Detailed Project Report

20 MW Solar Power Project atJalukie
District : Peren
Nagaland

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GLOSSARY

Photovoltaic	The physical effect of direct conversion of light (sunlight) to electrical energy
PV Cell	The smallest photovoltaic (PV) element that generates electricity from light
PV Module	A collection of interconnected PV cells, encapsulated between protective materials such as glass and back sheet (Poly Vinyl Fluoride) or glass and glass, and mounted in an aluminium frame. This is a hermetically sealed unit
Array	Several strings of modules with the same orientation and tilt angle, located together
Inverter	An electronic device that converts direct current electricity into alternating current electricity suitable for feeding directly to the electrical grid or to normal AC loads
Insolation	It is a measure of solar radiation energy received on a given surface area in a given time. It is commonly expressed as average irradiance in watts per square meter (W/m^2) or kilowatt-hours per square meter per day ($kW \cdot h/ (m^2 \cdot day)$) (or hours/day)
Mounting Structure	Device used to hold modules in place, at desired angle &direction
Power Evacuation	Power generated from Solar PV Power Plant is transmitted to a point (sub-station) where it is distributed for consumer use
Sub-station	The place where the generated power from solar is synchronized with utility grid and metered
Control Room	Room housing control equipment
Cable	A conductor with one or more strands bound together, used for transmitting electrical energy
Junction Box	Inputs of several strings are connected to this box and taken as single output
Current	A flow of electricity through a conductor measured in Amps
Voltage	The rate at which energy is drawn from a source that produces a flow of electricity in a circuit; expressed in volts. It is the difference of electrical potential between two points of an electrical or electronic circuit, expressed in volts. It is the measurement of the potential for an electric field to cause an electric current in an electrical conductor
Lightning Arrestor	Device used to protect all the components from lightning strikes
Transformer	An electrical device by which alternating current of one voltage is changed to another voltage
Grid	A system of high/low tension cables by which electrical power is distributed throughout a region
SCADA	Instrumentation & Control system for the solar power plant used to

detect malfunctions and give information at a given time interval about the availability and performance of the plant

ABBREVIATIONS

General:

ACB	Air Circuit Breaker
AC	Alternate current
ACSR	Aluminium Conductors Steel Reinforced
BOS	Balance Of the System
CO2	Carbon Dioxide

CT	Current Transformer
DC	Direct Current
DP	Double Pole
DPR	Detailed Project Report
HT	High Tension
LT	Low Tension
LV	Low Voltage
MNRE	Ministry of New and Renewable Energy
KWh	Kilo Watt Hour
MCB	Main Combiner Box / Miniature Circuit Breaker
PLF/ CUF	Plant Load Factor/ Capacity utilization factor
PPA	Power Purchase Agreement
PV	Photo Voltaic
PT	Power Transformer
VCB	Vacuum Circuit Breaker
XLPE	Cross Linked Polyethylene

Units

%	Percentage
˚C	Degree Centigrade
Kg	Kilogram
kV	Kilo Volt
kW	kilo Watt
kWp	kilo Watt peak

Lt	Litre
M	Meter
m2	Square meter
m3	Cubic meter
Tons	Tons

Profile of Halo Energie Pvt Ltd: (www.haloenergie.com)

Halo Energie is an Independent Power Generation and Trading company. The company's mission is to establish power plants in the renewable energy segment and to address the ever-growing world energy demand. As world development continues, population growth and technological advancements contribute to increasing energy demand. From 1990 to 2008, the IEA recorded an average energy use per person increase of 10%, while population increased 27%. Energy consumption growth grew 2% in 2011 alone. This current trend presents a profitable opportunity to enter the electricity market as an Independent Power Producer (IPP).

In order to address the global electricity demand, Halo Energie envisages to install utility scale power plants in locations all over the world. Halo Energie involvement in current Indian government energy policies has progressed the company's IPP capability, resulting in obtaining permissions to construct Solar PV Power Plants, to a total capacity of 5 MW (Megawatts) in its early days of inception. Halo Energie has just begun realizing its growth potential through acquired interest from various State Governments for installation of Solar PV Power Plants.

Halo Energie believes that success of an energy investment company relies on its ability to execute intelligent investment decisions. Halo Energie plans to take full advantage of various state renewable energy policies in India to maximize the business's profitability. In addition, the company retains the competitive strategy of being able to adapt to the energy technologies that are the most profitable and advantageous to the business. While solar renewable energy in India is currently an excellent market to enter, Halo is constantly looking for future business opportunities to expand its generating capacity, in India as well as other countries.

Project commissioned so far:

1. Gadag 3MW, Karnataka

2. Challaki 2 MW, Karnataka
3. Chitranayaki, 2 MW at Karnataka.
4. Chitradurga 2 MW, Karnataka
5. Jadchelra 5 MW, Telangana.

Projects under pipeline:

1. Halo Energie will be the first company to execute a 20MW solar power project in the North-East India.
2. Halo will be pursuing its first international project in Africa where discussions have already started for setting up 40MW solar power project.
3. Halo is also developing a new vertical to the company by expanding its business into rooftop systems under a Solar- Wind Hybrid model.
4. Halo is also executing another project in Karnataka under the open access scheme to supply power to a software solutions company in Bangalore.

Executive Summary

- In synchronization with Government of India's plan to significantly increase the share of solar energy in the total energy mix while recognizing the need to expand the scope of other renewable and non-fossil options, Halo Energie proposes that the Government of Nagaland should also progress in implementing solar-based technologies in its vicinity.

- The present report is prepared in view of setting up a 20MW capacity power project near Jalukie, Nagaland. The survey of land has to be done; power evacuation options have to be analyzed, and based on metrological data of Jalukie detailed system design will be worked out.

- This project report covers technology selection, location & satellite image of plant site, site infrastructure, description & comparison of solar PV technologies, design criteria for SPV power plant including electrical equipments, plant facilities, and power evacuation requirements.

- The grid connected solar PV power generation scheme will mainly consist of solar PV array, power conditioning unit (PCU), which convert DC power to AC power, transformers and associated switch gears (with metering and protection).

- The broad system specification for proposed 20MW grid interactive solar PV project are as follows:

    - The solar PV power will be generated at 280V AC, 50 Hz and then supplied to the AC Distribution panel
    - Expected electrical energy generation for sale will be approximately 2,81,85,910 kWh/year.

- The project shall be designed to produce approximately 20MW of clean solar power. Installation shall be modular from crystalline solar PV technology and shall take about 8 months from commencement to completion.

Proposed Project at a Glance:

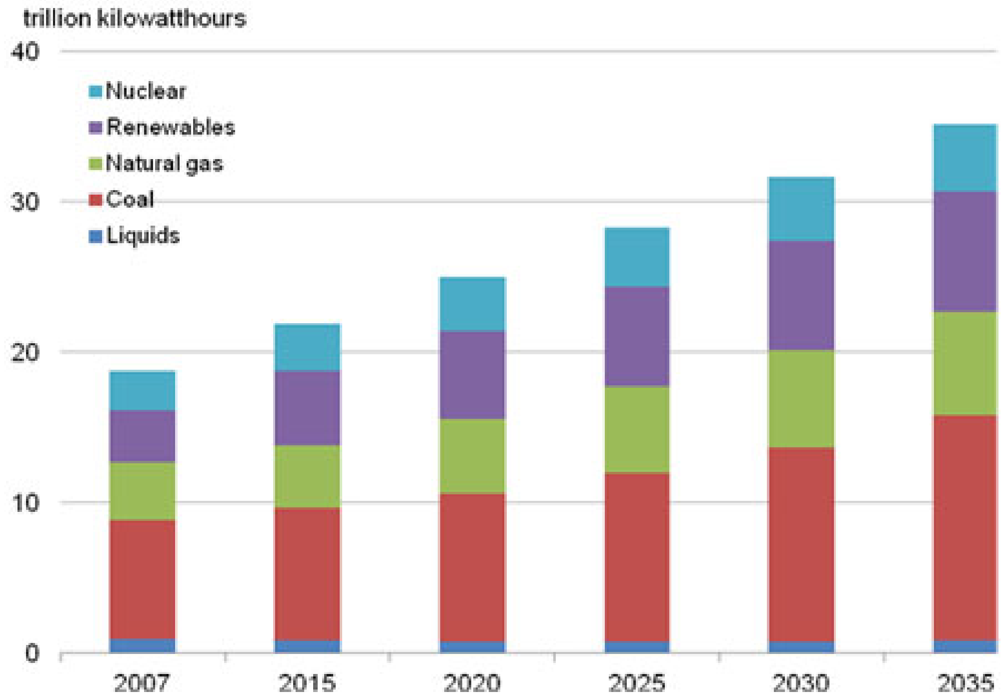
Serial Number	Parameters	Details
1	Project Name	20 MW Solar Photovoltaic Grid Connected Project at Peren District, Nagaland
2	Plant Capacity	20 MW
3	Location	Jalukie Town
4	Location Details	Latitude: 25°39'40"N Longitude: 93°38'51"E Elevation: 145m above sea level
5	Connectivity	Nearest National Highway: NH 39 Nearest Major Railway Station: Dimapur Nearest Airport: Dimapur Airport Nearest Sea Port: Port of Kolkata
6	Climate	Avg. Max Temp (Yearly): 35ºC Avg. Min Temp (Yearly): 22ºC
7	PV Array Capacity	19,998.36 kW Peak (kWp)
8	PV Technology	Mono/Poly -Crystalline Silicon
9	Module/Panel Capacity	Watt Peak (Wp)
10	No. of modules	75,000 (approx)
11	Module Efficiency	18.0%

12	Solar Inverter Capacity	1.0MW Grid Inverters
13	No. of Inverters	20
14	Inverter Efficiency	98.4%
15	Inverter Technology	IGBT
16	Solar Insolation	4.57 kWh/m2 per day
17	Total Energy Generation	2,81,85,910 kWh/year
18	Total Required Land Area	120 Acre
19	Source of Water Required	Bore Wells
20	Power Evacuation	66 kV substation should be available within 2 km from the site
21	Proposed Date of Commissioning	Eight months from date of project initiation

1 INDUSTRY OUTLOOK

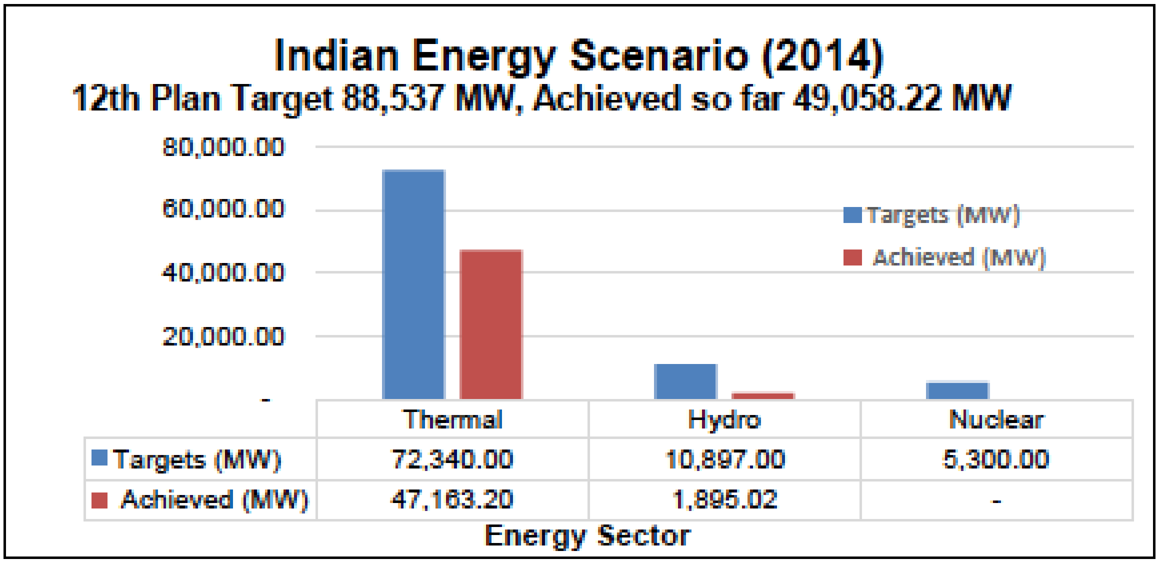
1.1 Global & Indian Energy Scenario

Electricity is one of the world's fastest-growing form of end-use energy consumption. It is estimated that, world energy consumption will increase by 56% by 2040. Renewable energy and nuclear power are the world's fastest-growing energy sources, each increasing 2.5% per year. Net electricity generation worldwide will rise by 2.3 percent per year on average from 2007 to 2035 as compared to 1.4 percent per year growth for total world energy demand. The growth in electricity generation for non-OECD countries increases by an average annual rate of 3.3 percent, as rising standards of living increases the demand. In OECD nations, where infrastructures are more mature and population growth is relatively slow, growth in generation is much slower, averaging 1.1 percent per year from 2007 to 2035.



GRAPH 1: WORLD ELECTRICITY CONSUMPTION PROJECTIONS

The Indian government has set ambitious goals in the 12th plan for power sector owing to which the power sector is poised for significant expansion. Under 12th Plan of Central Electricity Authority, the capacity addition target was 88,537 MW in December 2014 while only 49,058 MW was achieved during April 2014 to December 2014. So, nearly 55.41% was achieved. The below graph shows, Indian Energy Targets and Achievements till December 2014:



GRAPH 2: INDIAN ENERGY SCENARIO

1.2Growth in Demand

Despite the rapid growth in this decade, solar photovoltaic is a young market. Thus, the different industry forecasters have different sizes even for the existing market, let alone their forecasts in the longer term. The European Photovoltaic Industry Association (EPIA) has comprehensive long-term forecasts for the photovoltaic industry. Its forecasts have been much more cautious than the break-neck speed of industry growth in the last 2-3 years; however, there is every possibility that the much higher results in comparison to forecasts over the last few years will result in over-estimation of the market.

Globally, the solar power industry has been growing rapidly in recent years. In 2010, an estimated total capacity of 17,000 MW was installed globally. Germany leads the race with more than 40 percent of the total global market.

The three leading countries (Germany, Japan and the US) represent nearly 89% of the total worldwide PV installed capacity. Currently, around 84% of solar industry demand is located in four countries where governments have actively promoted its development through favorable regulation: Germany, Japan, Spain and the US in selected states. Spain was one of the fastest growing markets in 2008 owing to very favorable legislation and attractive feed-in tariffs. In 2008, Spain accounted for 45% of the new photovoltaic installments. However, in 2009, Spain market reduced considerably due to government policy change on the FIT.Going forward, the growth in Sunbelt countries is expected to increase considerably due to the higher demand for power and better solar resource in these countries such as India, MENA, China, etc.

2. INDIAN MARKET FOR SOLAR POWER

A Solar PV Project Developer can set up a solar power project in India in one of the following three ways:

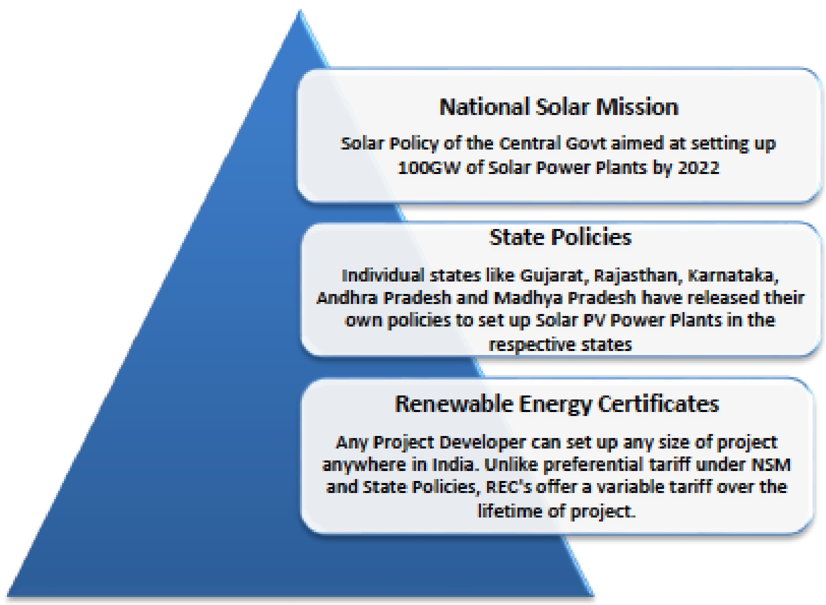


FIGURE 1: INDIAN MARKET FOR SOLAR POWER

2.1 The National Solar Mission and State Policies

The Jawaharlal Nehru National Solar Mission is a major initiative of the Government of India with active participation from States to promote ecologically sustainable growth while addressing India's energy security challenge. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change. The objective of the Mission is to establish India as a global leader in solar energy, by creating the policy conditions for its large-scale diffusion across the country as quickly as possible. The Mission has set a target, amongst others, for deployment of grid connected solar power capacity of 100 GW by 2022 and is planned to be implemented in three phases with phase-1 by 2013, phase-2 by 2017 and phase 3 by 2022.

The plan of action to achieve the target of 100 GW by 2022 is under preparation which broadly consists of 40 GW Grid Connected Rooftop Projects and 60 GW Large and Medium Size Land based Solar Power Projects. No direct financial assistance is provided by the government for setting up solar power projects connected to the grid.Since launch of the JNNSM, the capacity of cumulative achievements of grid-connected solar power projects has grown from 8 MW in January 2010 to over 3743.97 MW in the country (as on 31st March 2015).

MNRE has established the Solar Energy Corporation of India (SECI) for handling the power procurement from the second batch of the JNNSM. SECI (MNRE)'s role would be limited to providing a subsidy known as Viability Gap Funding (VGF), which is basically a part payment, made by SECI to the project developer in order to make the project viable. MNRE has recently unveiled guidelines for allocation of solar power project worth 750 MW under the VGF route, out of which, half if earmarked for projects opting for cells and modules of domestic origin.

2.2 State Policies

Subsequent to the launch of the JNNSM, many states have acknowledged the importance of solar energy and hence formulated their own respective policies regarding the same.

To facilitate the use of solar energy and to fulfill their Renewable Purchase Obligations (RPOs) many states have released their solar policies. For example, under the Gujarat state solar policy had about 500 MW allocations target by 2014. However, looking at the rapid advancements 968 MW of Solar power projects have been allocated in 2 phases at a tariff of Rs.15 for first 12 years and Rs.5 for 13 years after that. At present about 708.81 MW have been installed in Gujarat alone making it the state with largest installed SPV capacity in India.

The Karnataka Renewable Energy Development Ltd. (KREDL) has announced the ten winners of the solar bidding out of 22, held in November 2011 under the Karnataka solar policy 2011.

The bidders were selected on the basis of Reverse Bidding. The original capacity to be allocated was 30MW of solar thermal and 50MW of solar PV, but as bids for only 20MW solar thermal capacity had been received, the excess 10MW has been allocated to solar PV. The lowest bid, which stood at Rs.7.94/KWh, was submitted by Helena Power Private Limited (allotted 10MW PV) and Welspun Solar AP Private Limited submitted the highest successful bid at Rs.8.50/KWh.

Total of 200 MW of projects were allotted under the Madhya Pradesh Power Trading Company (MPPTC) solar policy with the majority being allotted to Welspun (130 MW) among 3 other project developers on the basis of reverse bidding. The tariff rates at which the projects were awarded ranged from Rs.7.90 to Rs.8.05 per unit. Madhya Pradesh government recently approved a new solar energy policy under which four solar energy parks each generating 200 MW of power will be set up in the state in public-private partnership.

These were some of the recent developments that have occurred across India in various states who have been promoting Solar power aggressively. The table below shows some of the targets set by various states to achieve installed capacities:

S.No.	State	Average Annual Solar Resource (kWh/m2/day)	Govt. Solar Policy/Target	Installed PV Capacity (MW)
1)	Rajasthan	5.0-6.3	Solar power of 10000-12000 MW capacity by 2022	195
2)	Gujarat	5.2-6.0	500 MW by 2014	708.81
3)	Karanataka	4.6-5.8	200 MW by 2016	11
4)	Tamil Nadu	4.8-5.8	3000 MW of power by 2015	15
5)	Andhra Pradesh	4.8-5.8	97.2 MW sanctioned	22.5
6)	Madhya Pradesh	5.0-5.6	500 MW by 2013	7.25
7)	Chattisgarh	5.0-5.6	500-1000 MW by March 2017	4
8)	Maharashtra	4.6-5.6	20MW/sq km potential, min. 5 MW capacity plants authorized	19.2
9)	Uttar Pradesh	4.6-5.2	1000 MW by 2017	1.2

3. PROJECT SITE

3.1 Location and Accessibility

Proposed site location is situated at latitude : 25°39'40"N and longitude 77°43’20.418”E near a town called Jalukie, in Peren District, State – Nagaland.

The available land area is 120 acres (approx.) to implement 20 MW power plant. The distance from substation to site is nearly 2 kms. The site has a decent irradiation level of 4.57 kWh/m2`/day. A minimum of 18.0% of (AC) PLF is expected.

The site is a little remote, but has connectivity through intra-state and interstates road, railway and airways. Distance from site till approach road is 3.5 km. The nearest airport (Dimapur) is roughly 45km from the town of Jalukie. The proposed land site has boundary by North with Mathew’s/ D.K.Zeliang’s Plantation/ Boundary nallah, boundary by South with Veterinary Departments land, boundary by East with Veterinary Departments land, and boundary by West with Shri. Hupen’s Land.

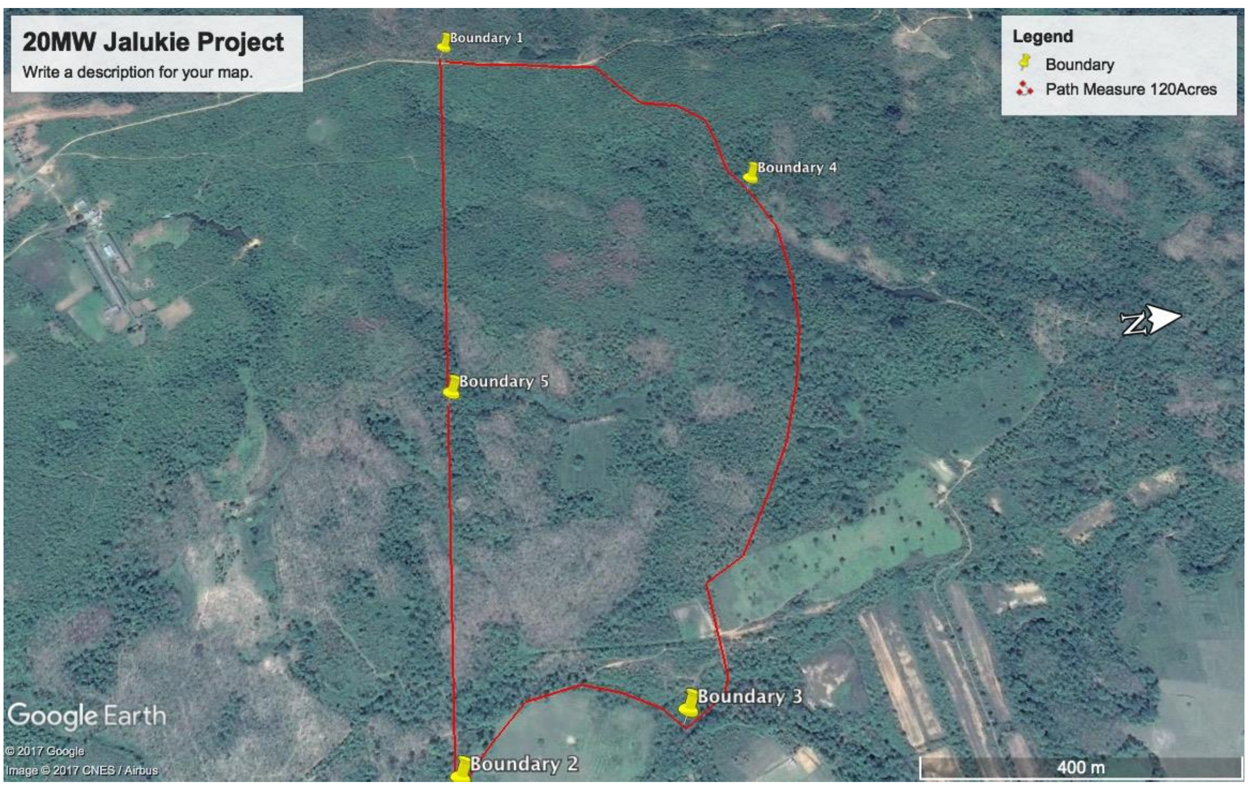
3.2 Substation Details

The nearest substation from the site is 33/11 kV Jalukie substation. Distance from the substation is nearly 2 km by aerial. This proposed substation is under process of being upgraded to 66/11 kV.

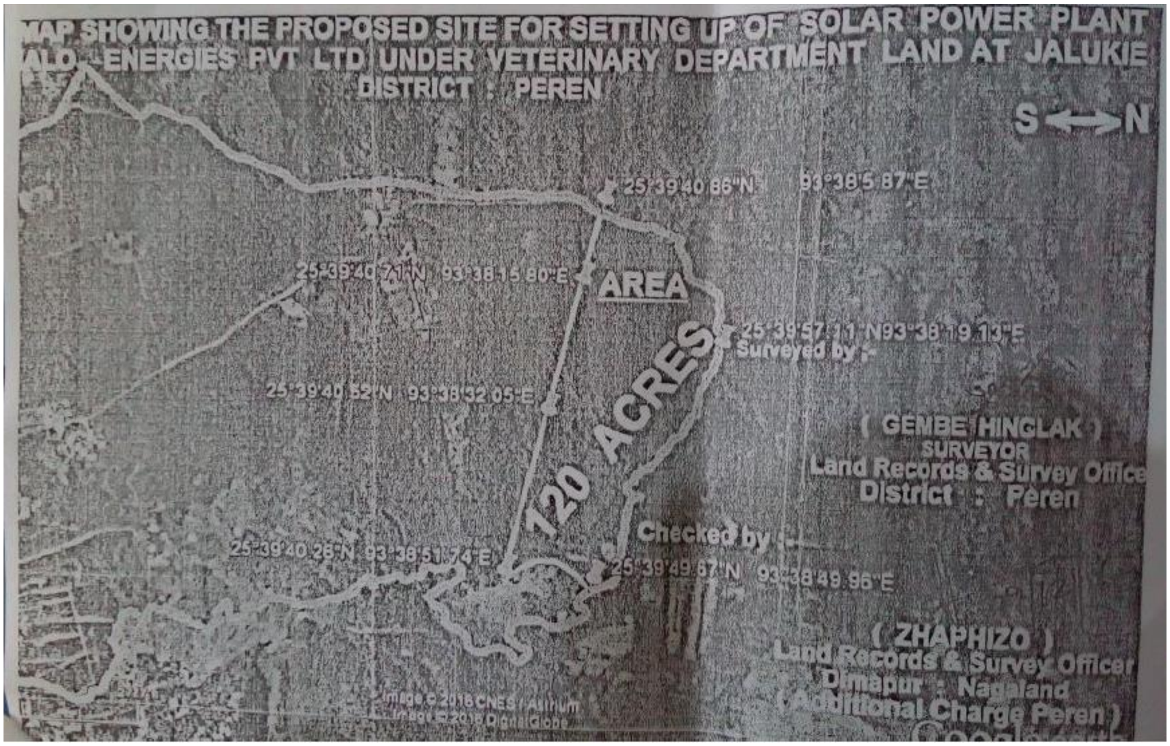
3.3 Land Requirement

The total land area available at the site is about 120 acres (approx.). The typical requirement for a 1MW c-Si SPV plant is approximately 5 to 6 acres. So, for 20 MW SPV plant, nearly 120 acres of land is required. This includes the array yard, inverter room and main control room, roads, drainage and other utilities. However, array yard occupies most of the space, hence, must be optimized. The present land parcel is sufficient to install 20 MW project.

Google Earth image of the proposed site:



Survey of the proposed land done by Government Officials:



4. SOLAR RESOURCE ASSESSMENT

4.1 Introduction to Solar Resource

The electrical output of a solar power plant is dependent on the incident solar radiation it receives. Outside the Earth's atmosphere, on a surface normal to the solar beam, the power density is 1,365 W/m2, which is known as 'Solar Constant'. As the solar radiation passes through the atmosphere, depending on the length of the atmospheric path traversed by the solar radiation and the quantity of dust, water vapour, ozone, CO2 and other aerosols/gases present, some amount of it is scattered and absorbed. The diffused radiation plus the direct irradiance from the sun are together termed as Global Irradiance. The diffused sunlight can vary from about 20% on a clear day to 100% in heavily overcast conditions. The peak irradiance of 1,000 W/m2 is taken as the standard value in the industry by which PV modules are rated. However, the total solar energy received in a day over a specific area, called daily solar irradiance or insolation, is more important than the instantaneous solar irradiance. The solar resource is not equally available in all regions of the world hence a site specific solar resource assessment is required for every project.

4.2 India's Solar Radiation Profile

India being a tropical country is blessed with good sunshine over most parts and the number of clear sunny days in a year also being quite high. The country receives solar energy equivalent to more than 5,000 trillion kWh per year. India's equivalent solar energy potential is about 6,000 million GWh of energy per year. Being a tropical country, India is blessed with good sunshine over most parts, and the number of clear sunny days in a year also being quite high.

The daily average global radiation is around 5 kWh/m2 in north-eastern and hilly areas to about 6 kWh/m2 in western regions and cold desert areas with the sunshine hours ranging between 2300 and 3200 per year. In most parts of India, clear sunny weather is experienced for 250 to 300 days a year. The annual global radiation varies from 1600 to 2200 kWh/m2. Following figure presents the global solar radiation map of India jointly developed by MNRE and NREL.

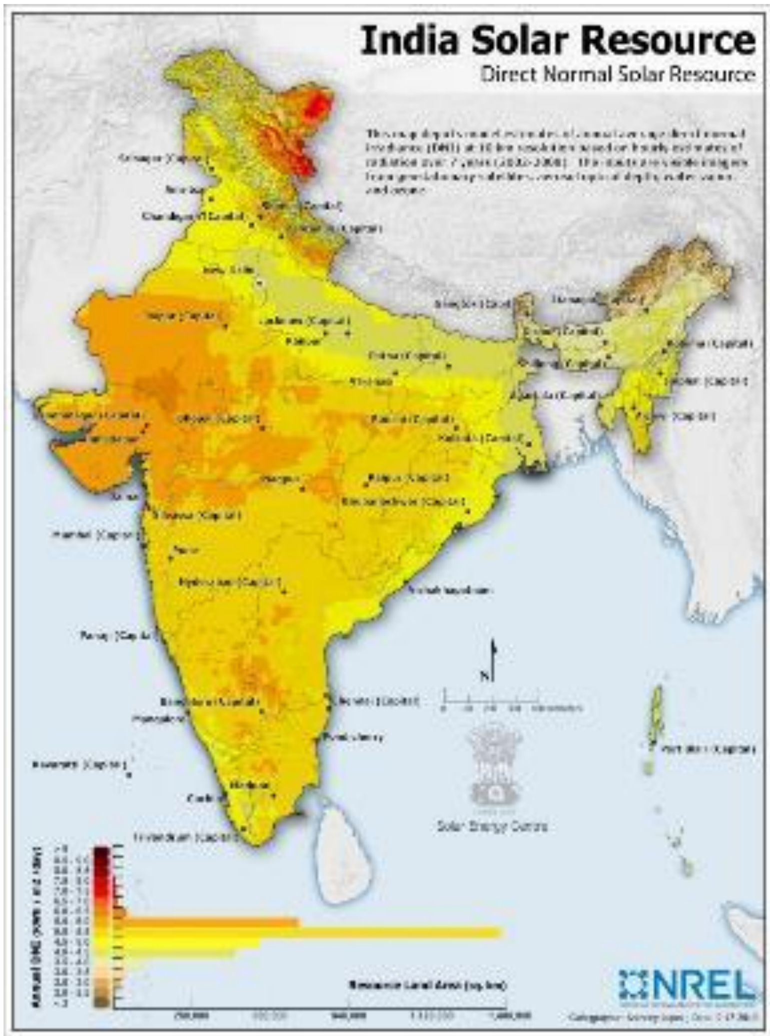


FIGURE 2: Solar Resource Map of India

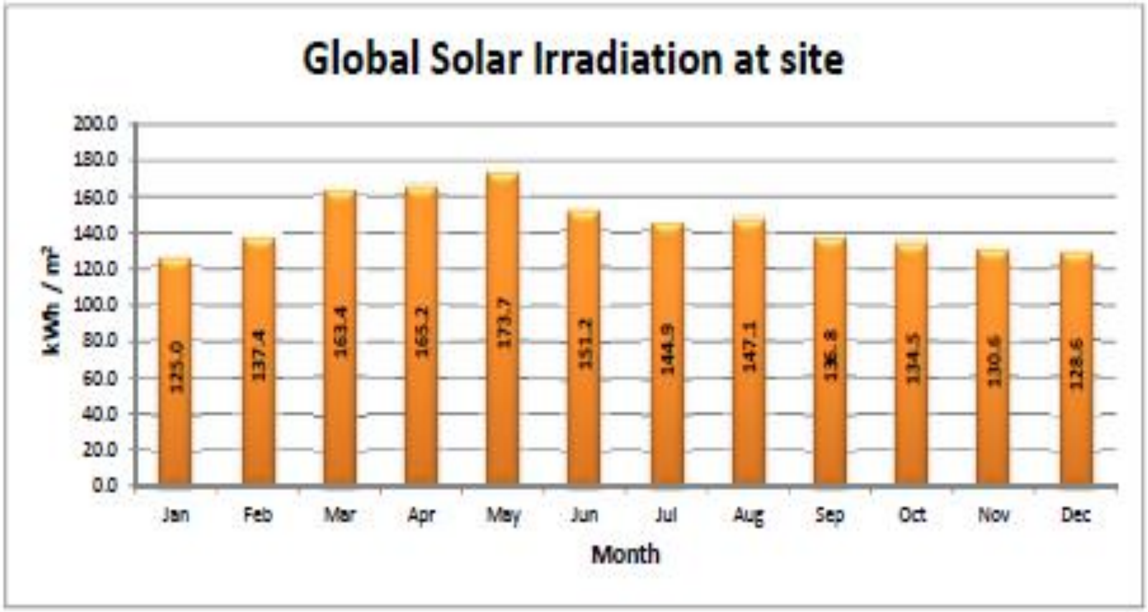
4.3 Radiation Profile of the Site

Solar radiation data can be collected from many sources like NASA-SSE, 3 Tier, Solar GIS, and Meteonorm. Meteonorm data is considered for this project since it uses both satellite as well as weather station data nearest to the site, while other data sources employ only satellite derived data.

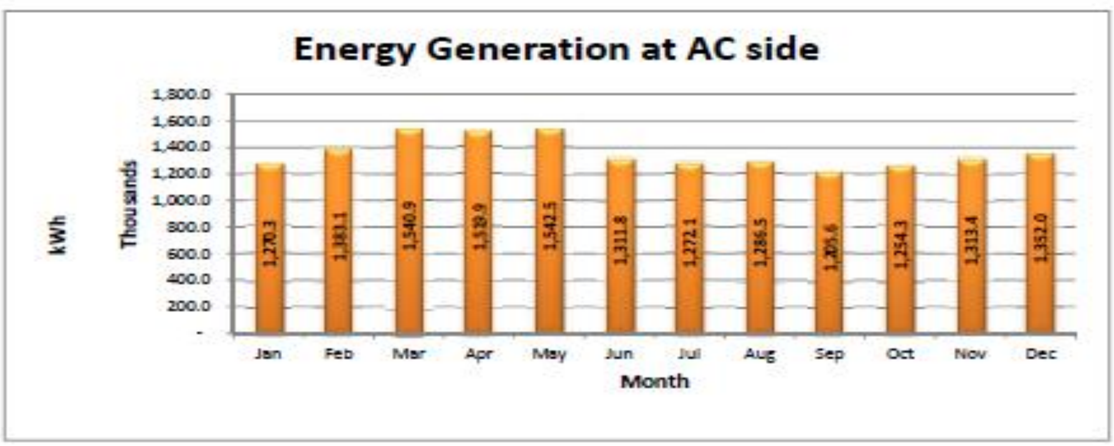
METEONORM database contains the TMY files of solar and climatic parameters for several Indian locations based on measured as well as estimated values. The software provides a facility to interpolate the solar and meteorological data for any location through geographical parameters.

Average horizontal solar radiation at the site comes out to be 4.57 kWh/m2/day as per Meteonorm data. Monthly averages of the same data are given as follows:

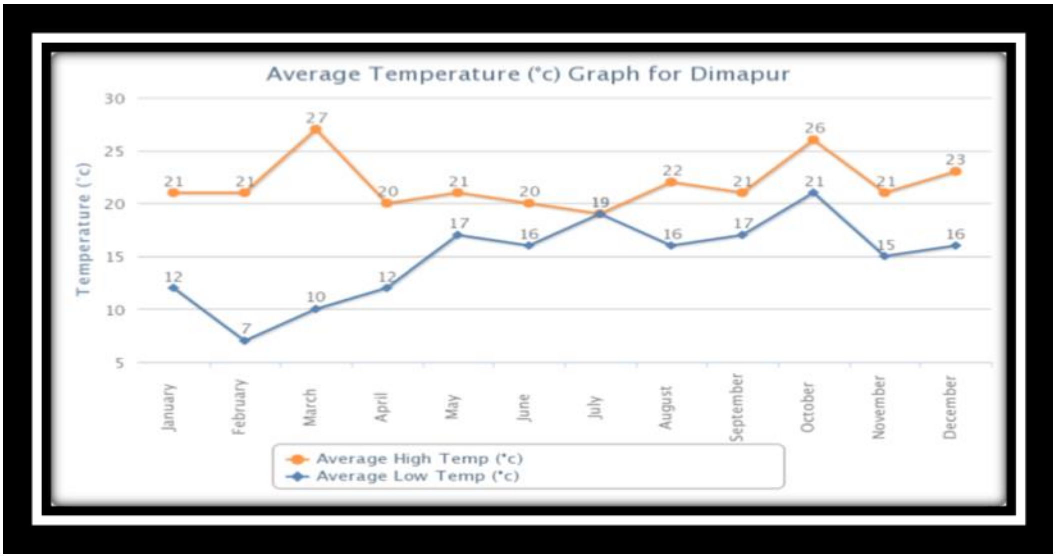
1.1. SITE Specific PV Array Irradiation



1.2 MONTHLY ENERGY Generation (assuming 100% Grid Uptime)



The graph below shows the average temperatures in Dimapur, Nagaland:



5.PROJECT JUSTIFICATION

Driven by advances in technology and increases in manufacturing scale and sophistication, the cost of photovoltaic panels has declined steadily since the first solar cells were manufactured. Net metering and financial incentives, such as preferential feed-in tariffs for solar-generated electricity have supported solar PV installations in many countries.

Advantages of Solar Technology

- The 89,000 TW of sunlight reaching the Earth's surface is plentiful – almost 6,000 times more than the 15 TW equivalent of average power consumed by humans. Additionally, solar electric generation has the highest power density (global mean of 170 W/mÇ) among renewable energies.

- Solar power is pollution-free during use. Production end-wastes and emissions are manageable using existing pollution controls. End-of-use recycling technologies are under development and policies are being produced that encourage recycling from producers.

- PV installations can operate for many years with little maintenance or intervention after their initial set-up, so after the initial capital cost of building any solar power plant, operating costs are extremely low compared to existing power technologies.

- Solar electric generation is economically superior where grid connection or fuel transport is difficult, costly or impossible. Long-standing examples include satellites, island communities, remote locations and ocean vessels.

- Photovoltaic Technology – A boom to the Indian Power Sector – is probably the only solution to improve the security of India’s energy supply. PV brings electricity to remote rural areas. Solar systems give an added value to rural areas (especially in developing countries where electricity is not available). House lighting, hospital refrigeration systems and water pumping are some of the many applications for off-grid systems. Telecommunication systems in remote areas are also well-known users of PV systems.

- PV creates thousands of jobs. The PV sector, with an average annual growth of 40% during the past years is increasingly contributing to the creation of thousands of jobs worldwide. A robust and expanding PV industry in India will create jobs right across the value chain from specialized high paying, high technology sector employment in R & D, to employment for manufacturing workers, technicians, construction workers, installers and in field maintenance. MNRE (India) estimated 100,000 jobs in PV by 2020. Industry sources suggest that if all job linkages are considered, PV jobs in India could exceed these values.

Specific drivers for PV in India include the country’s rapidly rising primary energy and electricity needs, the persistent energy deficit situation, the country’s overdependence on coal for electricity generation and on oil and gas imports (amounting to 7% of its GDP). These factors coupled with India’s endowment with abundant irradiation, with most parts of the country enjoying 300 sunny days a year, make PV particularly attractive to the country’s energy strategy. In India Solar PV currently is used primarily in a decentralized manner for home lighting, lanterns, street lighting systems, stand-alone (off-grid) PV power plants, water pumping systems. Solar thermal energy is used primarily for cooking, water heating and drying. Amongst various solar thermaltechnologies, only solar water heating systems and solar cookers have reached a stage of commercialization. Even though the solar PV technology has potential for Grid Interactive Solar PV Power Generation but because of technological barriers, high capital investment and power generation cost large-scale commercialization and usage has not been achieved till date. The table below shows the capacities required by each in 2017 through solar power:

Solar Capacity Required by States in 2017

Sr.No.	States	Demand (2016-17) (MU)	RPO Target (2016-17)	Solar Power Capacity Required (MW)	State initiatives (MW)	Capacity tied - JNNSM Phase -1 (MW)	Capacity likely to be allocated under Phase- 2 of JNNSM(MW)*	Gap to be fulfilled by States(MW)
1	**Andhra Pradesh**	139457	1.25%	1047.35	2.20	75.50	314	**655**
2	**Arunachal Pradesh**	823	1.25%	6.18	0.03	0.00	**2**	**4**
3	**Assam**	9556	1.25%	71.77	0.00	5.00	22	**45**
4	**Bihar**	25602	1.25%	192.28	38.00	0.00	58	**97**
5	**Chhattisgarh**	26497	1.25%	199.00	0.00	29.00	60	**110**
6	**Delhi**	37122	1.25%	278.79	2.53	0.00	84	**193**
7	**JERC (Goa & UT)**	17002	1.25%	127.69	1.69	0.00	38	**88**
8	**Gujarat**	104102	1.25%	781.83	968.50	0.00	235	**-**
9	**Haryana**	55918	1.25%	419.96	0.00	8.80	126	**285**
10	**Himachal Pradesh**	10989	1.25%	82.53	0.00	0.00	25	**58**
11	**Jammu and Kashmir**	16492	1.25%	123.86	0.00	0.00	37	**87**
12	**Jharkhand**	8712	1.25%	65.43	0.00	36.00	20	**10**
13	**Karnataka**	85455	1.25%	641.79	89.00	70.00	193	**290**
14	**Kerala**	26598	1.25%	199.76	0.03	0.00	60	**140**
15	**Madhya Pradesh**	77377	1.25%	581.12	206.50	5.25	174	**195**
16	**Maharashtra**	197671	1.25%	1484.55	163.50	37.00	446	**838**
17	**Manipur**	959	1.25%	7.20	0.00	0.00	2	**5**
18	**Mizoram**	677	1.25%	5.09	0.00	0.00	2	**4**
19	**Meghalaya**	2801	1.25%	21.03	0.00	0.00	6	**15**
20	**Nagaland**	764	1.25%	5.73	0.00	0.00	2	**4**

21	**Orissa**	31372	1.25%	235.61	50.00	28.00	71	**87**
22	**Punjab**	63171	1.25%	474.43	-0.67	52.50	142	**280**
23	**Rajasthan**	72393	1.25%	543.68	65.65	340.50	163	**-**
24	**Sikkim**	537	1.25%	4.03	0.00	0.00	1	**3**
25	**Tamil Nadu**	118724	1.25%	891.64	274.11	12.00	268	**338**
26	**Tripura**	1324	1.25%	9.94	0.00	0.00	3	**7**
27	**Uttarakhand**	14559	1.25%	109.34	0.05	5.00	33	**71**
28	**Uttar Pradesh**	126323	1.25%	948.71	0.38	93.00	285	**571**
29	**West Bengal**	57735	1.25%	433.61	2.05	50.00	130	**251**
		Total Solar Power Requirement (2016-17) (MW)		**9,994**	**1,864**	**848**	**3,000**	**4730**

6. SELECTION OF TECHNOLOGY

Photovoltaic comprises the technology to convert sunlight directly into electricity. The term “photo” means light and “voltaic,” electricity. A photovoltaic (PV) cell, also known as “solar cell,” is a semiconductor device that generates electricity when light falls on it. Since its first commercial use in powering orbital satellites of the US space programs in the 1950s, PV has made significant progress with total photovoltaic module industry growing at more than 40% in the past decade.

The PV modules combined with a set of additional application-dependent system components (e.g. inverters, batteries, electrical components, and mounting systems), form a PV system. These PV systems are highly modular, i.e. modules can be linked together to provide power ranging from a few watts to tens of megawatts (MW).

The solar PV panels typically produce DC electricity that is fed to a grid interactive inverter, which in turn converts the DC electricity into AC electricity at a required voltage level. In order to achieve a higher system voltage, the output of inverters is fed to step up transformers to increase the voltage levels at the desired level. From the transformer, the power is routed through the high voltage panel and eventually to other required measuring & protection devices before connecting to the grid. The major equipment and components of a typical solar plant are shown in the following figure.

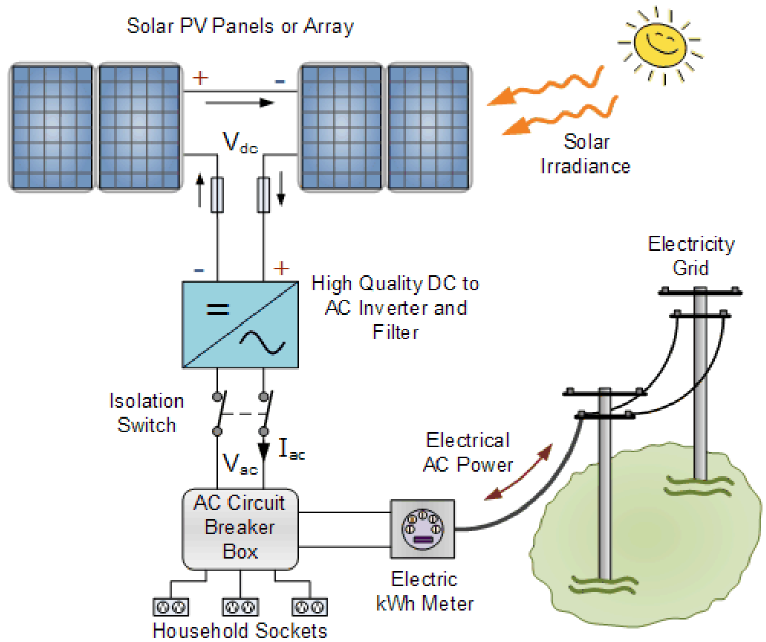


FIGURE 6: TYPICAL SOLAR PV SYSTEM COMPONENTS

6.1 Photovoltaic Technologies

Traditional solar cells are made from silicon, are usually flat-plate, and generally are the most efficient. Second-generation solar cells are called thin-film solar cells because they are made from amorphous silicon or non-silicon materials such as cadmium telluride. Thin film solar cells use layers of semiconductor materials only a few micrometers thick. Because of their flexibility, thin film solar cells can double as rooftop shingles and tiles, building facades, or the glazing for skylights.

Third-generation solar cells are being made from variety of new materials besides silicon, including solar inks using conventional printing press technologies, solar dyes, and conductive plastics. Some new solar cells use plastic lenses or mirrors to concentrate sunlight onto a very small piece of high efficiency PV material.
In spite of availability of all the technology, crystalline technology has maximum number of installation world wise and has been demonstrated to perform in the field in excess of 30 years. In addition to this, the technologies are described concisely as follows:

6.1.1 Crystalline Technology

Typically, there are two types of crystalline technology mono-crystalline and multi-crystalline. Both the technologies are made up of silicon material and have some pros and cons. Basic features of individual technology are as follows:

Mono-Crystalline Silicon

Mono-crystalline Silicon has a continuous crystal lattice structure with practically zero defects or impurities. Mono-crystalline Silicon is superior to other types of silicon cells in terms of higher efficiencies – which are typically around 18-23%. However, the mono crystalline Si-cell production is an expensive process when compared to other types of PV cells. Mono-Crystalline panels are mostly considered where the space is limited as in the case of rooftops. The lifespan of mono-crystalline cells is a minimum of 25 years and can go more, making them a worthwhile investment for long-term use.

FIGURE 7: MONO-CRYSTALLINE SILICON MODULE FIGURE 8: MULTI-CRYSTALLINE SILICON MODULE

Multi-Crystalline Silicon

Multi-crystalline (or poly-crystal) silicon panels are made by using polycrystalline wafers. Multi crystalline wafers consists of number of crystallites with different grain sizes will be having grain boundaries and several defects. Multi-crystalline Si growth is relatively cheaper than the mono crystalline Si and the cells made up of these wafers are relatively cheaper. Due to the less pure crystals, the efficiency of these cells reduces and the module efficiencies typically range in between 14-16%. The lifetime of these modules is also around 25 years or more and these panels are cheaper option where the space is not a limitation. These panels are commonly preferred ones for grid connected applications.

6.1.2 Thin Film Technology

Thin film modules are potentially cheaper to manufacture than crystalline cells have a wider customer appeal as design elements due to their homogeneous appearance present. Disadvantages include low-conversion efficiencies and requiring larger areas of PV arrays and more material (cables, support structures) to produce the same amount of electricity.

FIGURE 9: THIN FILM PV MODULE

Material costs and manufacturing costs are lower per unit area as compared to those of crystalline silicon cells.The comparison between both the technologies has been done below:

S. No.	Parameter	Crystalline	Thin Film
1)	Types of Materials	Polycrystalline/Monocrystalline	Amorphous Silicon, CdS, CdTe, CIS/ CIGS, etc.
2)	Handling	Better protection against breakage. Generally come with frames and are robust.	Frameless thin-film modules are common and require special care while installation
3)	Power Efficiency	14-18%	7-12%
4)	Technology	Well developed and has a track record for field performance of over 30 years	Relatively new technology with lesser track record on performance with respect to years of field operation
5)	Module Weight	Light weight modules (0.1Kg/W)	Slightly heavy modules (0.17 Kg/W)
6)	Area utilization	Higher power generated per unit area	Less power per unit area
7)	Temperature Effects	Highest impact of Temperature variations	Lesser impact of Temperature variations
8)	Irradiance	Used particularly for Normal radiations	Better performance with Diffuse radiations
9)	Module quantity	Lesser number required	More modules required
10)	Output per MW installed	High	Higher
11)	Land Requirement	Lesser space required per MW	Larger space requirement
12)	Cost	Highest cost per Watt	Lowest cost per Watt
13)	Environment Effects	Less Sensitive	Sensitive
14)	Stabilization	Stable power output from initial stages	Stability achieved after 1-2 months
15)	Availability	Easily available	Easily available
16)	Power Degradation	Less degradation	Higher degradation
17)	Plant Maintenance	Less maintenance required after installation so lower cost	High maintenance required, so high maintenance cost
18)	Repair	Relatively easy	Easy
19)	Cooling Requirement	Required	Not required
20)	Cabling	Well known, and lower cabling losses	Well known, and lower cabling losses
21)	Suitability for Grid Technology	Good	Good

6.2 PV Technology Recommendation

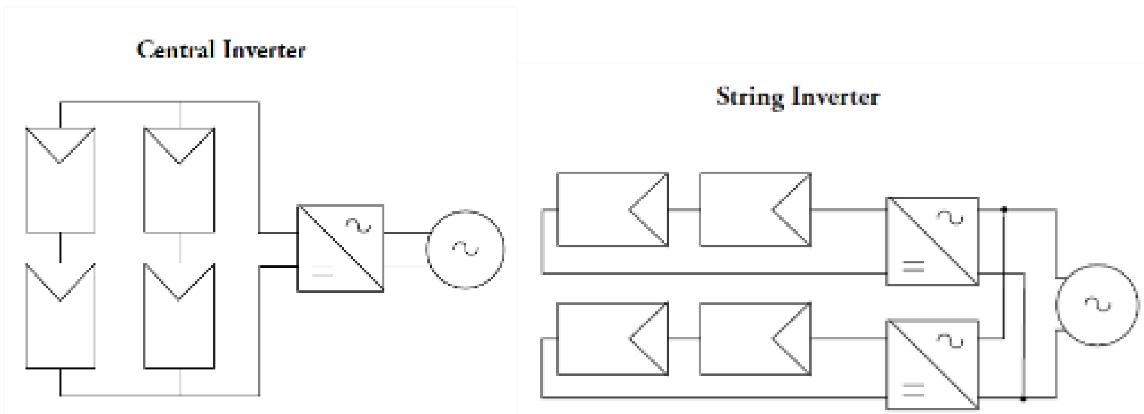
Each of the above technologies has their own particular strengths and limitations. Multi crystalline silicon photovoltaic technology is recommended for the project on the grounds of easy availability, cost effectiveness and technological stability.

6.3 Balance of Plant Systems (BoS)

On an average, BoS constitutes 40-45 % of the total project cost of a solar PV Project. For a solar PV Plant, the BoS comprises of inverters, cables, mounting structures, foundations and power electronics. Often assigned secondary importance irrespective of their being a significant cost component, BoS are critical determinants of the actual plant life. High technical standards of BoS components should therefore be ensured as a matter of standard practice.

6.4 Inverter Technologies

Solar inverter is a critical component in the solar energy system. It performs the conversion of the variable DC power output of array (string of the Photovoltaic (PV) modules) into a utility frequency AC power, which can be fed into the commercial electrical grid. There are mainly two category of solar inverters are available central, and string. A central inverter is generally for adopted for MW scale plant and string inverter can handle comparatively less power.



Inverter is the heart of a solar power project. It is also known as Power Conditioning Unit (PCU). A PCU consists of an electronic Inverter along with associated control, protection and data logging devices. Typically the utility scale inverters are unidirectional and supply the power to the grid in the form of AC power conforming to IEC 61727 or equivalent standard. The inverter has a feature that it automatically adjusts with the grid conditions such as the voltage & frequency levels to suit the Grid. It is advised that following key points can be considered while specifying your inverter requirements to various vendors.

a) Proven Technology: The inverter should be selected based on the proven technology and it is advisable that the inverter has completed at least one year successful operation in the high temperature weather conditions and fluctuating grid conditions.

b) Grid Compliance: At times you may require changing some of the key parameters of the inverters to match with your local grid conditions, hence the inverter should have features of changing some of the threshold parameters, and it can be programmed accordingly. It should also have features of grid islanding through Air Circuit Breakers. Some of the new generation inverters have provision of self-protective and self-diagnostic features so that it can protect itself from the PV array faults and adjust with the changing parameters of the solar PV array. The Inverter should have provisions of automatically ‘wake up’ in the morning and begin to export power provided there is sufficient solar energy and the grid voltage and frequency is in range.

The inverter should have MPPT control algorithm in such a way that it adjust itself with the voltage of the SPV array to optimize solar energy fed into the grid. The MPPT must have provision for constant voltage operation. The inverter MPPT feature should comply with EN50530 or Equivalent standard.

The inverter output always follows the grid in terms of voltage and frequency. This should be achieved by sensing the grid voltage and phase and feeding this information to the feedback loop of the inverter. Thus control variable then controls the output voltage and frequency of the inverter, so that inverter is always synchronized with the grid.

c) Inverter Efficiency: The efficiency of the inverter is another key factor, and most of the inverters are available in the efficiency range of about 97-98% efficiency levels. However it is important to make a note of the inverter efficiency at the part load conditions. Typically the part load efficiency levels are more than 97 % at 75% load as per IEC 61683 or equivalent standard. It is important to assess the inverter efficiency levels at different load say 25%, 50%, 75% and 100% and it should meet the IEC 61683 standard.

d) Control and Protection: The inverter should have internal protection arrangement against any sustained fault in the feeder line and against lightning in the feeder line. It should also have the required protection arrangements against earth leakage faults. The inverter should also have suitable rated DC disconnecting arrangement to allow safe startup and shut down of the system. Inverter should also have required protection arrangements against reverse polarity of DC Connection. There should be suitable surge protection arrangement to pass the fault current to earthing system. During the earth fault condition, the inverter should be having provision of disconnection.

e) Operational Flexibility: The inverter should have provision of parallel operation. Generally two inverters are connected to a single 3 winding transformer, the inverter should have flexibility to work in such combinations. The inverter should have feature of “ON” and “OFF” automatically based on solar radiation variations during the day.

The inverter should have suitable display panels so that all important parameters such as DC input voltage, DC input current, all phase to phase AC voltages, all phase AC current, AC output power, frequency, apparent power, reactive power etc. are visible to the plant operators. Some of the inverters come with a suitable PCU with display, and can be connected to the SCADA system.

During the sleep mode the inverter should be having the automatic control provisions so that the threshold dc voltage of the inverter can decide the inverter to enter in sleep mode and back to standby mode. The inverter must also automatically re-enter standby mode when threshold of standby mode.

The standard warranty of these inverters is 5 to 10 years. However many inverter manufacturer offer extended warranty also considering string inverter is a costlier proposition as compared to a central inverter, however an apple to apple comparison can only be made consideration of not only cost per watt of string versus central, but also cost reduction of DC cables and other associated benefits such as reduced down time in case of string inverter.

The central inverter takes input from number of arrays and operates at single MPP. Hence the inverter MPP (maximum power point) is governed by the arrays which are having partial shading, mismatch losses, modules with tolerances which may lead to reduce output in case of central inverter. However, this can be reduced by selection of string inverter as different strings have different MPP so that the output is maximized.

6.5 Cabling

a) DC Cables and Connectors: Working with solar PV arrays can be hazardous since Solar panels connected together in an array are often configured to produce high DC voltage. Furthermore, DC voltages are constant in nature so, effect of electric shock due to DC voltage will surely be severe. Hence, DC Cables should be double insulated and polarized and DC connectors should always be used. The minimum technical requirements for Cables laid down by MNRE states that they should conform to ‘’General Test and Measuring Method PVC insulated cables for working voltage up to and including 1100 V and UV resistant for outdoor installation’’ (Standard: IEC 60227 / IS 694 IEC 60502 / IS 1554 (Pt. I & II)). However, operating temperatures at the proposed Solar PV plant are expected to be high. Additionally, the corrosive conditions at the site would put the cable strength to test. Therefore, Electron–beam cross-linked DC cables, though marginally costlier, may be used. Adequate size of cable is selected for minimal voltage drop i.e. maximum voltage drops in the string designed to be around 1%.

b) AC Cables: In order to make the system more reliable and facilitate maintenance and management, output of three phase AC cables from the inverter are connected to AC disconnector unit. The voltage output of the inverter is connected to the transformer using required rating LT cables to step up the voltage. From the transformer, the lines are connected to grid. AC cables sizing are designed to achieve less than 1% of AC voltage drop from inverter to transformer. However, size of cable varies by relative position of inverter, transformer and grid supply lines.

6.6 Module Mounting System

Solar PV modules are mounted on the structure, generally casted of galvanized steel. Designing of mounting structure is majorly depended on two factors namely orientation scheme and wind load. In case orientation scheme is sun tracking scheme (Single tracking or duel tracking) then scope of movement in the tiled part of the structure is provided. Generally, this movement is achieved through a motor.

Second important consideration in the design of mounting structures is the nature of wind loads in the proposed location, taking into cognizance any seasonal /local winds that may exert additional load. Accordingly, the concrete blocks are to be designed to counter balance the load. This is done through STAAD Pro analysis or Field flow analysis. Inaddition, the material of the structure is to be selected in such a way that it serves at least for 25 years. In general, "galvanized steel" is used to make the structures. The mounting structures shall be designed as per the soil and wind conditions at the site. However, the typical practice is to design mounting structure to withstand a wind load of 160-170 km/hr. The support structure design & foundation shall also be designed to withstand wind speed applicable for the site conditions. Nut & bolts, supporting structures including Module Mounting Structures shall have to be adequately protected from atmosphere and weather prevailing in the area.

7. MAJOR COMPONENTS OF THE POWER PLANT

7.1 Introduction

The solar electricity is produced when the photons from the sun rays hit the electrons in the solar PV panels, this will generate Direct Current (DC). The DC electricity from the panels passes through inverter, which converts the DC electricity into 400V three phase AC which is stepped up through transformers at about 11 kV voltage levels and then to 66 kV to feed this electricity into the grid.

In order to achieve a higher system voltage, modules are connected in series, called a string. A higher system voltage has the advantage of less installation work (smaller conductor cross sections). Lower currents flow at the same efficiency so that cable losses are reduced. The strings are connected with the photovoltaic branch or the PV-distributor (Smart connect box). This distributor is connected with the Main Combiner Box (MCB) which acts as the main DC collecting unit which passes the power to be converted to the central inverters.

Central inverters combine the various advantages of the other installation technologies. Thus, the module fields are less sensitive towards partial darkening, as is the case with string inverters. This results in a very good MPP-matching of the inverters. Furthermore, installations can be expanded with additions of more modules without problems. Thus, photovoltaic installations of greater efficiency can be constructed economically.

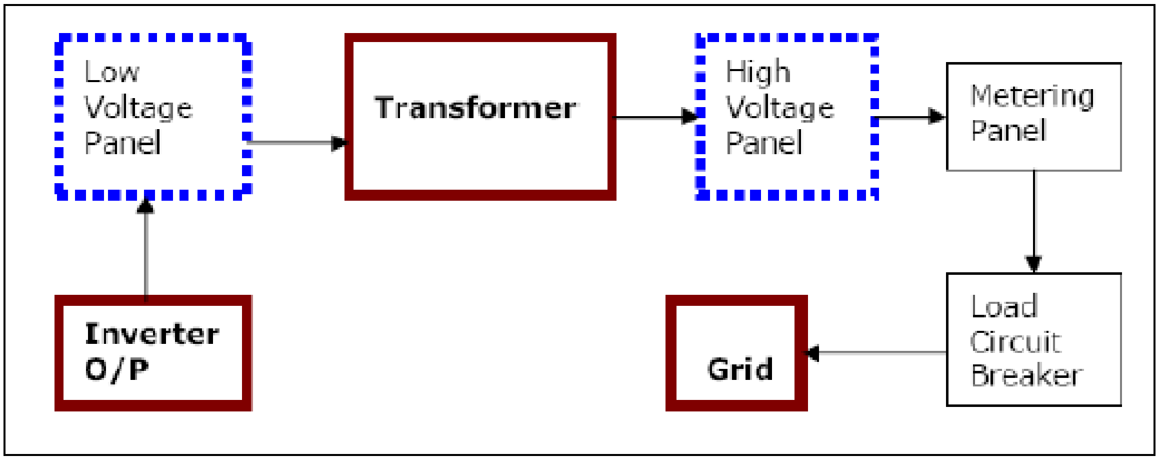
The AC power from the inverter are passed to low voltage panel and then to the main transformer. From the transformer, the power is routed through the high voltage panel and eventually to other required measuring & protection devices before connecting to the grid.

Grid connected solar power plant comprises of the main equipment and components listed below.

- Solar PV Modules
- Central inverters
- Module mounting system
- Grid connect equipment
- Monitoring system
- SCADA
- Cables & connectors

- Buildings for housing the electronics (Power-house)

A simple block diagram, related to the interconnection of various systems for grid connectivity, is shown below for reference. The power from modules is directed to the central inverters through the DC combiner boxes and from the inverters it is routed though the Low voltage panel to the transformer. From the transformer, the high voltage power is routed to the metering panel and eventually to grid through the High Voltage Panel.



7.2 Solar PV Modules

A photovoltaic module is a packaged interconnected assembly of photovoltaic cells, which converts sunlight into energy. For this project, multi crystalline PV technology solar module of 300 Wp is considered (Specification sheet enclosed in Annexure-III). Modules of higher capacity may also be used. The modules shall conform to IEC 61215, IEC 61730 and IEC 61701 standards. The proposed tilt angle for the modules is 18° (all the modules will be facing south).

7.3 Inverter

Inverters are used for DC voltage to AC voltage conversion. According to output voltage form they could be rectangle, trapezoid or sine shaped. The most expensive, yet at the same time the best quality inverters have output voltage in sine wave. Inverters connecting a PV system and the public grid are purposefully designed, allowing energy transfers to and from the public grid. Central inverters are used in large applications. Many times they can be connected according to the "master-slave" criteria, when the succeeding inverter switches on only when enough solar radiation is available or in case of main inverter malfunction. Inverters connected to module strings are used in wide power range applications allowing for more reliable operation.

In the proposed project the inverters will connect string of modules (each module of 300 Wp. The output of the strings will be connected to an ABB_Multi_MPPT 1000 kW inverter. For 20 MW solar PV plant, 20 inverters are required. The inverter converts the DC Power into AC power and feeds it to the grid. The inverters are designed with a high efficiency >98% with IGBT technology. It has a provision to deliver the maximum power generated through solar modules in to grid due to its in-built feature of MPPT operations. The inverter is having internal self-protection in case of any fault in the grid in addition to the inbuilt contactors/breakers with fuses for self-protections.

The inverters are self-synchronizing with the utility (grid) power with respect to the Voltage and frequency of grid and it gets corrected itself according to the grid parameters within its settable limits. The inverter is designed in such a way that it will sense the array power and grid power; if both are available it starts and stops automatically in the morning and evening respectively. Each inverter is having a remote and local data monitoring system with which we can monitor all the parameters and current energy generation & past generation for the given period. The output voltage of the inverter shall be connected to a step-up transformer of 0.400/11 KV.

FIGURE 14: TYPICAL SOLAR INVERTER

7.4 Module Mounting System

The module mounting structure is designed for holding suitable number of modules in series. The system will be fixed-tilt type hence requiring negligible maintenance requirements.The frames and leg assembles of the array structures is made of mild steel hot dip galvanized of suitable sections of Angle, Channel, Tubes or any other sections conforming to IS:2062 for steel structure to meet the design criteria. All nuts & bolts considered for fastening modules with this structure are of very good quality of stainless steel. The array structure is designed in such a way that it will occupy minimum space without sacrificing the output from SPV panels at the same time.

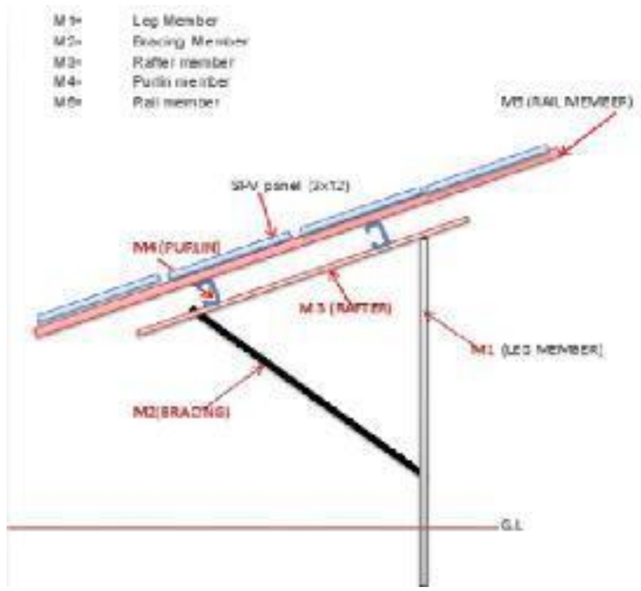


FIGURE 15: TYPICAL FIXED TILT MODULE MOUNTING STRUCTURE

7.5 String Combiner Box

Dust, water and vermin proof string combiner boxes of adequate rating and adequate terminal facility made of Fire Resistant Plastic (FRP) shall be provided for wiring. Each box shall be provided with fuses and surge arrestors of adequate rating to protect the solar arrays from accidental short circuit.

7.6 Monitoring System

System proposed will maintain and provide all technical information on daily solar radiation availability, hours of sunshine, duration of plant operation and the quantum of power fed to the grid. This will help in estimation of generation in kWh per MWp PV array capacity installed at the site. The system also enables diagnostic and monitoring functions for these components. Communication: Data modem (analogue/Ethernet), few features are presented as follows.

- Monitors the performance of the entire power plant (string wise monitoring, junction boxes, inverters, etc.)
- Evaluates (strings, inverter, nominal/actual value), quantity of DC Power & AC Power produced.
- Measures instantaneous irradiation level and temperature at site. It also measures the module back surface temperature.
- Alerts in case of error (discrepancy in normal operation of components, like module string/ diodes/ inverter/ junction box / loose contacts/ etc.) to facilitate recognition and correction of the fault with minimum downtime.
- Visualizes nominal status of the connected components via Control Center PC

Software (diagnosis on site or remote)
- Logs system data and error messages for further processing or storing
- Stores and visualizes energy yield data (for life of the plant) in the Portal from where the data can be accessed remotely.

SCADA
- The instrumentation & control system for the solar power plant will be based on the prevailing standard engineering practices
- Design will ensure full compliances of codes and standards as applicable the field of instrumentation & control for power plant
- The whole plant will be operated through SCADA system

The SCADA system shall have the following features:
- Monitoring: Ability to control, using specially designed devices, the state & evolution of one or various physiologic (or others) parameters to detect possible malfunctions
- Remote control: Group of devices which allow modifying the state of the equipment and devices of the plant, from a remote location

The SCADA system shall be used for the following minimum tasks:
- To invoice the produced energy
- To detect the incidences and malfunctions (up to logical string level)
- To give the information at a given time interval: a) Availability, b) Performance Ratio and Energy Production

The SCADA System will be reliable and robust and some components need redundancy for trouble free operation.

7.7 Cables and Connectors

The size of the cables between array interconnections, array to junction boxes, junction boxes to PCU etc. shall be so selected to keep the voltage drop and losses to the minimum. The bright annealed 99.97% pure bare copper conductors that offer low conductor resistance, they result in lower heating thereby increase in life and savings in power consumption. These wires are insulated with a special grade PVC compound formulated. The skin coloration offers high insulation resistance and long life. Cables are flexible & of annealed electrolytic grade copper conductor and shall confirm to IS 1554/694-1990 and are extremely robust and resist high mechanical load and abrasion.

Cable is of high temperature resistance and excellent weather proofing characteristics which provides a long service life to the cables used in large scale projects. The connectors/lugs of copper material with high current capacity and easy mode of assembly are proposed.

7.8 Buildings for Plant Equipment (Inverter Rooms and Control Room)

Concrete or pre-fabricated buildings will be utilized for housing the inverters, Low Voltage panels, High Tension panels, Plant Monitoring system, Safety equipment, Office room etc.

The buildings will be equipped with all necessary safety equipment as per the safety rules and shall be appropriately ventilated. The equipment will be erected as per the Indian Electrical Standards. The cables will be routed through cables trenches or cable trays as required. Alarm system will be provided to alert the operator in case of emergency or plant break-down.

The proposed power transformer will be installed outside next to the main control room.

The civil engineering and building works shall include the design, detailing, and construction of all foundations, structures, buildings, installation and service of facilities required for the installation, commissioning, operation and maintenance of all equipment associated with the power plant.The civil works includes preliminaries, additional survey, soil exploration, piling if needed, ground improvement, foundations, and all necessary site investigation associated with the operations: Site roads, site leveling and grading with boundary fences, and gates. In order to avoid flooding, rain water drainage system is provided all around the plant layout.

FIGURE 16: TYPICAL CONTROL ROOM SECTION

7.9 Other Facilities Including Water

The other important requirement for the power plant is water, which will be used pre-dominantly for module cleaning. An over-head tank / underground sump will be constructed as per the requirement for the water storage.

A first-aid station will be located as part of the power house/office room. Sufficient space will be provided for vehicle parking near to the power house. Within the layout approach roads will be made for easy movement of man & machines.

8. POWER EVACUATION AND INTERFACING WITH GRID

It is important that the power plant is designed to operate satisfactorily in parallel with grid, under the voltage and frequency fluctuation conditions, so as to export the maximum possible units to the grid. It is also extremely important to safeguard the system during major disturbances like tripping, pulling and sudden over loading during the fluctuation of the grid loads on the generating unit in the island mode, under fault/feeder tripping conditions.

8.1 Power Evacuation Plan

The Direct Current (DC) from modules is converted into Alternating Current (AC) by Inverters. The inverter outputs are given to a 0.400kV/11kV and then stepped up into 132 kV external transformers located outside the inverter rooms. Then power shall be evacuated to the nearest substation.

The Power evacuation system comprises of following major components:

- 11kV Transformer – Oil immersed type with Off circuit tap changer with all accessories
- 66kV Transformer – Oil immersed type with Off circuit tap changer with all accessories
- Low Voltage (LV) Panel
- High Tension (HT) Panels
- LT & HT cables
- Control & Power evacuation cables

8.2 Transformers

The proposed transformer shall be installed outdoor suitable for hot, humid and tropical climate. The transformer will be free from annoying hum and vibration when it is in operation, even at 10% higher voltage over the rated voltage. The noise level will be in accordance with respective standards.

The transformer will be designed and constructed so as not to cause any undesirable interference in radio or communication circuits. The oil filled transformer will be capable

of operating continuously at its rated output without exceeding the temperature rise limits as given below over design ambient temperature of 50 deg C.

- In oil by thermometer 50 deg C
- In winding by resistance 55 deg C

The transformer will be designed to withstand without injury, the thermal and mechanical effect of short circuit at its terminal with full voltage maintained behind it for a period of 1 second. The transformer will be capable of continuous operation at the rated output under voltage and frequency variation without injurious heating at that particular tap for all tap positions.

Phase connections will be delta on LV side and star on HV side. HV side shall be resistance earthed. HV side shall be suitable for connection to HT panels for the respective transformers. LV side shall be suitable for connection to LV panel. Transformer will be designed for over fluxing withstand capability of 110% continuous and 125% for at least 1 minute. Further it shall be capable of withstanding 140% of rated voltage at the transformer LV terminal for a period of 5 seconds to take into account sudden load throw off conditions.

Overloads will be allowedwithin conditions defined in the loading guide of applicable standard. Under these conditions, no limitations by terminal bushings, off circuit tap changers or other auxiliary equipment shall apply.

8.3 66 kV Switchyard

66kV Switchyard has been envisaged for evacuation of power through Step up Transformers for the proposed plant. The switchyard shall be located in adjacent to Central Control Building. The switchyard shall be interconnected with the 66kV grid Substation by means of overhead conductor.

Switchyard equipment:

a) Circuit beakers

The circuit breakers and accessories will be in general conforming to IEC: 600 56, IS 60947 Part I, II, III, EN 50521 and IS: 13118 as applicable. The circuit breaker will betotally re-strike free under all the duty conditions and will be capable of breaking magnetizing current of transformer and capacitive current of unloaded overhead lines without causing over voltages of abnormal magnitudes.

b) Disconnecting Switches

Electric motor operated center rotating post horizontal double break triple pole disconnecting switch with or without earth switch will be provided. Operation of the disconnecting switch will be interlocked with associated breaker and earth switch.

c) Current Transformers

Live or dead tank type single phase multi-core multi ratio current transformers will be provided for indication, metering and protection requirements. Accuracy of tariff metering cores shall not be less than Class 0.2. Separate CT cores will be provided for Main and Check Tariff Metering.

d) Inductive Voltage Transformers

Inductive voltage transformers (IVTs) with multiple secondary windings will be provided on lines, bus bars and step up transformers for metering, protection and synchronism requirements. Separate cores with Class 0.2 accuracy will be provided for metering.

e) Lightning & Surge Arresters

Metal oxide (gapless) surge arresters of heavy duty station class (discharge class III) shall be provided on each phase of 11 kV bays. The arrester will include a digital impulse counter and leakage current detector.

Lightning Arrestor will be of non-linear resistor type. Unless otherwise modified in the specification the lightning arrestor shall comply with IS 3070(Pt.1)1974 or the latest version thereof.

f) LT Switchboard

The auxiliaries would be obtained from 11/0.415 kV auxiliary transformers. The system will be a stable earthed system. The switchgear would be of metal enclosed design with a symmetrical short circuit rating of 50 kA for 1 sec. All power and motor control centers will be compartmentalized and will be of single/double front execution.

8.4 HT, LV, 66 kV Metering Equipment

Under the normal climatic and earthquake conditions, the HT and LV panels will meet the following requirements:

1. The physical alignment of switchgear panel along with incoming and outgoing feeder connections, supporting insulators & structures of bus bars will not get disturbed and there will not be any internal flashover and/or electrical fault.

2. All relays, transducers, indicating instruments, devices in switchgear panels will not mal-operate.

3. Current carrying parts, supporting structure, earth connection etc. will not get dislocated and /or will not break or distort.

4. Co-ordination with other systems

All equipment will have necessary protections. Every switchgear will be provided with necessary arrangement for receiving, isolating, distributing and fusing of 230V AC and DC supplies for various control, lighting, space heating and spring charging circuits. DC supply for control shall be duplicated for each board which shall run through auxiliary bus wires.

8.5 Cables

Cables will be unearthed grade suitable for use in medium resistance earthed system, with stranded & compacted aluminum conductors, extruded semi-conducting compound screen, extruded XLPE insulated, extruded semi-conducting compound with a layer of non- magnetic metallic tape for insulation screen, extruded PVC (Type ST-2) FRLS outer sheathed, multi-cored conforming to IS 7098 (Part II) IEC-60502 for constructional details and tests.

LT Power Cables

LT Power Cable will be unearthed grade, multi-core, stranded aluminum conductor, XLPE insulated with PVC outer sheath made on FRLS PVC compound. All other details will be as applicable. Minimum conductor cross section of power cables will be 6 Sq.mm.

Control Cables

Control cables will be 1100V Grade, multi-core, minimum 2.5 mm2 cross section, stranded copper conductor having 7 strands, PVC insulated, and outer sheath made of FRLS PVC compound. In situations where accuracy of measurement is or voltage drop in control circuit is not warrant, higher cross sections as required will be used. 4 sq.mm copper conductor cables will be used for CT circuits all other specifications remaining same.

Power Evacuation Cable

XLPE insulated, aluminum cable confirming to IS 7098 of required length shall be provided for power evacuation.

8.6 Grid Synchronization Scheme

The output power from inverter is stepped up into 11 kV then again stepped up into 66kV and fed to the transmission line through 66 kV metering and protection equipment located in the plant’s switchyard.Transmission line towers shall be installed at equal intervals. The number of towers required is determined based on sag calculation. The location of structures will be decided during detailed engineering.

9. PROJECT IMPLEMENTATION STRATEGY

9.1 Project Phases

It is envisaged that the project will have the below mentioned phase of activities. These phases are not mutually exclusive; to implement the project on fast track basis some degree of overlapping is envisaged.

1. Project Registration and Financing
2. Finalization of the Equipment and Contracts
3. Procurement and Construction
4. Plant Commissioning and performance testing

9.2 Project Registration and Financing

In a power project, registration and financing of the project is the first critical step towards development. The below listed tasks will be under project development:

1. Preparation of Detailed Project Report (DPR)
2. Participation in RFQ/submission of application with documents for registration
3. In Principle clearancefrom state nodal agency
4. Financial closure

9.3 Finalization of the Equipment and Contracts

In the power plant, PV modules, inverters and transformers are the long lead items and the planning schedule for the project implementation should provide adequate time period for the installation of these equipment. The specifications for major equipment like the Modules, Inverters and Transformer design shall be drawn up at an early stage of the project. Program of design information, from the equipment suppliers, that satisfies the overall project schedule shall be drawn up.

Since, the project execution calls for closer coordination among the contractors, consultants and the company, proper contract co-ordination and monitoring procedures shall be made to plan and monitor the project progress.

9.4 Procurement and Construction

The contractor for construction will be chosen from market competitive assessment taking into consideration:

- How many MW of projects have they commissioned in the past few years in India or globally
- Performance of their plants in terms of generation output since commissioning of the various projects.
- Their relationships with key suppliers such as modules and inverter suppliers
- The strength of their balance sheet to be able to support the guarantees they will have to provide.
- Their design approach to ability to be innovative to optimize generation
- Ability for construction plus evacuation
- Reference check from some of their customers.

10. PROJECT TEAM

The project implementation can be executed with perfection without any time & cost overruns, by forming a Project team within the Company which will be responsible for project supervision and involved in execution from the start of the project i.e., from engineering stage itself and later on takeover the operation of the power plant. This will enable the project team to get familiarized with the technology and equipment they are going to handle.

This project team will be having a Project Managers who will be supported by Engineers with multi-disciplinary specializations.

This team will also get actively involved in the construction and commissioning phase and as such trained manpower is not available in the country with exposure to technology will become a valuable resource for the company.

This team will become responsible for:

- Implementation
- Soil investigation
- Co-ordination and arranging for all requisite statutory compliances / consents for project implementation
- Project planning & programming in consultation with the Technical consultant
- Co-ordination with the Turnkey project executor for smooth implementation as per the contractual agreement
- Ensuring the terminal points and provide site support services w.r.t. land availability, storage space availability, utilities, construction power, civil front construction.
- Inspection of equipment
- Monitoring work progress & generation of reports
- Periodic project reviews and interactions
- Control over the project cost
- Ensure the grid connectivity to the project site from the nearest sub-station, as it will have a major impact on timely project commissioning on completion of construction,
- Check for proper implementation of the project as per specifications & drawings.
- To ensure all statutory compliances required for commissioning of the project.
- Assist the Turnkey Project Executor in Plant commissioning & stabilization activities.
- Performance tests & Trial runs
- On successful of above, takeover plant operation

11. PROJECT COST ESTIMATE

11.1 EPC including Plant & Machinery:

The plant machinery cost is inclusive of all costs associated with mechanical, electrical & control requirements of a solar power project. Apart from main equipment, the project cost also includes all auxiliary equipment and all the civil and structural work covered in this cost. All costs involved in the plant erection, testing and commissioning are included in the overall plant & machinery cost. Considerable amount for requisite operation spares have been accounted. The total cost of EPC is given in the Annexure

11.2 Financing – Debt component:

It is anticipated that Financial Institutions / commercial banks normally finance a power project in the Debt: Equity ratio of 70:30 and the same will be made applicable to the solar power project by the developer

- 70% of the project cost will be the term loan component
- Project Developer will bring in 30% of the project cost as equity
- Term loan interest for the project is assumed as 13%
- Loan tenure of 10 years.

The project also has a potential to get various subsidies once it has been commissioned. There is a scope to get 20% VGF on the project cost and another 20% potential through DoNER for this project. The economics of the project would change after acquiring these funds and make it more profitable.

11.3 Contingency

The technology & implementation is new and there is an over dependency of supply from outside the country and hence a contingency of 2.5% of total cost of project has been considered

11.4 Working Capital Margins

Given in Annexure

11.5 Total Project cost

The project specific breakdown for 1MW based on NERC/CERC specifications is given below. We have also given a table indicating the total project cost per 1MW.

PV Modules

As mentioned in the justification sheet, we will be using Tier-I Company Solar PV Mono- Crystalline Modules with 25year performance guarantee and 10year product warranty. This consists of using a mixture of 320Wp - 350Wp modules. These TEIR I modules will have an efficiency above 19% under STC and will have a depreciation of only 0.5% per year. Given below are the description for your understanding:

- A Tier 1 manufacturer is vertically integrated and exists for more than 5 years. This means that all production steps, including wafer manufacturing and up to assembly of the modules, are done in-house and are automated. These companies are usually the product innovators and first to introduce the latest, efficient techniques.

- A Tier 2 manufacturer is a somewhat younger company that does not always have R&D activities and usually buys the wafers from a Tier 1 manufacturer. Not all is automated in a Tier 2 company which means there is a higher fault risk.

- A Tier 3 manufacturer is usually a young company. They employ techniques of the Tier 1 group. The cells are mainly soldered by hand which again means that there is a higher fault risk than with an automated process.

The table below shows the price ranges/quotes of the modules available in the current market.

Type	Wattage Range	Price (Rs./Wp)
Tier – 1 (Canadian Solar, Trina, etc)	330Wp – 355Wp	Rs. 24.50
Tier – 2 (REC, Waree, etc)	320Wp – 330Wp	Rs. 22.0
Tier – 3 (Surana, Vikram Solar, etc)	320Wp – 325Wp	Rs. 30.0

Please keep in mind the above prices are the landing cost to Chennai or Kolkata port. We have to bare additional cost such as GST (5%) and transportation cost to the Peren (which adds up a lot of cost).

Quotation offered by Canadian Solar dated 01/11/2017 is attached below.

CanadianSolar

DATE: 01.11.2017

To,

Halo Energie Pvt Ltd

Hyderabad

Subject: Proposal for supply of PV Modules for 1.1 MW DC (1.0MW AC) Solar PV project in Nagaland

Dear Sir/Madam,

With reference to subject cited, our company would like to give you our proposal for supply of Mono Crystalline PV Modules on MW basis. We will supply 330Wp - 350Wp Mono/Poly Crystalline PV Modules with RFID, performance guarantee of 25 years and product warranty up to 10 years.

Taking into consideration the location, ship liner charges, C&F clearances, logistics, transit insurance, unloading, etc., our quote for this Supply would be INR 350.0 Lacks (Three Hundred and Fifty Lakhs) for 1.10 MW. Additional GST of 5% is applicable.

We look forward to hearing from you.

Thank you.

For Canadian Solar

199 Lushan Road, Suzhou New District, Jiangsu, China 215129

Civil & General Cost

As mentioned in the justification sheet, under this section we will cover RCC Foundations to the designed depth with 50MT/MW TMT bars, construction of Inverter & Control Rooms, Watch Towers, Compound wall. Cutting and filling the areas according to contour (Area grading and clearing of jungle) and laying of water pipelines for cleaning purpose.

One of the biggest reasons for the increment in price is due to the location. The logistics, transportation, labor components are increased by approximately 15% to 22% when compared to other areas. The detail breakdown is as per Nagaland PWD Schedule rate and is as shown as below:

Type	Description	Price
Steel (JSW grade 1 TMT bars)	We will be using 10mm 500D (ductility) TMT bars. Each bar is roughly 10ft long	Rs. 48,000 to Rs. 50,000 per Ton
Construction of inverter rooms, security rooms, storage areas, compound wall (some portions for security), watch tower, internal roads	We will be using sand, cement (best quality), 40mm and 20mm jelly beans, concrete mixers	Our estimate is anywhere between Rs. 2100 to Rs. 2500 per sft (square feet). Cement: Rs.350 – Rs.380/bag Sand: Rs. 60,000 per 10Ton Jelly beans: Rs. 12,000 per 300cc
Land clearance involves jungle clearing, grading of the land cutting and filling of certain areas (based on contour)	We need multiple JCB’s, dozers, rollers, vibrators to do this activity. We will also need heavy load Hitachi machines and chainsaws as well. These machines work on hourly basis. We not only have to pay rent, but also have to transport these machines in special vehicles to the site.	JCB: Rs. 1000 per hour Dozer: Rs. 1000 per hour Vibrator: Rs. 1600 per hour Hitachi Chainsaw: Rs. 2200 per hour

Also keep in mind, these are all subject to availability around the project site. Some might have to be brought from longer distances. The GST is extra on all the above components varying from 5% to 18%.

Mounting Structures

As mentioned in the justification sheet, under this section we will cover hot dipped Galvanized MMS above the ground level of 25 MT per/MW such as rafters, purlins etc.

This is an extension of the civil and general works section, but more specifically we will use rafters, purlins, structures, nuts, bolts, L shaped cleads etc. All of these components are galvanized. Usually galvanization cost based on tonnage. Since there are no galvanization units near the site, we have to galvanize them in a different area and transport it to the site. The rough estimate for galvanization based on our past projects is Rs.1.7Lks per 1Ton. Transportation is extra.

Power Conditioning Unit

As mentioned in the justification sheet, under this section we will cover Tier-I Company Inverters with smart controller, HT, LT breakers, power transformers, AC & DC cables from SCB. Scada and weather monitoring system with online UPS.

The table below shows the various components that will be used and their supplier quotes:

Type	Description	Cost
Tier 1 Inverters (ABB, Schneider,AEG,etc) Tier 2 Inverters (TMEIC, Delta,etc)	We will be using the latest string inverters of capacity 1.73MW each. Depending on the design we might also use 1MW inverters as well.	1.73MW inverter: Rs. 35Lks 1MW inverter: Rs .20 Lks (Tier 2 Inverter companies make 1MW and 500kW inverters ranging between Rs. 15lks to Rs. 18Lks)
Breakers (ABB, Megawin, etc)	We will be using both HT and LT breakers. The number of breakers will be arrived after confirmation of the design.	HT breaker: Rs. 4.5Lks LT breaker: sometimes inbuilt in the inverter.
Transformer (PETE)	Correct number will be determined after design confirmation. But usually we will be using 5MVA transformers for a capacity upto 4MW or 2 x 3.5MVA breakers for up to 5MW.	Each 3.5MVA breaker: Rs. 28lks
AC & DC Cables (Polycab, Havels, Schneider,etc)	We will be using armored cables all over the site. We will be using 6Sq.mm, 185sq.mm, 240sq.mm cables. The core varies from 4 core to 10 core aluminum.	6sq.mm: Rs.75/meter 185sq.mm: Rs. 1,500/meter 240sq.mm: Rs. 1,800/meter
String combiner boxes and online UPS SCB companies: (Armax, ABB,etc) Online UPS: (Delta, Eaton, etc)	Roughly we would be needing 6 SCB's per 1MW. Coming to the UPS, we will be using 5kVA capacity. We need 2 online UPSs for 1MW.	SCB: Rs.1Lk per box Online UPS: 1.5Lks per 5kVA
Scada and weather	We need hardware and	Both put together our

monitoring system Companies: (FlexiMC, Pheonix, etc)	software components along with cloud data storage for the SCADA and weather monitoring. High speed internet cables are also a part of this. We will also use PLCs and local scada as well.	estimate is Rs.7lks to Rs. 7.5Lks per 1MW

Additional GST is applicable for all components. Most of them fall under the 5% category, while some imported components have 28%.

Evacuation up to Interconnection point:
As mentioned in the justification sheet, under this section we will cover transmission line (66kv) up to the Government substation along with RCC 9.5M poles and 18M tripod towers. This also includes Bay extension (ABT meters, breakers, 6 pole structure along with CT, PT set up) at government substation. Auxiliary transformer, switchyard breaker, CT, PT setup at the plant evacuation point

We will have to lay transmission line not only from the end point of the site to the substation, but also from the plant switchyard (which might be located on the opposite side of the land entrance). This will increase the distance for laying. This will only be finalized after the design is confirmed.

The tables below show the components that will used and their supplier quotes involved in 3 areas (substation, switchyard, and Transmission line):

At the Substation:

Type	Description	Cost
CT & PT on top of busbar	We will install 3 CTs and 3 PTs	Estimate of Rs. 1.8Lks (all 6)
Lightening Arrestor	6 arrestors will be installed	Around Rs. 20,000
6 pole structure	This will be a 9.5M structure poles	Rs. 50,000
ODS Material	This will be galvanized. We need roughly 5 tons	Rs. 120/kg
Breaker	Single breaker(MEI)	Rs. 5.5Lks
ABT Meters	3 meters will be installed; Main, check, standby	Rs. 1lk
GI flat + Earth mat	We have internally dig the substation ground and lay the flats and sloder them to avoid earthing	As per estimate
Jelly bean + erection + Labour		As per estimate

Additional GST applicable

The above details are for 2MW capacity. For 2MW, the bay size is roughly 4M x 6M. For our 20MW, the size will increase and so will the components by 10 times. The exact number and size will be arrived after design finalization.

At the switch yard (plant end):
Same components as given in the substation. We will repeat the same set. The only extra component will be Auxiliary Transformer. We will be using 40kVA for 4MW (company PETE) which roughly costs around Rs. 1.2 Lks. GST is extra @ 5%.

Transmission Line:

Type	Description	Cost
Tripod Towers	These are 18M height tripod towers. The distance between each of the tower will be roughly 50 Meters	Estimate for all the components put together is roughly Rs. 2.5Lks per 1KM
Coed Conductor	On each pole, there will be three lines running. (RYB)	
Ls and other fitting equipment	Where required	

GST is extra. We are estimating the entire distance to be roughly 10km.

BILL OF MATERIALS FOR 1.0 MW SOLAR PV PROJECT				
Sl No	**Particulars**	**Capital Cost (Lks)**	**Percentage**	**Description**
1	PV Modules	203.28	48.40%	Tier-I Company Solar PV Mono- Crystalline Modules with 25 year performance guarantee and 10 year product warranty. This consists of using a mixture of 345Wp - 350Wp modules. These TEIR I modules will have any efficiency above 18% under STC and will have a depreciation of only 0.5% per year
2	Land Lease (Per MW per Year)	0.21	0.05%	Government fixed rate for 5 acres (1MW requires 5 acres) per year
3	Civil & General Works	50.40	12.00%	RCC Foundations to the designed depth with 50MT/MW TMT bars, construction of Inverter & Control Rooms, Watch Towers, Compound wall. Cutting and filling the areas according to contour (Area grading and clearing of jungle) and laying of water pipelines for cleaning purpose
4	Mounting Structures	35.70	8.50%	Hot dipped Galvanised MMS above the ground level of 25 MT per/MW such as rafters purling etc
5	Power Conditioning Unit	33.60	8.00%	Tier-I Company Inverters with smart controller, HT, LT breakers, power transformers, AC & DC cables from SCB. Scada and weather monitoring system with online UPS
6	Evacuation cost upto interconnection point (Cables & Transformers)	54.60	13.00%	Transmission line (66kv) upto the Government substation along with RCC 9.5M poles. This also includes Bay extension (ABT meters, breakers, 6 pole structure along with CT, PT set up)at government substation. Auxillary transformer, switchyard breaker, CT, PT setup at the plant evacuation point
7	Pre operative& preliminary expenses including IDC & Contingency	42.00	10.00%	SPV formation, debt syndication, processing fee and other permission approvals. Transportation of all equipments, custom clearences, procurement of skilled & unskilled manpower, travel expenses, lodging and boarding of engineers, etc.
	Total Capital Cost	**420.00**	**100.0%**	

12. LIST OF SUPPLIERS

For present analysis PV modules from Canadian Solar and inverters from ABB have been used. The suppliers for modules/inverters may change before procurement stage without any significant impact on energy generation. Supply of equipment is planned to be sourced from either of the reputed suppliers listed as follows:

TABLE 14: PV MODULE SUPPLIERS

S.No.	Supplier	Website
1	Renesola	http://www.renesola.com/
2	Tata Power Solar	http://www.tatapowersolar.com/Globally-Trusted-Modules/Speciality-Modules
3	Jinko Solar	http://www.jinkosolar.com/
4	Canadian Solar	http://www.canadiansolar.asia/in/
5	Trina Solar	http://www.trinasolar.com/
6	Yingli Solar	http://www.yinglisolar.com/en/
7	Suntech Power	http://www.suntech-power.com/
8	REC Solar	http://www.recsolar.com/
9	JA Solar	http://www.jasolar.com/

The following table contains a list of major PV inverter suppliers having presence in India:

TABLE 15: MAJOR PV INVERTER SUPPLIERS IN INDIA

S.No	Manufacturer	Website
1	ABB Ltd.	http://new.abb.com/indian-subcontinent/about
2	AEG Power Solutions Ltd.	http://www.aegps.com/en/
3	Delta Energy Systems	http://www.solar-inverter.com/in/index.htm
4	Refusol	http://solarenergy.advanced-energy.com/en/refusol.html
5	SMA India	http://www.sma-india.com/
6	Schnider Electric	http://www.schneider-electric.com/
7	Hitachi	http://www.hitachi-hirel.com/res.htm
8	Toshiba	http://www.toshiba-tds.com/tandd/technologies/smartgrid/en/solar.htm

The following table contains a list of 5 major cable suppliers in India:

TABLE 16: MAJOR CABLE SUPPLIERS IN INDIA

S.No.	Manufacturer	Website
1	Polycab Wires Pvt .ltd	(http://www.polycab.com/)
2	KEI Industries Ltd., Delhi	(http://www.kei-ind.com/)
3	Finolex Cables Ltd., Pune, Maharashtra	(http://www.finolex.com/)
4	Siechem Cables	(http://www.siechem.com/)
5	Havells India Ltd., Noida, Uttar Pradesh	(http://www.havells.com)

13 CONCLUSION

The expected annual generation of electricity from the proposed 20 MW power plant will be about 2,81,85,910 KWh of energy for the first year which gives a minimum of 18.0% (AC) PLF. The proposed location has good solar Insolation and the project is financially viable.

Form 1.1

Sl. No	Assumption Head	Sub-Head (1)	Sub-Head (2)	Unit	Parameter Values
1	Power Generation	Capacity	Installed Power Generation Capacity	MW	20
			Capacity Utilization Factor	%	19.2
			Commercial Operation Date	mm/yyyy	08/2021
			Useful Life	Years	25
2	Project Cost	Capital Cost / MW	Normative	Rs. lakh / MW	420.0
			Capital Cost	Rs. lakh	8400
			Capital Subsidy, if any	Rs. lakh	-
			Net Capital Cost	Rs. lakh	8400
3	Financial Assumptions	Debt Equity	Tariff Period	Years	25
			Debt	%	70
			Equity	%	30
			Total Debt Amount	Rs. lakh	5880
			Total Equity Amount	Rs. lakh	2520
		Debt Component			
			Loan Amount	Rs. lakh	5880
			Moratorium Period	Years	1
			Repayment Period (incld Moratorium)	Years	10
			Interest Rate	%	11.0
		Equity Component			
			Equity amount	Rs. lakh	2520
			Return on Equity for First 10 years	% P.a	10
			Return on Equity 11th year onwards	% P.a	18
			Discount Rate	%	12.2
		Depreciation			
			Depreciation Rate for first 12 years	%	7%
			Depreciation Rate 13th year onwards	%	1%
		Incentives	Generation Based incentives, if any	Rs. lakh P.a	NA
			Period for GBI	Years	NA
4	Operation & Maintenance	Normative O&M Expenses		Rs. lakh / MW	6.02
		O&M Expenses per annum		Rs. lakh	120.4
		Escalation factor for O&M Expenses		%	5.72%
5	Working Capital	O&M Expenses		Months	10
		Maintenance Spare	(% of O&M expenses)	%	1
		Receivables		Months	2
		Interest on Working Capital		% P.a	0

10.6 Total Project cost

The total project with Interest during construction works out to Rs.84.0 Crores. Out of this, 70% i.e., Rs.58.8 Crores Approx will be term loan component from Financial Institution / Banks and the rest 30 % i.e., Rs.25.20 Crores Approx will be brought in as equity for the project by the project developer i.e, M/s Halo Energie Pvt. Ltd. The Cost per MW Rs.4.20 Cr.

10.7 Tariff

Over the period of 25 years, the tariff charged to the government has been given below. These tariffs are subject to change based on any incentives/subsidies received from the government.

Year	Levelised Tariff
1 – 25	Rs.4.20/kWh

For Halo Energie Pvt Ltd

Director