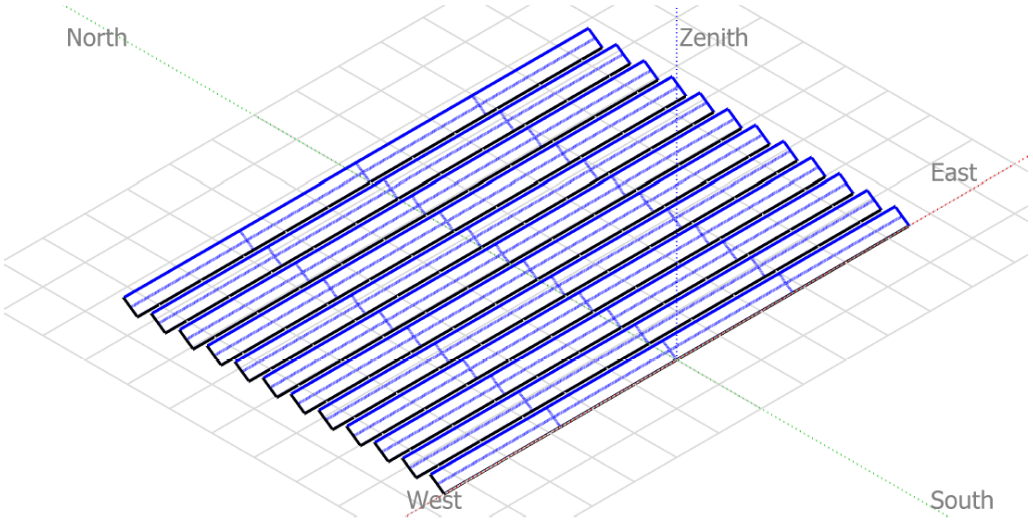
Pre-Feasibility Study Report of Grid Connected Solar PV project In Rajgadh Rural Municipality, Province 2



08 October 2021

NEPAL RENEWABLE ENERGY PROGRAMME (NREP)
House No. 62, Mukti Marg Thapathali, GPO 46, Kathmandu 44600

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SALIENT FEATURES

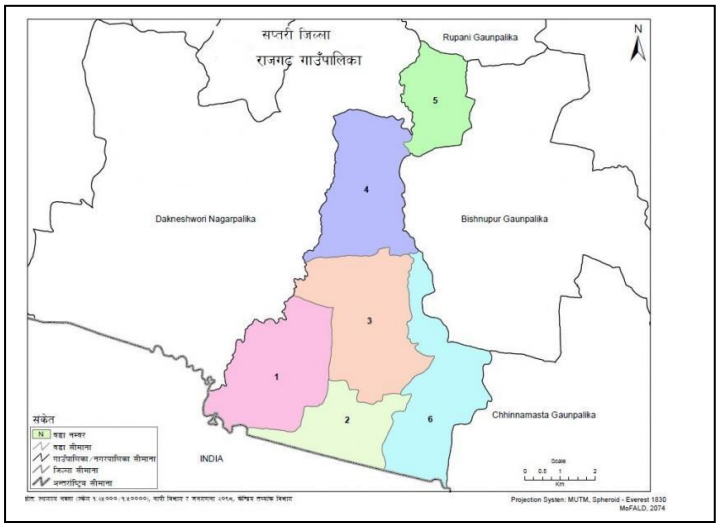
S.N.	Heading	Particulars	Description
1	Plant Location	Proposed Site coordinate	26.47° N
			86.66° E
		Province	Province 2
		District	Saptari
		Local Government	Rajgadh
2	Accessibility	Approx. distance from road-head (meters)	350
		Type of road-head	Highway
3	Land Profile	Ownership of Land	Municipality
4	Solar Resource, Potential Technology, Capacity	Solar Insolation (kWh/sq.m./day)	5.42
		Proposed project capacity(kW)	1000
		DC to AC ratio	1.11
		Capacity of each module (Wp)	400
		Approx. number of modules	25000
		Total Inverter Capacity (kW)	875
5	Substation	Name of nearest substation	Rajbiraj
		Approx. transmission distance (km)	10
		Transmission voltage (kV)	11
6	Electricity generation	Estimated annual energy generation (MWh/year)(@ P50)	1599
		LCOE (NPR/kWh)	5.64
7	Cost Estimate	Estimated Project Cost (NPR)	
8	Financial Findings	NPV (NPR)	21,967,409.2
		IRR (%)	17.79
		Payback period (Years)	8.16

1. INTRODUCTION

Nepal has significant potential for solar energy system. Nepal receives 3.6 to 6.2 kWh of solar radiation per square meter per day, with roughly 300 days of sun a year, making it ideal for solar energy. White paper 2018 has envisioned renewable energy in national energy mix for energy security and proposes 5-10% from renewable energy source for power generation mix. It aims for distributed generation in each of 753 local units – "Providing Energy Access to All Settlement". Under the concept of " One Province, One Mega Projects" the white paper recommends atleast 200 MW solar power generation in province no. 2. The 15th periodic plan depicts renewable energy as mainstream energy source. Public as well as private investment have been prioritized for the energy mixing strategy and for generating enough power to meet the demand for development and electricity services. 15th plan articulates that energy efficiency programs and programs to connect rooftop solar energy plants to the grid based on net metering and net payment will be promoted under the concept of "Every Home, Energy Home". The plan also puts forward the proportion of renewable energy in energy consumption to increase from 7 to 12 per cent and electricity consumption per capita to reach 700 kilowatts per hour. For the achievement of its target it offers development of solar energy system and its integration into national grid through the collection and verification of field data on solar energy sources. It also aims to establish and operate Special Economic Zones (SEZ), Industrial Zones, and Industrial Villages.

As per department of electricity development, all together 17 solar power projects with estimated generation capacity of 110.47 MW have received license so far for construction of solar projects. 3 projects of 17 MW capacity among others lies in province no. 2. Similarly, survey license has been issued to 34 projects with 495.32 MW capacity and Province 2 shares major fraction with 11 projects of capacity 340.2 MW. Likewise, 2 solar projects have applied for construction license and has capacity of 5 MW. Both the projects fall under territory of province no. 2. Also 3 projects with 120 MW capacity has applied for survey license and a project with 100 MW capacity belongs to Province 2. Recently, Butwal solar power with 8 MW capacity has been connected to national grid. Similarly, Nepal government utility inaugurated the first phase of its first 25MW solar array that will feed electricity directly into the national grid. The project employs solar panels without storage batteries, meaning electricity produced is fed directly into the grid when sunlight is available. As per the study carried out by national planning commission, the highest number and installed capacity of Solar PV sites in the country with cumulative capacity of 127 MW were selected in Province 2. The solar power helps to reduce power outages in winter seasons when hydropower potential is reduced. Furthermore, it is expected to increase the reliability of the power supply system and minimize system loss.

The Local Government Operation Act, 2074 that came into effect since 15 October 2017 has paved a strong legal foundation towards institutionalizing legislative, executive and quasi-judiciary practice of the local government. The Act has stipulated several arrangements related to authorities, duties and responsibilities of local government, assembly meeting and working system, assembly management procedures, plan formulation and implementation, judicial works, financial jurisdictions, administrative structure, and district assembly, among others. Without adversely affecting the universality of Schedule-8 of the Constitution, it clarifies the function, duties, and rights of municipalities/ rural municipalities. The act clearly states that the local government can formulate, implement, monitor, evaluate and regulate local level policies, laws, standards, and plans related to hydro power projects up to one megawatt. Further, the municipality can manage, operate, and regulate local electricity distribution system and services.



In the above background, Rajgadh Rural municipality has decided to set up a ***1 MWp*** Solar Power Plant. The municipality lies in Saptari district under the Sagarmatha region of Eastern Nepal. B.S. The Ministry of Federal Affairs and Local Development has implemented 744 local levels in 2073 BS. The total area of Rajgad village municipality is 47.9 sq. Km. This village municipality is divided into 6 wards According to the 2068 census, the total population of this village municipality is 29,459 It is bounded on the east by Chhinmasta and on the west by Bishnupur, on the west by Dakneshwari, on the north by Rupni and on the south by Bihar (India). This Pre-Feasibility Report (PFR) brings out all technical details and overall costs justifying the selection of the project. The total power generation is envisaged to be 1682.2 MWh from the plant. The total project cost is expected to be **NPR 82.08 Million** and the average cost of generation (LCOE) is expected to be **Rs. 5.64/kWh.**

Client' details	
Country	Nepal
Location	Rajgadh RM, Saptari
Coordinates	26.49° N and 86.66° E
Contact Number	9801565113
Contact Person	Paramanand Yadav
Name of Client	Rajgadh Rural Municipality
Purpose	Power generation & distribution to grid

Site & Meteo Details			
Location coordinates	26.47^{0}N, 86.66^{0}E		
Ambient Temperature(^{0}C)	Max	Average	Min
	31.10	26.0	15.4
Relative humidity	67.1%		
Daily Solar irradiation-Horizontal	4.89 KWh/m^2/day		
Atmospheric Pressure	101.325 kPA		
Wind Speed	1.6 m/s		
Altitude (from sea level)	60 m		

Project Details	
Type of installation	Ground-mounted
Estimated array peak power	1000 kWp
Shading consideration	Shade-free
Grid voltage	11 KV
Phase connection	3-phase
Grid frequency	50Hz
Available/required area	15,000 m^2(approx)
Safety level	IP65

2. SITE LOCATION

Figure 1: Site location

3. PRELIMINARY PROJECT DESIGN AND ANALYSIS

3.1. System Design

The global horizontal irradiation and horizontal diffuse radiation along with temperature, wind velocity, linke turbidity and relative humidity shown below are taken as the primary inputs for system design using PV Syst 7.1 software. (Annex 1: PV Syst Simulation report)

Site	**Rajgadh (Nepal)**
Data source	Meteonorm 7.3 (1991-2010), Sat=100% (Modified by user)

	Global horizontal irradiation	Horizontal diffuse irradiation	Temperature	Wind Velocity	Linke turbidity	Relative humidity
	kWh/m²/mth	kWh/m²/mth	°C	m/s	[-]	%
January	116.3	49.1	15.4	0.90	5.977	75.1
February	131.3	52.5	20.2	1.40	5.669	65.8
March	169.2	76.0	26.0	1.60	6.150	50.5
April	182.4	87.6	30.6	2.40	7.000	45.4
May	190.7	103.2	31.9	2.70	7.000	55.6
June	162.8	97.8	31.1	2.39	7.000	69.6
July	152.9	95.0	30.3	2.01	5.934	78.7
August	154.1	93.0	30.3	2.00	5.253	78.9
September	142.0	73.7	29.2	1.79	5.282	81.0
October	142.7	68.4	27.4	0.81	5.871	73.6
November	127.5	46.8	22.4	0.49	7.000	70.5
December	114.0	47.9	17.3	0.49	6.986	73.7
Year	**1785.8**	**890.9**	**26.0**	**1.6**	**6.260**	**68.2**

Global horizontal irradiation year-to-year variability 4.7%

Figure 2: Site Details

A project life of 25 years has been considered. The azimuth of 0^0 (true south) the the fixed plane tilt angle of 35^0 are assumed based on the optimization in regard to specific energy production for the site.

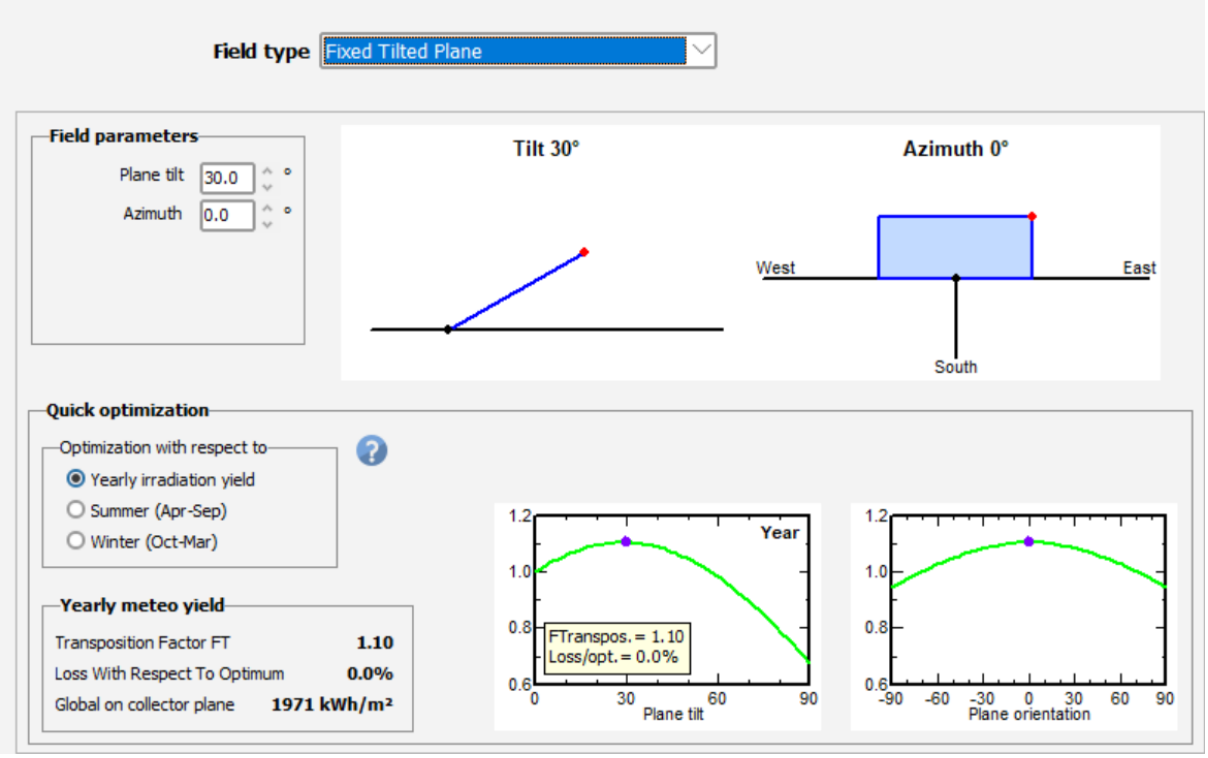


Figure 3: Tilt and azimuth considered for the design

3.2. System Summary

For preliminary design, Solar PV Modules from Jinkosolar has been selected. A total number of 2,500 "Jinko Solar JKM 400M-72V" monocrystalline PERC PV modules of 400 Wp rating, 35.35 Vmpp (at 60^0 C) and 19.88% efficiency has been considered to convert the solar energy into DC electricity. Seven units of Sungrow 125 kW "SG 125 HV" inverters which has internal MPPT system has been considered to convert DC to three phase.

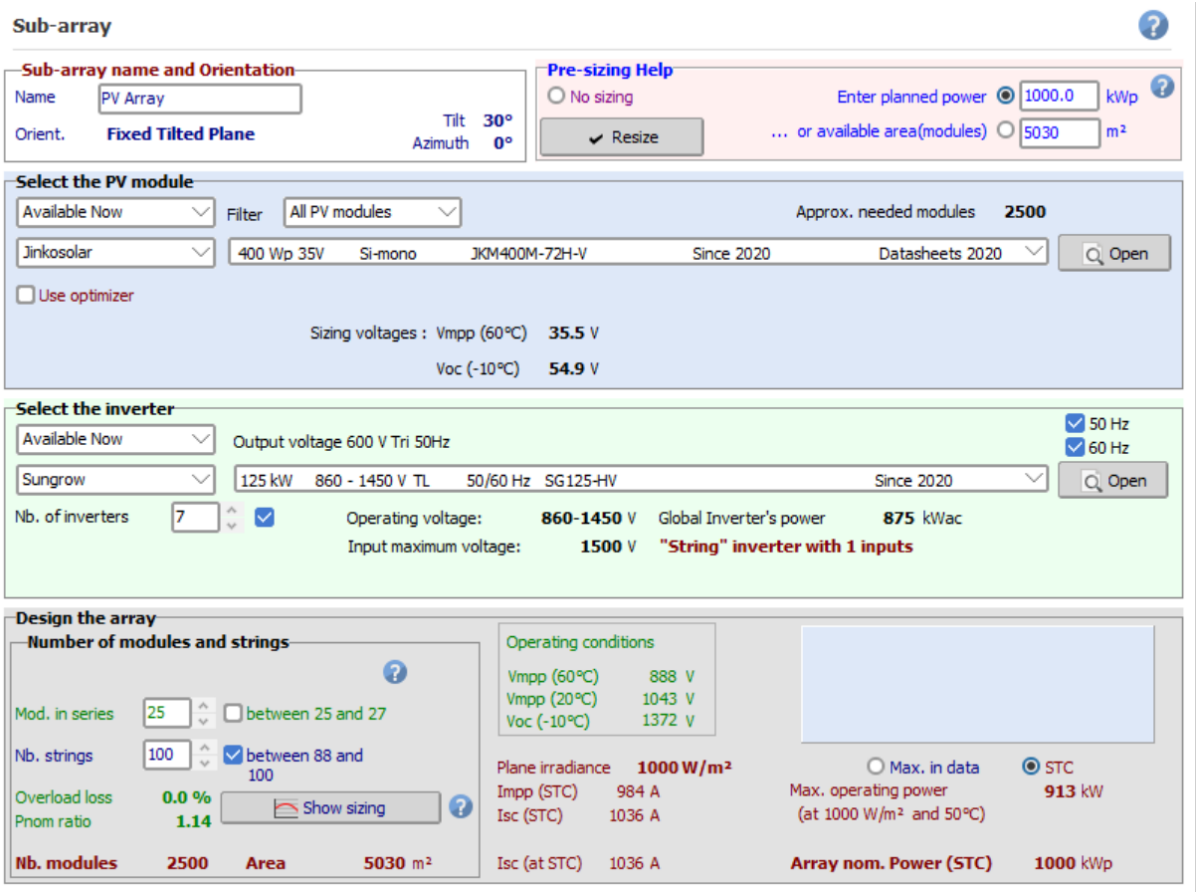


Figure 4:System Design

The operating voltage range of inverter is 860-1450 Vdc. Here it was considered that 25 number of modules will be connected in series to form a string. A total of 100 such strings will be connected in parallel to form an array with cumulative capacity of 1000 kWp. These 100 strings will be connected using string combiner boxes (SCBs). One main combiner box (MCB) will connect these SCBs together and transfer energy to the inverter. Thus, the AC rating of the plant will be 875 kW.

PV Array Characteristics

PV module		**Inverter**	
Manufacturer	Jinkosolar	Manufacturer	Sungrow
Model	JKM400M-72H-V	Model	SG125-HV
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	400 Wp	Unit Nom. Power	125 kWac
Number of PV modules	2500 units	Number of inverters	7 units
Nominal (STC)	1000 kWp	Total power	875 kWac
Modules	100 Strings x 25 In series	Operating voltage	860-1450 V
At operating cond. (50°C)		Pnom ratio (DC:AC)	1.14
Pmpp	913 kWp		
U mpp	928 V		
I mpp	984 A		
Total PV power		**Total inverter power**	
Nominal (STC)	1000 kWp	Total power	875 kWac
Total	2500 modules	Nb. of inverters	7 units
Module area	5030 m²	Pnom ratio	1.14
Cell area	4464 m²		

Figure 5: Summary of Solar Panel and Inverter Configuration

The output of the inverter pack will be connected to one number of 0.6/11 kV, 1.25 MVA, 3-phase step-up transformer and the generated AC power will be safely evacuated through 10 kms long 11 kV single-circuit transmission line to NEA's substation. Evacuation route is shown below:

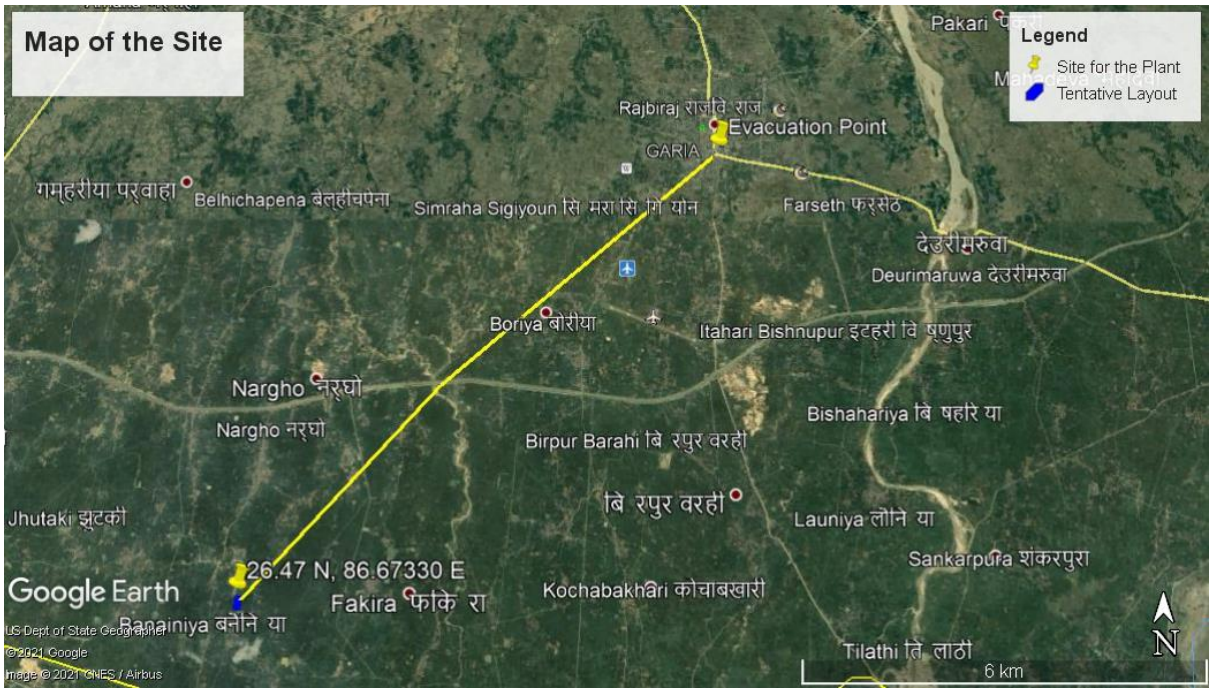
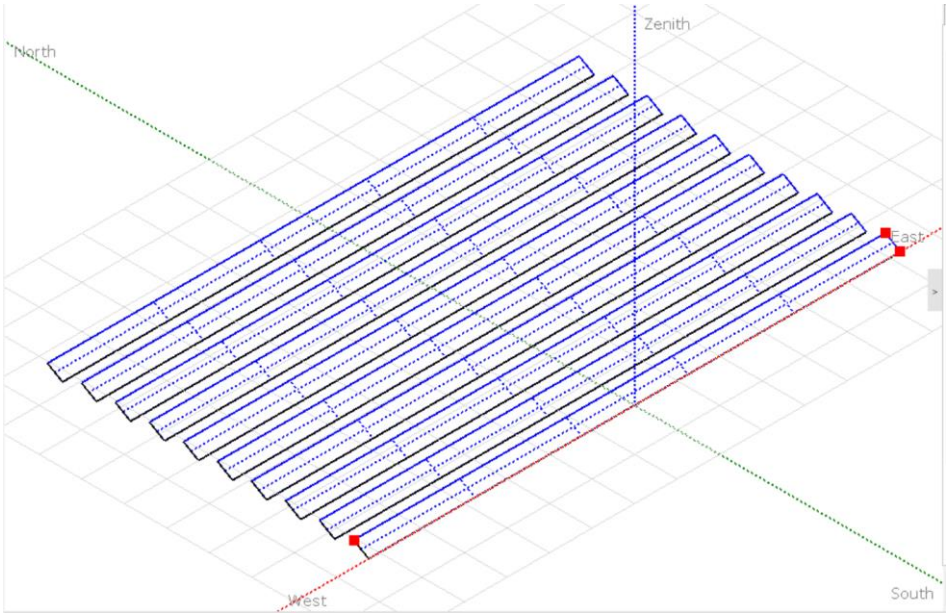


Figure 6: Power Evacuation route

3.3. Solar Module Placement



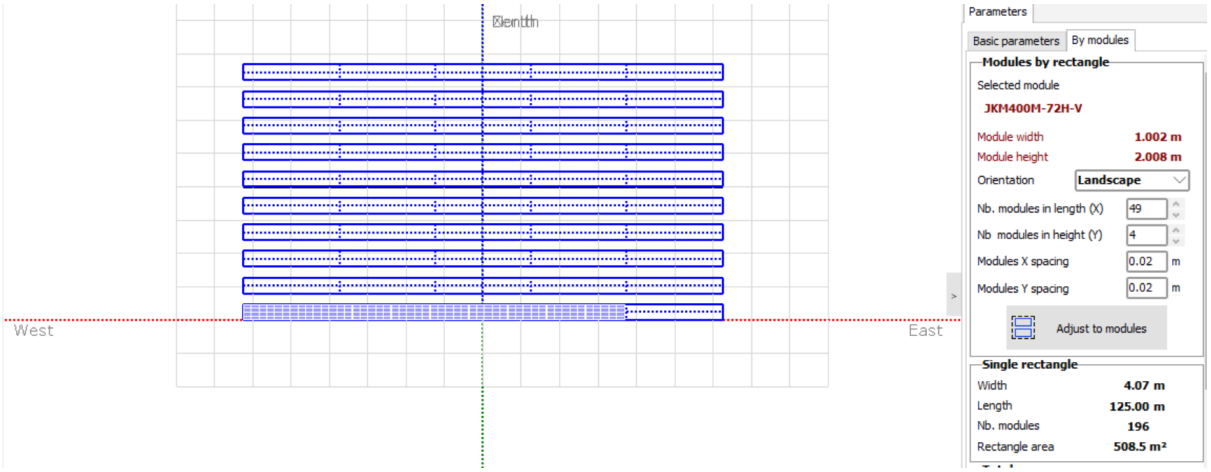


Figure 7: Top-view showing multiple sheds

Placing 107 modules in landscape mode results in ideal physical size of 125 meters by 4.07 meters shed. This is known as shed or row of solar panels. The pitch, which is the ground clearance between adjacent sheds is optimized at 8.00 meters to allow for minimum inter-row shading on adjacent solar panels. This pitch will accommodate solar panels and mounting structures and also includes space for the inter-row space, which will also serve as the walking, cleaning and maintenance path as well as receive most of the shadows of the structures. Ground coverage ratio (GCR) is 50.8%.

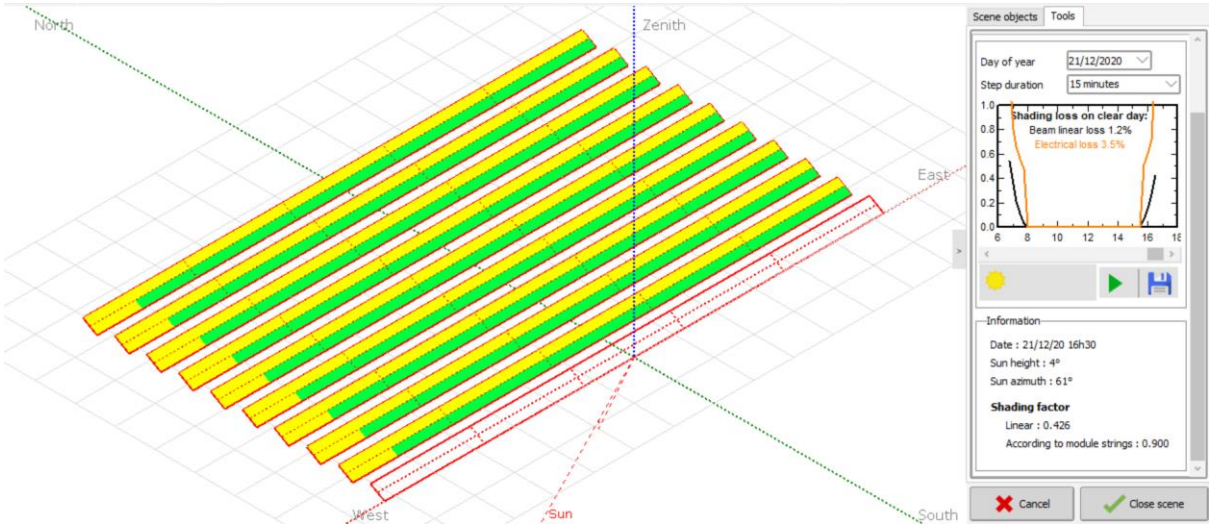


Figure 8: Shading Analysis

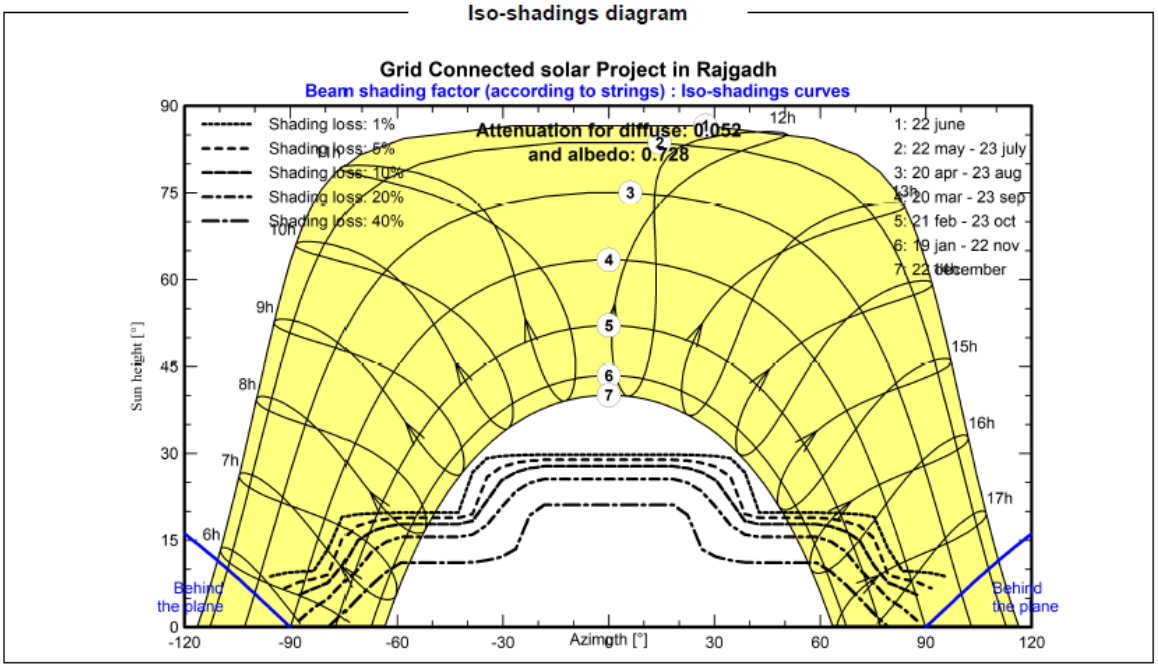


Figure 9: Iso Shading diagram for near shadings

3.4. Energy Generation:

The plant will generate 1,599 MWh/year with specific yield of 1,599 kWh/kWp/year. The performance ratio is estimated to be 81.6%, Pnom ratio is designed to be 1.14, and the average near shading loss will be 2.42%.

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	116.3	49.1	15.37	161.0	153.0	144.4	139.4	0.866
February	131.3	52.5	20.20	165.8	158.1	145.6	140.6	0.848
March	169.2	76.0	25.96	189.4	179.9	161.6	151.0	0.797
April	182.4	87.6	30.59	182.9	172.7	152.3	139.2	0.761
May	190.7	103.2	31.87	176.2	165.3	146.1	141.0	0.800
June	162.8	97.8	31.13	145.0	134.9	120.5	116.1	0.801
July	152.9	95.0	30.27	138.0	128.2	115.2	110.9	0.804
August	154.1	93.0	30.25	147.4	137.6	123.6	119.1	0.808
September	142.0	73.7	29.16	149.4	140.5	126.4	121.8	0.816
October	142.7	68.4	27.38	169.4	160.5	145.4	140.4	0.829
November	127.5	46.8	22.37	173.2	165.4	151.5	146.1	0.844
December	114.0	47.9	17.25	161.1	153.3	143.9	133.5	0.829
Year	1785.8	890.9	26.00	1958.7	1849.4	1676.5	1599.3	0.816

Figure 10: Balances and output results

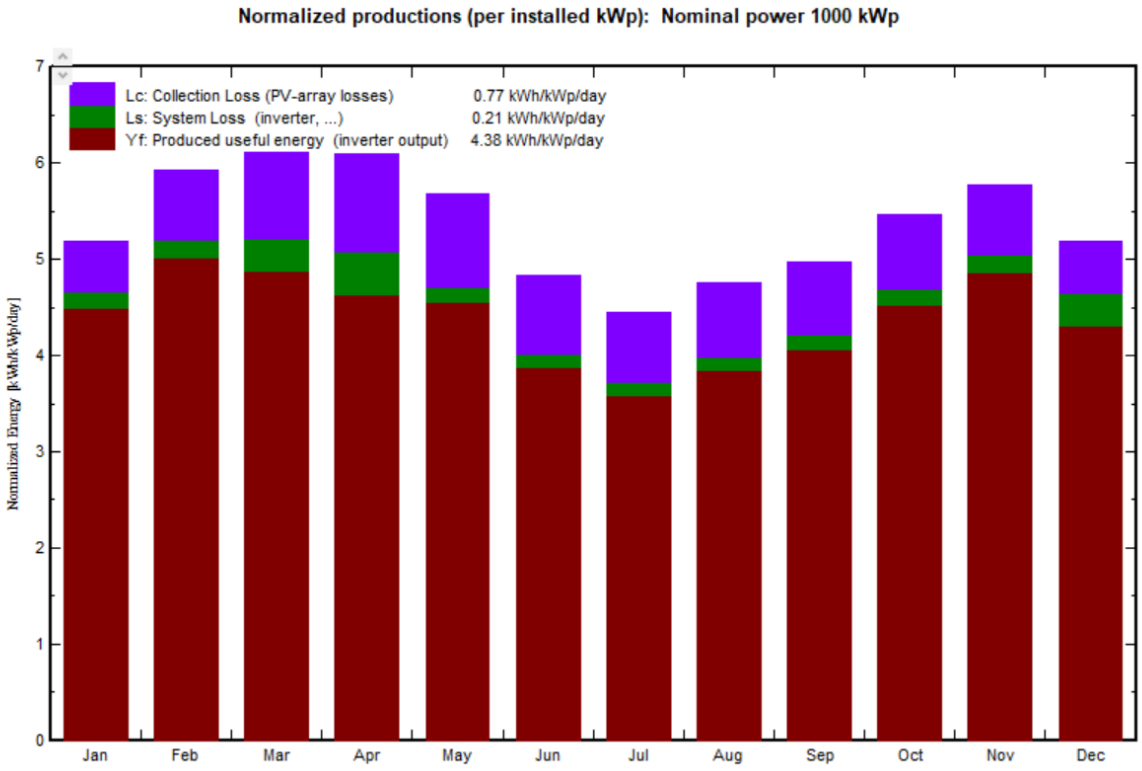


Figure 11: Normalized Production

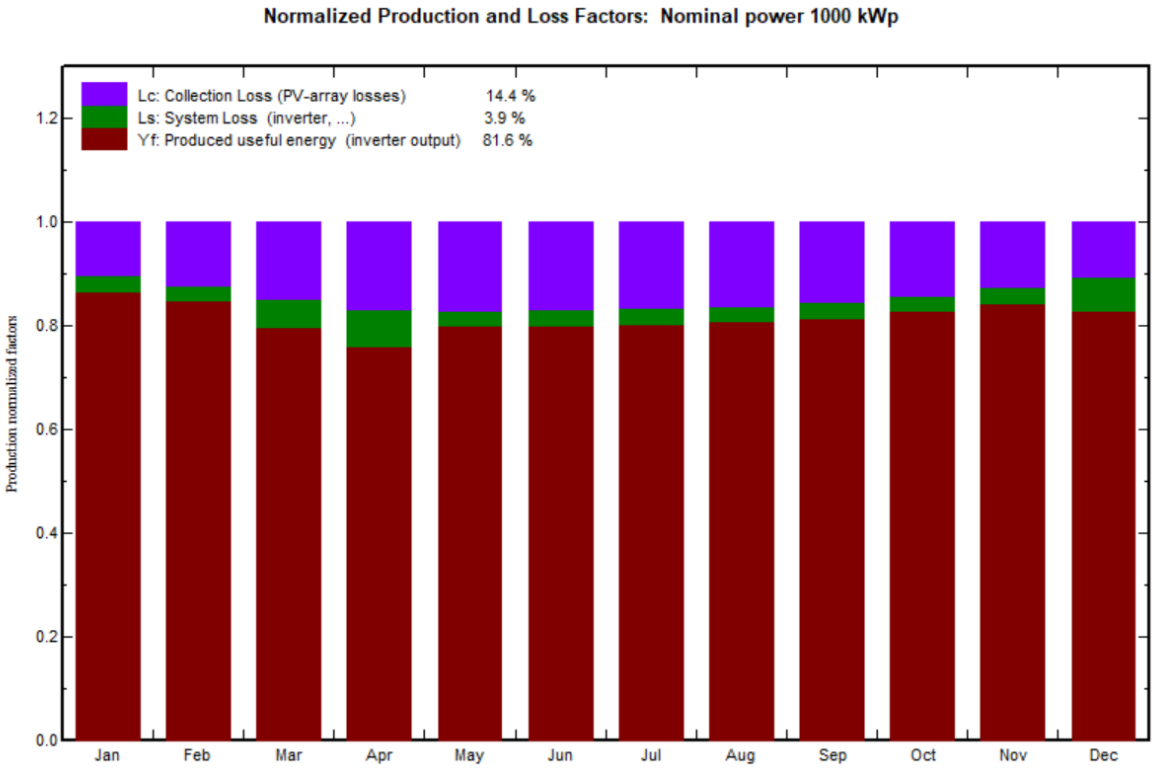


Figure 12: Normalized Production and Loss factors

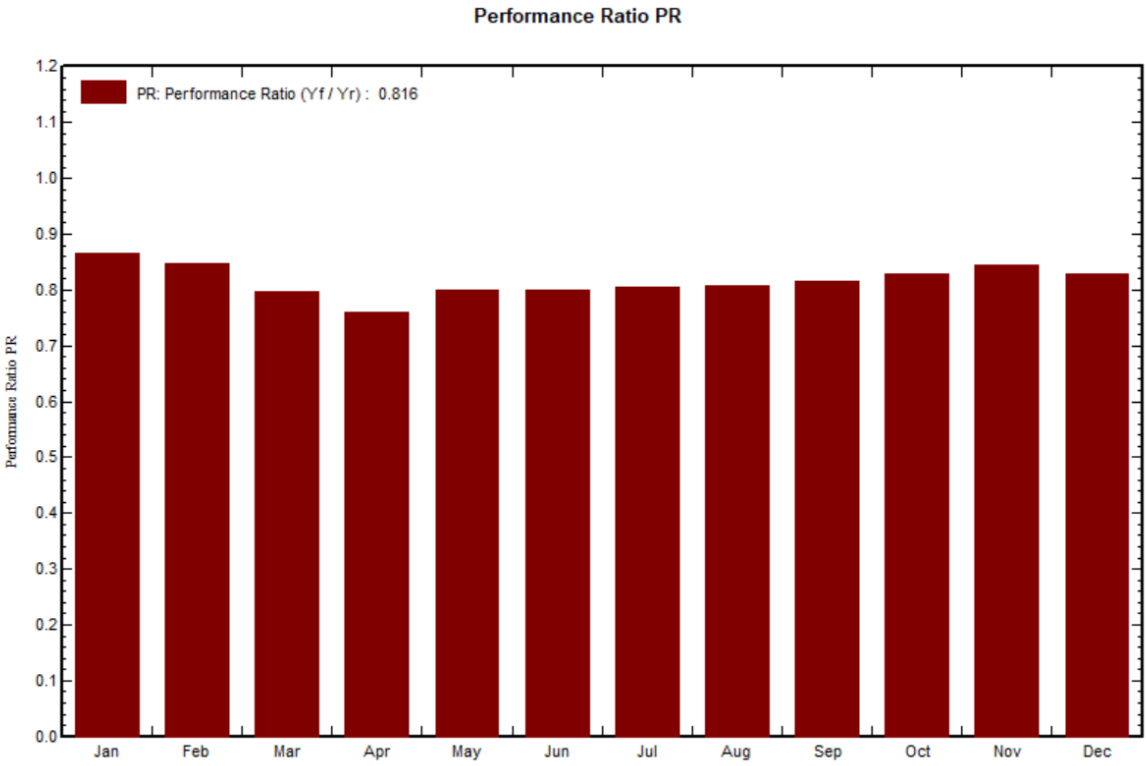


Figure 13: Monthly Performance ratio of the plant

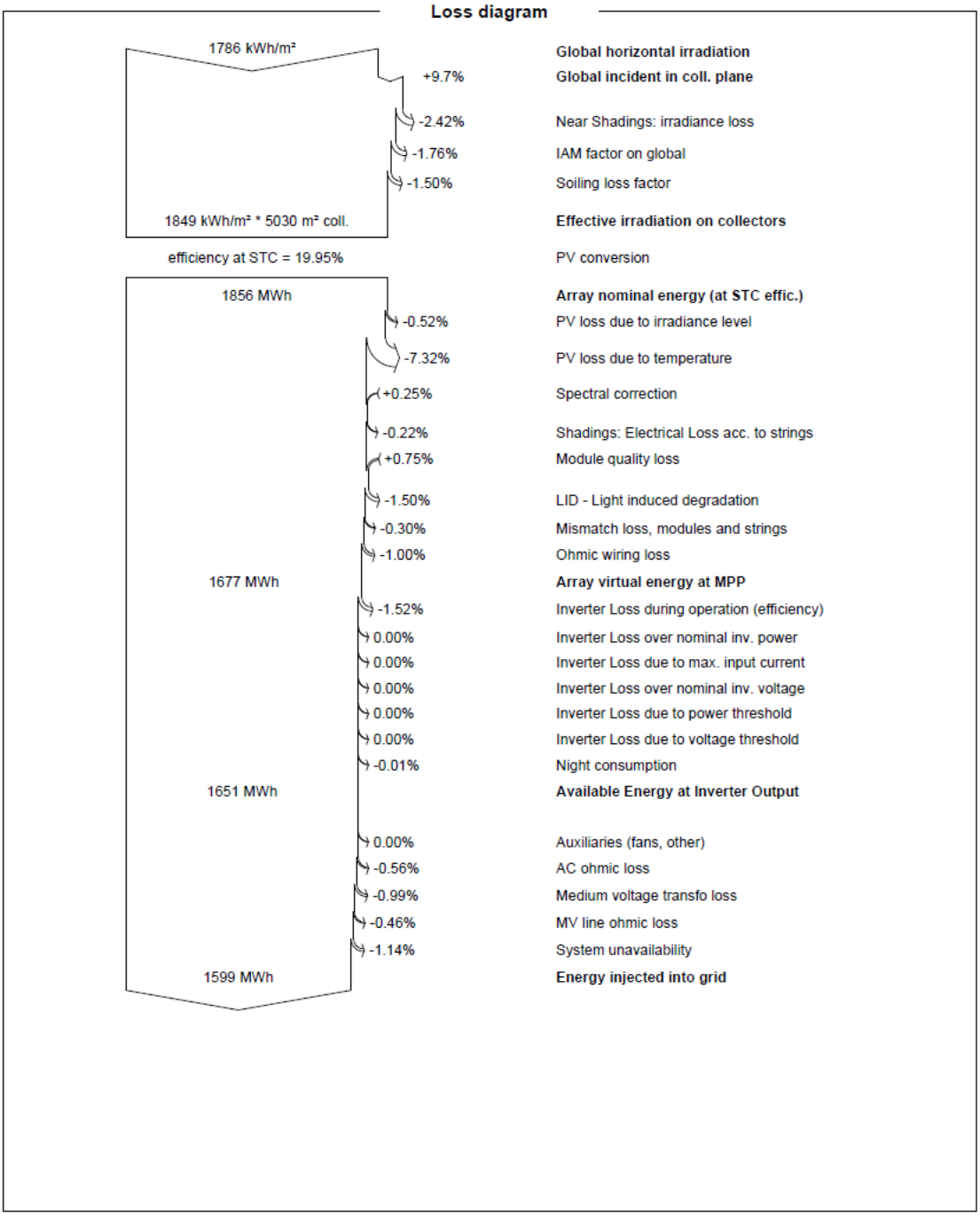


Figure 14: Loss Diagram

4. COST ESTIMATE OF THE PROJECT

The detailed cost estimate breakdown of the project is given below:

Table 1: Cost Breakdown for the project

S.N.	Detail of Cost	Cost (NPR)	% of total cost
1	Solar Modules	45000000	54.82%
2	Inverter and accessories	8400000	10.23%
3	Mounting structures	2994000	3.65%
4	DC Cable, Electrical Side	3992000	4.86%
5	SCADA, Weather Monitoring Station, Data logger	1300000	1.58%
6	All Civil Works, land leveling, fencing, control house with AC facilities	3500000	4.26%
7	DC side erection work	1197000	1.46%
8	Plant side substation, including transformer	2495000	3.04%
9	Supply of Transmission Line(11kV)	4680000	5.70%
10	Erection of 11 kV line	1105000	1.35%
11	Spares of Solar Modules (0.20%)	900000	1.10%
12	Transportation	1197600	1.46%
13	DPR Preparation Cost	1200000	1.46%
14	Custom and Duties	1996000	2.43%
15	Project Insurance	767606	0.94%
16	Social Mitigation Expenses	30000	0.04%
17	Contingency	1327660	1.62%
	Total Cost	**82,081,866**	**100%**

5. PRELIMINARY FINANCIAL ANALYSIS

Assumptions:

- Project operation lifetime: 25 years
- Capital Cost per kWp: 82,081.66 NPR
- Equity to Debt ratio: 30:70
- Loan Interest rate: 9%
- Loan Tenure: 7 years
- Discount rate: 10%
- Capacity Utilization Factor (CUF): 18.25%
- Annual Energy Degradation: 0.50%
- Annual O&M cost: 1% of capital cost
- Annual O&M escalation: 3%
- Inverter Lifetime: 10 Years
- PPA rate: NPR 7.30/kWh
- Depreciation: 5% over 20 years
- Salvage Value: 0

Findings:

- IRR:15.08%
- NPV:74,619,690.60
- Payback Period:9.15 years
- LCOE:5.64 Rs/kWh

6. ANNEXURE

Version 7.1.8

PVsyst - Simulation report

Grid-Connected System

Project: Grid Connected solar Project in Rajgadh

Variant: New simulation variant

Sheds, single array

System power: 1000 kWp

Rajgadh - Nepal

Author

DAI Europe Ltd. - NREP (Nepal)

Project: Grid Connected solar Project in Rajgadh

Variant: New simulation variant

DAI Europe Ltd. - NREP (Nepal)

Project summary

Geographical Site
Rajgadh
Nepal

Situation

Latitude	26.50 °N
Longitude	86.67 °E
Altitude	0 m
Time zone	UTC+5.5

Project settings

Albedo	0.20

Meteo data
Rajgadh
Meteonorm 7.3 (1991-2010), Sat=100% - Synthetic

System summary

Grid-Connected System

Sheds, single array

PV Field Orientation

Fixed plane	
Tilt/Azimuth	30 / 0 °

Near Shadings

According to strings	
Electrical effect	100 %

User's needs
Unlimited load (grid)

System information

PV Array

Nb. of modules	2500 units
Pnom total	1000 kWp

Inverters

Nb. of units	7 units
Pnom total	875 kWac
Pnom ratio	1.143

Results summary

Produced Energy	1599 MWh/year	Specific production	1599 kWh/kWp/year	Perf. Ratio PR	81.65 %

Table of contents

PVsyst V7.1.8
VC0, Simulation date:
27/09/21 10:58
with v7.1.8

General parameters

Grid-Connected System

Sheds, single array

PV Field Orientation

Orientation	
Fixed plane	
Tilt/Azimuth	30 / 0 °

Sheds configuration	
Nb. of sheds	10 units
Single array	
Sizes	
Sheds spacing	8.00 m
Collector width	4.07 m
Ground Cov. Ratio (GCR)	50.8 %
Top inactive band	0.02 m
Bottom inactive band	0.02 m
Shading limit angle	
Limit profile angle	24.6 °

Models used	
Transposition	Perez
Diffuse	Perez, Meteonorm
Circumsolar	separate

Horizon
Free Horizon

Near Shadings
According to strings
Electrical effect 100 %

User's needs
Unlimited load (grid)

PV Array Characteristics

PV module

Manufacturer	Jinkosolar
Model	JKM400M-72H-V
(Original PVsyst database)	
Unit Nom. Power	400 Wp
Number of PV modules	2500 units
Nominal (STC)	1000 kWp
Modules	100 Strings x 25 In series
At operating cond. (50°C)	
Pmpp	913 kWp
U mpp	928 V
I mpp	984 A

Inverter

Manufacturer	Sungrow
Model	SG125-HV
(Original PVsyst database)	
Unit Nom. Power	125 kWac
Number of inverters	7 units
Total power	875 kWac
Operating voltage	860-1450 V
Pnom ratio (DC:AC)	1.14

Total PV power

Nominal (STC)	1000 kWp
Total	2500 modules
Module area	5030 m²
Cell area	4464 m²

Total inverter power

Total power	875 kWac
Nb. of inverters	7 units
Pnom ratio	1.14

Array losses

Array Soiling Losses
Loss Fraction 1.5 %

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 29.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 16 mΩ
Loss Fraction 1.5 % at STC

LID - Light Induced Degradation
Loss Fraction 1.5 %

Module Quality Loss
Loss Fraction -0.8 %

Module mismatch losses
Loss Fraction 0.2 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

Array losses

IAM loss factor

Incidence effect (IAM): Fresnel AR coating, n(glass)=1.526, n(AR)=1.290

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.999	0.987	0.962	0.892	0.816	0.681	0.440	0.000

Spectral correction

FirstSolar model

Precipitable water estimated from relative humidity

Coefficient Set	C0	C1	C2	C3	C4	C5
Monocrystalline Si	0.85914	-0.02088	-0.0058853	0.12029	0.026814	-0.001781

System losses

Unavailability of the system
Time fraction 1.0 %
3.7 days,
3 periods

Auxiliaries loss

AC wiring losses

Inv. output line up to MV transfo

Inverter voltage	600 Vac tri
Loss Fraction	1.0 % at STC
Inverter: SG125-HV	
Wire section (7 Inv.)	Alu 7 x 3 x 120 mm²
Average wires length	100 m

MV line up to Injection

MV Voltage	11 kV
Wires	Copper 3 x 185 mm²
Length	10000 m
Loss Fraction	0.8 % at STC

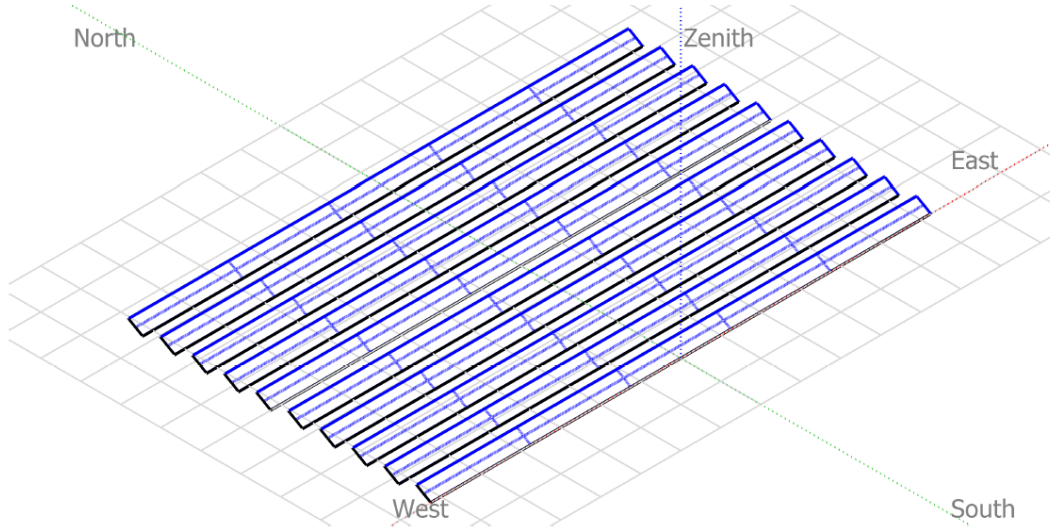
AC losses in transformers

MV transfo

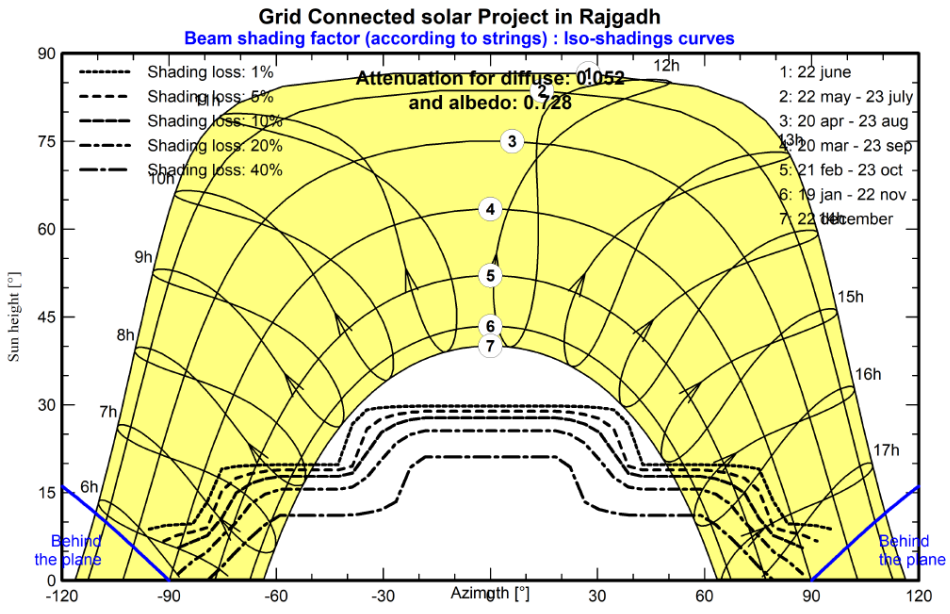
Grid Voltage	11 kV
Operating losses at STC	
Nominal power at STC (PNomac)	989 kVA
Iron loss (24/24 Connexion)	0.99 kW
Loss Fraction	0.1 % at STC
Coils equivalent resistance	3 x 3.09 mΩ
Loss Fraction	0.9 % at STC

Near shadings parameter

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram

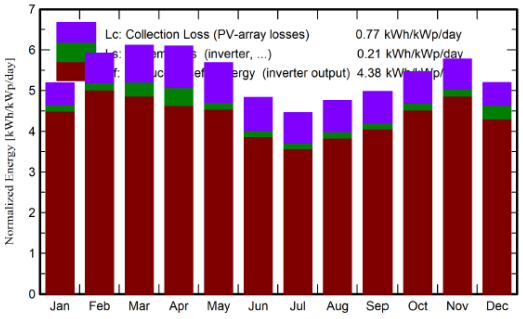


Main results

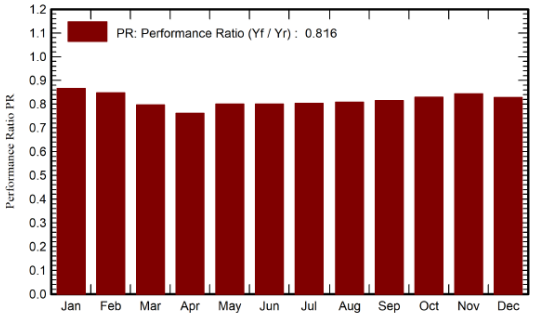
System Production

Produced Energy	1599 MWh/year	Specific production	1599 kWh/kWp/year
		Performance Ratio PR	81.65 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

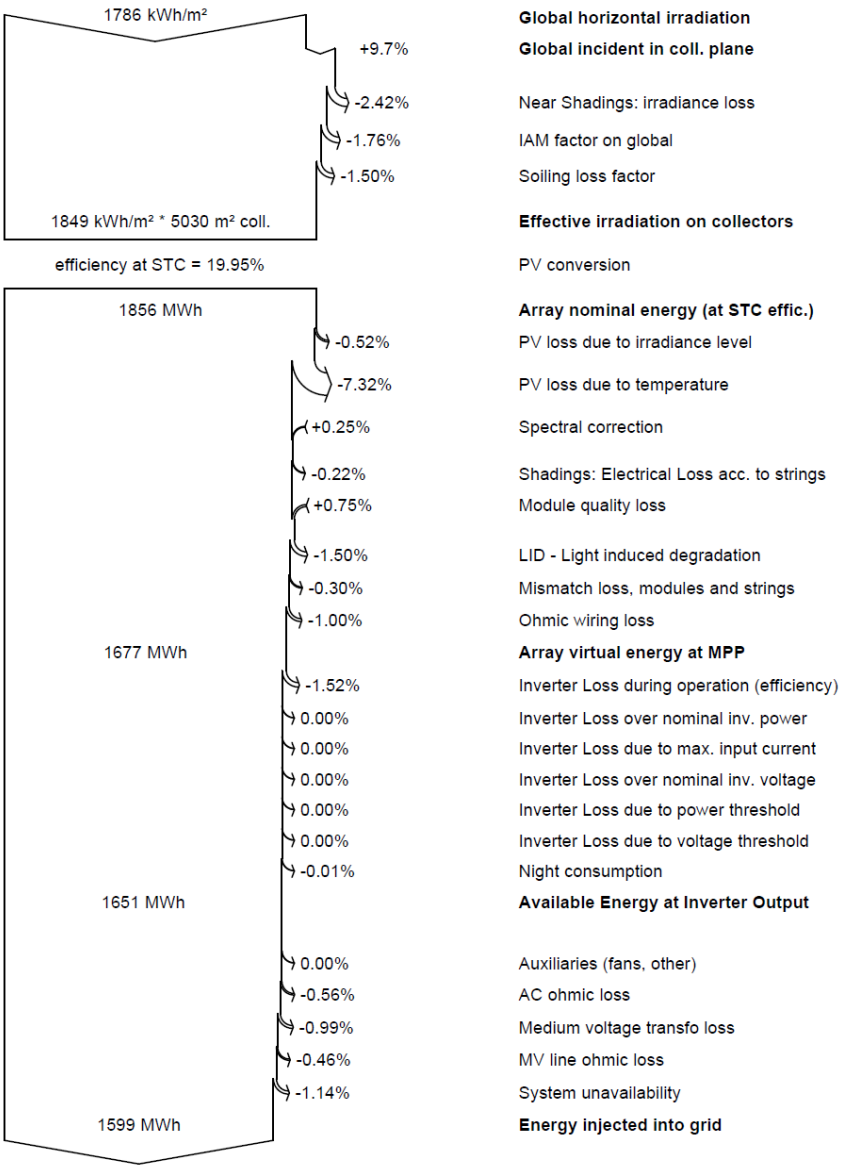
	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	116.3	49.1	15.37	161.0	153.0	144.4	139.4	0.866
February	131.3	52.5	20.20	165.8	158.1	145.6	140.6	0.848
March	169.2	76.0	25.96	189.4	179.9	161.6	151.0	0.797
April	182.4	87.6	30.59	182.9	172.7	152.3	139.2	0.761
May	190.7	103.2	31.87	176.2	165.3	146.1	141.0	0.800
June	162.8	97.8	31.13	145.0	134.9	120.5	116.1	0.801
July	152.9	95.0	30.27	138.0	128.2	115.2	110.9	0.804
August	154.1	93.0	30.25	147.4	137.6	123.6	119.1	0.808
September	142.0	73.7	29.16	149.4	140.5	126.4	121.8	0.816
October	142.7	68.4	27.38	169.4	160.5	145.4	140.4	0.829
November	127.5	46.8	22.37	173.2	165.4	151.5	146.1	0.844
December	114.0	47.9	17.25	161.1	153.3	143.9	133.5	0.829
Year	1785.8	890.9	26.00	1958.7	1849.4	1676.5	1599.3	0.816

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

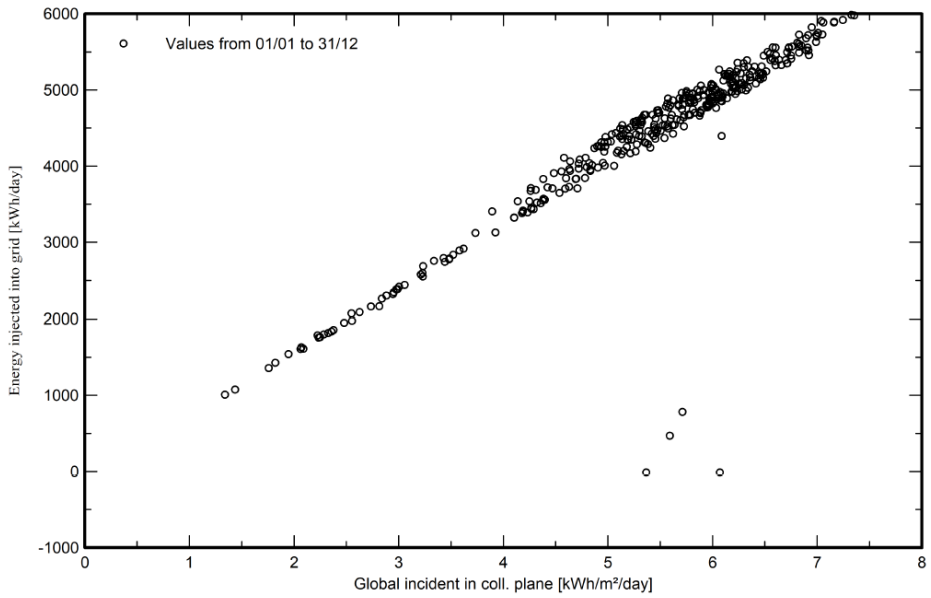
PVsyst V7.1.8
VC0, Simulation date:
27/09/21 10:58
with v7.1.8

Loss diagram

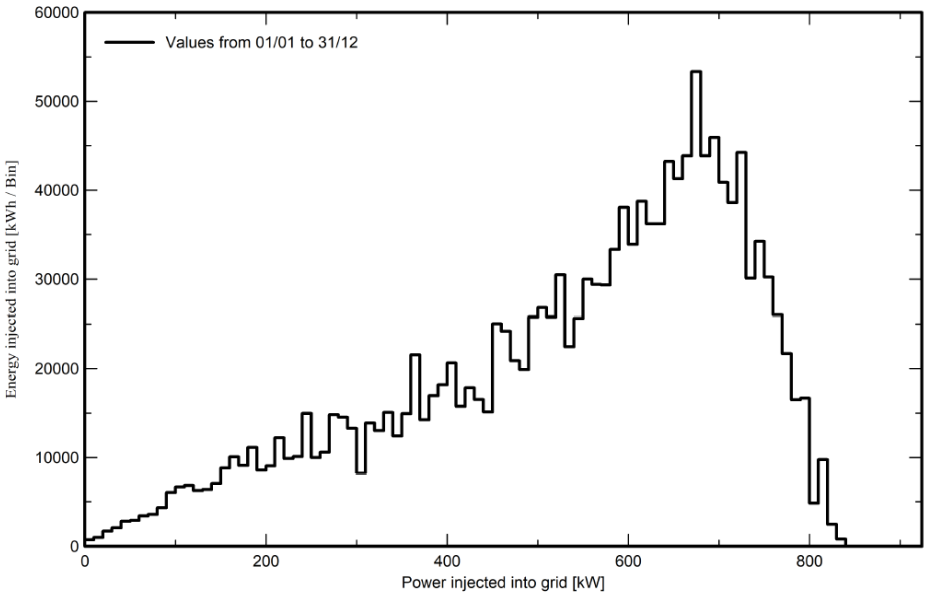


Special graphs

Daily Input/Output diagram



System Output Power Distribution



PVsyst V7.1.8
VC0, Simulation date:
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with v7.1.8

P50 - P90 evaluation

Meteo data

Meteo data source: Meteonorm 7.3 (1991-2010), Sat=100%

Kind	TMY, multi-year
Year-to-year variability(Variance)	4.8 %

Specified Deviation

Climate change	0.5 %

Simulation and parameters uncertainties

PV module modelling/parameters	1.0 %
Inverter efficiency uncertainty	0.5 %
Soiling and mismatch uncertainties	1.0 %
Degradation uncertainty	1.0 %

Global variability (meteo + system)

Variability (Quadratic sum)	5.1 %

Annual production probability

Variability	82.4 MWh
P50	1607.3 MWh
P90	1501.6 MWh
P75	1551.7 MWh

Probability distribution