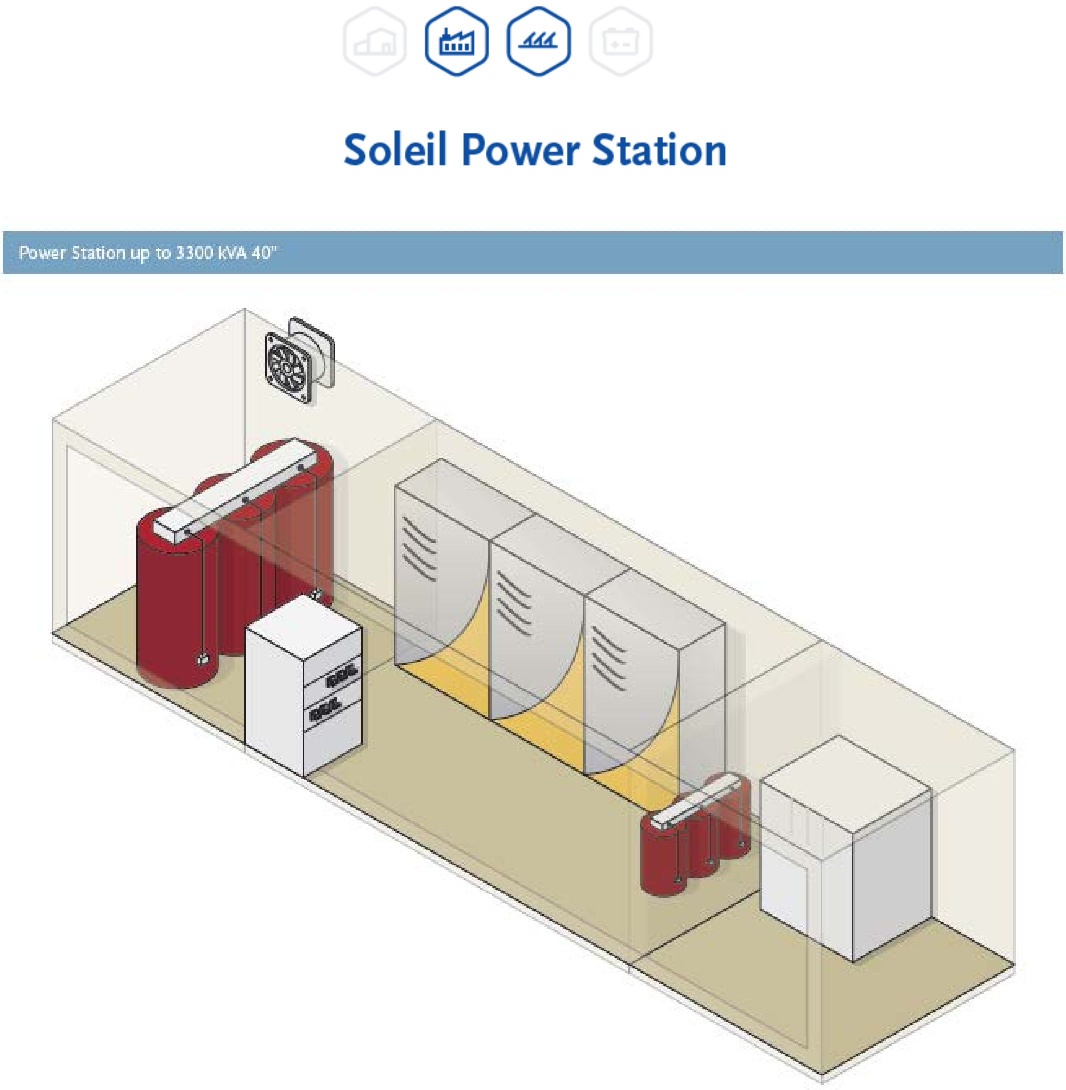
Hanwha Q CELLS America Inc.
300 Spectrum Center Drive, Suite 1250, Irvine, CA 92618, USA | TEL +1 949 748 59 96 | EMAIL inquiry@us.q-cells.com | WEB www.q-cells.us

Solar inverters

Inverters are electrical devices which convert the electricity from the Direct Current (DC) to the Alternate Current (AC) which is finally sent to the grid. Within such transformation, no modifications of the nominal voltage are involved, but some losses are expected to occur, due to the electrical operations necessary to the DC/AC conversion.
With reference to inverters technical features, the quality of such devices can be evaluated through the analysis of the following parameters:

- Efficiency curve
- Power derating due to environmental conditions

Concerning Maputo , large-sized inverters from ABB – or similar – have beenselected. In detail, such solution will allow to install devices having optimal efficiencies, to be placed in dedicated transformer cabins. Such cabins will be equipped with adequate cooling systems, so to control the working temperature of the inverters during their operation in the view of the optimization of the performances. Pictures below show the data-sheet of a sample large-sized inverter selected for the Project in exam:



Caratteristiche Tecniche Technical Data

Modello Model	Soleil PS500	Soleil PS660	Soleil PS760	Soleil PS833
CARATTERISTICHE DI INGRESSO / INPUT PARAMETERS				
Potenza max moduli (kWp) Max power of modules (kWp)	608	800	918	1006
Tensione min / max di MPPT (V) Min/max MPPT voltage (V)	460 / 780		560 / 780	
Tensione max (V) @ -10°C Max. voltage (V) @ -10°C	1000			
N° inverter	DSPX 500TLH	DSPX 660TLH	DSPX 760TLH	DSPX 833TLH
CARATTERISTICHE DI USCITA / OUTPUT PARAMETERS				
Potenza nominale AC (kW/kVA) Nominal Power (kW)	500	660	760	833
Tensione nominale AC (V) Nominal voltage (V) AC	6-10-15-20-30-36 (others on request)			
Fattore di potenza Power factor	0,9 - 1 Leading/Lagging			
CARATTERISTICHE GENERALI / GENERAL FEATURES				
Temperatura operativa (°C) Operative temperature (°C)	-5°C / + 50°C			
Dimensioni (LxPxH) mm Dimensions (WxDxH) mm	6057(20')x2438x2896 (RINA approved)			
Certificazioni nazionali e internazionali National and international certificates	CE - LVD -2004/108/EC - 2006/95/EC - EN62109-1/2 - EMC - EN61000-6-2/6-3/6-4 - Regio Decreto - CEI 0-16 - CEI 0-21 - Allegato A70 di Terna - AEEG 243/2013 - G83/1-1 - G59 Issue 2 - RT30 Romanian norme 10/2013 Norma Tecnica de Seguridad De calidad de Servicio (NTSCS-Chile) BDEW - AS4777 - Código redes fotovoltaico ASEP			

Soleil PS990	Soleil PS1320	Soleil PS1520	Soleil PS1670	Soleil PS1980	Soleil PS2280	Soleil PS2500	Soleil PS3300
1200	1606	1836	2012	2400	2754	2754	4024
460 / 780		560 / 780	560 / 780	460/780	560 / 780		
1000							
DSPX 660+330TLH	2x DSPX 660TLH	2x DSPX760TLH	2x DSPX 833TLH	3x DSPX 660TLH	3x DSPX 760TLH	3x DSPX 833TLH	4x DSPX 833TLH
990	1320	1520	1666	1980	2280	2500	3320
6-10-15-20-30-36 (others on request)							
0,9 - 1 Leading/Lagging							
-5°C / + 50°C							
12192x(40')x2438x2896 (RINA approved)							
CE - LVD -2004/108/EC - 2006/95/EC - EN62109-1/2 - EMC - EN61000-6-2/6-3/6-4 - Regio Decreto -CEI 0-16 - CEI 0-21 - Allegato A70 di Terna - AEEG 243/2013 - G83/1-1 - G59 Issue 2 - RT30 Romanian norme 10/2013 - Norma Tecnica de Seguridad De calidad de Servicio (NTSCS-Chile) - BDEW - AS4777 - Código redes fotovoltaico ASEP							

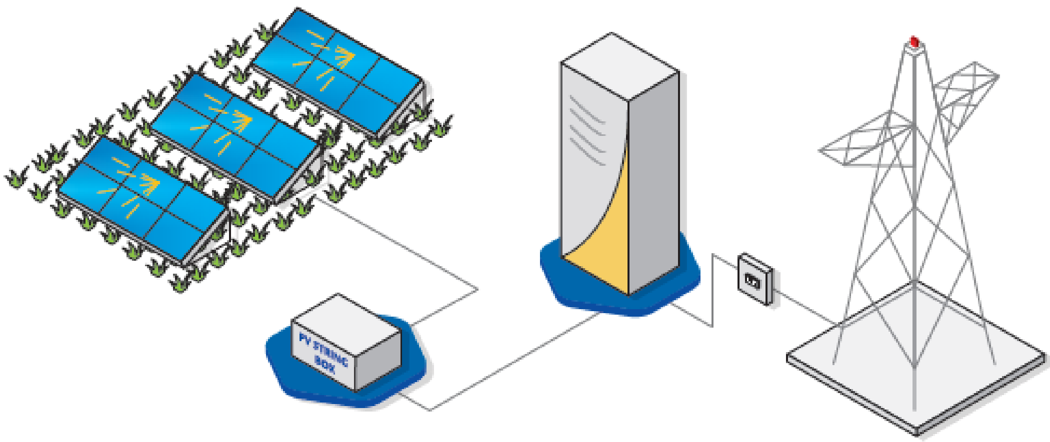
SOLEIL POWER STATION

Model No.	Soleil PS500	Soleil PS660	Soleil PS760	Soleil PS833	Soleil PS990	Soleil PS1320	Soleil PS1520	Soleil PS1670	Soleil PS1980	Soleil PS2280	Soleil PS2500	Soleil PS3320
INPUT PARAMETERS												
Max power of modules (kWp)	608	800	918	1006	1200	1606	1836	2012	2400	2754	2754	4024
Min/max MPPT voltage (V)	460/780		560/780		460/780		560/780		460/780	560/780		
Max input voltage (Voc)	1000											
No. inverter	DSPX 500TLH	DPSX 660 TLH	DSPX 760 TLH	DSPX 833 TLH	DSPX 660+330 TLH	2x DSPX 660TLH	2x DSPX 760TLH	2x DPSX 833TLH	3x DSPX 660TLH	3x DPSX 760TLH	3x DSPX 800TLH	4x DSPX 833TLH
OUTPUT PARAMETERS												
Nominal Power (kW)	500	660	760	833	990	1320	1520	1666	1980	2280	2500	3320
No. Phases	3F											
Nominal voltage (V) AC	6-10-15-20-30-36 (others on request)											
Power factor	0,9 – 1 Leading / Lagging											
GENERAL FEATURES												
Operative temperature (°C)	-5°C/+50°C											
Dimensions (LxWxH) mm	6057x2438x2896 (RINA approved)				12192x2438x2896							
Installation	Suitable for outdoor installations											
Communication system	MODBUS / LAN / ADSL / GPRS											
National and International certificates	CE - LVD -Mbb^/abQ/EC - Mbbf/K_/EC - ENfMabK-a/M - EMC - ENfabbb-f-M/f-d/f-^ - Regio Decreto - CEI baf - CEI bMa - Allegato ALb di Terna -AEEG M^d/Mbad - GQd/a-a - G_K Issue M - RTdb Romanian norme ab/Mbad Norma Tecnica de Seguridad De calidad de Servicio (NTSCS-Chile) BDEW - AS^LLL -											

<u>String Box</u>

Each group of strings (12 strings) is equipped with a string box
The individual string currents are accurately measured with 'hall effect' sensors. Any mismatch is promptly detected by the system supervisor and communicated to the inverter to allow for quick identification of any fault of the solar panels.
All string combiner boxes include surge protection with removable elements as well as fuse protection for each couple of string channels. It is available with an optional fully-integrated DC switch, fuse and remote controlled DC disconnect function.
The use of PV-STRING BOX with a monitoring system makes it possible to have a continuous and instant view of the complete installation.
Its control logic makes possible to monitor all involved parameters: voltage, current, power, status of the individual string, fuse status, output switch status, and surge protections.

- Available in high current version;
- Available in IP66 version certified.



Caratteristiche Tecniche Technical Data

nuovo prodotto
new product

Modello Model	PV-STRING BOX
CARATTERISTICHE DI INGRESSO / INPUT PARAMETERS	
Corrente massima di ingresso per canale (12 canali) Max input current per channel (12 channels)	10A (16A for high current version)
Tensione massima d'ingresso Max input voltage	1000 VDC
Connessione morsetti ingresso Input terminals connection	A vite Screw type

CARATTERISTICHE DI USCITA / OUTPUT PARAMETERS	
Corrente massima d'uscita Max output current	120A (200A for high current version)
Tensione di isolamento Insulating voltage	1000V
Sovratensioni fra + e -, fra + e T, fra - e T Overvoltages between + and -, between + and T, between - and T	Varistori 40kA Varistors 40kA
Sovraccarico nei varistori fra + e -, fra + e T, fra - e T Overloads in varistors between + and -, between + and T, between - and T	Scollegamento termico dello scaricatore Thermally operated lightning arrester
Sezionatore generale General disconnecting switch	160 A 1100Vcc. (TMAX serie T1) 160 A 1100Vdc. (TMAX series T1)

CARATTERISTICHE GENERALI / GENERAL FEATURES	
Temperatura operativa (°C) Operative temperature (°C)	-20 °C / +60 °C
Grado di protezione Protection degree	IP44 (IP66 certified)
Dimensioni (LxPxH) mm Dimensions (LxWxH) mm	560x760x250
Peso (Kg) Weight (kg)	16kg
Norme di riferimento Reference standards	EN 62109-1 / EN 62109-2 EN 61000-6-2:2005 / EN 61000-6-3:2007

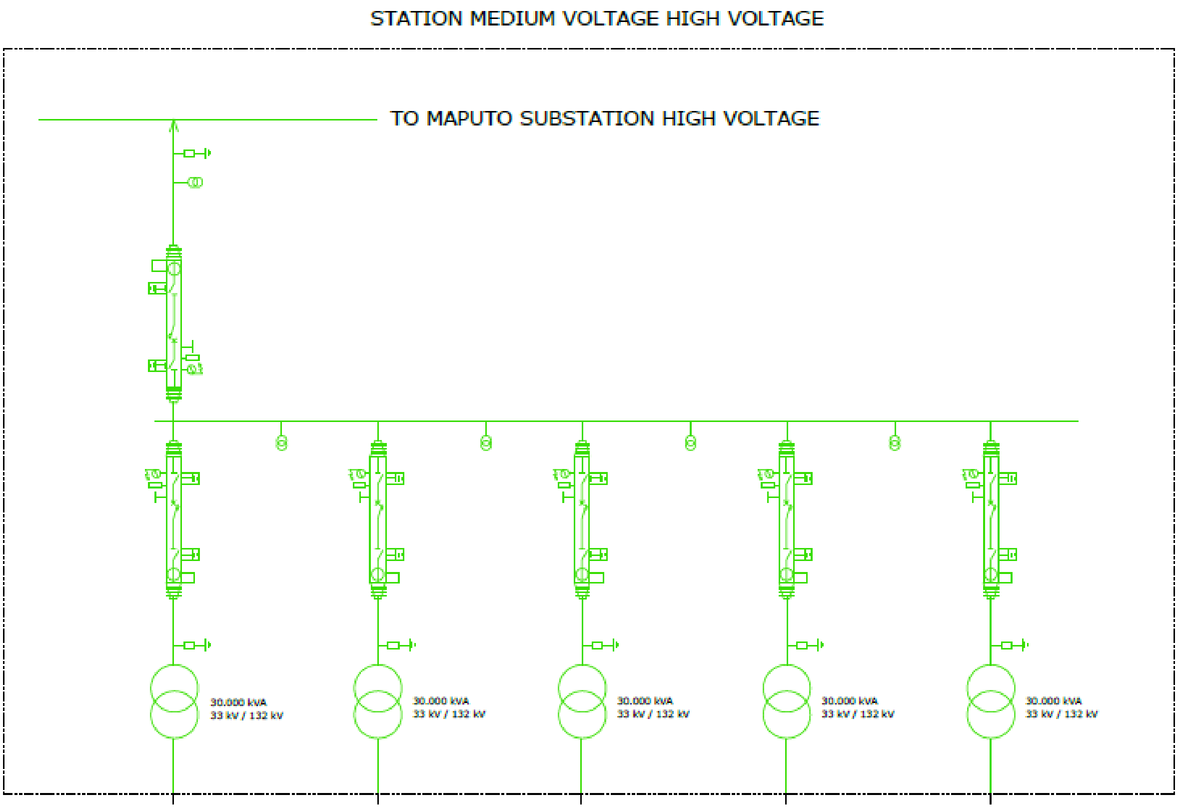
D.4. LV ELECTRICAL DIAGRAM

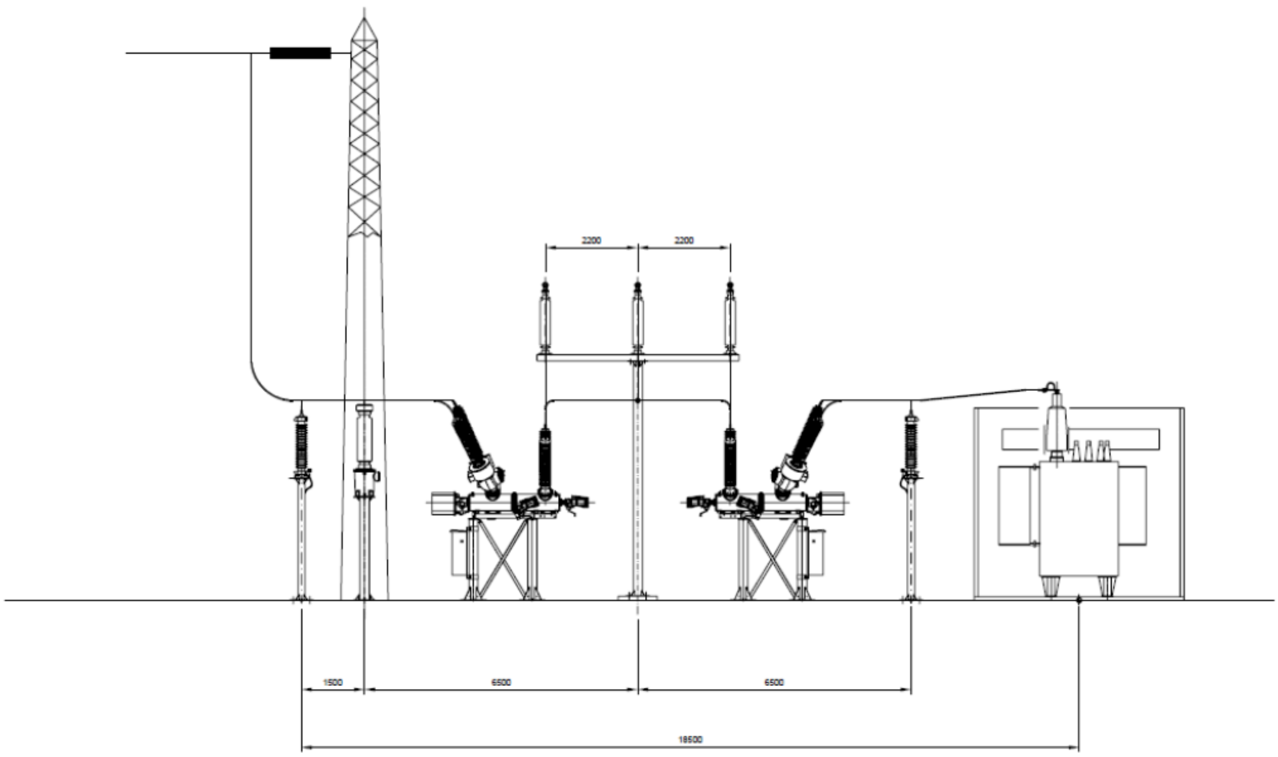
As far as it concerns the connection between the PV strings and the inverter devices, the inverter electrical features must be in compliance with the electrical parameters (power and voltage) deriving from the plant PV section to which it is connected. In particular, the plant output voltage must be linked to the input voltage of the inverter according to the following relations:

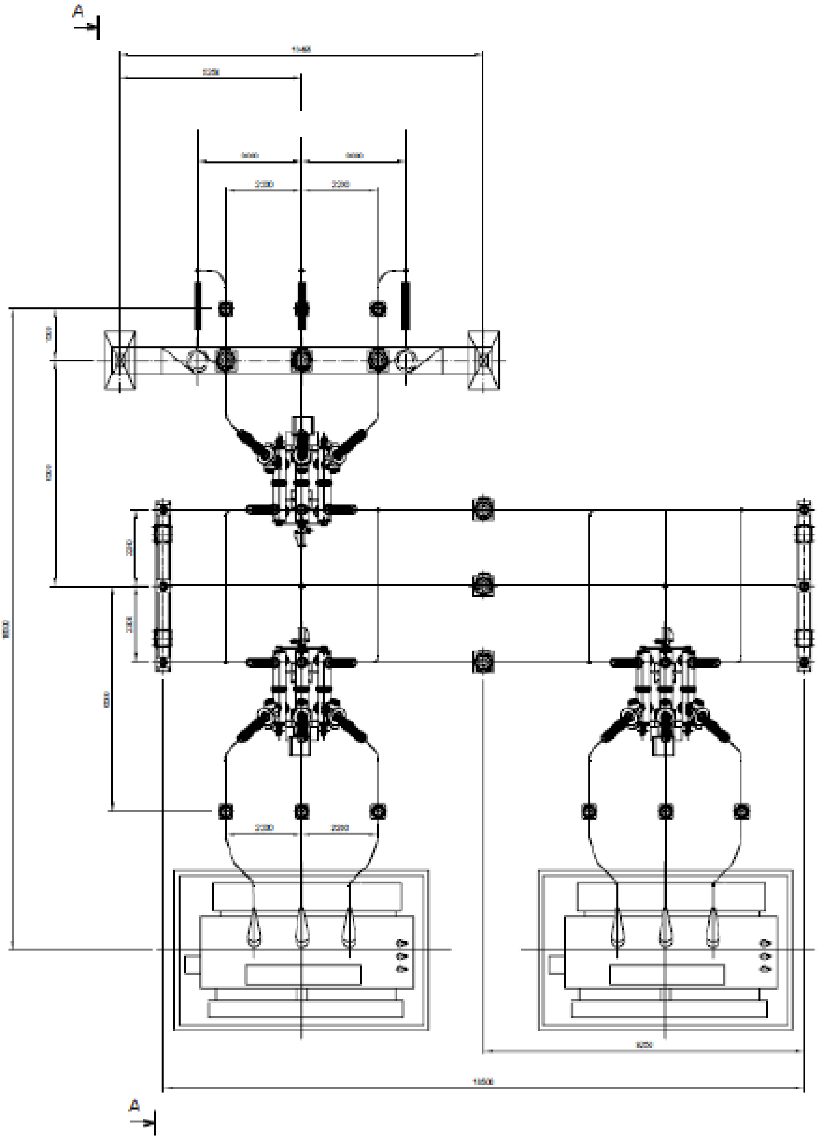
- The maximum open circuit voltage from the generators shall be not higher than the maximum input voltage allowed by the inverter.
- The minimum operative voltage from the generators shall be not lower than the minimum voltage which can be managed by the MPPT system (which is the Maximum Power Point Tracker, a special device used by the inverter to optimize the current conversion) specific of the inverter.
- The maximum operative voltage from the generators shall be not higher than the maximum voltage which can be managed by the MPPT system specific of the inverter.
- The inverter nominal power (DC), shall be in the range 90% - 110% of PV plant nominal power.
- The selected PV modules and solar inverters will allow to respect the aforementioned technical guidelines, as evaluated on the basis of the weather conditions expected for Comicho site.

D.5. HV CONNECTION

The PV plant will be connected to the Mozambique electrical grid. In particular, the connection point has been identified on an existing substation HV in the north-east side of the site; since the electricity will be delivered to the HV grid, a MV/HV transformer substation 30 MVA sized has been foreseen within the intervention area.
Concerning this element, the preliminary electrical diagram has been designed, as represented below:




2200
2200
1500
6500
6500
18500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D.6. YIELD ASSESSMENT

In the following section, an estimation of the electrical energy theoretically deliverable to the grid by the Project has been carried out. The following analysis has been performed on the basis of the data sheets, technical drawings and layouts as represented and outlined in the previous sections above.
The expected energy production evaluations have been executed by modeling the PV plant's technical features and performances through PVGIS, which is a software designed to analyze and simulate the performances of PV plants of any size and typology. In details, PVGIS allows to define the input data concerning the PV devices, the features of the intervention site (type of roofing, meteo-climatic data, shadings), the modules orientation and the specificity of the layout.
The criteria and data used for the realization of the output models are described in the following sections.

D.7. TECHNICAL FEATURES OF THE PLANT

The PV plant in exam will be installed on the ground through fixed structures, so the PV generators will be characterized by homogeneous orientations (in terms of tilt and azimuth). As per the PV devices, PV modules from Q-CELLS, solar inverters from Soleil and String Box have been considered. An overview on the plant's major technical features is briefly reported in the following chart:

Nominal Power	29.971,00 MWp (singol plant)
Module type Multicrystalline	Q-Cell BFR 280 Wp
Modules number	107.040
Nominal power of the modules	280 Wp
Tilt	25°
Azimuth	-180°
Inverter Type and Number	8 Soleil Station PS3300 + 1 Soleil Station PS1670

D.8. YIELD PV SYSTEM

The energy produced by the photovoltaic field in a year is equal to 48.852,73 MWp; below the table with the monthly production:

Month	**E_m**	**Et (MWh)**
Jan	131	3.926,20
Feb	133	3.986,14
Mar	151	4.525,62
Apr	133	3.986,14
May	145	4.345,79
Jun	136	4.076,05
Jul	140	4.195,94
Aug	148	4.435,70
Sep	137	4.106,02
Oct	129	3.866,25
Nov	121	3.626,49
Dec	127	3.806,31
Yearly average	**136**	48.852,73
Total for year	**1630**	

E. ANNEX

ANNEX I: TECHNICAL DRAWINGS

ANNEX II: FINANCIAL ANALISYS