Project code 2016EF22

Detailed Project Report for Installation of Grid-Connected Solar Rooftop Power plants at GHMC Buildings

Prepared for

Greater Hyderabad Municipal Corporation

Hyderabad, Telangana State

The Energy and Resources Institute

...towards global sustainable development

© The Energy and Resources Institute 2017

Suggested format for citation

T E R I. 2017

Detailed Project Report for Installation of Grid-Connected Solar Rooftop Power generating plants for GHMC Properties

New Delhi: The Energy and Resources Institute. 56pp

[Project Report No. 2016EF22]

For more information

Project Monitoring Cell

T E R I

Darbari Seth Block

IHC Complex, Lodhi Road

New Delhi – 110 003

India

Tel. 2468 2100 or 2468 2111

E-mail pmc@teri.res.in

Fax 2468 2144 or 2468 2145

Web www.teriin.org

India +91 • Delhi (0)11

Executive Summary

This report presents the detailed feasibility study for installation of solar power generation system at Greater Hyderabad Municipal Corporation (GHMC) area at Hyderabad, Telangana State. The site visit was conducted to first assess the suitable space for solar power plant installation considering availability of space, future plans of expansion and shadow analysis of the select locations. Considering these criteria, various buildings in the campus were identified as potential locations for installation of solar PV power plants on rooftops of these buildings. Feasible Rooftop Area for SPV is identified to be 15557 sq.m on the rooftops of various buildings, which is sufficient for installation of 1295 kWp (Feasible Solar Plant without Shadow Analysis and 941 kWp with shadow analysis done via Helioscope.

It was observed that all of these buildings had substantial loads in the same premises. Typically the electrical loads comprised of indoor loads and Outdoor loads. Indoor loads mainly consisted of lighting, fans, air conditioners (AC's), water coolers etc. The outdoor loads are mostly for outdoor lighting. But this load is not very suitable for solar power generation systems as the load is only during night time. The final sizes of the proposed rooftop solar systems at all the buildings were decided after analysing the shadow free area available at the rooftops via Helioscope.

Solar PV power is a rapidly emerging sector with lot of new emerging technologies such as crystalline solar PV (mono crystalline and poly crystalline), Thin film solar PV and third generation technologies such as Concentrating PV, dye sensitized PV and organic solar PV. Out of these crystalline PV technology is commercially well proven and reliable technology considering Indian as well as global experience. The same technology is therefore recommended.

The basic engineering for solar PV power plants is also prepared along with detailed bill of material. Considering the initial discussions with GHMC employees, grid tied plant without storage was considered for designing.

The total capacity of 941 kWp generates about 1.56 MUs annually. For the techno-commercial study, capital cost of the system is considered as INR 52/Wp comprising of capital costs of all major components and operation and maintenance costs. The techno-commercial study also includes the evaluation of the tracking systems for solar PV panels. The use of tracking systems (single and double axis tracking systems) is not recommended as the increase in annual energy generation does not justify increase in capital cost (trackers) and operation and maintenance costs.

To assist in actual implementation of the solar PV power plants, the report has also given project implementation schedule of around 15 weeks. The various operation and maintenance activities related to the project, necessary man-power and organizational structure for O&M activity and typical cost for O&M activity is also given. The total operation and maintenance staff of 4 people is suggested with estimated operation and maintenance costs of about 1.3 % of the capital costs per annum with 3% annual escalation.

There are also various government initiatives to promote solar PV power generation. The Government of India and State Governments have been promoting use of solar energy technologies through variety of promotional schemes, policies and regulatory measures. Some of the measures such as capital subsidies to user and manufacturers, low interest loans, duties & taxes exemptions and so on form part of fiscal and financial incentives while

others such as mandatory renewable energy purchase obligations are Part of regulatory initiatives.

RPOs (Renewable Purchase Obligations) are one the major of the government policy initiatives wherein the government is making it mandatory for power consumers to buy certain percentage of its power consumption to be met from power produced using renewable energy sources. These obligations are for utilities (also known as DISCOMs (Distribution Companies) and consumers who use captive power or who buy power from generators directly and not through utilities. The RPOs are part of the EA2003 (Electricity act 2003) which is the basis for the development of regulatory frame-work in power sector in India.

At GHMC area a total of 15557 sq. m. of rooftop area is feasible for the installation of solar PV power plant. This area is suitable for maximum capacity installation of 941 kWp considering shadow area.

- Suggested type of photovoltaic technology is c-Si
- Suggested type of system is grid tied system without storage backup
- The module mounting structures will have to be such that current roof slabs are not disturbed. Typical load of rooftop solar power plant is about 15-20 kg/sq.m., which seems manageable for the existing building structures. However, this detail will need to be confirmed by structural consultant during actual implementation.
- Average Capacity Utilization Factor (CUF) of the power plants is ~ 16%.
- Installing solar PV system is a viable business proposition as NPV is positive and project IRR is more than 13 %.

The detailed financial analysis is also carried out to calculate important financial parameters such as NPV, IRR, simple payback period etc. These parameters would be very much helpful for decision makers to evaluate financial side of the solar PV power plants that can be installed at the GHMC. The financial results for the proposed PV power plant are as given below.

Table 1: Results of financial analysis (Grid tied solar PV system)

	E:D 30:70	
Parameter	**Without subsidy**	**With subsidy**
System capacity (kWp)	941	941
Solar generation (kWh)	156,62,004	156,62,004
Capital cost (INR)	489,32,000	366,99,000
LCOE (INR/kWh)	6.7	5.09
Equity IRR (%)	10.94%	13.47%

Table of contents

List of figures

List of tables

Detailed Project Report for Installation of Grid-Connected Solar Rooftop Power generating plants for GHMC Properties

1. Introduction

Telangana is the 29th state of India which was created on 2nd June, 2014 after its separation from Andhra Pradesh. The capital of Telangana state is Hyderabad which it will be sharing with the state of Andhra Pradesh for next 10 years. Telangana will have 10 districts of Andhra Pradesh under its jurisdiction. It has an area of 114,840 square kilometres (44,340 sq mi), and a population of 35,286,757 (2011 census). Its major cities include Hyderabad, Warangal, Nizamabad, and Karimnagar. Electricity is a critical element required for the smooth functioning of the state economy. The availability of reliable, quality and affordable power helps in the rapid development of agriculture and industrial sector and the overall economy of the state.There are two DISCOMs in Telangana – TSSPDCL that supplies power to the districts of Hyderabad, Rangareddy, Mahbubnagar, Nalgonda and Medak, and TSNPDCL that supplies to Warangal, Karimnagar, Khammam, Nizamabad and Adilabad. Telangana has a vast solar potential with average solar insolation of nearly 5.5 kWh/m2 for more than 300 sunshine days. Government of Telangana (GoTS), intends to make use of the positive environment in solar market and the push given by GoI for substantially harnessing the solar potential in the state of Telangana.

The Greater Hyderabad Municipal Corporation in short (GHMC) is the civic body that oversees Hyderabad the capital and largest city in the State of Telangana. Its geographical area covers most of the urban development agency the Hyderabad Metropolitan Development Authority (HMDA). GHMC pays huge power consumption charges for various office buildings. To promote solar energy and reduce electricity bills, the Greater Hyderabad Municipal Corporation (GHMC) has planned to install rooftop grid-connected power generation plants on GHMC-owned buildings in a phased manner.

The report presents detailed project report for feasibility study and detailed techno-economic assessment of solar PV rooftop power plant in GHMC area. Various buildings suitable for installation of rooftop solar PV power plant were identified in the campus for this. Chapter 2 covers details of site survey such as assessment and selection of suitable space for PV plant installation, assessment of available loads and resource assessment. Chapter 3 presents the comparison of various solar PV technologies and selection of appropriate technology based on the local conditions. Performance evaluation is given for the selected technology for grid interactive system without any storage system. Chapter 4 presents the basic engineering of the proposed solar PV power plant covering actual layout and technical specifications of PV power plant and estimation of annual energy generation by the proposed system. Chapter 5 presents the detailed techno-commercial study elaborating financial analysis, operation and maintenance requirement. The conclusion recommendations of the report are presented in Chapter 6.

1.1 Power supply position in Telangana

The Southern Region has been reeling under huge shortage of power over the last 3-4 years because of multiple reasons. This shortage not only kept the electricity prices in the region on a higher side, but also kept a large section of consumers devoid of increased hours of supply they could have received, had the planning of generation, transmission and demand been done efficiently. Telangana is a crucial part of a large interconnected grid spanning across the country, covering every single State/UT and Region. Energy deficit in Telangana for last three years was in the range of 4%-12%. Energy requirement in Telangana was 50,916 MU in FY 14-15, of which only 2,128 MU could not be met resulting in an energy deficit of nearly 4.2% with a maximum historic peak demand of 8,331 MW in 2014-15. As can be seen from the table below, peak demand has increased by over 2,588 MW during the period FY 2008-09 till FY 2014-15 as against which peak met has increased by 1,345 MW. The State is likely to face power shortage for two-three years till it manages to augment fresh capacities. It is hoping to have adequate power to provide 24x7 supply within three years. The immediate focus is on augmenting fresh supplies procuring power from Chhattisgarh, Karnataka and Central generating stations.

According to Central Electricity Authority (CEA), the total installed capacity of the state is 12691.68 MW as on January 2017. Out of the total installed capacity, renewable energy is 1230.21 MW which is 9.7% in the in the total installed capacity. The Telangana Government is working on near-term strategy and long-term roadmap to bridge the demand-supply gap in the power scenario in the new State. While the State currently has access to 4,400 MW, it requires about 7,000 MW. The State Government has planned to work out modalities to procure additional power and ensure uninterrupted power supply in the State. It is proposed that the State will seek to have a generation capacity of 20,000 MW, which includes 6,000 MW of the Telangana Genco. The Energy department has also been asked to consider stepping up power generation from various hydel-power sources across all the major river systems passing through the State.

1.2 Regulatory and Policy Framework to promote solar roof-top in Telangana

The net metered rooftop solar installations are growing at a brisk pace, with the TSSPDCL site showing 652 commissioned projects as of date with a total capacity of 9.9 MW (an average of 15kW per installation). The Government of Telangana has announced its new solar policy. The new policy will remain in operation for five (5) years and all the Solar Projects that are commissioned during the operative period will be eligible for the incentives declared under this policy, for a period of ten (10) years from the date of commissioning. The objective of the Policy includes long term energy security, sustainable fuel for energy generation, promoting solar parks in the state and promoting investment in the solar sector. The policy also targets on promoting distributed and decentralized generation and off-grid solar applications. For availing benefits under this policy, power generated through solar projects has to be consumed within the state. The policy offers good number of incentives to the project developer, in terms of tax relaxations, must run status, exemptions from various charges, single window clearance etc.

Also, Telangana recently came up with its net metering regulation for connectivity with the Grid and sale of electricity from the Rooftop Solar Photovoltaic. This Regulation will be applicable to the distribution licensee, an eligible consumer and a third party owner of a Roof Top Solar PV System in the state of Telangana. The tariff payable to an eligible consumer under the net-metering shall be the average power purchase cost of a Distribution Licensee. The quantum of electricity consumed by an Eligible Consumer from the Rooftop Solar PV System under the Net Metering Arrangement shall qualify towards his compliance of Solar RPPO, if such Consumer is an Obligated Entity.

Central Policy for Grid Connected Solar Rooftop System MNRE is providing "Achievement linked incentives to Government Departments for the installation of Solar Rooftop Systems in the Government Buildings having the vacant rooftops. Following steps need to be taken to implement the Achievement linked incentives:[1]

1. The government will undertake assessment of rooftop area and surplus area of all Government/ PSU buildings and premises and collate data on RTS potential (10 sq.m area for 1 kWp RTS) as also on present level of electricity consumption, average tariff being paid.
2. Based on the RTS potential, present electricity consumption and average tariff, financial savings would be assessed
3. The Government will confirm their willingness to participate in this scheme based in their RTS potential and possible savings and intimate MNRE and/ or State Nodal Agency regarding preferred model and methodology for its RTS project
4. MNRE/ Sate nodal Agency will assess RTS potential and set target capacity for RTS potential projects of those entities who agree (as and when they agree) to participate in the programme and are willing to seek incentive. Year- wise target will be finalized.
5. The target, if not completed, shall be rolled over to the next year and will be added in the next year's targets in consultation with the entities.
6. The provision of the achievement linked incentive will be as follows:[2]

Achievement vis-à-vis target allocation	Incentives for general category states	Incentives for special category states
80% and above within the sanctioned period	Rs. 16,250/- per kW	Rs 39,000/- per kW
Below 80% and upto 50% within the sanctioned period	Rs 9,750/- per kW	Rs 23,400/- per kW
Below 50% delayed commissing upto 6 months beyond the sanctioned period	Rs 6,500/- per kW	Rs 15,600/- per kW

In case the Government Department opt for the CAPEX mode of the installation of the System:

The cost/tariff of the project should be firmed up through a transparent bidding process. The maximum incentive for S.No. 1 in the above table, will be limited to 25 % of the benchmark cost or the cost arrived through competitive bidding process, whichever is lower, for general category States /UTs and 60 % of the benchmark cost or the cost arrived through competitive bidding process, whichever is lower, for special category States/U'I's/ Islands. Similarly, for S. No. 2 above, it will be limited to 15 % for general category States/ UTs and 36% for special category States/UTs/ Islands. For S. No. 3 above, it will be limited to 10 % for general category States/U'I's and 24% for special category States/U'I's/ Islands.

[1] Source: MNRE(http://mnre.gov.in/file-manager/UserFiles/gcrt-incentives-award-040516.pdf)

[2] Source: MNRE(http://mnre.gov.in/file-manager/UserFiles/Notification-Incentive-&-Award-scheme-for-Govt-Sector-30032017.pdf)

In case the Government Department opt for the RESCO mode of the installation of the System:

In this case, the developers are selected through a tariff-based reverse bidding. The incentive amount will be up to 25% of the bench mark cost as mentioned in the table above for general category States/U'I's, The benefit of the incentives should be passed on to the customer in the form of reduced tariff by factoring incentive. In case of special category States/U'I's/Islands the applicable incentives will be up to 60% of the bench mark cost.

1.3 Procedure for availing net-metering

1. Identification of vacant rooftop to install solar panels. The area required is 10 Sq. M. for each KWp capacity.
2. Apply for consent to the local Divisional Engineer (Operations), DISCOM in the prescribed format along with an application fee of Rs. 1,000/-. 3. DE(Operations), DISCOM will conduct feasibility analysis of the DTR and issue consent within 15 days on receipt of completed application form
3. DISCOM will accord approval on first come first serve basis till solar installed capacity reaches 50% of the closest upstream DTR's rated capacity. After reaching this limit, the capacity of DTR shall be enhanced within next 45 working days to process received applications from other consumers.
4. After obtaining the consent from the DISCOM, the installation of the Solar Rooftop PV system with net metering facility shall be installed.
5. The consumer may select the vendor for installation of rooftop system either from the list of approved channel partners of MNRE or suppliers/system integrators empanelled by NREDCAP.
6. The components installed under the Solar Rooftop net metering shall be as per the technical standards and specifications notified by Ministry of New and Renewable Energy (MNRE) and AP Transco / DISCOMs.
7. To avail the subsidies the following procedures shall be followed.
   (i) MNRE subsidy (30%): The consumer may avail the eligible MNRE subsidy (upto 30% of system cost) as per the guidelines of MNRE directly through the channel partners or may submit proposals to NREDCAP before installation of the system and after obtaining the consent from DISCOM in the prescribed format uploaded in the NREDCAP website. In respect of capacities more than 50 KWp, the proposal shall accompanied by a Detailed Project Report. The sanction of the subsidy by MNRE will be based on the guidelines being issued from time to time and availability of fund. The sanctioned subsidy will be released on commissioning of the system as per the MNRE guidelines.

   (ii) In case of State subsidy (20%) for capacities upto 3 KW, the claim shall be submitted with 2 months net bills to NREDCAP for release of subsidy as per the eligibility.
8. Non-refundable processing fee of Rs. 1,000/- (Rupees one thousand only) plus service tax of Rs.123.60 in case of domestic consumers (upto3 KW) and Rs. 5,000/- plus service tax of Rs 618 in case of other category consumers (upto 100 KW) by way of demand draft drawn in favour of NREDCAP payable at Hyderabad shall be paid along with the proposal.

1.4 Applicability of project under REC scheme

The basic procedure for accreditation of the RE generation project or Distribution Licensee shall cover following steps:

STEP 1: An application for availing accreditation shall be made by the applicant to the host State Agency, as defined under Clause 2(1) (n) of the CERC REC Regulations. The applicant shall apply for Accreditation on the Web Based Application and shall also submit the same information in physical form to the State Agency.

For RE Projects the application for accreditation by the generating company shall contain

(i) owners details,
(ii) operator details (in case the owner and operator are different legal entities),
(iii) Generating Station details,
(iv) Connectivity details with concerned licensee (STU/DISCOM),
(v) metering details,
(vi) Statutory Clearance details,
(vii) Undertaking of not having entered into any power purchase agreement for the capacity related to such generation to sell electricity, with the obligated entity for the purpose of meeting its renewable purchase obligation, at a tariff determined under section 62 or adopted under section 63 of the Act by the Appropriate Commission for which participation in REC scheme is sought as per the CERC REC Regulations,
(viii) In case, the Applicant has multiple RE generation projects then, separate Applications will have to be submitted by the Applicant for each RE generation project. Accreditation of each RE generation project shall be carried out separately. In case, the applicant has single unit, break up in capacity for application of Accreditation will not be allowed. The RE Generation Project shall comply with the requirements of Connectivity standards for Grid Connectivity at particular injection voltage/grid interface point as specified by State Transmission Utility or concerned Distribution Licensee, as the case may be. The Application made for accreditation of RE generation shall be accompanied by a non-refundable processing fee and accreditation charges (one time and annual, if any) as determined by the Appropriate State Electricity Regulatory Commission from time to time, and (ix) any other relevant information as per the enclosed format (FORMAT- 1.1 : Application for Accreditation of RE Generation Project).

STEP 2: The applicant shall be assigned a unique acknowledgement number1 for accreditation of its RE generation project or Distribution Licensee, as the case may be, for any future correspondence and after accreditation, Accreditation Number shall be used for the same.

STEP 3: After receipt of physical application for accreditation, the State Agency shall conduct a preliminary scrutiny to ensure Application Form is complete in all respect along with necessary documents and applicable processing fees. The State Agency shall undertake preliminary scrutiny of the Application within 7 working days from date of receipt of such Application.

STEP 4: After conducting the preliminary scrutiny, the State Agency shall intimate in writing to the Applicant within 7 days for submission of any further information, if necessary, to consider the application for accreditation or reject application.

STEP 5: While considering any application for accreditation, the State Agency shall verify and ascertain availability of following information:

For RE Generation Projects

- (i) Undertaking of 'Availability of Land' in possession for setting up generating station,
- (ii) Power Evacuation Arrangement permission letter from the host State Transmission Utility or the concerned Distribution Licensee, as the case may be,
- (iii) Metering specifications and metering Location on single line diagram, d) Date of Commissioning of RE project for existing eligible RE Project or Proposed Date of Commissioning for new RE for accreditation
- (iv) Copy of Off-take/Power Purchase Agreement. Copy of Off take/Power Purchase Agreement. In case PPA is yet to be signed, the generator can submit an undertaking that it will enter PPA with Discom in near future and will submit the same on later date before commissioning of the project.
- (v) Proposed Model and Make for critical equipment (say, WTG, STG, PV Module) for the RE Project. Confirmation of compliance of critical equipment with relevant applicable IEC or CEA Standards
- (vi) Undertaking for compliance with the usage of fossil fuel criteria as specified by MNRE/Competent Authority.
- (vii) Details of application processing fees.

STEP 6: The State Agency, after duly inspecting/verifying conditions elaborated in Step 5, shall intimate the applicant regarding its eligibility and thereafter, the applicant shall pay One Time Accreditation fee and Annual fee for that financial year and submit the required documentary proof to the State Agency. In case the applicant is not eligible and accreditation is not granted then the reasons for rejecting the application for accreditation shall be recorded and intimated to Applicant in writing within 30 days.

STEP 7: After the receipt of one time Accreditation fees and Annual fees, State Agency shall grant 'Certificate of Accreditation' to the concerned Applicant and a specific Accreditation number shall be assigned to that effect which shall be used by such Applicant (Eligible Entities) for all future correspondence with the State Agency. The process of accreditation shall normally be completed within 30 days from date of receipt of complete information by State Agency.

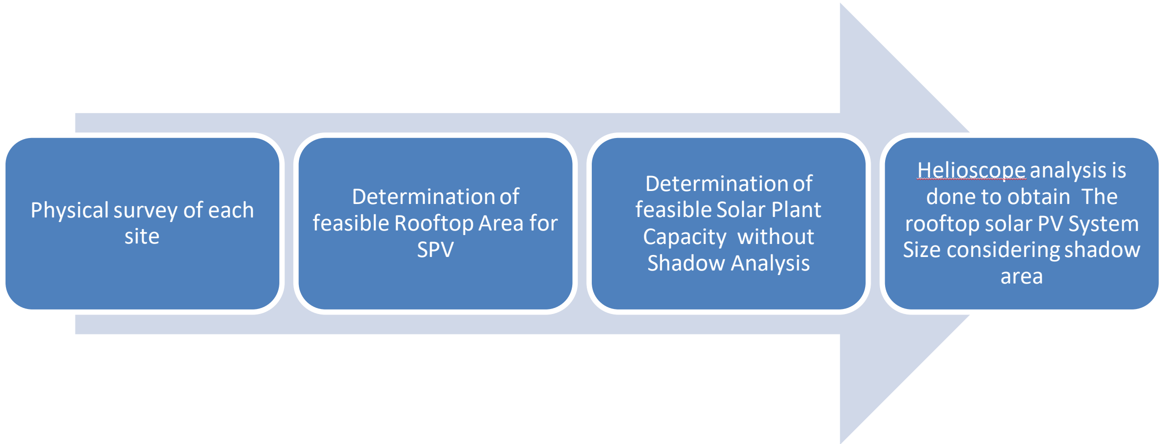
STEP 8: If accreditation is granted, the State Agency shall also intimate accreditation of particular RE generation project or Distribution Licensee, as the case may be to the following entities:

a. The Central Agency, as defined under Clause 2(1) (b)

b. The host State Load Despatch Centre

c. The distribution company in whose area the proposed/existing RE generation project would be located (not applicable in case of distribution licensee).

2. Methodology adopted to determine actual potential on identified buildings in GHMC area, Telangana.



2.1 Site survey

To assess the feasibility of the solar PV power plants and to prepare the technical feasibility report, with ensuring optimal utilization of available roof area, the experts' team visited GHMC area, Telangana to collect site specific information. Critical information including geographical location, roof area of administrative and substation buildings, type of roof, and type of load were collected as they have a major impact on the system design and performance. It has been observed that adequate roof area is available at the site for solar PV plant installation. Based on the discussions with the senior official and other information collected during site visits such as building layout and usage plan, sun direction, load pattern etc., it is proposed that the different sections of roof-top can be used for solar PV installation. The following factors were investigated under the survey.

- Shadow-free area available on the roof and orientation of the roof (if sloping)
- Near shading and its impact on plant layout
- Rooftop structure, its strength and topography
- Access to site

2.2. Assessment and selection of suitable space with Helioscope

With the help of Helioscope the shadow free area for installation of solar photovoltaic power plants have been identified during site visit. Conducting shadow analysis through Helioscope helps is realizing the loss due to the shadow caused by various structures internal and external to the roof. This in-turn helps us reduce these losses by eliminating those modules that have a" loss due to shading" more than 8%.

Central Zone

Helioscope simulation Abids Complex_821369_summary

Design 1 GHMC_Abids Complex, 17.388159,78.476026

Report

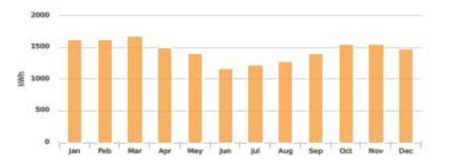
Project Name	GHMC_Abids Complex
Project Address	17.388159,78.476026
Prepared By	Arun Joshy arun.joshy@teri.res.in

System Metrics

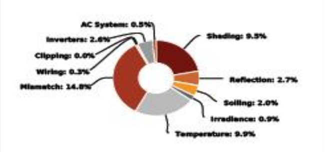
Design	Design 1
Module DC Nameplate	12.6 kW
Inverter AC Nameplate	13.2 kW Load Ratio: 0.95
Annual Production	17.53 MWh
Performance Ratio	63.4%
kWh/kWp	1,391.3
Weather Dataset	TMY, 10km Grid, meteonorm/suny high resolution (meteonorm)
Simulator Version	e514e6d0a9-98a8399a96-0e4fbc0576-9644a3d402

Project Location

Monthly Production



Sources of System Loss



Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	2,105.9	
	POA Irradiance	2,194.5	4.2%
	Shaded Irradiance	1,985.4	-9.5%
	Irradiance after Reflection	1,931.6	-2.7%
	Irradiance after Soiling	1,893.0	-2.0%
	Total Collector Irradiance	**1,893.1**	**0.0%**
Energy (kWh)	Nameplate	23,867.7	
	Output at Irradiance Levels	23,645.2	-0.9%
	Output at Cell Temperature Derate	21,296.8	-9.9%
	Output After Mismatch	18,144.7	-14.8%
	Optimal DC Output	18,085.0	-0.3%
	Constrained DC Output	18,084.8	0.0%
	Inverter Output	17,617.9	-2.6%
	Energy to Grid	**17,529.8**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		29.1 °C
	Avg. Operating Cell Temp		39.9 °C
Simulation Metrics			
		Operating Hours	4610
		Solved Hours	4610

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, 10km Grid, meteonorm/suny high resolution (meteonorm)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model

Temperature Model Parameters

Rack Type	a	b	Temperature Delta
Fixed Tilt	-3.56	-0.075	3°C
Flush Mount	-2.81	-0.0455	0°C

Soiling (%)

J	F	M	A	M	J	J	A	S	O	N	D
2	2	2	2	2	2	2	2	2	2	2	2

Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	-2.5% to 2.5%
AC System Derate	0.50%

Module Characterizations

Module	Characterization
JKM 300P-72-J4 (Jinkosolar)	Manufacturer, PAN

Component Characterizations

Device	Characterization
SOLIVIA 7.6 NA G4 TL (208V) (Delta Electronics)	CEC 2014-08-16

Components

Component	Name	Count
Inverters	SOLIVIA 7.6 NA G4 TL (208V) (Delta Electronics)	2 (13.2 kW)
Home Runs	500 MCM (Copper)	4 (115.2 m)
Combiners	1 input Combiner	8
Strings	10 AWG (Copper)	4 (17.8 m)
Modules	Jinkosolar, JKM 300P-72-J4 (300W)	42 (12.6 kW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	12	6-13	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	Fixed Tilt	Horizontal (Landscape)	10°	181.86767883943412°	0.7 m	1x1	47	42	12.6 kW

Detailed Layout

Table 2: Feasible rooftop area and Potential assessment

Sl No	Location	Zone	Feasible Rooftop Area for SPV (in sq.m)	Feasible Solar Plant without Shadow Analysis (in kWp)	System Size obtained from Helioscope (kWp)	Remark
1	Zonal Office,Kothapet	EZ	259	22	9	
2	Kapra Circle Office,Kapra	EZ	141	12	11	
3	L.B.Nagar Circle Office,Kothapet	EZ	242	20	29	
4	Uppal circle Ofice,Uppal	EZ	329	27	26	
5	e Seva, Vanasthalipuram, Red tank, Ph.II	EZ	58	5	5	
6	Vanasthalipuram, Ph-II, park with compound wall	EZ	0	0	0	
7	Vanasthalipuram ph-iv community hall	EZ	54	5	2	
8	Vanasthalipuram, ph-III NGO's colony, busstop back side	EZ	306	26	16	
9	Prashanth nagar, mahila mandala	EZ	68	6	5	
10	Prashanth nagar, welfare association	EZ	112	9	6	
11	Kakathiya nagar Community Hall	EZ		0		Denied by site incharge saying its not feasible for solar rooftop installation
12	Chaitanyapuri Ward office	EZ	77	6	2	
13	Sardarmahal, Zonal office	SZ		0		Denied by site incharge saying its not feasible for solar rooftop installation
14	Rajendranagar Circle office	SZ	350	29	37	
15	Mogulpura sports complex	SZ	628	52	50	
16	Doodbowli sports Complex	SZ	65	5	5	
17	Ramnathspura slaughter House	SZ	634	53	50	
18	Goulipura slaughter House	SZ		0		Site is under court case

Sl No	Location	Zone	Feasible Rooftop Area for SPV (in sq.m)	Feasible Solar Plant without Shadow Analysis (in kWp)	System Size obtained from Helioscope (kWp)	Remark
19	Mithra Sports Complex	SZ	112	9	10	
20	GHMC Head office	CZ	268	22	28	
21	Khairathabad Circle office	CZ	801	67	26	
22	Abids Complex	CZ	293	24	13	
23	Amberpet sports stadium	CZ	263	22	12	
24	Amberpet swimming pool	CZ	388	32	7	
25	D.K.Road Sports stadium/MCH	CZ	149	12	8	
26	Chaderghat Sports complex/ Victory	CZ	345	29	24	
27	Animal Birth Care centre(ABC),Amberpet	CZ	434	36	10	
28	Amberpet slaughter House	CZ	636	53	41	
29	Putlibowli Complex, Pultibowli Chowrasta	CZ	513	43	41	
30	Sainikpuri shoppingmall	CZ		0		Site is under court case
31	Red Hills	CZ		0		Site is not accessible for inspection
32	Vijayanagar colony(football ground)	CZ		0		Not feasible for solar rooftop
33	Vijayanagar colony(swimmingpool)	CZ		0		Not feasible for solar rooftop
34	PJR stadium, Chandanagar	WZ	286	24	8	
35	Circle 12 office Chanda nagar	WZ	206	17	10	
36	Kalyan mandapam	WZ	379	32	14	
37	Kukatpally Circle office	WZ	939	78	47	
38	Lingampally new municpal office building	WZ	590	49	20	
39	Circle-11 office building(Zonal office)	WZ		0		Roof is not owned by circle -11 office
40	KPHB ward office	WZ	159	13	6	
41	KPHB 9th Phase Vasant Nagar indoor stadium.	WZ		0		Not feasible for solar

Sl No	Location	Zone	Feasible Rooftop Area for SPV (in sq.m)	Feasible Solar Plant without Shadow Analysis (in kWp)	System Size obtained from Helioscope (kWp)	Remark
						rooftop
42	KPHB THIRD Phase indoor stadium	WZ		0		Not feasible for solar rooftop
43	Vivekanandanagar Ward Office,Div 122	WZ		0		Fully shaded
44	Balajinagar Ward Office	WZ	194	16	6	
45	Moosapet ward Office	WZ	48	4	4	
46	Old Bowenpally ward office	WZ	116	10	6	
47	Marredpally GHMC Complex(Zonal office),Backside of HMWS &SB	NZ	491	41	33	
48	Quthubullapur Circle office	NZ	98	8	7	
49	Alwal Circle Office	NZ	126	11	22	
50	Sanjaypuri Community Hall, Alwal	NZ		0		Denied by site incharge saying its not feasible for solar rooftop installation
51	Inidra Bhavan	NZ	16	1	0	
52	Malkajgiri Circle Office	NZ	255	21	46	
53	GHMC Guest House	NZ		0		Fully shaded
54	Harihara kala Bhavan	NZ	1085	90	69	
55	Buddhabhavan Complex	NZ	633	53	45	
56	Swimming pool	NZ	368	31	17	
57	NTPC	NZ	338	28	11	
58	Slaughter house	NZ	1705	142	97	
	Total		15557	1295	941	

2.3 Identification of installed electrical equipment and loads

At different identified sites there are varieties of loads such as light, fan, ACs and water coolers, auxiliary consumption by power and control equipment at different substations. The connected load at different buildings is mentioned in the table below.

Table 3 Connected loads in different buildings

Location	Zone	Connected load (kW)	Sanctioned load (kW)
Sardarmahal, Zonal office	SZ		
Rajendranagar Circle office	SZ	NOT PROVIDED	NOT PROVIDED
Mogulpura sports complex	SZ		50
Doodbowli sports Complex	SZ	53	53
Ramnathspura slaughter House	SZ		120
Goulipura slaughter House	SZ		
Mitra sports complex	SZ	8	8
PJR stadium, Chandanagar	WZ	78.98	55
Circle 12 office Chanda nagar	WZ	19.91	17
Kalyan mandapam	WZ	19.02	50
Kukatpally Circle office	WZ	128.89	45
Lingampally new municpal office building	WZ		
Circle-11 office building(Zonal office)	WZ	126	30
KPHB ward office	WZ	2.89	1
KPHB 9th Phase Vasant Nagar indoor stadium.	WZ	3	-
KPHB THIRD Phase indoor stadium	WZ	3	-
Vivekanandanagar Ward Office,Div 122	WZ	1.86	1
Balajinagar Ward Office	WZ	1	
Moosapet ward Office	WZ	1.74	1
Old Bowenpally ward office	WZ	2.8	5
Zonal Office,Kothapet	EZ		55
Kapra Circle Office,Kapra	EZ	38.63	55
L.B.Nagar Circle Office,Kothapet	EZ		33
Uppal circle Ofice,Uppal	EZ		33
e Seva, Vanasthalipuram, Red tank, Ph.II	EZ	0.760	---
Vanasthalipuram, Ph-II, park with compound wall	EZ	0.080	---
Vanasthalipuram ph-iv community hall	EZ	0.300	2
Vanasthalipuram, ph-III NGO's colony, busstop back side	EZ	0.750	2
Prashanth nagar, mahila mandala	EZ		No load
Prashanth nagar, welfare association	EZ	1.350	2
Kakathiya nagar Community Hall	EZ		
Chaitanyapuri Ward office	EZ	2	NOT PROVIDED
GHMC Head office	CZ		
Khairathabad Circle office	CZ	62	62
Abids Complex	CZ	25	25
		54	54
		25	25
		25	25

Location	Zone	Connected load (kW)	Sanctioned load (kW)
		25	25
		13	13
		13	13
Amberpet sports stadium	CZ	11	11
Amberpet swimming pool	CZ		
D.K.Road Sports stadium/MCH	CZ	34	34
Chaderghat Sports complex/ Victory	CZ	NOT PROVIDED	NOT PROVIDED
Animal Birth Care centre(ABC),Amberpet	CZ	NOT PROVIDED	NOT PROVIDED
Amberpet slaughter House	CZ	NOT PROVIDED	NOT PROVIDED
Putlibowli Complex, Pultibowli Chowrasta	CZ	NOT PROVIDED	NOT PROVIDED
Marredpally GHMC Complex(Zonal office),Backside of HMWS &SB	NZ	100	50
Quthubullapur Circle office	NZ	17	20
Alwal Circle Office	NZ	17.24	20
Sanjaypuri Community Hall, Alwal	NZ	NOT PROVIDED	NOT PROVIDED
Inidra Bhavan	NZ	NOT PROVIDED	3
Malkajgiri Circle Office	NZ	42.5	35
GHMC Guest House	NZ	3	5
Harihara kala Bhavan	NZ	86	120
Buddhabhavan Complex	NZ	18.4	43
Swimming pool	NZ	23	10
NTPC	NZ	6	20
North Zone Slaughter House	NZ	18	260

2.4 Load management

In the identified buildings, there are light, fan, AC and water cooler loads. As solar generation is variable in nature and generation occurs in the day time only. It is advised to use solar generation optimally in the day time.

3. Technology selection

Solar photovoltaic conversion is the direct conversion of sunlight into. Photovoltaic devices are rugged and simple in design requiring very little maintenance and their biggest advantage being their construction as stand-alone systems to give outputs from micro to mega. Hence, they are used for power source, water pumping, remote buildings, solar home systems, communications, satellites and space vehicles and for even megawatt- scale power plants.

A photovoltaic power generation system consists of multiple components like solar cells, mechanical and electrical connections, mountings, and means of regulating and/or modifying the electrical output. These systems are rated in peak kilo (kWp), which is an amount of electrical power that a system is expected to deliver under standard test conditions, when the sun is directly overhead on a clear day.

A grid connected system is connected to a large independent grid which in most cases is the public electricity grid and feeds power into the grid. They vary in size from a few kWp for residential purpose to solar power plants up to tens of GWp. This is a form of decentralized electricity generation.

- Thin films do not have the cost advantage in terms of initial investment costs over the crystalline solar cells – important from both equity and debt perspectives.
- The return on equity is higher for crystalline PV as compared to thin film technology important from both equity and debt perspectives.
- Projects based on crystalline technology will have lower technology risk as compared to thin film technology.
- Evaluated over the entire project lifetime of 25 years, i.e. in longer term, crystalline technology scores significantly higher than thin film technology. Moreover, projects based on crystalline technologies can probably continue generating beyond 25 years, making them more attractive.
- Apart from other factors, crystalline technologies require less land per MW compared to thin film technologies.
- Power output from any kind of solar cell decreases with increase in temperature. It is reported that temperature coefficient of thin film modules is lower (-0.3%/°C) as compared to crystalline (-0.4%/°C). Hence, it is claimed that they are more suitable for hot climate and hence will give more generation for the equivalent capacities of power projects. However, in Indian states like Delhi, Gujarat, and Rajasthan also have winter which is favourable for creating less NOCT. Therefore, low output in summer will be compensated by higher output in winter, for crystalline PV technology.

Based on the above considerations, it is concluded that crystalline PV technologies perform significantly better than thin film technologies in our assessment.

4. Basic engineering of solar power generation system

4.1 Layout of solar PV power plant

The plant design was carried out and a detail estimation of nominal capacity of Solar PV plant, sizing of different components such as Solar PV panel, inverter etc. with their required technical specifications were done. The schematic of solar PV power plant is shown in Figure 1.

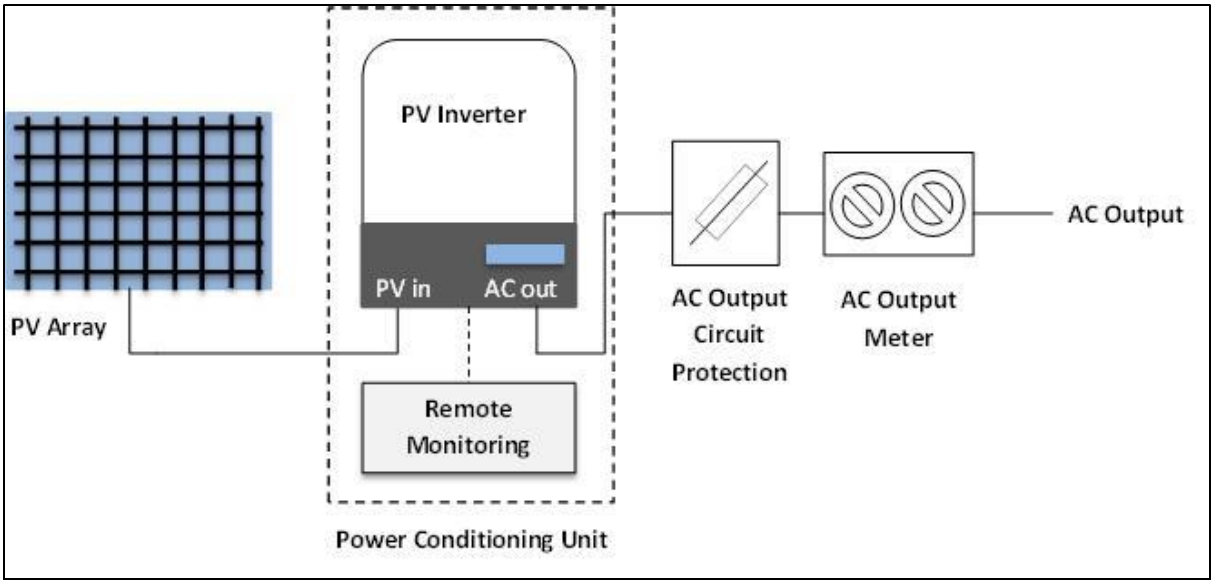


Figure 1 Schematic diagram of a solar PV power plant

4.2 Technical description and specifications

Table 4: Technical description and specifications

Items	Description & Specifications	Unit
Solar Photovoltaic (SPV) module and array	Supply of poly c-Si modules, (PV module of capacity 250 Wp to 300Wp is preferred) of total capacity: 60 kWp net electrical output at STC; Stabilized net output of the solar PV array for the power plant should not be less than nominal array capacity of 60 kWp under STC after one year of operation from the day of commissioning. The modules should conform to IEC 61215* Ed- 2 or latest. In addition, the modules shall also qualify to IEC 61730 Part I & II, for safety qualification testing, IEC 61215, IEC 61730, IEC 62804, IEC 61853, IEC 62548, and IEC 61701 / IS 61701. The Photoelectric conversion efficiency of SPV module shall be greater than 15.5% with rated output power not more than 3% from the average. The modules must be warranted for output wattage, which should not be less than 90% at the end of 10 years and 80% at the end of 25 years. Each module shall be provided with protective devices against surges at the SPV module. Low voltage drop bypass and/or blocking diode(s) should also be provided. The module Junction box should be weather resistant and designed for long life outdoor operation in harsh environment. Each PV module must use a RF identification tag (RFID).	kWp
PV Module mounting structure	Supply of array structure made of suitably sized hot dip galvanized MS frames, support members etc. as per requirement for fixing of different capacities of PV array on RCC foundation base. The tilt angle should be in line with site requirements for PV system capacity and energy yield optimization or at the latitude of the site (27 degree). The minimum thickness of galvanization shall be at least 100 microns. All nuts & bolts shall be made of very good quality stainless steel with anti-theft provisions. SS 304 fasteners shall be used. The structure shall be designed to allow easy replacement of any module and shall be in line with site requirements. The array structure shall be so designed that it will occupy minimum space without sacrificing the output from SPV panels. At the same time it should withstand wind speed up to maximum 150 km/h. The minimum clearance between roof and lower side of PV panel should be about 300 mm. Weight of PV panel with mounting structure will be about 20 kg/m^2.	nos.
String Combiner Box	Supply of ABS /Thermoplastic/Equivalent type string combiner box with adequate size current collection terminal having 1000 V grade insulation. It should be dust, water & vermin proof with IP 65 (for outdoor)/IP 21(for indoor) protection. The copper bus bars/terminal blocks housed in the junction box should have suitable termination threads. It should also have earth terminal for earthing. A reverse blocking diode and by pass diode should be provided in the Array Junction Box of maximum DC blocking voltage of 600V with suitable arrangement for its connecting. The Junction boxes should be equipped with input and output fuses to protect the PV module from short circuits. Array junction box and main junction box should have appropriate surge protection devices to protect	nos.

Items	Description & Specifications	Unit
	the circuits from surges created due to lightning. The AJB's should be equipped with DC current monitor as specified in the monitoring system. Metal oxide Variastors shall be provided inside the Array Junction Boxes.	
Power Conditioning Unit (PCU)	Supply of PCU, comprising of inverter, charge controller, visual display and necessary protections. The inverter shall be bi-directional, have integrated PV charger controller and rated for continuous operation at full load. It shall have solar priority grid charging and automatic re-start after over load triggered shutdown. The PCU shall have provision for PCU by-pass arrangement so as to cater load directly through grid, in case of PCU failure. There shall also be emergency stop switch on the front panel of PCU. The PCU shall also have web enable data Logger with all required hardware, software for performance monitoring including supply of SIM, IP address and GSM Modem. The data logger shall have features for simultaneous monitoring and recording of various parameters of different sub-systems and power supply of the Power Plant. PCU should have efficient energy optimization and load prioritization capabilities. The detail specifications of charge controller and inverter are provided below: <u>Charge Controller</u> MPPT, DC-DC PV Charge Controlling Unit suitable to charge the battery bank from the SPV system. The Charge Controller Unit should have bulk, boost and float charging sequence including temperature compensation. It should have short circuit, deep discharge, input surge voltage and over current protections. It should have measuring instruments for measuring solar charging and battery charging and discharging current and solar charging voltage. The finish of the charge controller should have epoxy powder coating. <u>Inverter</u> The nominal inverter capacities should be specific to site (20kW, 17kW, and 23kW), mentioned in the plant specification part, given in the section below. Its usual operating voltage range should be between 600 - 800 V DC. The inverter output voltage: 415V+/- 2% , 3 Phase, sine wave with output frequency: 50 Hz +/- 0.5%, maximum efficiency ≥ 96% and weighted efficiency ≥ 95%. The no load power consumption: < 2.5% of total O/p rating. The total harmonic distortion: < 3%, maximum current ripple: 4% peak to peak, dielectric strength: 1.1 kV between input / output and ground with EMI, operating ambient temperature: 0 to 50 ^{O}C. It should have short circuit, overload, surge current, over temperature, over/under voltage, over/under frequency, lightning, phase imbalance and reverse polarity protections. The cooling should be via temperature controlled fan forced. It should have free standing, steel enclosure, IP 20, Epoxy powder coated, IP 54 and IP 65 protection. Also both AC and DC lines should have suitable MCB/MCCB and user to allow safe start up and shut down of the system. The inverter shall have provision for input & output isolation (automatic & manual). The Power Conditioners/ Inverters should conform to IEC 61683 for efficiency measurements and IEC 60068 2 (6, 21,	nos.

Items	Description & Specifications	Unit
	27, 30, 75, 78) for environmental testing. Power output from inverters should confirm to CEA (Technical Standards for connectivity of the Distributed Generation Resources) Regulations, 2013.	
AC Distribution Board	Supply of AC distribution box with epoxy powder coated, IP 54 or IP 65 protection. The no. of outputs: Four feeders with MCBs with a load limiter: One for each feeder. It should have measuring instruments: 3phase electronic energy meter of suitable ratings (for measuring SPV peak power), Ampere meter and Volt meter shall be provided for each feeder. The MCB & fuses should have suitable rating for feeders and MCB/MCCB should have suitable rating for connection & disconnection The audio buzzer and LED indication should be provided in case of overload on any feeder.	nos.
Cables & Accessories	Sizes of cables between array interconnections, array to junction boxes, junction boxes to inverter etc. shall be so selected to keep the voltage drop (power loss) of the entire power plant to the minimum. Bright annealed 99.97% pure copper conductors, that offer low conductor resistance, insulated with a special grade PVC compound formulated for outdoor use may be used in the power plant. The cables and accessories shall conform to the relevant national/ international Electrical Safety Standards. Cables should be properly insulated and sheathed. It should have working voltage: Up to 1100 V; test voltage 1000V/1.1kV and should be temperature resistant: -15 ^{0}C to +70 ^{0}C; UV resistant for outdoor installation. Cable conduits should be used.	sets
Earthing systems	The array structure of the PV yard will be grounded properly using adequate number of earthing kits. All metal casing / shielding of the plant shall be thoroughly grounded to ensure safety of the power plant. PV modules should be connected to each other for grounding. Chemical Earth kits (maintenance free) should be provided. It should have copper bounded electrode with Dia > 14 mm and Length - 3000 mm (along with earth enhancement chemical compound). Relevant international standards should be followed while designing the protective earthing system.	sets
Lightning and Switching Surge Arrester	Supply of appropriate lightning cum switching surge arrester at the input side of PCU, output side of inverter and on each building rooftop to protect the PV panels and other associated equipment. The lightning protection system should conform to IEC 62305 standards. The radial distance coverage and height accordingly of the lightening arrester should be accurately estimated and the lightening arrester should be chosen.	nos.
Installation Accessories	As per site requirement	set

**IEC61215: This is an internationally acceptable standard for the design testing of Crystalline-Si PV modules.*

All other design code standards mentioned in this document are internationally acceptable. For quality assurance the supplier/manufacturer has to follow standard codes. A table of internationally acceptable quality standards are listed in Annexure IV.

The description of construction, erection and commissioning activities should be as per below:

Table 5: Technical description and specifications of Civil Work

Item	Description
RCC foundation base for PV array mounting	The array structure and RCC foundation should be designed in such a way that it will occupy minimum space without sacrificing the output from SPV panels. At the same time it should withstand wind speed up to maximum 150 km/h. The minimum clearance between roof and lower side of PV panel should be about 300 mm. The RCC foundation without grouting the roof for fixing the mounting structure of the PV panel is suggested. The weight of PV panel with mounting structure will be about 50 kg/m2 weight of RCC pedestal will be extra.
Erection Work	The Erection work with respect to the following but not limited to: solar PV array, solar inverter, ACDB, DCDB, power & control cables, good quality hard PVC conduits may be used inside control room building, hume pipes, ferrules, lugs, glands, terminal blocks, junction boxes, cable fixing clamps, nuts and bolts etc. as required. Supply of necessary steel materials for field fabrication of cable trays, supports, brackets, grounding system etc. Local monitoring may be done directly through inverter. Name board to be fixed at the entry point of solar plant of approved design.
Pre-commissioning & Commissioning of all supplied Equipment's	Test running of Grid Connect Solar Power Plant as well as load trials at site should be done, prior to handover and implementation of maintenance contract.

4.3 Estimation of water and auxiliary power requirements

The thumb rule for estimating water requirement is 2 litre of water for cleaning one panel (300Wp PV module); hence water requirement for 1kWp plant will be around 7.5 litres. Actual water requirement can be calculated specific to site. The auxiliary power consumption will be about 2 per cent of total generation. Auxiliary power will be utilised for lighting in PV array field at night time, and fan and light in control room.

4.4 Project implementation schedule

A tentative project implementation schedule is given in Table 6. The total duration for project implementation is 15 weeks.

Table 6 Project implementation schedule

	Week														
Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Supply of materials															
Civil work (Foundation)															
Installation of mounting structure															

	Week														
Activity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
and PV panel															
Electrical installation															
Testing and commissioning															

4.5 Proposed solar PV power system

The solar PV power plant can be connected to the distribution panel as an additional source of generation. Central electricity Authority of India has given configurations of grid interconnection arrangement which is explained below.

Grid interactive solar PV system without storage backup

This is a simplest configuration of the grid interactive solar PV system. In this arrangement inverter which is heart of the entire solar system continuously supervises the grid condition and in the event of grid failure or under voltage or over voltage, the solar system is disconnected by the circuit breaker /auto switch provided in the inverter. Since there is no power back up in the system, it cannot supply the consumer load in the event of grid failure. Block diagram of the derived scheme is shown in Figure 2.

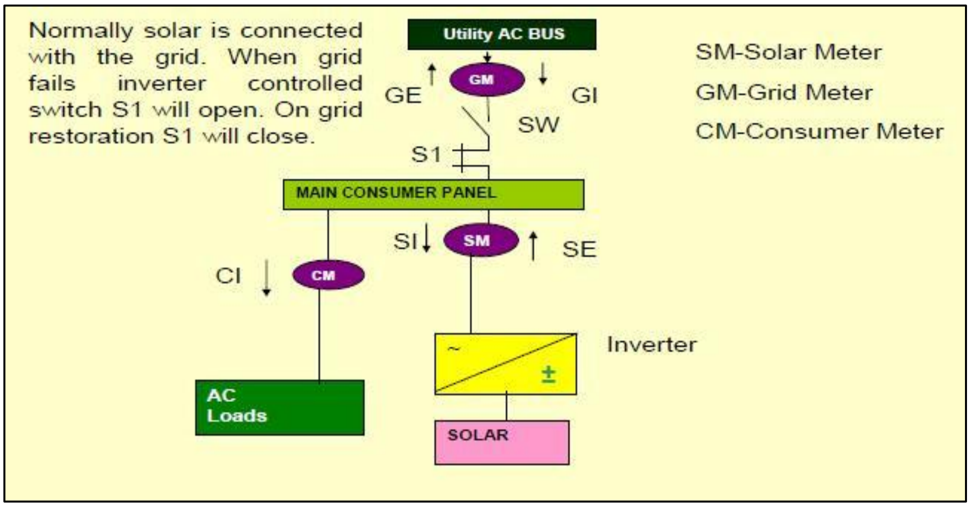


Figure 2: Grid interactive solar PV system without storage backup

CI-Consumer energy import
GI-Import of energy from grid
GE-Export of energy to the grid
SE-Export of energy from solar system
SI-Import of energy by solar system
SW-Manual lockable switch for distribution feeder maintenance by the distribution company

Energy Consumption and Generation at each site

Clause 10.3 of the Telangana state Net-Metering regulation states that the unadjusted net credited Units of electricity shall be settled by the Licensee twice in a year viz., in June and December. The net export units credited for the six month period shall be settled at its average cost of power purchase as approved by the Commission for that year. This APPC may be much lesser than the cost of generation that is achieved by the rooftop Solar PV plants. The table shows the percentage of annual generation to the total consumption. The size of the system in this table satisfies the limit placed on the size of the system as a percentage of the sanctioned load.

Furthermore, this study could not be conducted for all the sites due to some of the reasons mentioned below

- Newly commissioned sites did not have the electricity consumption details .
- Some sites faced disconnection from the DISCOM connection.
- Some sites were not feasible for rooftop solar PV installation altogether.

Note: We assumed that the sanctioned load was high enough to accommodate the maximum size of the rooftop Solar PV system for sites at which the sanctioned load was not provided.

Table 23: Energy Consumption and Generation at each site

Location	System Size obtained from Helioscope (kWp)	Sanctioned load(kW)	Capacity allowed (kW)	Consumption (kWh)	capacity generation (kWh)	Percentage of generation to the total consumption (%)
GHMC Head office	28	Not Provided	28	1048944	48945.9	5%
Khairathabad Circle office	26	62	26	138001	44196.3	32%
Abids Complex	13	180	13	250819	17529.9	7%
Amberpet sports stadium	12	11	11	40603	13925.8	34%
Amberpet swimming pool	7	45	7	78854	10067.3	13%
D.K.Road Sports stadium/MCH	8	34	8	52562	12842.1	24%
Chaderghat Sports complex/ Victory	24	Not Provided	24	15649	39162	250%
Animal Birth Care centre(ABC),Amberpet	10	6	6	19519	9602.04	49%
PJR stadium, Chandanagar	8	55	8	6701	13045.9	195%
Circle 12 office Chanda nagar	10	17	10	27387	11407.7	42%
Kalyan mandapam	14	50	14	6701	16296.1	243%
Kukatpally Circle office	47	45	45	64652	78720.9	122%
Lingampally new municpal office building	20	NA	20	108842	31753.8	29%
KPHB ward office	6	1	1	5361	1577.37	29%

Balajinagar Ward Office	6	1	1	3241	1560.45	48%
Moosapet ward Office	4	1	1	3642	1534.55	42%
Old Bowenpally ward office	6	5	5	4408	7972	181%
Zonal Office,Kothapet	9	55	9	60086	15423.6	26%
Kapra Circle Office,Kapra	11	55	11	56828	18297.1	32%
L.B.Nagar Circle Office,Kothapet	29	33	29	84059	49284.6	59%
Uppal circle Ofice,Uppal	26	33	26	52008	43222	83%
Vanasthalipuram, ph-III NGO's colony, busstop back side	16	2	2	777	3447.1	444%
Prashanth nagar, welfare association	6	2	2	1576	3543.1	225%
Marredpally GHMC Complex(Zonal office),Backside of HMWS &SB	33	252	33	186400	54043.1	29%
Quthubullapur Circle office	7	20	7	50509	3998.7	8%
Alwal Circle Office	22	20	20	39618	34136.8	86%
Malkajgiri Circle Office	46	35	35	54213	52752.2	97%
Harihara kala Bhavan	69	120	69	133516	113263	85%
Buddhabhavan Complex	45	43	43	69689	72815.4	104%
MCH Swimming Pool,Sardar Patel Rd	17	10	10	53633	5822.53	11%
NTPC, Rashtrapati Road, Gandhi Nagar	11	20	11	8107	18555.6	229%
Rajendranagar Circle office	37	Not Provided	37	70105	64181.9	92%
Doodbowli sports Complex	5	53	5	73031	8991.1	12%
Ramnathspura slaughter House	50	120	50	57751	87509.2	152%

Specifications of the power plants

The specifications of the maximum capacity power plants at all identified buildings identified after doing helioscope analysis are given in following table 7

Table 7: Site wise specifications of the maximum capacity

Project Name	Zones	Module DC Nameplate (kW)	Inverter AC Nameplate (kW)	Annual Production (MWh)	Performance Ratio (%)	kWh/kWp
GHMC_Abids Complex	CZ	12.6	13.2 Load Ratio: 0.95	17.53	63.4	1,391.30
Amberpet slaughter House	CZ	40.5	36.4 Load Ratio: 1.11	71.49	79.4	1,765.20
Amberpet sports stadium	CZ	12	11 Load Ratio: 1.09	15.7	58.8	1,308.30
Amberpet swimming pool	CZ	6.9	5.79 Load Ratio: 1.19	10.07	71.9	1,459.30
Chaderghat Sports complex Victory	CZ	24	23.8 Load Ratio: 1.01	38.39	71.9	1,599.50
D.K.Road Sports stadiumMCH	CZ	7.8	8.8 Load Ratio: 0.89	12.84	77.9	1,646.40
GHMC Head office	CZ	27.6	24 Load Ratio: 1.15	48.94	79.7	1,773.30
Khairathabad Circle office	CZ	26.4	24 Load Ratio: 1.1	44.61	76	1,689.90
Putlibowli Complex	CZ	41.1	40 Load Ratio: 1.03	68.38	74.8	1,663.70
Animal Birth Care centre(ABC),Amberpet	CZ	10.2	13.3 Load Ratio: 0.76	16	70.6	1,569.00
Chaitanyapuri Ward office	EZ	1.8	2.5 Load Ratio: 0.72	2.734	68.3	1,519.00
e Seva, Vanasthalipuram, Red tank, Ph.II	EZ	4.8	4.65 Load Ratio: 1.03	6.448	69.6	1,343.30
Kapra Circle office	EZ	11.4	12 Load Ratio: 0.95	18.18	73.2	1,594.40
L.B.Nagar Circle office, Kothapet	EZ	29.4	28 Load Ratio: 1.05	47.64	76.2	1,620.40
Prashanth nagar, mahila mandali	EZ	5.4	4.65 Load Ratio: 1.16	8.2	77.1	1,518.40
Prashanth nagar, welfare association	EZ	6.3	5.5 Load Ratio: 1.15	10.63	75.9	1,687.20
Uppal circle Ofice,Uppal	EZ	25.5	24 Load Ratio: 1.06	43.22	76.2	1,695.00
Vanasthalipuram ph-iv community hall	EZ	2.1	1.93 Load Ratio: 1.09	3.423	73.9	1,629.80
Vanasthalipuram, ph-	EZ	15.6	15 Load	27.58	79.6	1,767.70

Project Name	Zones	Module DC Nameplate (kW)	Inverter AC Nameplate (kW)	Annual Production (MWh)	Performance Ratio (%)	kWh/kWp
III NGO's colony, busstop back side			Ratio: 1.04			
Zonal Office, Kothapet	EZ	9.3	10 Load Ratio: 0.93	15.42	78.5	1,658.40
Balajinagar Ward Office	WZ	5.7	5.4 Load Ratio: 1.06	9.363	74.3	1,642.60
KPHB ward office	WZ	5.7	5.08 Load Ratio: 1.12	9.464	74.8	1,660.40
Kukatpally Circle office	WZ	47.1	44 Load Ratio: 1.07	82.22	78.6	1,745.60
Lingampally new municpal office building	WZ	19.8	22 Load Ratio: 0.9	31.75	72.2	1,603.70
Moosapet ward Office	WZ	3.6	3.49 Load Ratio: 1.03	6.138	77.1	1,705.00
Old Bowenpally ward office	WZ	6	6.6 Load Ratio: 0.91	9.567	74.9	1,594.40
PJR stadium, Chandanagar	WZ	7.8	6.64 Load Ratio: 1.17	13.05	76.3	1,672.60
Marredpally GHMC Complex(Zonal office),Backside of HMWS &SB	NZ	33	31.5 Load Ratio 1.05	54.41	78	1,648.80
Quthubullapur Circle office	NZ	6.6	6.60 Load Ratio 1.00	7.699	52.5	1,166.60
Alwal Circle Office	NZ	22.2	20 Load Ratio 1.11	37.55	76.6	1,691.50
Sanjaypuri Community Hall, Alwal	NZ					
Inidra Bhavan	NZ					
Malkajgiri Circle Office	NZ	123.3	100 Load Ratio 1.23	220.8	80.3	1,790.60
GHMC Guest House	NZ					
Harihara kala Bhavan	NZ	68.7	66.6 Load Ratio 1.03	113.3	78	1,648.70
Buddhabhavan Complex	NZ	45.3	40 Load Ratio 1.13	76.2	79.6	1,682.20
Swimming pool	NZ					
NTPC	NZ	11.4	11 Load Ratio 1.04	18.56	77	1,627.70
Slaughter House	NZ	96.9	94.5 Load Ratio 1.03	169.8	78.8	1,752.80
Sardarmahal, Zonal office	SZ					

Project Name	Zones	Module DC Nameplate (kW)	Inverter AC Nameplate (kW)	Annual Production (MWh)	Performance Ratio (%)	kWh/kWp
Rajendranagar Circle office	SZ	37.2	37.8 Load ratio 0.98	64.18	77.7	1,725.30
Mogulpura sports complex	SZ	50.4	50 Load ratio 1.01	81.43	74.2	1,615.80
Doodbowli sports Complex	SZ	5.4	6.3 Load Ratio 0.86	8.991	74.9	1,665.00
Ramnathspura slaughter House	SZ	49.5	50 Load ratio 0.99	87.51	79.5	1,767.90
Goulipura slaughter House	SZ					
Mitra sports complex	SZ	10.2	10.8 Load Ratio 0.94	17.45	77	1,711.00

5. Techno-commercial study

5.1 Business models

Various business models prevailing in the market based on the ownership of the rooftop solar PV system are described as follows:

1. Self-owned solar PV system
2. Third party owned solar PV system
3. Roof renting for Solar Rooftop System

- In self-owned system, the roof owner owns, operates, and maintains the roof top SPV system. The generated electricity is either consumed by the end-use loads or supplied to the utility grid or combination of both.
- In third party owned system, the third party (solar developer/system integrator or any other company) owns the roof top solar PV system and sale electricity either to the roof owner or consumer or both. Third party owned model does not allow roof owner to avail certain financial benefits, such as tax benefits, capital subsidy, etc.
- In roof renting model, the roof owner neither owns the solar plant nor consumes the electricity generated from the solar PV rooftop system. The owner rents out the roof to third party developer who installs the solar PV system on the roof and sells the electricity to DISCOM or through Open Access. Third party developers pay the rent to the roof owner for utilizing the vacant roof space in terms of certain paisa per unit of electricity generated.

  This type of model is mostly applicable in agricultural warehouses where the owner doesn't have high consumption of electricity but he wants to utilize the vacant roof space for generation of electricity from solar plant and gain some income from roof rent.

The following table gives a brief idea on the various business models available

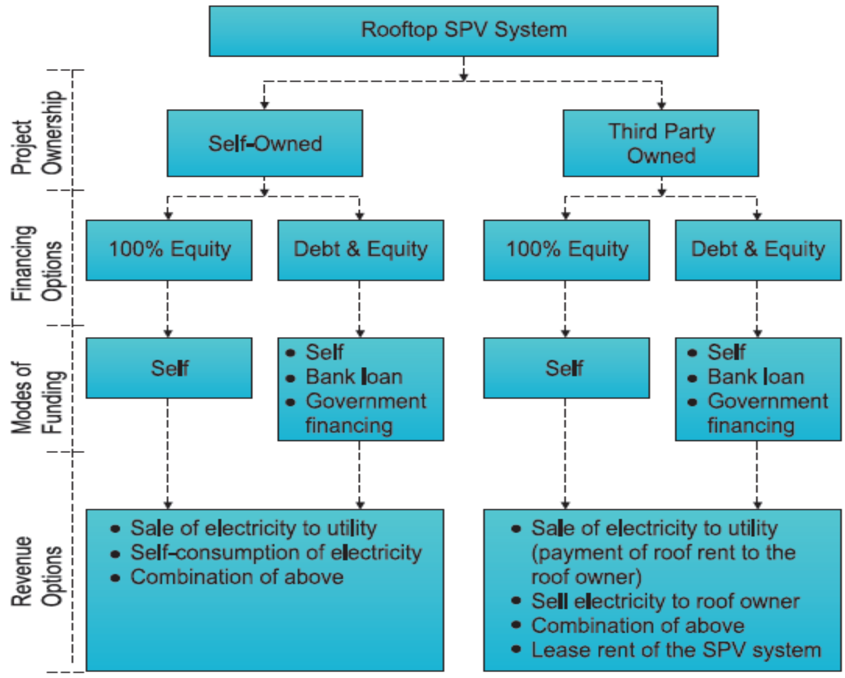


Figure 3: Different modes of financing based on system ownership

The two primary business models that could be implemented are explained below

1. (Self-Consumption and Supply to Utility Grid) and Self-Owned Model

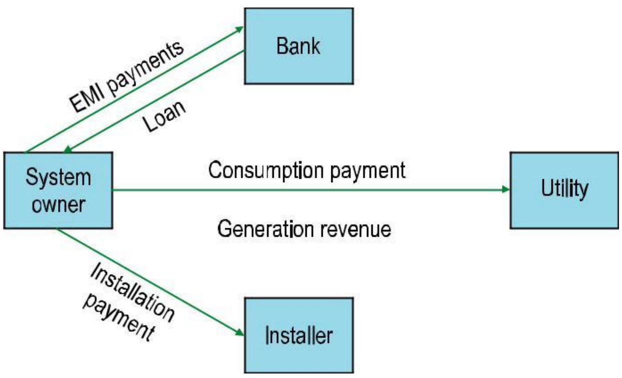


Figure 4: Revenue flow in net metering and self-owned model

In this model, as shown in Figure 4 the rooftop SPV system is owned by the roof owner. The generated electricity is supplied to roof owner's end-use loads and the surplus power is fed into the grid. The utility can purchase the surplus power or provide banking facility for a particular period of time.

2. (Self-Consumption and Supply to Utility Grid) and Third Party Owned Model

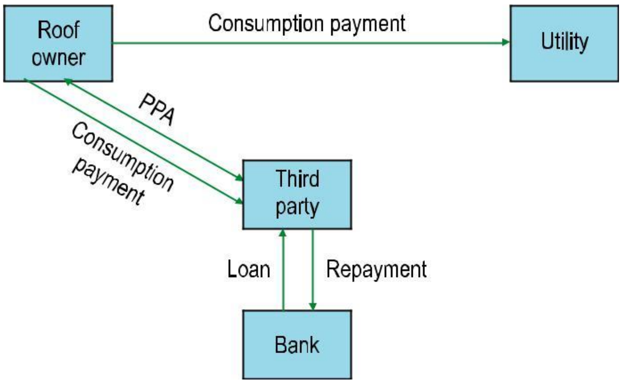


Figure 5: Revenue flow in net metering and third party owned model

In this model, the third party owns the system. The generated electricity is supplied to the roof owner's end-use loads and the surplus power is fed into the grid. The utility can Purchase the surplus power or provide banking facility for a particular period of time.

3. Roof renting model

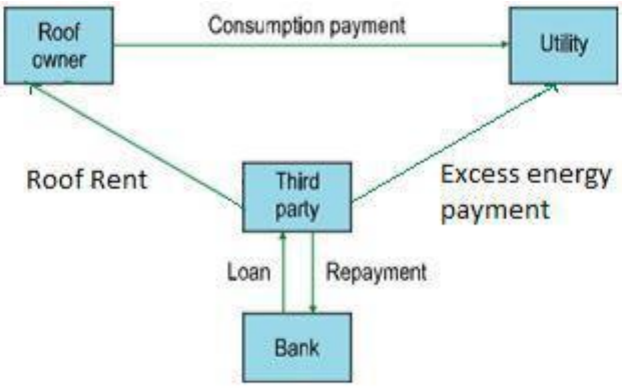


Figure 6: Revenue flow in net metering and third party owned model

The owner rents out the roof to third party developer who installs the solar PV system on the roof and sells the electricity to DISCOM or through Open Access. Third party developers pay the rent to the roof owner for utilizing the vacant roof space in terms of certain paisa per unit of electricity generated.

5.2 Advantages and Disadvantages of each business model

Advantages of CAPEX Model

- Consumer is the owner of the solar plant. Profits making industrial and commercial consumers are eligible to avail accelerated depreciation.

The consumer gets payback in 7-11 years.

Disadvantages of CAPEX Model

- Upfront cost of the system has to be borne by the consumer.

Advantages of RESCO Model

- No upfront investment is required for the installation of the solar plant.
- Electricity generated from the SPV system will be sold to the consumer at a rate lower than that supplied the DISCOMS.

Disadvantages of RESCO Model

- Savings much lower as compared to CAPEX model

5.3 Financial analysis

5.3.1 On RESCO Model

With a view to ascertain the commercial viability of a 941 kW_p grid-connected rooftop solar PV project distributed over a number of premises in Hyderabad, a detailed financial analysis was carried out which comprised determination of the following major financial indicators:

- Pre-tax project IRR
- Post-tax project IRR
- Equity IRR
- Levelized Cost of Electricity, i.e. LCOE
- Net Present Value of financial benefit to GHMC
- Debt Service Coverage Ratio, i.e. DSCR

For the feasibility assessment, certain assumptions were taken in carrying out the financial analysis. These are listed below:

- Given a total lot size of 941 kW_p (as determined through Helioscope analysis) and the fact that this capacity is distributed across 53 premises of government buildings across Hyderabad, it is understood that a RESCO business model with one project developer for the entire capacity is the most suitable way forward. In that context, the financial analysis has been carried out with the assumption that the cumulative lot size of 941 kW_p will be awarded to a single RESCO project developer.
- Standard assumptions for the various input parameters in the financial analysis are based on general market values and the Consultant's own experience. These are listed in Table 8.
- It is assumed that the project will be eligible for the Government Incentive of 25% subsidy on capital cost of system.

NOTE: The current REC mechanism envisages that project should not avail other benefits provided to renewable energy plants. The REC prices (floor and forbearance) are declining since 2011. Being very high compared to cost of generation at current capital cost of SPV systems, the REC plants are unable to sale RECs. Hence, we have not considered impact of REC in financial calculation for rooftop SPV systems.

Table 8: Assumptions for financial analysis

PARAMETER	UNIT	VALUE	REMARKS
		Project Specifications	
Cumulative project size (design capacity)	kW	941	*As per Helioscope system design*
per-W capital cost	Rs./W	52	*Based on Consultant's experience*
Project Capital Cost	Rs.	48,932,000	
Government incentive	%	25%	*As per MNRE guidelines*
Realized Project Capital Cost	Rs.	36,699,000	
Useful life	years	25	*General market assumption*
Degradation	%	0.60%	*General market assumption ; generation values sourced from Helioscope analysis*
Grid availability	%	100%	*General market assumption*
Inverter cost	Rs./W	6	*Based on Consultant's experience*
Inverter life	years	10	*Based on Consultant's experience*
Escalation in inverter prices due to inflation	%	3.00%	*Based on Consultant's experience*
		Debt	
Debt component	%	70%	*General market assumption*
Debt amount	Rs.	25,689,300	
Cost of debt	%	12.00%	*Based on Consultant's experience*
Debt tenor	years	14	*General market assumption*
Moratorium period	years	0	*General market assumption*
		Equity	
Equity component	%	30%	*General market assumption*
Equity amount	Rs.	11,009,700	
Cost of equity	%	20%	*General market assumption*
		Operating parameters	
O&M Expenses	%	1.30%	*Based on Consultant's experience*
O&M Expenses Escalation rate (p.a.)	%	3.00%	*Based on Consultant's experience*
		Working Capital	
O&M Charges	months	1	*As per CERC norms*
Maintenance Spare	%	15%	*As per CERC norms*
Receivables from Debtors	months	1	*General market assumption*
Interest on Working Capital	%	12.00%	*General market assumption*
		Depreciation	
Book SLM Depreciation	%	5.28%	*As per Companies Act 2013*
Useful Life	years	19	*As per Companies Act 2013*
WDV Depreciation (per Income Tax Act)	%	15.00%	*As per Income Tax Act 1961*
Max. Depreciation extent (as % of asset value)	%	90%	*As per Income Tax Act 1961*
Salvage Value	%	10%	*As per Income Tax Act 1961*
(for LCOE) SLM Depreciation for years 1-12	%	5.83%	*As per CERC norms*
(for LCOE) SLM Depreciation for year 12 onwards	%	1.54%	*As per CERC norms*
		Other Financial Assumptions	

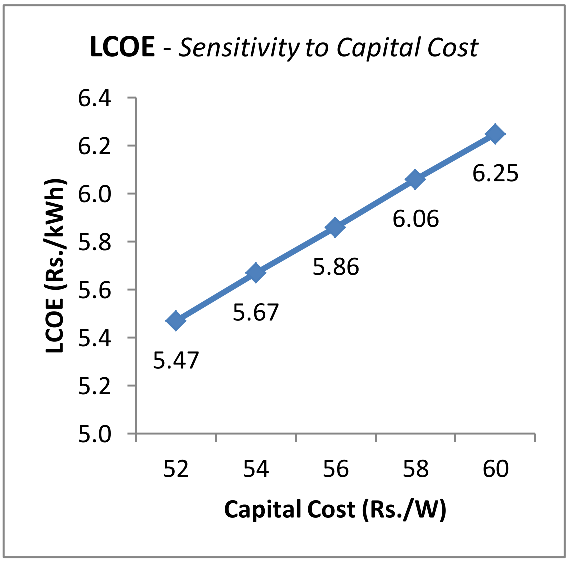
PARAMETER	UNIT	VALUE	REMARKS
Income Tax rate	%	34.61%	*General market assumption*
MAT rate	%	18.50%	*General market assumption*
Discount Rate	%	11.49%	*As per WACC formula*
Inflation rate	%	5.00%	*General market assumption*
	Revenue model for RESCO		
Project tariff	Rs./ kWh	5.50	
	GHMC electricity costs		
Avg. grid electricity cost for GHMC	Rs./ kWh	9.70	*Based on GHMC electricity consumption and bill details*
Escalation in grid electricity tariff	%	2.00%	*General market assumption*

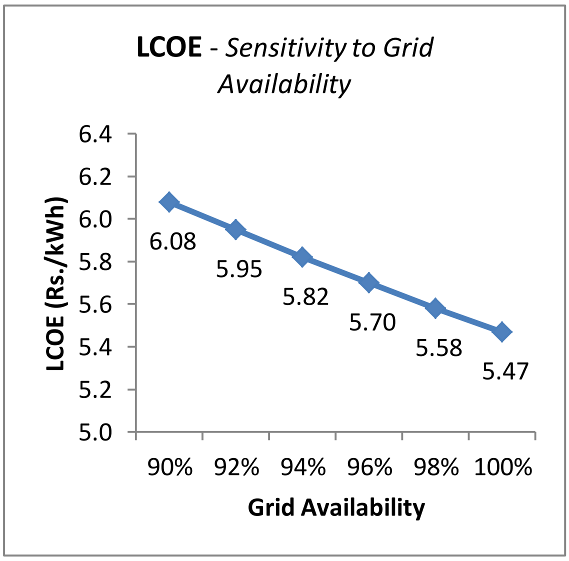
5.4 Results and Discussion

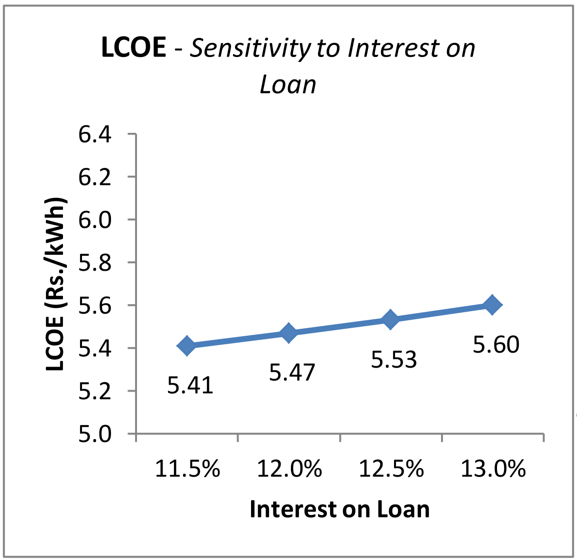
The financial analysis revealed that the project would be financially viable and satisfy the major criterions of return on equity, profitability and cash flow at a levelized tariff of ~ Rs. 5.50 /kWh.

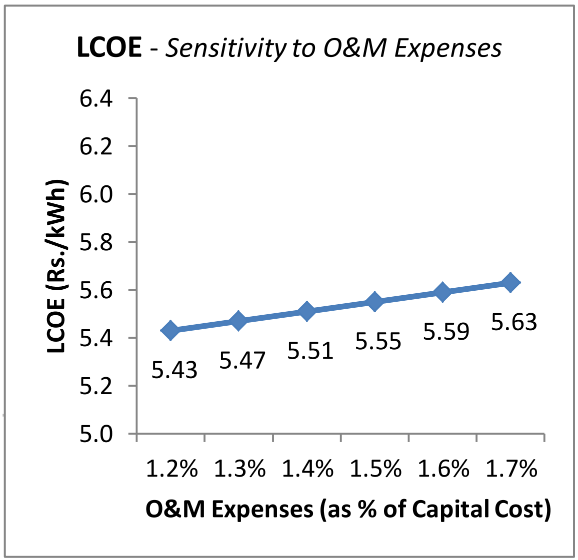
However, it is important to note that this levelized tariff is based on a number of assumptions, and is therefore sensitive to changes in the values of some of the input parameters.

The following graphs depict the sensitivity of the levelized tariff to the major input parameters:









The results of financial analysis are given in Table 9.

Table 9: Results of financial analysis

Parameter	Unit	Result
System capacity	kW_p	941
Capital Cost	Rs. (lakhs)	489.32
LCOE	Rs./kWh	5.47
Pre-tax Project IRR	%	16.0%
Post-tax Project IRR	%	14.9%
Equity IRR	%	16.2%
DSCR (min.)	%	1.30
1st year cost savings to GHMC	Rs. (crore)	1.24
Cumulative cost savings to GHMC (Present Value)	Rs. (crore)	12.37

5.3.2 On CAPEX Model

With a view to ascertain the commercial viability of a 941 kWp grid-connected rooftop solar PV project distributed over a number of premises in Hyderabad, a detailed financial analysis was carried out which comprised of the determination of the following major financial indicators

- Payback Period
- Project IRR

For the feasibility assessment, certain assumptions were taken in carrying out the financial analysis. These assumptions are as per table 10

Table 10: Assumptions for financial analysis

PARAMETER	UNIT	VALUE	REMARKS
		Project Specifications	
Cumulative project size (design capacity)	kW	941	*As per Helioscope system design*
per-W capital cost	Rs./W	65	*Based on Consultant's experience*
Project Capital Cost	Rs.	611,65,000	
Government incentive	%	25%	*As per MNRE guidelines*
Realized Project Capital Cost	Rs.	458,73,750	
Useful life	years	25	*General market assumption*
Degradation	%	0.60%	*General market assumption ; generation values sourced from Helioscope analysis*
Grid availability	%	100%	*General market assumption*
Inverter cost	Rs./W	6	*Based on Consultant's experience*
Inverter life	years	10	*Based on Consultant's experience*
		Equity	
Equity component	%	100%	*General market assumption*
Equity amount	Rs.	458,73,750	
Cost of equity	%	8%	*General market assumption*
		Operating parameters	
O&M Expenses	%	1.30%	*Based on Consultant's experience*
O&M Expenses Escalation rate (p.a.)	%	3.00%	*Based on Consultant's experience*

PARAMETER	UNIT	VALUE	REMARKS
		Working Capital	
O&M Charges	months	1	*As per CERC norms*
Maintenance Spare	%	15%	*As per CERC norms*
		GHMC electricity costs	
Avg. grid electricity cost for GHMC	Rs./ kWh	9.70	*Based on GHMC electricity consumption and bill details*
Escalation in grid electricity tariff	%	2.00%	*General market assumption*

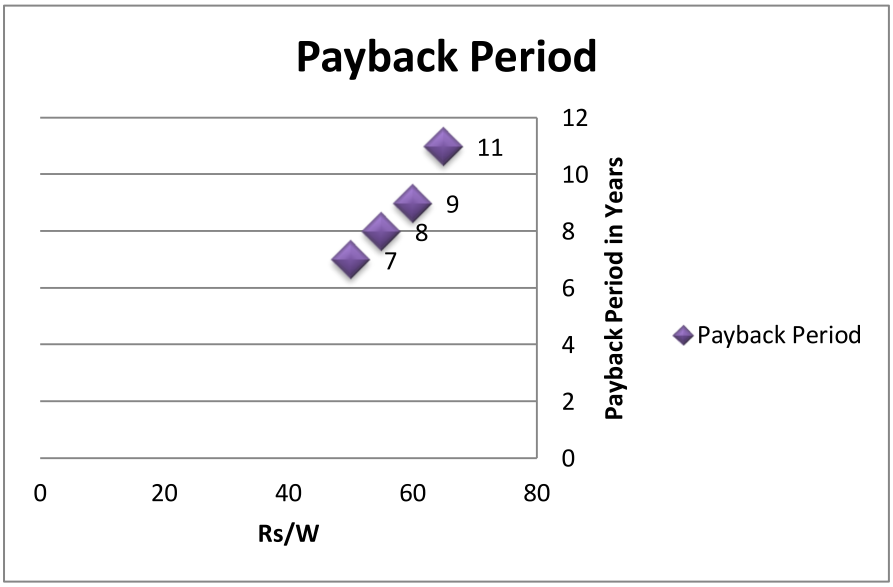
5.5 Results and Discussion

The financial analysis revealed that the project would be financially viable and provide a payback in 11 Years at an IRR of 15.94%.However, it is important to note that this Payback period is based on a number of assumptions as mentioned in the previous table.

The following graph depicts the sensitivity of the Payback Period to cost per watt of solar PV modules.

If we do not consider the interest on the loan amount (we consider 0% interest on debt), we would obtain a payback period of 7 years with an IRR of 20%. While a simple payback period for this project would be 6 years. The results are as per table 12

Table 11: Sensitivity of the Payback Period to cost per watt of solar PV modules



The results of the financial analysis is as per the following table

Table 12: Results of financial analysis

Parameter	Unit	Result		
		As per Assumption sheet	Without considering the cost of capital	Simple payback
System capacity	kW_p	941	941	941
Capital Cost	Rs. (lakhs)	458.73	458.73	458.73
Project IRR	%	15.94%	20.08%	20.08%
Payback Period	Years	11	7	6

6. Reduction of CO_2 emissions

According to the CEA report on CO2 Baseline Database for the Indian Power Sector, the emission factor that was considered was 0.82 tCO2 /MWh. Considering the total size of the system installed to be 869 kWp and generating roughly around 1.009 MU. The reduction in CO_2 emissions would be as per the following table

Total Allowed system size in kWp	Annual Energy generation in kWh	Avoided CO_2 emissions in (kg/kWh
869	1009427.052	827730.1829

7. Power plant operation planning

7.1 Man-power planning

The following personnel will be sufficient for the overall operation and maintenance of the Solar PV plant of 60 kWp capacity;

- One person as a plant manager
- One trained technician having experience in operation and maintenance of solar PV power plant
- One person for cleaning of PV panels

7.2 Operation and maintenance

In the solar PV power plant, there is little maintenance involved, which is one of the biggest advantages. This is so because of no mechanically moving parts involved. The only maintenance required is janitorial work such as cleaning of the solar panels periodically. The annual O&M cost could be around 1% of the capital cost.

Duties involving the operation and maintenance of the PV generating plant will be provided in greater detail by the technology provider based on the selected technology. There shall be a properly designed operation and maintenance manual available with the operators of the PV plant. This manual, provided by the technology provider, shall describe the instructions on cares to be taken while plant is in operation and the schedule of maintenance (including preventive maintenance) of the plant components.

The following minimum scheduled maintenance activities will have to be undertaken for sustainability:

- Cleaning of solar panel with clean water and cotton cloth: Once in a week
- Checking of module mounting structure and tighten the nut & bolts: Once in six months
- Check and measure DC and AC current and voltage periodically

The following personnel will be sufficient for the overall operation and maintenance of the Solar PV plant of 250kWp capacity;

- One trained technician having experience in operation and maintenance of solar PV power plant
- One person for cleaning of PV panels

The following equipment will be required at the site for O&M purpose:

- Facility for water spraying and cotton clothes for cleaning
- Miscellaneous hand tools includes electrical and mechanical

7.3 Viability of tracking system

Due to additional capital cost, auxiliary electricity consumption by tracking system, and additional operational and maintenance cost involved in tracking system, it is not a techno-economically viable proposition.

7.4 Risk analysis

There are a myriad of risks present in the PV project cycle. Some, such as construction risk, are confined to specific phases of development, while others persist throughout the entire cycle from planning through operation (such as default risk). Most project risks will be allocated to a number of the parties involved in the project's development, and these parties will be responsible for a portion or all of the potential losses arising from these risks. A degree of uncertainty or the total maximum loss for an individual risk will not necessarily disqualify the whole project from acquiring investment as long as the other risks are demonstrated to be under effective management. For example, a project that uses a new technology or is sited in a location without a strong proven resource may be investment grade as long as other aspects of the project's development are perceived as low risk. Tax equity investors may take on high-risk developments if they deem the expected return on capital to compensate for the level of risk. However, these institutions are generally conservative and place greater value on project quality than on higher yields.

Technical risks

Technical risks are those that arise from the module, inverters, and other mechanical and electrical components, as well as system engineering, energy modelling, and installation.

- **Project Development Risks**

The technical risks during the PV project development cycle (planning and construction) include various aspects of system design, resource estimation and validation, siting evaluations, and grid interconnection.

- **Operational Project Risks**

The principal risk in the operational phase of a project is the uncertainty of energy production. If actual project performance does not meet the budgeted generation estimates, the project will generate less revenue from power sales, and the sponsor may experience difficulty in servicing its debts or earning its investors their returns. Production shortfalls can result from plant operation contingencies, such as component failures (serial and otherwise), latent defects, forced outages, module degradation, and resource variability.

Non-Technical risks

- **Development Risks**

Two of the largest non-technical risks affecting PV projects are the (1) macroeconomic and (2) policy/regulatory environment that prevail in the market. The former determines capital availability, and the latter determines the facility with which financiers can commit that capital and the certainty that they can earn their returns. Both conditions can significantly influence the volume of development in a given year.

- **Operational Risks**

While the technical operational risks are mostly related to a project's power production, the non-technical operational risks are associated with a project ability to sell power and maintain its economics throughout its lifetime.

7.5 List of Solar PV technology providers

Telangana New & Renewable Energy Development Corporation Ltd. has provided a list of Empanelled Suppliers for 1KWp, 2KWp, 3KWp and 5KWp Grid Connected Solar Rooftop PV Systems. The same can be accessed by the link provided below

http://tnredcl.telangana.gov.in/PDFs/Solar_Net_Metring/List_of_empannelled_suppliers.pdf

- Their scope of work covers Design, Supply, installation & Commissioning of SPV Rooftop as per the technical specification.
- The cost is inclusive of all taxes, duties, packing, forwarding and transportation costs upto the site.
- The processing charges payable to APDISCOMs(Rs.1000) and NREDCAP (Rs.1000 (1-3 KWp) or Rs.5000 (5 KWp) + Service Tax@12.36%) and also cost of
- Bi-directional meter shall be borne by the beneficiary.
- Wiring upto the Distribution Board from the SPV Rooftop system will be in the scope of the Supplier. The maximum cable length of 25m for every Solar power plant installed shall be in the scope of the supplier and supply of excess cable length if required shall be in the scope of purchaser.

- Mounting Structure within the scope of the supplier for flat RCC roofs. If the roof is not flat and requires additional mounting structure then that cost will have to be separately borne by the applicant.
- Performance testing of the complete system.
- The Supplier shall supply spares free of cost for the maintenance of the offered items during the warranty period.
- A leaflet containing the details of the service centres shall be provided to each purchaser.
- If the operation or use of the system proves to be unsatisfactory during the warranty period, the supplier shall replace the faulty ones or carry out necessary repairs as per the warranty terms and conditions.
- The Comprehensive Maintenance Charges (CMC) from 6th to 10th year to be paid to the Supplier is optional.
- The eligible MNRE and State subsidy will be released based on MNRE /State Govt. Policies and guidelines either directly to the supplier or to the beneficiary, based on the declaration submitted by the beneficiary.
- The procedure for availing subsidy and for submission of proposals shall be as per details uploaded in the web-site: www.nedcap.gov.in.
- The proposals for installation of the system shall be made before installation of actual system.

8 Conclusion and recommendations

8.1 Conclusion

At all the selected sites of GHMC, a total feasible rooftop area of 15557 sq.m was obtained. This area is suitable for maximum capacity installation of 941 kWp considering shadow area.

- Suggested type of photovoltaic technology is c-Si
- Suggested type of system is grid tied system without storage backup
- The module mounting structures will have to be such that current roof slabs are not disturbed. Typical load of rooftop solar power plant is about 15-20 kg/sq.m., which seems manageable for the existing building structures. However, this detail will need to be confirmed by structural consultant during actual implementation.
- Average Capacity Utilization Factor (CUF) of the power plants are ~ 16%.

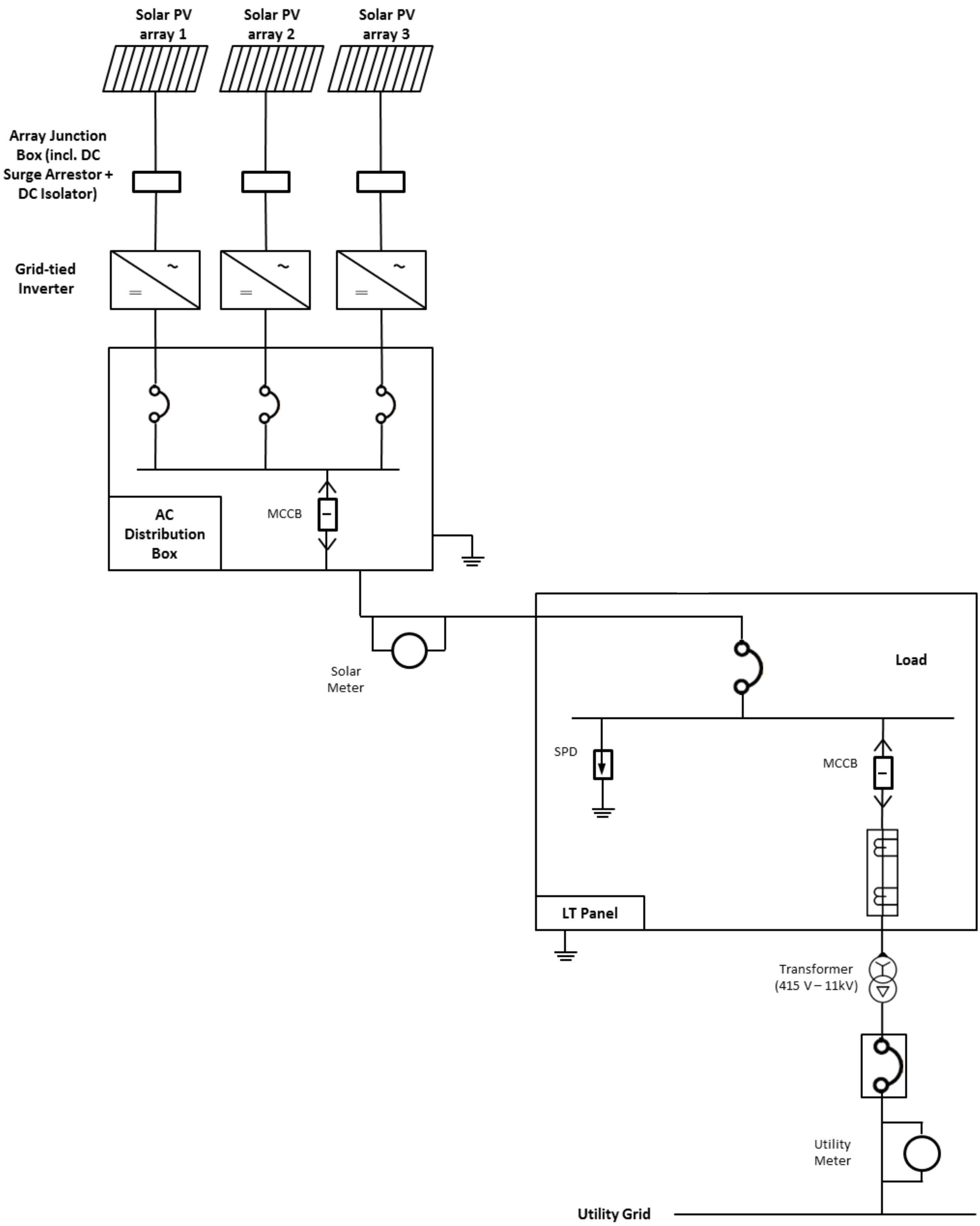
8.2 Recommendation

As per the MNRE notification no. 03/88/2015-16/GCRT dated 4th May, 2016[3] and 30th March, 2017[4] for the installation of Grid Connected Rooftop and Small Solar Power Plants Programme , GHMC has carried out the potential estimation of solar rooftop system in government buildings. As per point 3 of the MNRE notification mentioned above, GHMC needs to communicate the intent for the installation of Solar Rooftop System in any of the Central Nodal Agencies or State Nodal Agency for the installation of system. TERI

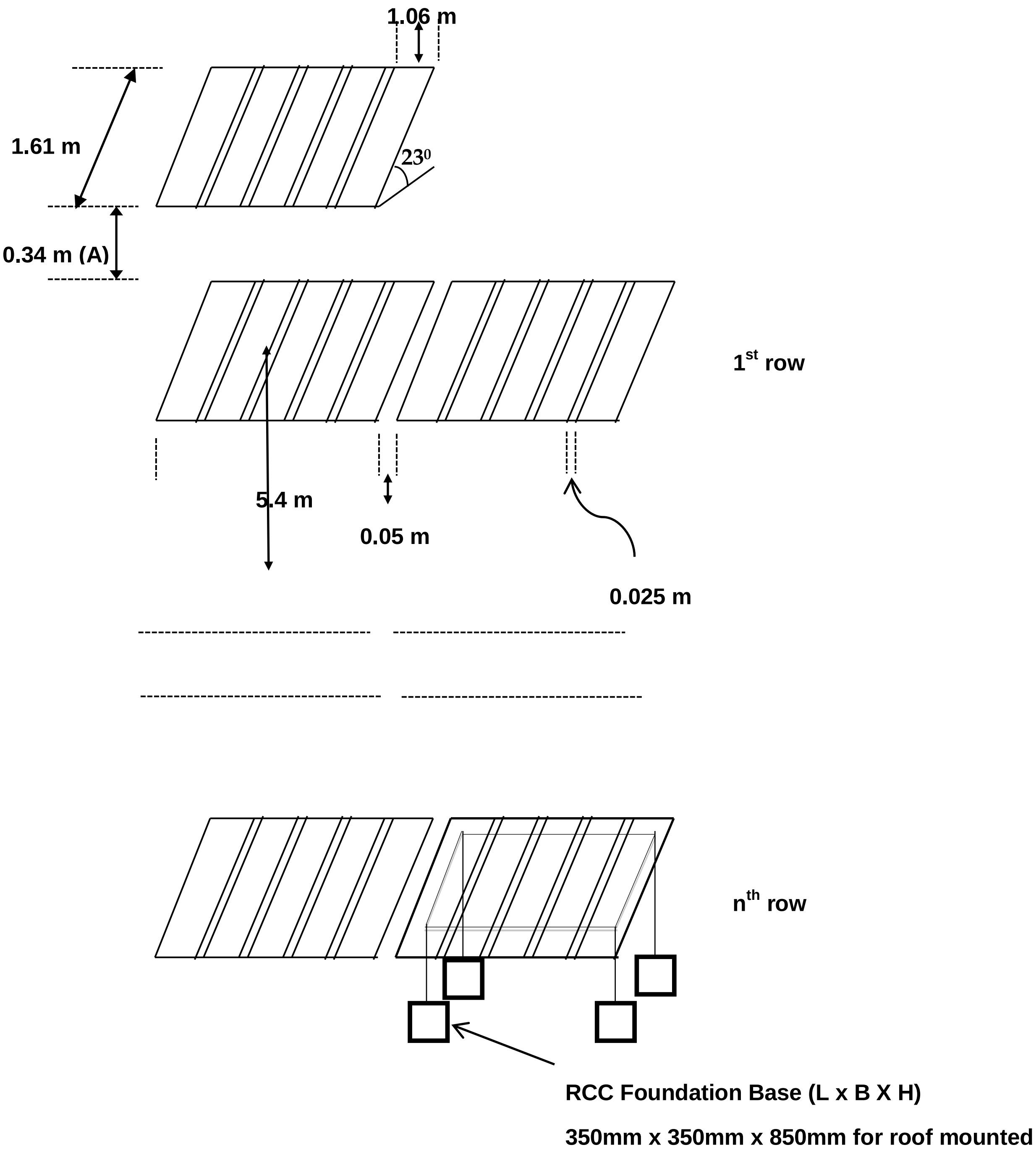
[3] Source : MNRE (http://mnre.gov.in/file-manager/UserFiles/gcrt-incentives-award-040516.pdf)
[4] Source: MNRE(http://mnre.gov.in/file-manager/UserFiles/Notification-Incentive-&-Award-scheme-for-Govt-Sector-30032017.pdf)

recommends going ahead with SECI for the installation of the system as they are in advance stage for the implementation of the "Achievement linked incentive scheme for Government Department of MNRE".

Annexure I: Proposed interconnection of solar PV system with existing electrical network



Annexure II: Solar PV module mounting structure



Annexure III: Assumptions for financial analysis

The assumptions made for the financial analysis are as mentioned below

Project Specifications		
Cumulative project size (design capacity)	kW	941
per-W capital cost	Rs./W	52
Project Capital Cost	Rs.	489,32,000
Government incentive	%	25%
Realized Project Capital Cost	Rs.	366,99,000
Useful life	years	25
Degradation	%	0.60%
Grid availability	%	100%
Debt		
Debt component	%	70%
Debt amount	Rs.	256,89,300
Cost of debt	%	12.00%
Debt tenor	years	14
Moratorium period	years	-
Equity		
Equity component	%	30%
Equity amount	Rs.	110,09,700
Cost of equity	%	20%
Operating parameters		
O&M Expenses	%	1.30%
O&M Expenses Escalation rate (p.a.)	%	3.00%
Working Capital		
O&M Charges	months	1
Maintenance Spare	%	15%
Receivables from Debtors	months	1
Interest on Working Capital	%	12.00%
Depreciation		
Book SLM Depreciation	%	5.28%
Useful Life	years	19
WDV Depreciation (per Income Tax Act)	%	15.00%
Max. Depreciation extent (as % of asset value)	%	90%
Salvage Value	%	10%
(for LCOE) SLM Depreciation for years 1-12	%	5.83%
(for LCOE) SLM Depreciation for year 12 onwards	%	1.54%
Other Financial Assumptions		
Income Tax rate	%	34.61%
MAT rate	%	18.50%
Discount Rate	%	11.49%
Inflation rate	%	5.00%
Revenue model for RESCO		
Project tariff	Rs./kWh	5.10
GHMC electricity costs		
Avg. grid electricity cost for GHMC	Rs./kWh	8.72
Escalation in grid electricity tariff	%	2.00%

Annexure IV: Internationally accepted quality standards and specifications for grid-connected rooftop solar PV system

	Solar PV Modules
IEC 61215 / IS 14286	Design qualification and type approval for crystalline silicon terrestrial PV modules
IEC 61646 / IS 16077	Design qualification and type approval for thin-film terrestrial PV modules
IS/IEC 61730: Part 1	Safety qualification for PV modules – Requirements for construction
IS/IEC 61730 : Part 2	Safety qualification for PV modules – Requirements for testing
IEC 60364-4-41	Certification for protection against electric shock of PV modules
IS/IEC 61701	Certification for resistance to salt mist and corrosion of PV modules
IS/IEC 61725	Analytical expression for daily solar profiles
IS 16170 : Part 1 / IEC 61853	PV module performance testing and energy rating – Irradiance and temperature performance measurement, and energy rating
IEC 62804 *(draft specifications)*	Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation
	Inverters / PCUs
VDE 0126-1-1, IEC 60255.5/IEC 60255.27	Anti-islanding protection
IEC 62109-1, IEC 62109-2	Safety compliance (Protection degree IP 65 for outdoor mounting, IP 54 for indoor mounting)
IEC 62116	Test procedure of islanding prevention measures for utility-interconnected PV inverters; briefly explains the requirements for setting up a test bench for anti-islanding testing
IEEE 1547 / UL 1741	Protection against islanding of grid
IS/IEC 61683	Procedure for Measuring Efficiency of Photovoltaic System Power Conditioners and Inverters
IEC 60068-2 (1, 2, 14, 30)	Environmental testing of PV system power conditioners and inverters
IEC 61727:2004	Photovoltaic (PV) systems - Characteristics of the utility interface; lays down requirements for interconnection of PV systems to the utility distribution system
	Fuse
IS/IEC 60947 (Parts 1, 2, 3), EN 50521	General safety requirements for connectors, switches, circuit breakers (AC/DC)
	Surge Arrestor
IEC 60364-5-53	DC surge protection device (SPD), class 2
IEC 60364-5-53	AC surge protection device (SPD), class 2
	Cables
IEC 60227 / IS 694, IEC 60502 / IS 1554 (Parts 1 & 2)	General test and measuring method for PVC insulated cables (for working voltages up to and including 1100 V and UV resistant for outdoor installation)
	Earthing
IS 3043-1986	Earthing shall be done in accordance with IS 3043-1986, provided that

	earthing conductors shall have a minimum size of 6.0 mm^2 copper, 10 mm^2 aluminum or 70 mm^2 hot dip galvanized steel
IEC 60364-5-53	The SPDs earthing terminal shall be connected to earth through the above mentioned dedicated earthing system; The SPDs shall be of type 2 as per IEC 60364-5-53
Junction Boxes	
IEC 529	Junction boxes and solar panel terminal boxes shall be of the thermo plastic type with IP 65 protection for outdoor use and IP 54 protection for indoor use
Meters	
CEA (Installation and Operation of meters) Regulations, 2006 (Amended in 2010 & 2014)	
IS 16444 *(optional)*	Specifications for AC static direct connected watt-hour smart meters, class – 1 & 2
System Performance Monitoring	
IS/IEC 61724	Guidelines for PV system performance monitoring – Measurement, data exchange and analysis

Other recommended quality practices also exist. These are summarized below:

Fuse:

- The fuse shall have DIN rail mountable fuse holders and shall be housed in thermoplastic IP 65 enclosures with transparent covers

Cables:

- For the DC cabling, XLPE or XLPO insulated and sheathed, UV-stabilized single core flexible copper cables shall be used; Multi-core cables shall not be used
- For the AC cabling, PVC or XLPE insulated and PVC sheathed single or, multi-core flexible copper cables shall be used; Outdoor AC cables shall have a UV-stabilized outer sheath
- The total voltage drop on the cable segments from the solar PV modules to the solar grid inverter shall not exceed 2.0%
- The total voltage drop on the cable segments from the solar grid inverter to the building distribution board shall not exceed 2.0%
- The DC cables from the SPV module array shall run through a UV-stabilized PVC conduit pipe of adequate diameter with a minimum wall thickness of 1.5mm
- Cables and wires used for the interconnection of solar PV modules shall be provided with solar PV connectors (MC4) and couplers
- All cables and conduit pipes shall be clamped to the rooftop, walls and ceilings with thermo-plastic clamps at intervals not exceeding 50 cm; The minimum DC cable size shall be 4.0 mm2 copper; The minimum AC cable size shall be 4.0 mm2 copper. In three phase systems, the size of the neutral wire size shall be equal to the size of the phase wires

About TERI

The Energy and Resources Institute (TERI) was formally established under the Registrar of Society in 1974 with the purpose of tackling and dealing with the immense and acute problems that mankind is likely to be faced with in the years ahead - on account of the gradual depletion of the earth's finite energy resources which are largely non-renewable and on account of the existing methods of their use which are polluting. While in the initial period the focus was mainly on documentation and information dissemination activities, research activities in the fields of energy, environment, and sustainable development were initiated towards the end of 1982. The genesis of these activities lay in TERI's firm belief that efficient utilization of energy, sustainable use of natural resources, large-scale adoption of renewable energy technologies, and reduction of all forms of waste would move the process of development towards the goal of sustainability.

Over the years the Institute has developed a wider interpretation of this core purpose and its application. Consequently, TERI has created an environment that is enabling, dynamic and inspiring for the development of solutions to global problems in the fields of energy, environment and current patterns of development, which are largely unsustainable. The Institute has grown substantially over the years, particularly, since it launched its own research activities and established a base in New Delhi, its registered headquarters. The central element of TERI's philosophy has been its reliance on entrepreneurial skills to create benefits for society through the development and dissemination of intellectual property. The strength of the Institute lies in not only identifying and articulating intellectual challenges straddling a number of disciplines of knowledge but also in mounting research, training and demonstration projects leading to development of specific problem-based advanced technologies that help carry benefits to society at large.

teri

The Energy and Resources Institute

www. teriin.org