TECHNICAL FEASIBILITY REPORT : – IPGCL, 2 MW ROOFTOP SOLAR PV PROJECT;

Developed By: Oakridge Energy Pvt. Ltd., Delhi (India)

PREPARED BY :

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1. INTRODUCTION

a. The Government of India is actively promoting the setting up of the Solar Power. The Prime Minister has set the ambitious target of Solar power generation capacity of 100 GW by 2022. The State Governments are also working with the Centre to encourage the adoption of Solar power through various policy interventions.

The Renewable Purchase Obligation (RPO) of the Government of Delhi is targeted at 10% of the total power procured (from all sources) by 2022. In pursuance of this target, the Govt of Delhi is encouraging Solar power by installation of PV power plants on the rooftops of various institutions like schools & residential societies.

b. Indraprastha Power Generation Company Ltd. (IPGCL) is an entity of Government of Delhi. IPGCL has invited bids from the qualified and capable vendors to set up rooftop Solar PV projects (RTSPV) over the roofs of various schools in Delhi. 'M/s Oakridge Energy Private Limited' (hereinafter called 'Oakridge') has won one such tender for setting up RTSPV projects aggregating to 2 MW.

c. M/s Oakridge would set up Solar PV projects over the rooftop of identified schools in Delhi of varying capacity (as per the roof area available, allowable capacity etc.) with cumulative capacity addition of 2 MW. These RTSPV projects would be set up under the 'Net Metering' policy of the Government of Delhi where the end client (Schools) would be charged only for the net electricity consumed (electricity imported from the grid minus Solar power exported into the grid)

2. TECHNICAL FEASIBILITY ASSESSMENT

a. Electricity yield calculation has been carried out for a typical site location (rooftop of school) at Delhi. The rooftop Solar PV capacity is assumed to be 50 KWp. The assumptions on shadow loss and cleanliness of the modules (soiling loss) has been made to have the least loss given proper upkeep of the PV plant during operation & maintenance stage. A Performance Ratio (PR) of 0.81 is assessed with the given input conditions.

b. The various module parameters as input are as below:

Item	Value	Unit
NOCT	45	^{o}C
Temperature Coefficient for P_{max}	0.39%	per ^{o}C
Annual Degradation	3%	per year for 0-1 year
Annual Degradation	0.65%	per year for 2-25 year

c. The losses as assessed by the PV module datasheet and the grid-tie Inverter data sheet are as given below:

Other Losses	
PV loss during operation	3.00%
Soiling loss	1.00%
Manufacturer Tolerance	0.00%
Inverter loss during operation	1.50%
Loss in DC cables	1.00%
Loss in transformer	0.00%
Loss in AC transmission	0.50%

d. The monthly specific yield output (kWh/kWp) and monthly PR is calculated for a South-facing tilt angle of 28deg and is as given below;

Month	Days	Average Daily Solar Radiation (kWh/sq.m./day)	Day Time Average Temp. (ºC)	Monthly Specific Yield (kWh/kW)	Monthly Performance Ratio
Jan	31	5.14	21.2	134.14773	0.84190
Feb	28	5.62	23.8	131.01634	0.83259
Mar	31	6.46	30.3	162.07527	0.80932
Apr	30	6.2	36.3	146.53977	0.78785
May	31	5.9	40.6	141.28240	0.77246
Jun	30	5.43	40	126.82362	0.77854
Jul	31	4.74	35.2	116.93554	0.79580
Aug	31	4.61	33.6	114.55104	0.80156
Sep	30	5.24	34	125.14388	0.79608
Oct	31	5.83	33	144.52255	0.79966
Nov	30	5.57	28.6	136.25486	0.81541
Dec	31	4.97	23.4	128.49771	0.83402

e. The PV Array-Inverter matching has been carried out with first principles and various input conditions are tabulated as below for the PV Module and the inverter:

PV MODULE - SUMERA 370W$_p$		
AMBIENT CONDITIONS & PLANT YIELD		
Item	**Value**	**Unit**
Max. Ambient Temperature	40.6	^{0}C
Min. Ambient Temperature	21.2	^{0}C
PR as per Yield Analysis	81%	
Max. DC Loss Allowed in DC Cabling	1%	
MODULE PARAMETERS		
Item	**Value**	**Unit**
Module NOCT	45	^{0}C

Max. Cell Temperature	65.6	^{0}C
Min. Cell Temperature	46.2	^{0}C
Module Rated Peak Power at STC	370	W_p
Module Open Circuit Voltage - V_{OC}	48.5	V
Module Short Circuit Current - I_{SC}	9.84	A
Module Max Power Voltage - V_{MP}	40.0	V
Module Max Power Current - I_{MP}	9.26	A
Temp. Coeff. For Max. Power - Y_{MP}	-0.390%	$\%/^{0}C/V$
Temp. Coeff, for Open Circuit Voltage - Y_{OC}	-0.280%	$\%/^{0}C/V$
Temp. Coeff. For Short Circuit Current - Y_{SC}	0.057%	$\%/^{0}C/A$

GRID-TIED INVERTER - HITACHI HIVERTER Si-50KPI		
Item	**Value**	**Unit**
Absolute Max. DC Input Voltage	1000	V
MPPT Window Lower DC Input Voltage	350	V
MPPT Window Upper DC Input Voltage	950	V
No. Of MPPT	3	Nos.
Rated DC Voltage of Inverter	600	V
Inverter Efficiency	98.5	%
Max. Input DC Power (All MPPT's)	65	kW
Max. DC Input Current / MPPT	30	A

f. The PV module annual degradation would result in lower output year-on-year and it was calculated for each modular PV power plant of 50kWp installed capacity.

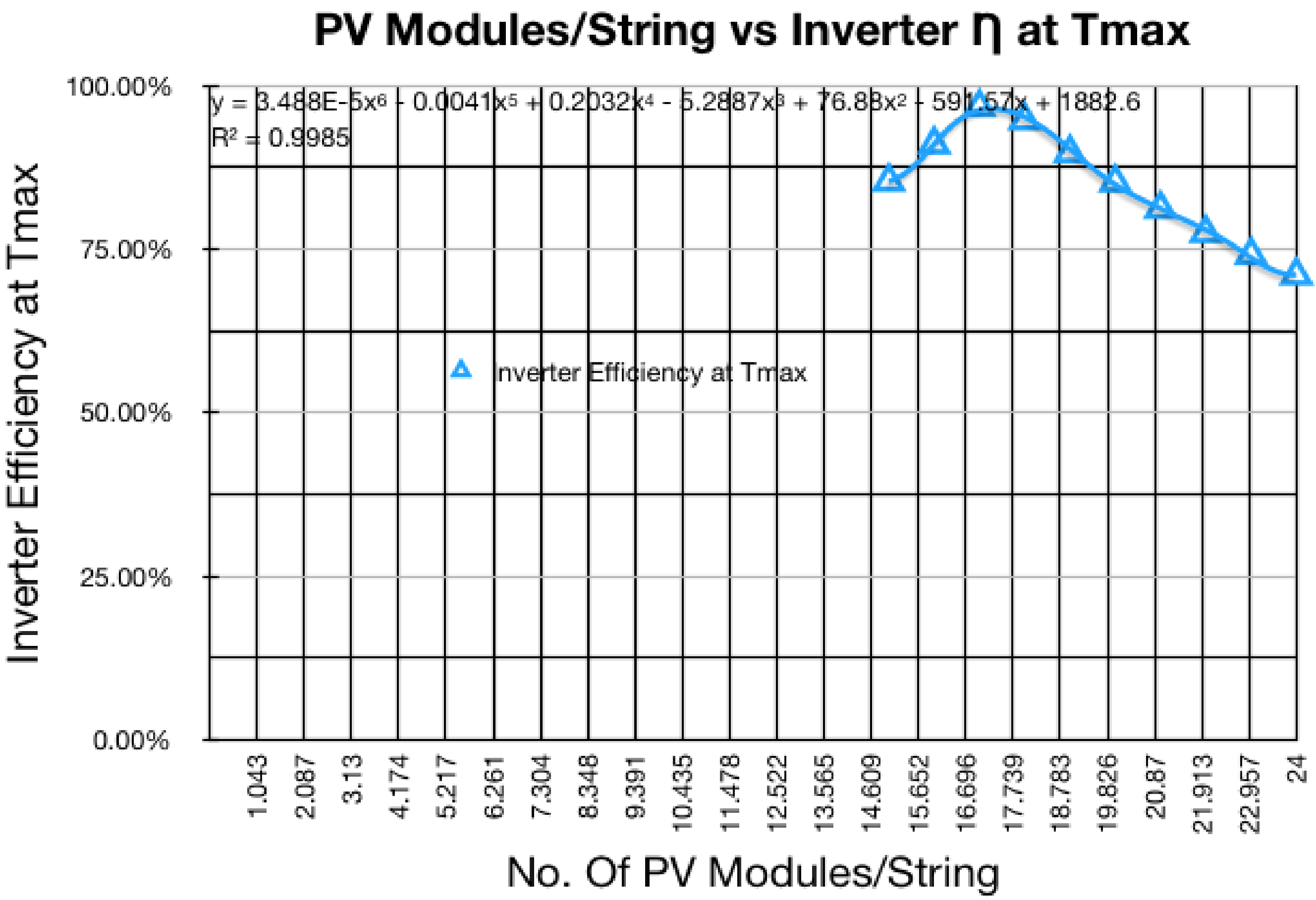
g. The PV array corrected parameters thus arrived as per the PV module data sheet are as below:

PV MODULES - TEMPERATURE CORRECTED PARAMETERS		
Item	**Value**	**Unit**
V_{OC} at T_{MAX}	42.99	V
V_{OC} at T_{MIN}	45.62	V
V_{MP} at T_{MAX}	33.67	V
V_{MP} at T_{MIN}	36.69	V
I_{SC} at T_{MAX}	10.07	A
I_{MP} at T_{MAX}	9.47	A
I_{SC} at T_{MIN}	9.96	A
I_{MP} at T_{MIN}	9.37	A

h. The array size thus worked out based on the Inverter-Array matching is as presented below:

DETAILS OF ARRAY SIZE	
Min. No. of Modules per String	12
Max. No. of Modules per String	20
Max. No. Strings/MPPT	2
Max. No. of Strings / Inverter	6

The optimum size of the PV array is worked out to be 17 PV modules per string and 2 strings per MPPT. For this arrangement, the array-inverter overall efficiency is maximum at the highest temperature corrected output. This is illustrated in the curve plotted below:



i. Component description / Component assembly – The key components of Module and Inverter are selected based on the tier-1 manufacturer. The module was selected from Sumera 370Wp from Vikram Solar and grid-tied inverter from Hitachi 50kW. The overall 2MW PV plant distributed at various site locations was modularised with each PV plant of capacity 50kW$_p$.

j. An independent check was also done with ‘PV Syst’ (a widely used industry software tool for PV system design). The results obtained from ‘PV Syst’ are attached as ‘Annexure I’ of this report. The results obtained from ‘PV Syst’ are in line with our technical due diligence carried out by the first principles.

3. ECONOMICAL FEASIBILITY ASSESSMENT

This has been separately carried out/got carried out by the project developer (M/s Oakridge Energy Private Ltd.) and as conveyed by them, the project is found to be economically viable. M/s Oakridge Energy Private Ltd. might be contacted for more details regarding the same.

4. CO_2 EMISSIONS ANALYSIS

a. The lifetime of the PV plant is designed to be 25 years. The savings of GHG emissions during this designed power producing period of the PV plant has been analyzed (with insolation data taken from NASA SSE Power database) and found to be as below for each of the 50kW$_p$ modular PV plant:

Year	Annual Energy Yield (kWh)	Annual Specific Yield (kWh/kW)	Annual Performance Ratio	GHG Emmisions Offset (kgs of CO_2)
1	80390	1608	0.80	69135
2	77978	1560	0.78	67061
3	77471	1549	0.78	66625
4	76967	1539	0.77	66192
5	76467	1529	0.77	65762
6	75970	1519	0.76	65334
7	75476	1510	0.76	64910
8	74986	1500	0.75	64488
9	74498	1490	0.75	64069
10	74014	1480	0.74	63652
11	73533	1471	0.74	63238
12	73055	1461	0.73	62827
13	72580	1452	0.73	62419
14	72108	1442	0.72	62013
15	71640	1433	0.72	61610
16	71174	1423	0.71	61210
17	70711	1414	0.71	60812
18	70252	1405	0.70	60417
19	69795	1396	0.70	60024
20	69341	1387	0.69	59634
21	68891	1378	0.69	59246
22	68443	1369	0.68	58861
23	67998	1360	0.68	58478
24	67556	1351	0.68	58098
25	67117	1342	0.67	57721

b. The similar calculation for savings of GHG emissions has been done with ‘PV-GIS SARAH database’ and the following result is obtained;

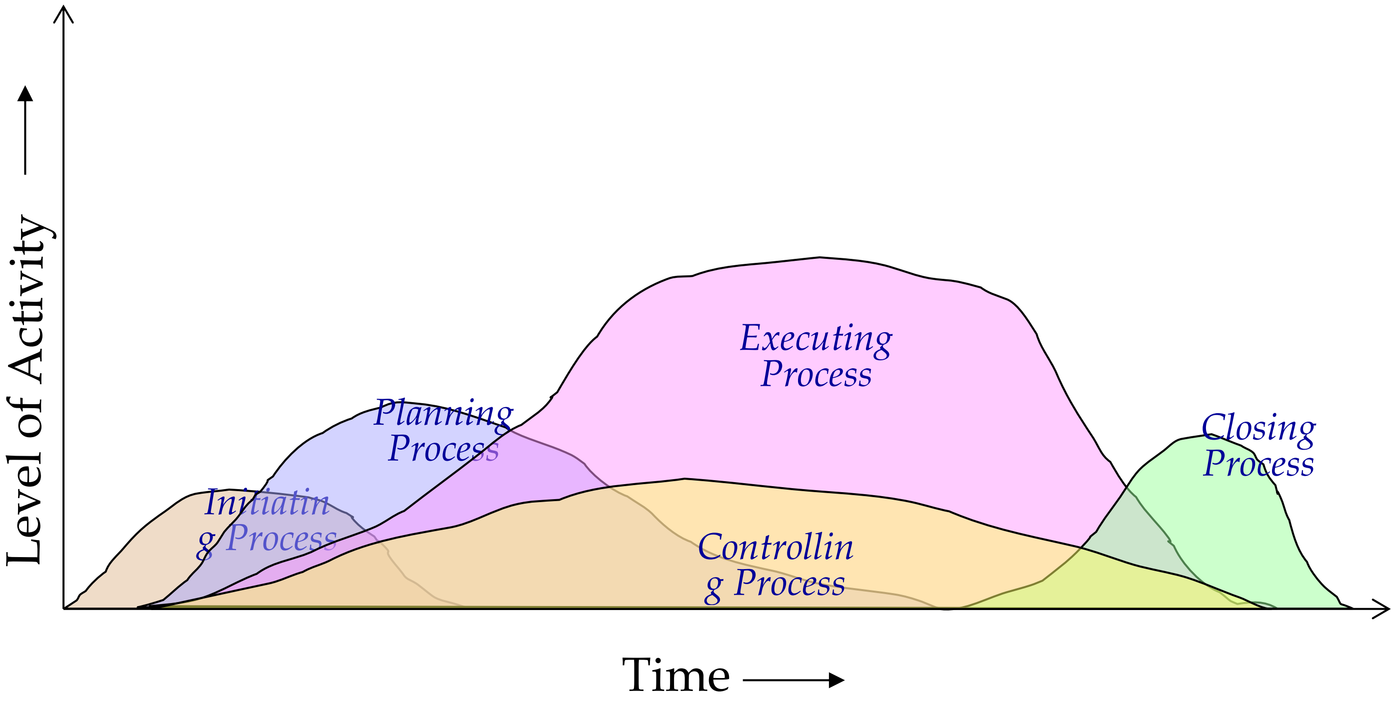
Years	Annual Energy Yield (kWh)	Annual Specific Yield (kWh/kW)	Annual Performance Ratio	GHG Emmisions Offset (kgs of CO_2)
1	85976	1720	0.804	84256
2	83396	1668	0.780	81728
3	82854	1657	0.775	81197
4	82316	1646	0.770	80669
5	81781	1636	0.765	80145
6	81249	1625	0.760	79624
7	80721	1614	0.755	79107
8	80196	1604	0.750	78592
9	79675	1593	0.745	78081
10	79157	1583	0.740	77574
11	78643	1573	0.735	77070
12	78131	1563	0.731	76569
13	77624	1552	0.726	76071
14	77119	1542	0.721	75577
15	76618	1532	0.716	75085
16	76120	1522	0.712	74597
17	75625	1512	0.707	74112
18	75133	1503	0.703	73631
19	74645	1493	0.698	73152
20	74160	1483	0.693	72677
21	73678	1474	0.689	72204
22	73199	1464	0.684	71735
23	72723	1454	0.680	71269
24	72250	1445	0.676	70805
25	71781	1436	0.671	70345

c. As the result in section 4(a) above is more conservative (gives lesser amount of savings in GHG Emissions), we have considered the same (insolation based on NASA-SSE Power Database) for our report.

For the complete 2MW Solar PV project, this amounts to average saving of ~ 60 million MT of CO2 emissions.

5. PROJECT MONITORING

M/s Oakridge Energy Private Ltd. has a full team of engineers, procurement executives and project managers. The subject project of 2 MW is about to start. As informed by M/s Oakridge, the entire project of 2 MW would be managed internally with the team of project managers, engineers and other support staff. The project team would follow the well established principles of project managent (as explained in the latest version of the PMBOK issued by Project Management Institute (PMI), USA).



The project team would develop the baseline project schedule and the budget. The project progress would be measured and reported from the respective sites and the project would be monitored at site level and also at the head quarter. The key metric like SPI (Schedule Performance Index), CPI (Cost Performance Index) would be calculated, variance analysis (planned v/s actual) would be done and necessary actions taken to commission the projects within time and the budget.

The project team would also separately plan and manage the following aspects of the sub projects under the ambit of the overall project management of 2 MW RTSPV project;

a) Procurement management of key equipment such as the Solar PV modules and the inverters

b) Procurement management of BoS (Balance of systems such as cables, ACDBs, earthing etc.) of RTSPV project

c) Construction management of the civil and electrical work at the respective sites

d) Risk management of the various sub projects under the 2 MW RTSPV project

e) Safety management of the work at the respective sites

6. SOCIAL & ECONOMIC IMPACTS

The project would have positive and beneficial social and economic impacts as stated below;

a) Economic Impact - The project is economically viable as stated in Section 3 (based on the information provided by M/s Oakridge) of this report. Thus, this project would yield the required return on the investment to the investors in the project.

The project would also help the end clients (Schools) as their electricity bill would get reduced considerably due to significant part of their electricity consumption being met with the installed rooftop Solar PV plants.

b) Social Impact – The project would be beneficial environmentally as stated in Section 4 of this report.

The project would lead to direct employment of the supervisors and labor for construction and installation work. There is minimal maintenance required for the Solar PV projects. However, maintenance of these projects also would lead to a few jobs being created.

7. SUMMARY & CONCLUSION

As explained above, the project is technically viable. The key equipment (Solar PV modules, Solar PV Inverters) proposed to be used are from the approved vendor list of the 'Bureau of Indian Standards' (BIS), Government of India. The technical analysis giving the monthly yield (electricity produced) from the typical 50 KW_p RTSPV has been done based on the data sheet of the equipment of the said vendors only.

As stated in Section 4 of this report, the implementation of the project would lead to considerable reduction in the emission of greenhouse gases over the life time of the Solar PV plant (considered as 25 years). As stated in Section 3 of this report, a separate economic feasibility for the project has been carried out and the project is found to be economically viable. Also, as explained in Section 6 of this report, the project would also lead to other social and economic benefits in terms of the direct job creation and reduction in the monthly electricity expenditure for the end clients (schools).

In the next section we have attached the details of the design carried out using 'PV Syst' (Popular industry software for Solar PV system Design) to further validate our above analysis.

8. ANNEXURE I – DESIGN BY 'PV SYST'

The details of PV system design using widely used industry software package 'PV Syst' are given in the following pages;

Grid-Connected System: Simulation parameters

Project : **Delhi Govt Schools IPGCL**

Geographical Site	**New Delhi**		Country	**India**
Situation	Latitude	28.58° N	Longitude	77.20° E
Time defined as	Legal Time	Time zone UT+5.5	Altitude	219 m
	Albedo	0.20		
Meteo data:	**New Delhi**	Meteonorm 7.1 (2001-2010) - Synthetic		

Simulation variant : **New simulation variant**

Simulation date 16/12/19 11h49

Simulation parameters

Collector Plane Orientation	Tilt	28°	Azimuth	24°
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Array Characteristics

PV module Si-mono	Model	**SOMERA VSM.72.370.03.04 (Grand)**		
Custom parameters definition	Manufacturer	Vikram Solar Limited		
Number of PV modules	In series	17 modules	In parallel	318 strings
Total number of PV modules	Nb. modules	5406	Unit Nom. Power	370 Wp
Array global power	Nominal (STC)	**2000 kWp**	At operating cond.	1806 kWp (50°C)
Array operating characteristics (50°C)	U mpp	606 V	I mpp	2981 A
Total area	Module area	**10490 m²**	Cell area	9474 m²

Inverter	Model	**Si- 50K**		
Custom parameters definition	Manufacturer	HITACHI		
Characteristics	Operating Voltage	250-960 V	Unit Nom. Power	50 kWac
			Max. power (=>25°C)	55 kWac
Inverter pack	Nb. of inverters	40 units	Total Power	2000 kWac

PV Array loss factors

Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	3.4 mOhm	Loss Fraction	1.5 % at STC
LID - Light Induced Degradation			Loss Fraction	2.5 %
Module Quality Loss			Loss Fraction	-0.3 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP

Incidence effect (IAM): User defined IAM profile

0°	20°	40°	60°	70°	75°	80°	85°	90°
1.000	1.000	1.000	0.970	0.900	0.830	0.690	0.450	0.000

User's needs : Unlimited load (grid)

Grid-Connected System: Main results

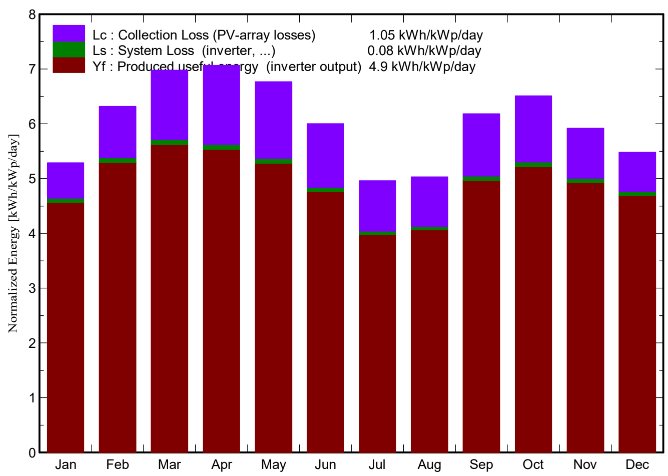
Project : **Delhi Govt Schools IPGCL**

Simulation variant : **New simulation variant**

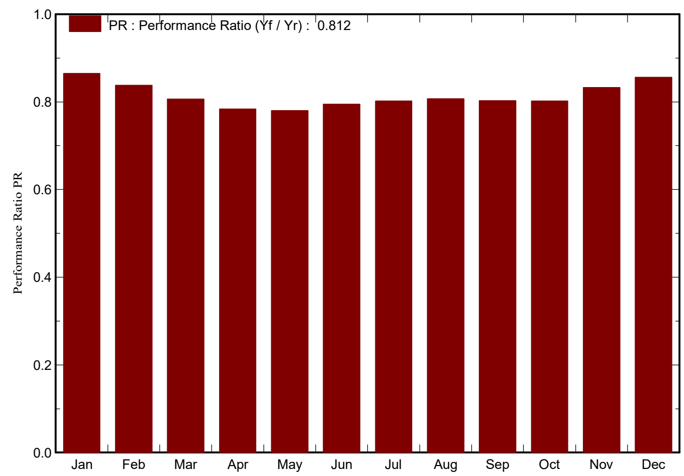
Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	28°	azimuth	24°
PV modules		SOMERA VSM.72.370.03.04 (Grand)	Pnom	370 Wp
PV Array	Nb. of modules	5406	Pnom total	**2000 kWp**
Inverter	Model	Si- 50K	Pnom	50.0 kW ac
Inverter pack	Nb. of units	40.0	Pnom total	**2000 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**3580 MWh/year**	Specific prod.	1790 kWh/kWp/year
	Performance Ratio PR	81.25 %		

Normalized productions (per installed kWp): Nominal power 2000 kWp



Performance Ratio PR



New simulation variant

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
January	118.2	37.29	13.23	163.9	161.2	288.1	283.4	0.865
February	136.9	36.13	17.24	176.8	174.1	301.2	296.3	0.838
March	188.2	50.14	23.29	216.3	212.5	354.2	348.6	0.806
April	206.5	66.68	29.22	212.0	207.8	337.7	332.1	0.783
May	222.1	88.27	32.60	209.8	205.1	332.7	327.4	0.780
June	196.5	96.71	32.14	180.1	175.5	290.8	286.1	0.794
July	166.4	93.01	31.42	153.7	149.6	250.7	246.5	0.802
August	159.9	93.20	30.36	156.0	152.1	256.2	251.9	0.807
September	170.6	71.58	28.58	185.5	181.6	302.9	297.9	0.803
October	164.5	46.82	25.49	201.8	198.4	328.9	323.6	0.802
November	128.5	33.61	19.32	177.6	174.7	300.4	295.7	0.832
December	115.1	29.81	14.85	169.9	167.5	295.7	290.9	0.856
Year	1973.4	743.23	24.85	2203.1	2160.1	3639.5	3580.4	0.812

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

Grid-Connected System: Loss diagram

Project : **Delhi Govt Schools IPGCL**

Simulation variant : **New simulation variant**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	28°	azimuth	24°
PV modules		SOMERA VSM.72.370.03.04 (Grand)	Pnom	370 Wp
PV Array	Nb. of modules	5406	Pnom total	**2000 kWp**
Inverter	Model	Si- 50K	Pnom	50.0 kW ac
Inverter pack	Nb. of units	40.0	Pnom total	**2000 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year