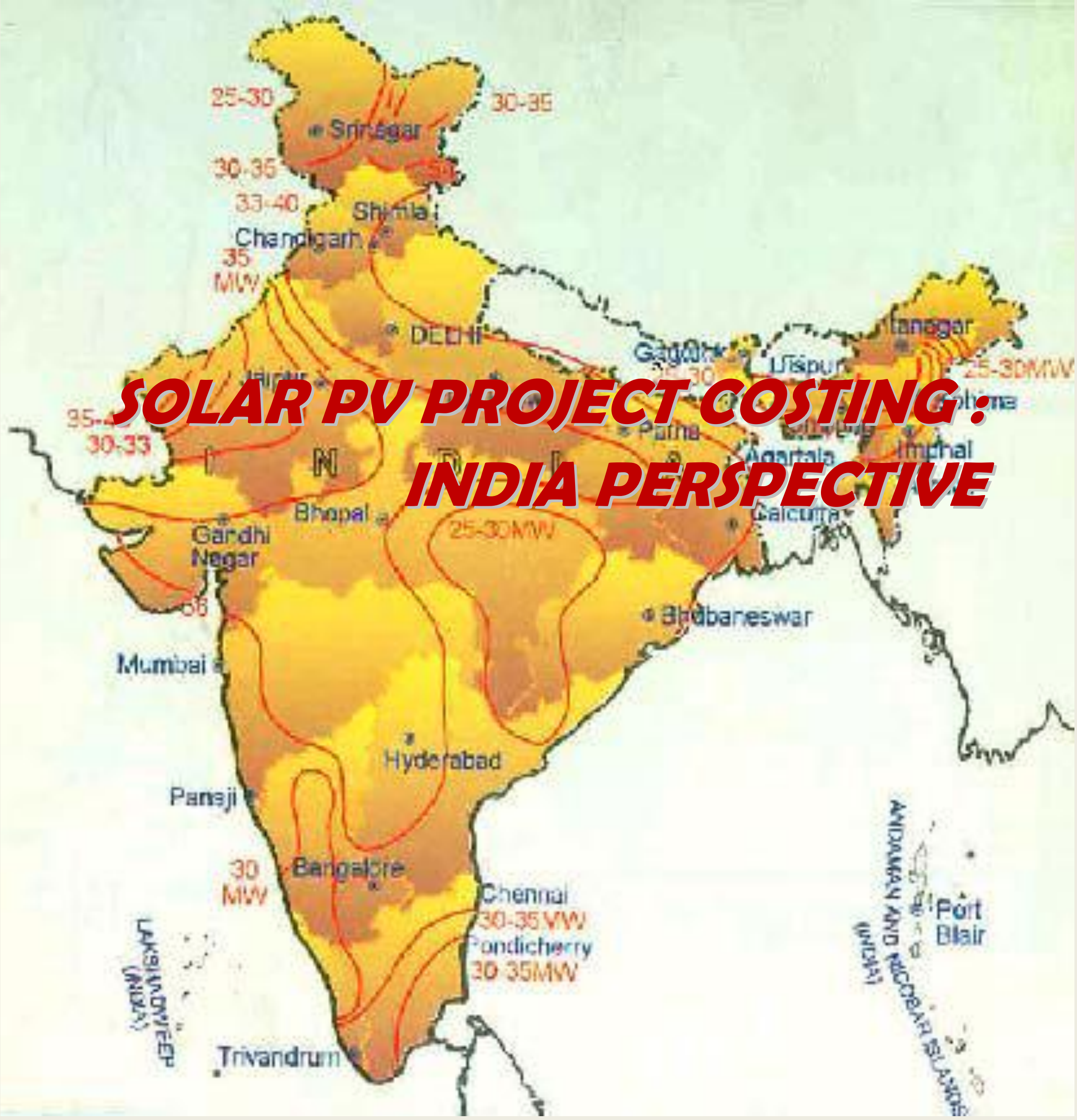
SOLAR PV PROJECT COSTING : INDIA PERSPECTIVE



Rear view of experience in last 2 years

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1.0 Background:

There are many queries from new developers, investors, users to have understanding of Solar Project – What, How… and to have simplified understanding of cost, land requirements, available technologies (Grid Connected / Off Grid, Ground Mounted / Roof Top, Hybrid, Fixed tilt / tracking… Thin Film / Poly Crystalline / Mono crystalline….).

This article is an attempt to provide consolidated academic understanding of above answers in Indian context with a rear view of Indian Solar Industry's experience in last 2-3 years. The inputs are consolidated as available on public domain without any responsibility of its accuracy or authenticity.

1.1 Introduction:

If we compare the cost of power from new coal-based plants, it will be at par with that of solar. If one takes into account the total duration of the power purchasing agreement, which is 25 years, grid-parity is already there.

Solar power needs only a one-time investment in the form of land and PV panels. Its fuel, which is sunshine, is free unlike coal where price will head only northwards.

Solairedirect, a solar power producer, was the lowest bidder at Rs 7.49 per unit for a 5MW plant auctioned under JNNSM in December, 2011 while the average tariff bid for 350MW under the mission was Rs 8.8 per unit.

Three years ago, the cost of generating a unit of solar energy was around Rs 18. In fact, solar has already taken over diesel as a cheaper form of energy and a lot of telecom towers are now being run on solar power.

In recent years, there has been a sharp decline in capital costs for solar PV plants. PV module prices have fallen a sharp 80% in the last five years and 30% during last year alone. Reports released a few weeks ago said, "Capital costs fell by 30% from a year ago to Rs 10 crore per MW (megawatt) by the end of 2011. The fall was driven by 50% drop in prices of solar PV modules, which account for almost half the capital costs of a PV project. The sharp fall in capital costs has improved the returns from the projects that were commissioned in FY12."

Heavy subsidies by China to its domestic manufacturers have been a major factor in driving down module prices. The recent reduction of subsidy to the sector by Germany, the largest solar power generator in the world, has also pushed down prices further.

While the solar power generators are basking in the sunshine with optimism, the module makers are fighting to stay afloat. The nascent solar equipment industry in India is facing the heat and looking for ways to survive the Chinese subsidy onslaught that has already consumed many leading global manufacturers as per the market news says, such as Solyndra (US), Q Cells and Solar Millennium (both in Germany) and 5 others which have filed for bankruptcy. Many have halted production and further expansion plans.

Funding to the sector has also seen an uptick, even though banks are still cagey about rock-bottom tariffs and higher debt levels. Banks are keen to assist solar projects as they are pollution free but would prefer a lower debt-equity ratio in the range of 60:40. Given its green energy status, it's also not surprising that agencies such as US EXIM bank, ADB and IFC have also been active in the space.

The information about the executed Solar Project experience is spread across which are subject to various assumptions & considerations thus a challenge to have it consolidated, authentic and accurate.

The objective of this document is just to give a simplified independent perspective at a common place based on collected information through interactions, sharing & exchanges on informal forums but no way intended to create any biases or creating any opinion or record or reference.

1.2 Solar Energy Potential in India:

India, due to its geo-physical location, receives solar energy equivalent to nearly 5,000 trillion kWh/year which is equivalent to 600 GW. This is far more than the total energy consumption of the country today. But India produces a very negligible amount of solar energy compared to other energy resources.

Following graph depicts solar energy potential in the country. While India receives solar radiation of 5 to 7 kWh/m2 for 300 to 330 days in a year, power generation potential using solar PV technology is estimated to be around 20MW/sq. km and using solar thermal generation is estimated to be around 35MW/sq. km.

Overall across very good inputs for Solar power generation through thermal, PV or CPV (Concentrated PV) technologies.

1.3 Capacity Utilization Factor :

For a Solar Photovoltaic (SPV) project, Capacity Utilization Factor (CUF) is the ratio of **actual energy generated** by SPV project over the year to the **equivalent energy output at its rated capacity** over the yearly period.

The energy generation for SPV project depends on solar radiation, measured in kWh/sq m/day and number of clear sunny days.

The output of Solar Cell is measured in terms of Wp (Watt Peak) and refers to nominal power under Standard Test Conditions (STC) (1000 W/m2, 250C, 1.5AM).

According to the Solar Radiation Handbook (2008), published by Solar Energy Centre, MNRE the daily average global radiation incident over India is in the range of 4.3 kWh/Sq m to 5.8 kWh/Sq m.

Mean Monthly Global Solar Radiant Exposure (kWh/sq m/day)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Srinagar	1.33	2.71	3.96	5.07	5.63	6.18	5.60	5.21	5.06	3.86	2.57	1.94	4.28
NewDelhi	3.70	4.56	5.73	6.69	6.79	6.26	5.30	4.94	5.25	4.67	3.93	3.31	5.07
Jodhpur	4.31	5.06	6.04	6.73	6.97	6.55	5.46	5.42	5.85	5.31	4.49	4.12	5.55
Jaipur	4.25	5.01	6.11	7.08	7.25	6.65	5.13	4.89	5.45	5.05	4.28	3.74	5.39
Varanasi	3.59	4.76	5.81	6.42	6.40	5.80	4.35	4.80	4.54	4.77	4.02	3.38	4.91
Patna	3.61	4.72	5.82	6.35	6.29	5.63	4.37	4.64	4.55	4.65	4.09	3.30	4.79
Shillong	3.92	4.63	5.35	5.87	5.11	4.56	4.46	4.15	3.90	4.22	4.34	4.01	4.52
Ahmedabad	4.54	5.44	6.35	6.95	6.99	6.02	4.31	4.31	5.18	5.26	4.65	4.23	5.36
Bhopal	4.39	5.20	6.24	7.04	6.75	5.53	4.01	3.80	5.20	5.33	4.73	4.58	5.18
Ranchi	4.34	4.91	5.78	6.17	5.89	4.65	4.03	3.86	4.14	4.38	4.26	4.08	4.55
Kolkata	3.76	4.36	5.28	5.85	5.73	4.77	4.19	4.33	4.14	4.24	3.85	3.52	4.49
Bhavnagar	4.98	5.81	6.71	7.29	7.37	6.20	4.52	4.49	5.53	5.85	5.09	4.60	5.83
Nagpur	4.49	5.34	6.09	6.65	6.55	5.24	4.11	4.11	4.87	5.18	4.54	4.27	5.09
Mumbai	4.60	5.41	6.18	6.62	6.49	4.86	3.74	4.03	4.54	5.00	4.61	4.29	5.07
Pune	4.80	5.72	6.42	6.80	6.99	5.37	4.47	4.36	5.20	5.35	4.90	4.57	5.42
Hyderabad	5.46	6.12	6.73	6.91	6.63	5.59	5.14	4.88	5.49	5.19	5.02	4.99	5.65
Visakhapatnam	4.84	5.56	6.06	6.39	6.16	4.86	4.45	4.54	4.74	4.89	4.56	4.53	5.14
Panjim	5.52	6.22	6.54	6.73	6.57	4.63	4.11	4.41	5.39	5.43	5.32	5.17	5.56
Chennai	4.89	5.85	6.51	6.60	6.26	5.72	5.28	5.20	5.39	4.56	4.00	4.16	5.37
Bangalore	5.67	6.49	6.58	6.57	6.36	4.92	4.64	4.49	5.25	5.12	4.85	4.82	5.47
PortBlair	5.12	5.85	5.89	5.76	4.38	3.87	3.83	4.03	4.30	4.48	4.65	4.75	4.80
Minicoy	4.94	5.61	6.05	5.94	5.05	4.45	4.58	4.89	5.09	5.00	4.64	4.61	5.09
Thiruvananthapuram	5.54	6.13	6.50	5.94	5.45	4.83	4.96	5.28	5.70	5.05	4.60	5.02	5.40
Minimum	**1.33**	**2.71**	**3.96**	**5.07**	**4.38**	**3.87**	**3.74**	**3.80**	**3.90**	**3.86**	**2.57**	**1.94**	**4.28**
Maximum	**5.67**	**6.49**	**6.73**	**7.29**	**7.37**	**6.65**	**5.60**	**5.42**	**5.85**	**5.85**	**5.32**	**5.17**	**5.83**

(Source: Solar Radiation Handbook, 2008, MNRE, ABPS Research)

Also, it is noted that around 290 to 320 clear sunny days are prevalent across most parts of India throughout the year.

Hence, considering an average clear sunny days around 300 and daily average global solar radiation to be around 5.8 kWh/Sq m/day, the capacity utilization factors for various Solar PV based power project installations is expected between 15% to 25 % based on SPV (thin film or crystalline) and up to 35% based on concentrated PV (CPV).

Accordingly, the **normative Capacity Utilization factor of 19%** has been proposed in case of grid connected Solar PV based power projects.

2.1 Setting up a Project:

The input for a project is Sun Radiation which is very conducive to setup a Solar PV plant across country.

The economical land is feasible, as India has sufficient deserted space without residential / agricultural or commercial use and has plenty of Roof Tops.

The technology is within reach and most technology providers are started focusing India, the knowledge base is developed with execution of >1000MW capacity addition in last 2 years.

There is an acute power shortage thus needy user to pay for energy generated.

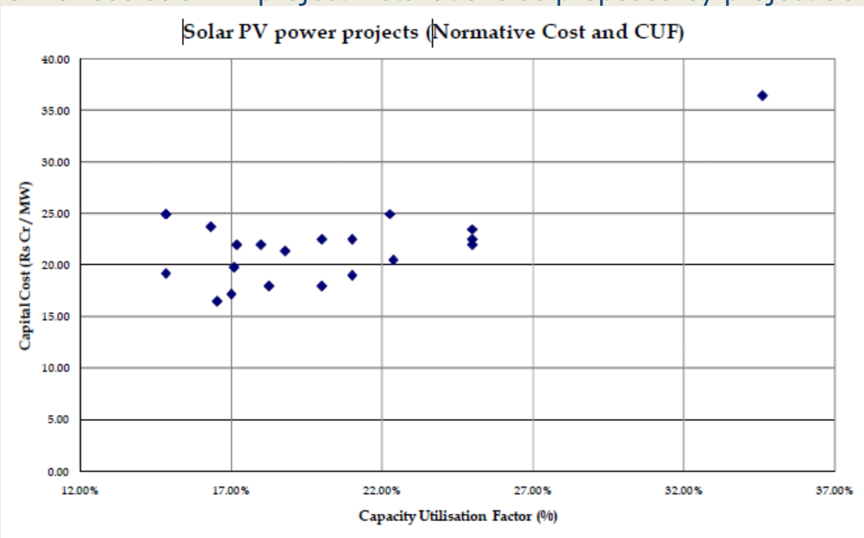
All the elements are available in India, except the big challenge of making financial sense from the investments i.e. to understand who delivers the **Lowest Cost per kWh over the Lifetime of the Project.** i.e. **$/kWh** (cost per kilo watt hour) and not cost per watt peak. **The return is governed from what is generated and not what is the installed capacity**!

In other words, **High returns** or **capacity factor** = lower BOS cost per watt or **more kWh/kW or maximum energy per square meter.**

In next sections, trying to compare various technical options and the cost around them but with few assumptions for simplicity & conceptual understanding. Thus it should not be considered as benchmark or reference.

2.2 Norm for Capital Cost

Following chart summarizes the capital cost (Rs Cr/MW) and capacity utilization factor (%) for various solar PV project installations as proposed by project developers.



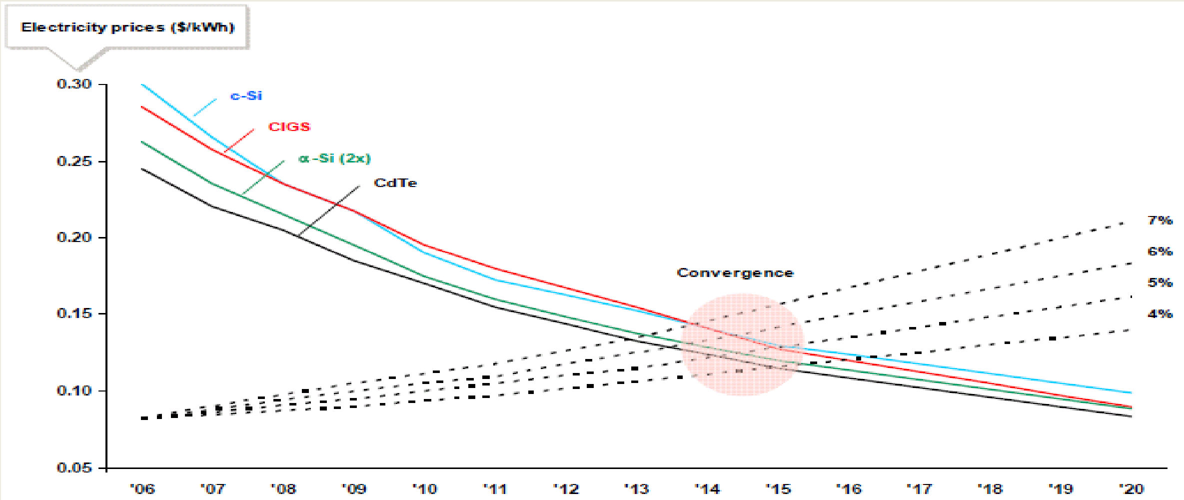
It is recognized that capital cost of the Solar PV power project shall be greatly influenced by the cost of PV modules, balance of plant and power conditioning system costs, taxes and duties, inter-connection costs etc. whereas the performance of the PV project shall depend upon the insolation, ambient conditions, conversion efficiencies, total system design and quality of execution, O&M etc.

$$\text{Cost/kWh}_{\text{over life of project}} = \frac{\text{Balance of Plant} + \text{Land} + \text{Module} + \text{O\&M Costs}}{\text{Sunlight Collection} \times \text{Conversion Efficiency}}$$

The capital cost and capacity utilization factor has varied over wide range. However, there exists a positive co-relation between capital cost and capacity utilization factor over this range.

2.3 Cost of realization

Further, it is envisaged that with worldwide proliferation of the solar PV based installations, the economies of scale would ensure that the capital cost for Solar PV installations would decrease over the period. Most predictions promises that the cost of generation for Solar PV based installations can be comparable with that of conventional power generation by 2015-16.



2.4 Comparison of Module and Cell Efficiencies for Different Technologies

As per report published by European Photovoltaic Industry Association (EPIA) a comparison of the cell/module efficiencies and the area required per kW installation for thin film and crystalline wafer technology respectively is presented in the table below:

Technology	Thin Film				Crystalline wafer based	
	Amorphous silicon (a-si)	*Cadmium telluride (CdTe)*	*CI(G)S*	*a-Si/m-Si*	*Monocrystalline*	*Multicrystalline*
Cell Efficiency at STC*	5-7%	8-11%	7-11%	8%	16 –19%	14 – 15%
Module Efficiency					13 – 15%	12 – 14%
Area needed per kW (for modules)**	15 m²	11 m²	10 m²	12 m²	app. 7 m²	app. 8 m²

* Standard Testing Conditions: 25°C, light intensity of 1,000W/m², air mass = 1.5
** kW = kilowatt. Solar PV products and arrays are rated by the power they generate at Standard Testing Conditions

(Source: European Photovoltaic Industry Association)
(CI(G)S = Copper Indium deselenide, a-Si/m-Si = Amorphous Silicon and Multi Crystalline Silicon)

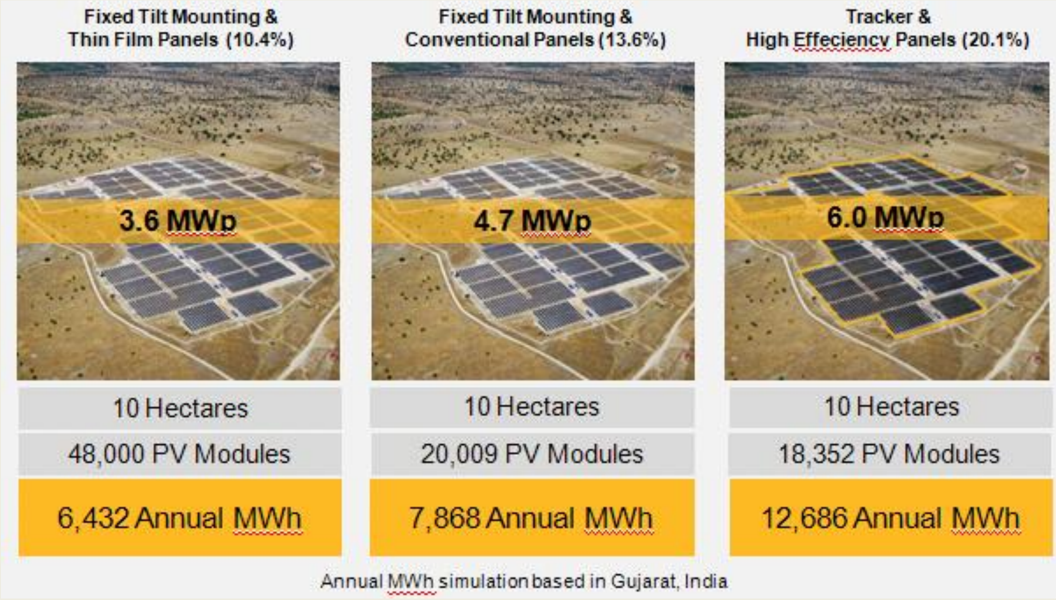
2.5 Land Requirement

It should be noted that for same plant capacity, Mono-crystalline needs less than half the space of Amorphous Silicon. i.e. If a 1MWp capacity plant is built in 7 Acre land using thin film, with Mono-crystalline (standard efficiencies as mentioned previously) it will be within 3 Acre.
With advancement of technology, even higher efficiency modules (>20%) are available thus reducing the surface area requirement, no of modules etc to build a plant. It is feasible now to build a **1MWp** capacity plant in **2.5 - 3 Acre** of land in India using High efficiency PV Modules.

The table below gives a typical comparison on minimum land requirement vs module efficiencies:

	Module Surface / Per MW	Ground	
Module Effeciency	SqM	SqM	Acre
7.0%	14,286	25,974	6.42
10.0%	10,000	18,182	4.49
12.0%	8,333	15,152	3.74
13.0%	7,692	13,986	3.46
14.5%	6,897	12,539	3.10
17.0%	5,882	10,695	2.64
19.0%	5,263	9,569	2.36
20.0%	5,000	9,091	2.25

This proportion holds good for all type of system i.e. Roof-top / Ground mounted, Grid Connected or Off-Grid.



Please note above is subjected to detail system design. Also additional space for Invertors, facilities and evacuation system needs to be considered. Further, a tracking system will require approximately 10-20% more area then fixed mounting.

2.6 Module

The module is the major cost (approx 60% of total project cost) and has variety from less than a USD/Wp to 2 USD/Wp. It is an important element of project as the return on investment totally depends upon this choice. There are choices available between technologies and the decision should be made considering all aspects as full cost and not only the initial capital cost.

2.6.1 Choice of Module - Total System Design & Project Cost
For same installed capacity of plant, no of modules increase will further increase the other direct cost like mounting structure, cabling, land development, fencing, security… and impacts indirect cost i.e. system losses, increased O&M / cleaning, more week points for chances of failures etc.

It is evident that the total system cost (excluding O&M, land cost) varies, Module cost increase is partially subset by other direct cost savings. But if Land cost is significant and taken into account, the it will be inverted!.

It is important to understand that low initial cost may not be the best investment choice unless **Return on Investment (ROI /IRR /NPV etc.) is calculated on Total system cost** (Module, Balance of System, Land lease, system losses etc.), O&M, spare, repair and replacement provisions etc. are taken into calculation.

So there is an optimum balance point where the choice should be made on Capex vs other Direct/Indirect costs. Please refer the table in Annexure which gives an indication on the Module efficiency vs System cost, Land requirement with assumptions.

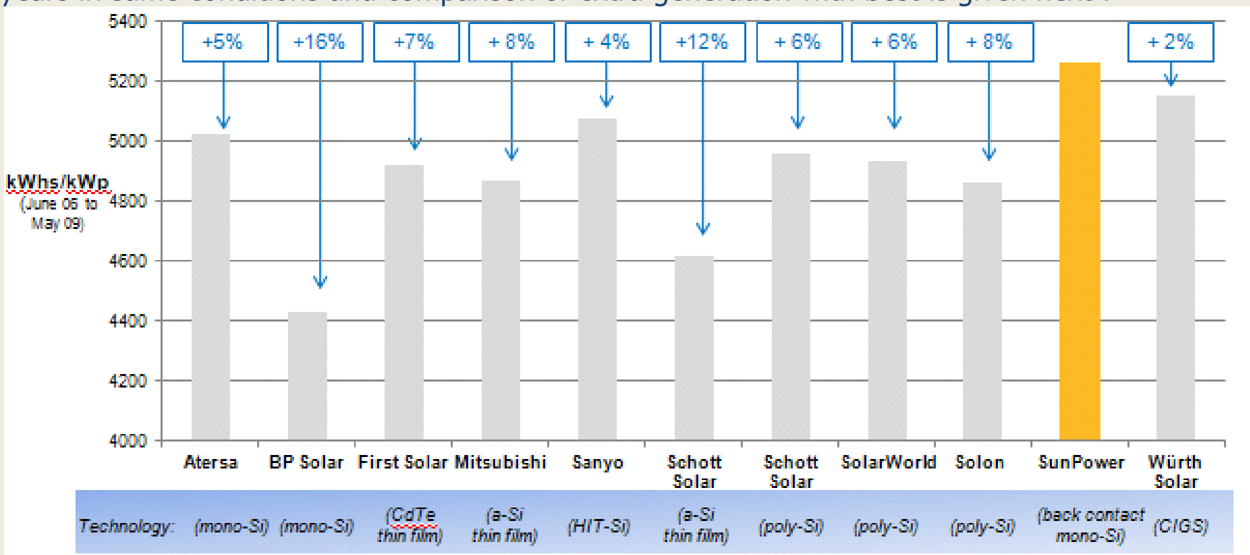
There are comparison scenarios presented to understand the trends. For every project this could be a way be have detailed comparison to form a balanced decision based total cost and yield.

2.6.2 Choice of Module – Energy Generation

The next important consideration is the Energy Generation over the life of the project, which will make the decision on financial returns out of investment. The tables in Annexure gives an indication on the Module efficiency, Capex vs Generation. Cost per kWh of investment over 25 years with assumptions.

Contrarily to popular understanding, **module technologies & efficiencies also impacts the energy generation in practice**. Higher efficiency modules operate at lower temperatures captures broad spectrum of light and thus convert more of the sun's energy to electricity – lower efficiency modules convert it to heat instead.

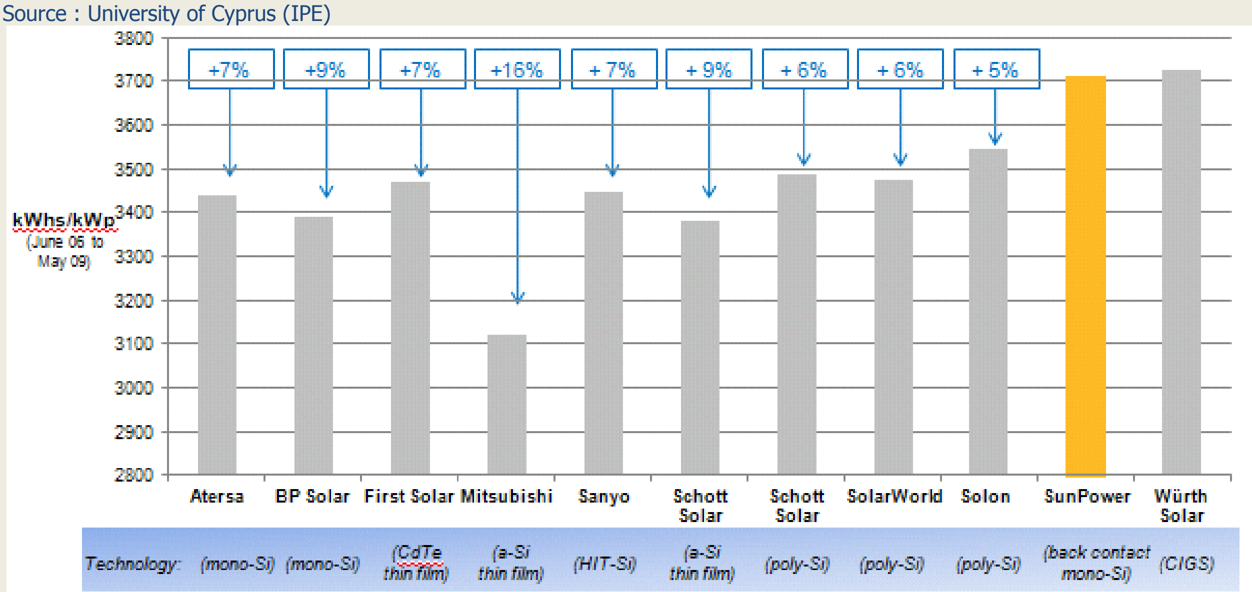
This is proven by independent researches on various modules and their generation over the years in same conditions and comparison of extra generation with best is given next :



Cumulative kWh yield (kWh ac / kWp rated) from June 2006 to June 2009 – Nicosia, Cyprus

Source: Department of Electrical and Computer Engineering - University of Cyprus in Nicosia. Testing started in June 2006 and is on-going - Note that SunPower modules in test are STM-200-FWB modules.

Source : University of Cyprus (IPE)



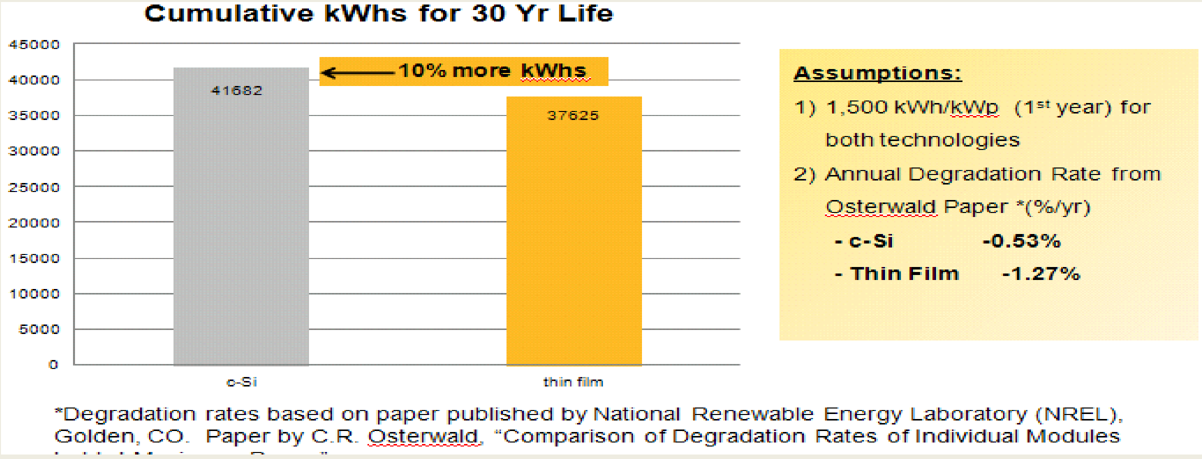
Cumulative kWh yield (kWh ac / kWp rated) from June 2006 to June 2009 – Stuttgart, Germany

Source: Institut für Physikalische Elektronik (ipe) University of Stuttgart, Germany. Testing started in June 2006 and is on-going - Note that SunPower modules in test are STM-200-FWB modules.

Source : University of Stuttgart, Germany (IPE)

2.6.3 Choice of Module – Performance Degradation

Further the consistent quality of module, its degradation over the life, past performance on generation (projected vs actual) becomes also very important. Higher Lifetime Energy Yield is feasible from the modules whose degradation is lower.



There are independent researches done on a large variety of panels and reports are published which indicates following:
Conventional p-type c-Si cells (crystalline silicon) lose 3% of their initial power once exposed to sunlight called as light-induced degradation while n-type solar cells don't (analysis of over 5 years of field performance show no measurable degradation). This is an important point while calculating generation.

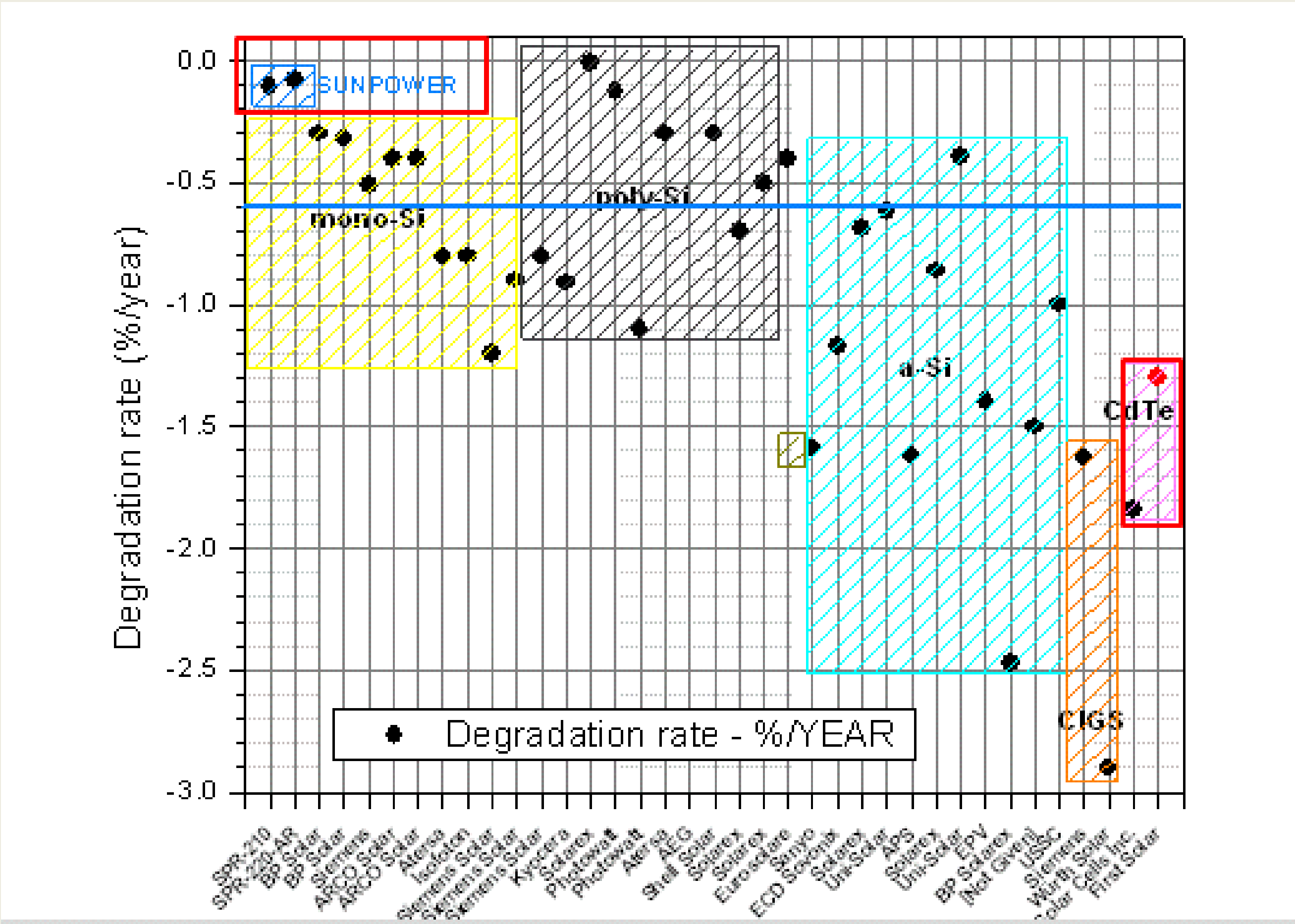
Crystalline solar cell technology is well understood and has been used for over 50 years in extreme environments (space, deserts, arctic). The degradation rate of standard cells has been well documented to be -0.6%/yr**.

Thin film is a relatively new technology, with less than 10 years of manufacturing and field experience, and the degradation is not yet well understood. But some studies show that crystalline modules degrade less year to year than thin film and some cases shows thin film degradation >10% in first few years.

The chart next shows the various modules of different technology researched & tested by an independent agency and plotted the degradation.

So far, the best modules shown by third-party testing to degrade at -0.1%/year** although it is recommended a more conservative -0.25%/year for economic calculations.

**Source 1 - Jordan, Dirk "Degradation Rates," National Renewable Energy Laboratory, Feb 2010.
2. National Renewable Energy Lab (NREL Colorado) measured degradation for 2 SunPower strings (5 years old):
3. Jordan, Dirk "SunPower Test Report," National Renewable Energy Laboratory, Dec 2011



Yearly degradation rate (Colorado) – Measured by NREL

2.6.4 Choice of Module - Total Quality & Reliability
This is ensured with the quality of testing's, as real life is tough on a solar panel system. The system can go through a variety of the tough exposures like :

- Temperature Variation
- Humidity
- UV/Visible Light
- Electrical Load
- Physical Stress etc.

The failures of PV modules in fields (Burning, bending, breaking etc. as shown in the photographs in the annexure) gives learning's that it should pass rigorous qualification test program like :

- Temperature Variation – Temperature cycle, Temp Cycle Sandwich (agitates metal) solder joint pull tests
- Humidity – Damp heat with Bias, Humidity Freeze Cycles, wet hi pot ACL
- UV/Visible Light – UV tron, 2 week outdoor exposure
- Electrical Load - wet HI pot , ACL, Forward bias soak, reverse bias soak, HVD , Polarization
- Physical Stress – dynamic load , hail tests etc

Thus manufacturer's qualification test program should include:
a. **Basic Industry Qualifications**: everyone needs to have these certifications for basic level of safety and quality. But these are not enough because they do not cover all types of testing and all types of failure modes

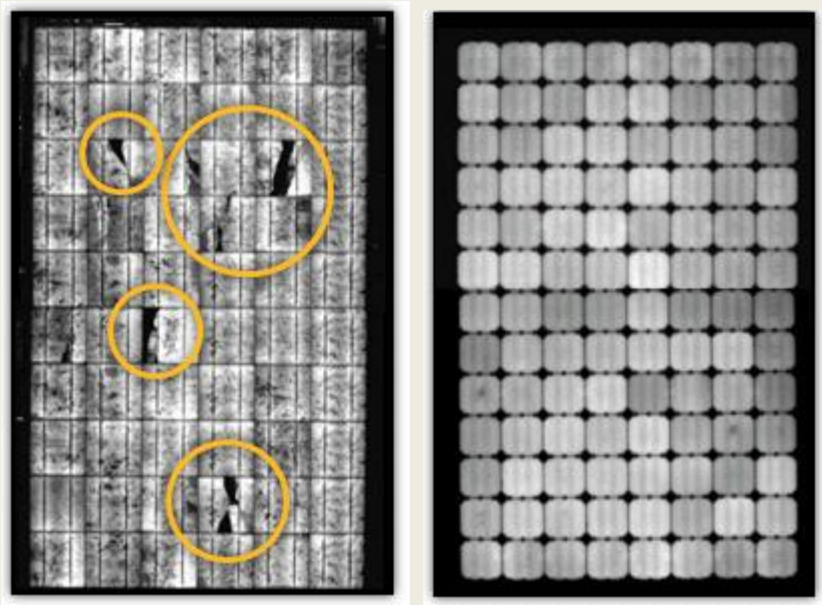
b. **Tests with extended qualifications** – an example is to do 10X the certification standard for temperature cycling to ensure highest level of reliability when the module needs to go through real life temperature variation over 25 years

c. **Custom tests** like **HALT** which tests the products to failure, or tests designed to test various light and heavy stresses, degradation over time and manufacturing tests like (HASS).

HALT testing is an accelerated testing mechanism that tests the panel all the way to failure. The HALT methodology consists of pushing the design to the point where failures occur and weaknesses are exposed. This is a method of discovering product weaknesses by applying stress combinations which are relevant to field deployment, but that are considerably beyond the normal operating environment - It is not a pass/fail test, but rather a test designed to activate the same failure modes one would encounter after many years in the field, in just a few days or weeks.

Examples of HALT tests :

- Solar Simulator (5 days) – tests for effects like de-lamination of interconnects, browning and bubbling of back-sheets etc.
- UV Tester – to test the response to radiation over the life time of 25 years
- Dynamic Load Testing – checks for cracking with stresses such as wind loads and hail
- Autoclave
- Damp Heat – failures in warm and humid conditions
- Oven bake at 130C - failures in extremely hot conditions
- Thermal Cycling with current – regular temperature variations



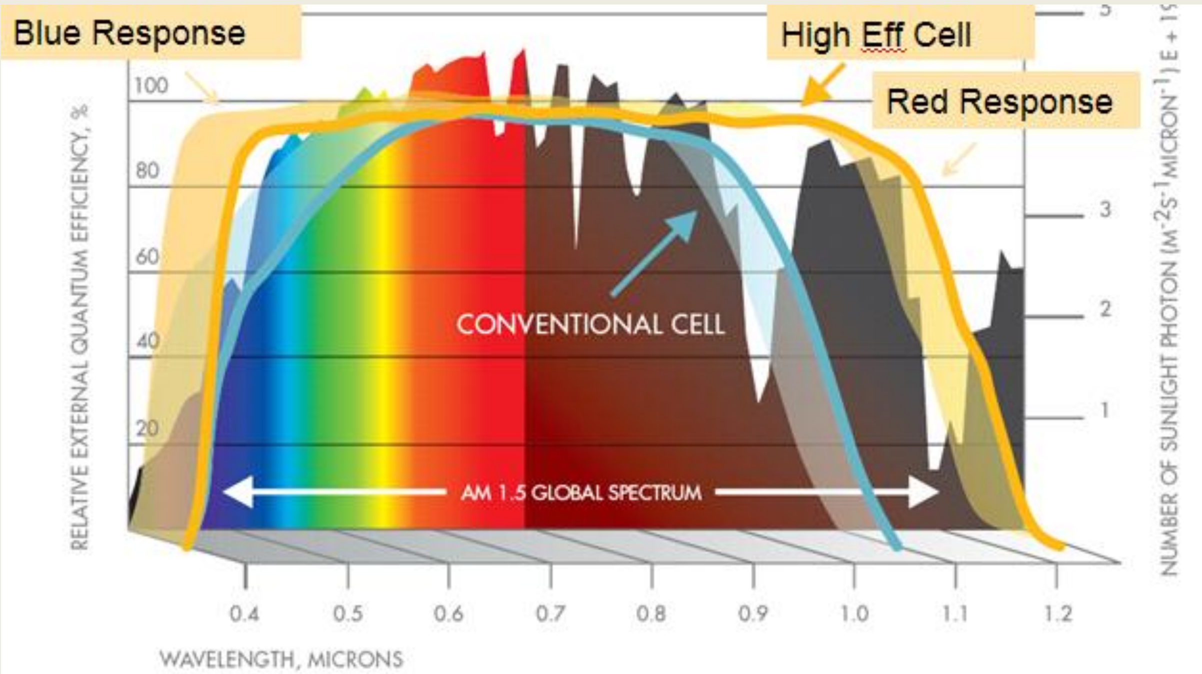
Electroluminescence images of a front-contact module and back contact module after dynamic load HALT stress (1000 cycles of +/-2400 Pa, equivalent to maximum wind load, of alternating pressure load on the glass)

The modules which pass through above tests are the one who promises to deliver the promises in real life and provide fail safe assurance and commitment to trust for quality.

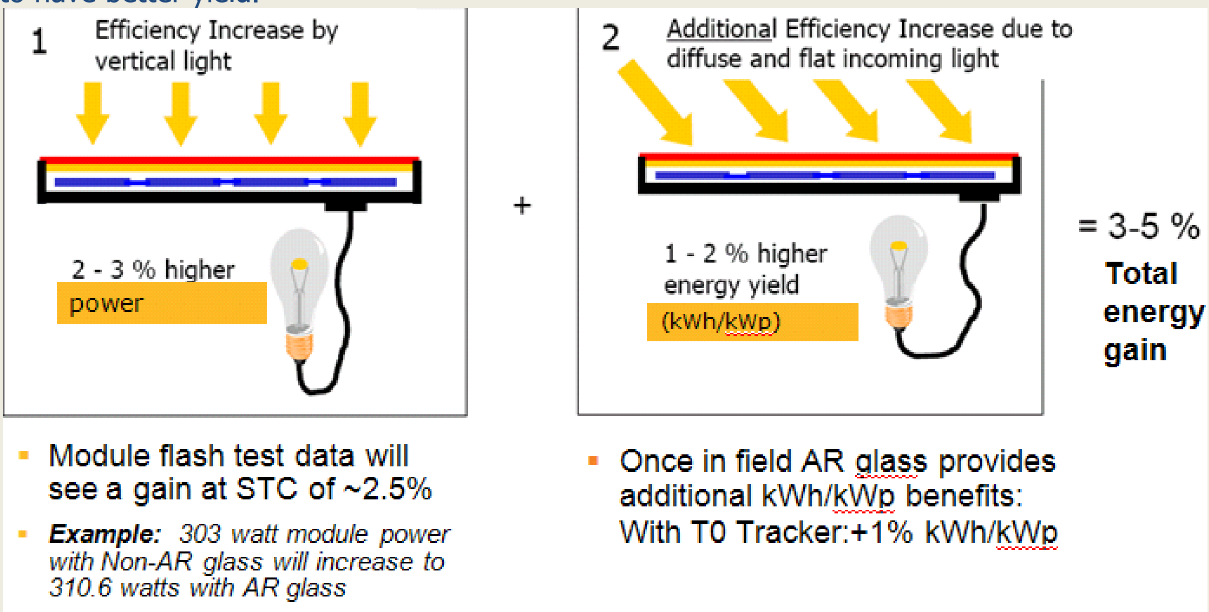
2.6.5 Choice of Module – Technology and features

Advanced module design added new functionality as **positive grounding free**, full **compatibility with market most efficient inverters**, either **with or without transformer**.

Module should be designed for **Maximum light capture** i.e. **broader light spectral response** and **better low light performance**, earlier in the morning to later in the evening i.e. Cells capture more light from the blue and infra-red parts of the spectrum through a lightly doped front surface and light trapping.



Use of **AR (Anti – reflecting) glass** is important to have better light absorption by the cell to have better yield.



Higher Performance at Higher Temperatures is very important in countries like India, South Africa which has most sunny days with high temperature and it is observed that plant don't give generation in those periods. In few cases burning of cells is observed due to high heat.

Modules with **lower temperature coefficients** and **lower normal cell operating temperatures** generate more energy at higher temperatures compared to standard ones. So lower the temp coefficient of the module, better chances of high yields in hot summer.

Module should be **robust designed to withstand high wind gusts** and should be simple for installation, connections.

There are various other important technical parameters which also need to be checked but not elaborating as this document is more focused for project costing evaluation.

2.6.6 Choice of Module – Manufacturing setup, Credibility

There should be due diligence on the **financial capacity** of the manufacturer to have worth for its power generation warranties.

The check should be done on the **litigation history on honoring the commitments of warranties**. This due care will help in obtaining warranties which are worth and can be used in case of dissatisfaction.

There are many stories across Europe where investor's felts lost when meager compensations arranged as settlement for lower performance thus sucked the project viability.

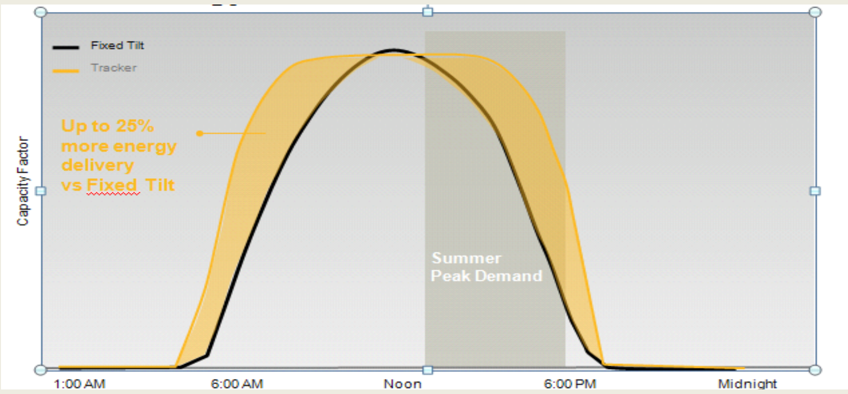
The investment is expected to yield profits not litigation. Select the right partner whose commitment for 25 years can be respected.

2.7 Mounting

There is always a debate between fixed vs Tracked structures'. Fixed are simple to design and easy operational considerations, they are economical and indigenous. While trackers are complex, so may not have proper results from all solutions providers.

If tracking system is the choice, due care needs to be given in selecting proven performance and track record of the supplier & installer. Successful Tracker are mostly imported in India thus costlier, demands the technology and skill while design, erection. They add to auxiliary consumption in drives and controls, needs GPS etc connections. So little complex then fixed systems.

But since they track the sun and align the movement of panels, yields 15-25% more energy generation. Tracker is expected to enhance generation periods even in low exposure periods as shown below:



This may not make good financial sense on very low efficiency modules which are spread over larger areas and the incremental yield with tracking may not worth enough the additional investment. Successful trackers will be 40-80% costlier then fixed tilt system.

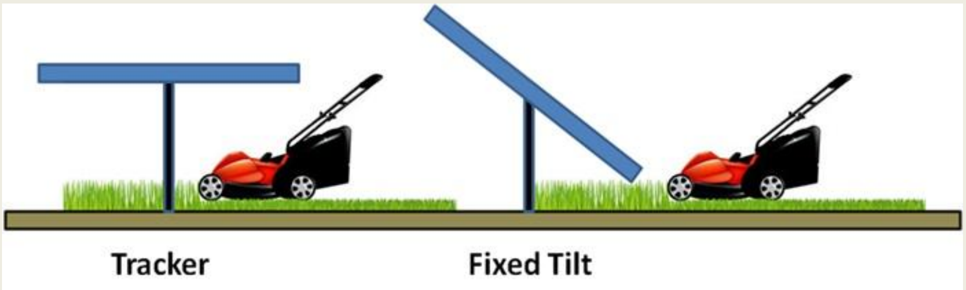
But with High efficiency modules this will make worth investment. In Indian conditions with long sunny duration, the additional investment 0f 20-40% compared to fixed system on tracking is recovered very fast and additional generation over life time is a big incentive.

On O&M, the real life observation is contrary to popular belief i.e. Tracking systems are proven to be simpler and economical and thus yielded higher generations (Less losses due to shedding, soiling etc.).

Most fixed tilt installations near to deserts has fast accumulation of dust demanding cleaning on very short intervals while cleaning is a tedious process due to availability of good quality of water.

However, tracking system proven to have low deposits because of movements (-45 to +45 Degree) during the day and thus comparatively lower need of cleaning the panels on short intervals.

Further in fixed tilt cutting the growing vegetation/weed etc. near to panels is positing challenges while tracked structures are flat in non sunny hours give sufficient clearance from ground to clear the vegetations.



Though they have auxiliary power requirement of approx 700 - 1500 units / MW / Annum, but they add 15-25% generation and simplicity in operation… may prove better solution to Indian environment having high dust but with more sunny hours, provided full system is designed, sourced and installed with perfection.

Moreover it is important to understand that all trackers are not the same, ensure to check the track record of the manufacturer, its tracking technology and experience. There are many options but not all are successful solution providers. Check their features, auxiliary power requirement, simplicity and reliability in operation etc. before making a decision.

Therefore selection of trackers by the developers is an important decision which should take in to consideration reliability, economics and proven designs such that bankability of the project is not adversely affected.

Another development is seasonal tilt but unable to comment as enough performance data could not be obtained.

2.8 BoS - Electrical, Civil & Mechanical works

If Modules amount 60-70%, BoS including structure is rest of the project cost.

It is important to note that though the Modules have higher designed and warranted life but not all the other critical equipments like Invertors, switchgear, cables are so. They may needs replacement in 10-15 years. Select them from reputed manufactures to have higher expected service life, or make provision for replacement in the span of life.

Balance of Systems like DC power collection, Invertors to evacuation are critical for overall plant efficiency and optimization here is an essential requirement. Thus it is equally important to select these equipments with low auxiliary consumption or losses to have minimum system losses.

Even best of the equipments will not be able to yield performance if not placed, installed and commissioned properly. The quality of overall system design will have optimum cabling, simple layouts, and smart customized solutions with best plant efficiency. Modules placement at an optimum angle and direction is critical and thus the array lay-out, placement of Invertors, grid evacuation design is critical to have optimum energy generation.

It is important to engage a skilled EPC to have proper system design, selection of right components, proper project management and installations & provisions for O&M.

Experienced project management will ensure smooth, proper, timely installations and on time power generations and lower O&M for the life time.

It is obvious quality needs investments and could cost 10-15% extra but quality of workmanship will pay for the life time.

2.9 Evacuation

It is equally important to pay attention to PPA and make timely arrangements to wheel the power and revenue earned from the day one of readiness. Normally a spare bay isn't available near to plant and thus a substation, transmission line is become necessity.

If feasible it will be a smart choice to work together with some other developers nearby and to have integrated pool in substations for optimal cost.

Substation, transmission line there are lot more standardization and quality work developed so not detailing more here.

3.1 Operation and Maintenance

There is very limited operating experience of MW scale solar PV Grid connected power plant till date in India and none has specified break up of operating expenses which comprises of employee expenses, A&G expenses, and maintenance expenses.

The information available about few projects and assumptions contained in the Orders in few States indicate that O&M cost for Solar PV installations varies in the range of 0.2% to 0.8% of capital cost.

In view of the limited availability of actual field data a **normative O&M expense** of 0.5% of the capital cost, which amounts to **Rs 9 Lakh/MW** had been considered during the first year of operation which will be escalated at a rate of 5.72% per annum over tariff period.

However, in reality, it is observed that this cost not in line with above assumption. It's not the capaex, it actually depends on other variables like area of installation, Size of land for spread of PV modules, no of PV Modules installed and how they are installed. Lower Capex are actually have higher % of O&M.

For the same MW capacity plant, higher no of panels spread over larger area demands more expense. In reality, it is cleaning of more no of panels, maintaining more ground, security of larger area, arranging higher quantity of good water and resources & staff. It also increases the chances of pilferage, theft, repair, replacement, break-down, shutdown, outage etc.

Vegetation management is a practical task that needs to be managed in O&M which turns out to be a big deal on solar farms and tilted panels make it even more difficult task.

Typically, fixed-tilt structures are mounted as close as possible to the ground to reduce costs, which can make maintenance more difficult. In addition, in the desert, condensed water can drip from the panels at night creating what is effectively a drip irrigation system which may foster vegetation growth with a fixed system, since the water will fall in a localized area.

Extra care needs to be taken with frameless thin-film panels mounted close to the ground, since a mower can easily kick up a rock which could crack the laminate make things even trickier.

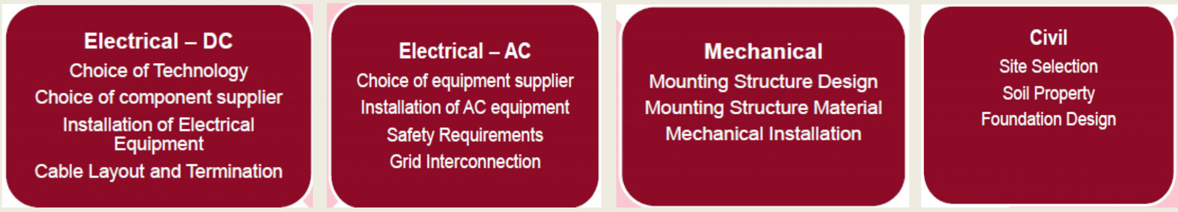
Although sometimes perceived as having higher O&M costs, trackers can actually have lower O&M costs than fixed-tilt structures on USD/kWh basis, and vegetation management is one of the reasons for this. Personnel can easily mow under a tracker placed in a horizontal stow position approximately four feet above the ground. (refer the discussion on Mounting).

There are some experiments on seasonal tilt but the results are yet to be analyzed in Indian context and thus difficult to comment on cost on O&M.

People can't overlook practical O&M costs, increasingly relevant to project economics as system prices come down and it becomes a higher percentage of total cost over life. **Considering above, the O&M cost is expected around 1-3% of the project cost with 8-10% increase every year for most project executed on 5-7Acre/MWp.**

4.1 Factors Contributing to Performance (or lack of it) of PV Power Plants :

There are learning's from the executed projects and the feedbacks on performance of plants. Financial sense of investments comes on focusing in details of all critical elements:



There are major challenges being faced in the investments on Performance issues* like -

- Overall system design isn't able to provide guaranteed yield, more losses and troubles in operations.
- Quality of engineering & project management, erection, testing & commissioning is not satisfactory and issues leading to delays, litigations and under performance, losses.
- PV Module – Reliability and Durability Issues, Power Degradation over time, Module Failure – Hot Spot, Delimitation, JB detachment etc.
- Potential Induced Degradation – PID
- PV Inverter – Performance Issues – Operation & Maintenance, Failure of Components, lower efficiency at the working environment, Central Inverter Vs String Inverters.
- BoS Equipment – Limited Warranty for Cables / Switchgear /Mounting Structure etc.
- Accuracy of Isolation Data for the site location.
- Cleaning and Maintenance of PV Modules

*refer Annexure for photographs.

Thus it is very important to have a proper selection of partners who has proper capabilities, capacities, resources, right intent to perform, experience, proven performance & reputation to live for. Wrong choices leads to losses, problems and issues to live with throughout the life and cannot be recovered with any kind of warranties, litigations.

4.2 Comparison of various options on Total system cost over Life-time basis

Based on whatever discussed till now, as an illustrative example to understand the comparison between various choices, we take a sample case and try to analyze total system cost with certain assumptions.

For simplicity, IRR, NPV will just compute on cash flow (without going into financial analytics' and effects of depreciation etc.) to understand the trending. This document is mainly aimed to understand the costs, while finance is a detailed subject and cannot be covered here.

The total system project cost is considered taking the references of only those executed projects which are able to deliver the designed performance. It is the total cost incurred for project implementation (plant, equipment, manpower, resources etc.) but excluding cost towards land, approvals, evacuation system outside the project boundaries etc.

We will make comparison assuming inflation @7%, cost of cash @14.5%, exchange rate @ 54 INR=1 USD and current per unit cost of Generation from DG is @14.5 INR. (Please refer Annexure for details).

a. We will make first comparison assuming performance, degradation of all modules is similar and generation difference is only due to BoS on fixed system.

b. Now we will take example high efficiency modules, degradation is lowest and best performance features like temp coefficient, light capture, AR… on Fixed system.

c. Last take best case i.e. highest module efficiency, best performance features like temp coefficient, light capture, AR… on tracking system.

d. The above 3 set of comparison's will be repeated now considering the O&M cost

e. The above 3 set of comparison's will be repeated now considering the O&M cost and land lease cost also.

f. Similar comparisons' can be repeated with Grid power @4-8.5 INR and would show similar trend.

It is evident from the trends from above comparisons' that the **return on investment (ROI) or Net Present value of Cash (NPV) or IRR improves with High efficiency, tracking, and better quality of modules in spite increased capex**.

It's worth to note that even in worst case comparisons, **high Capex also pays return in similar time frame**. The additional investment is recovered in first few years and **then the benefit of extra generation is lasting returns and thus increased profits.**

Lower Capex also pays and worth investment and with higher Capex there is significant improvement in returns and thus improved bankability of the project.

4.2 Conclusion

All technology has its own benefits and is proving to provide good returns. With higher investments, the yields are higher and could be a choice if funds are available.

With depleting reserves, we are enjoying the present on the cost of dark future. Water is scare and should be preserved for drinking then Polluting Thermal power plants and same is for other fossil fuels.

Solar is most clean & simple way of electricity generation and thus beneficial to the nation in broader terms whichever technology is been used. The green environment will lead to prosperity across and power to deprived and remote areas.

It is worth to promote even as a Social obligation so that next generations will be healthy and have a decent life to live.

Solar is a very good alternate source of energy with preservation of environment, health and thus overall long lasting prosperity.

Let's move ahead, make a sensible investment properly comparing the choices and make the world beautiful around us.

5.1 Disclaimer

The information presented is independent view of author and not validated or supported by any organization etc. The inputs are consolidated as available on public domain without any responsibility of its accuracy or authenticity

The readers are requested to take the inputs only for a broad academic understanding and not form any opinion without further detail investigation. Any references to any Brand, Organization or information is just compilation of information available on public domain only for academic purpose and to promote investments in solar but has no intent to malign or harm any business or commercial entity.

Information is consolidated from various sources on public domain only for academic interest and no claims on any of the content or representations will be feasible to entertain.

6.1 Feedback

Please connect with your respective departments for more details.

7.1 Annexure

I. Costing analysis is enclosed in next sheets :

- Module choices vs Capex, Land, ROI (revenue with comparison to Diesel) considering standard degradation.
- Module choices vs Capex, Land, ROI (revenue with comparison to Diesel) considering actual degradation (0.25% / PA on linear basis).
- Module choices vs Capex, Land, ROI (revenue with comparison to Diesel) considering actual degradation (0.25% / PA on linear basis) and using tracking.

II. Photographs / Examples of performances issues faced at site on executed projects.

Annexure 1A: Sample comparison of projects costing with respect to various PV technologies

Assumptions: INR → USD @ 56, Cost of Inflation/Annum 7%, Unit Cost of Diesel Power @ 14.5INR, Cost of Borrowing @14.5%

OPEX & Interest on CAPEX, is compensated with accelerated Depreciation, Carbon credit, Subsidy and other intangible benefits of Green Power.

Module Effeciency	Area			roject Cos	Generatic	Enrichment Ratio (Revenue / Capex) in 25	IRR in 25 Years	NPV of Cash Flow @	O&M / Annum	Land Lease / Annu	Cash Flow (Years)																									
	Module Surface / Per MW	Ground /MW		Cost / MWp	Units / Annum (Avg)						ROI (Cum MINR) compared with power purchased from DG (with O&M and Land Lease Cost Considered)																									
	SqM	SqM	Acre	MINR	Milion KWh			14.50%	MINR	MINR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Modules Placed on Fixed Structurere and performing on Stand:						Degradatio	Standrad / Gurranteed -->					3.0%	3.8%	4.6%	5.3%	6.1%	6.9%	7.7%	8.4%	9.2%	10%	11%	11%	12%	13%	13%	14%	15%	15%	16%	17%	17.3%	18.0%	18.7%	19.3%	20.0%
7.0%	14,286	25,974	6.42	111.92	1.34	7.86	43.09%	₹ 721	2.85	3.85	(116)	12	25	39	55	72	90	110	132	155	180	207	237	268	302	338	378	419	464	512	564	619	678	741	808	880
10.0%	10,000	18,182	4.49	112.22	1.36	8.45	46.82%	₹ 823	2.00	2.70	(115)	14	30	47	65	84	105	127	151	177	205	235	267	301	337	377	418	463	511	562	617	675	737	803	873	948
12.0%	8,333	15,152	3.74	108.27	1.38	9.12	49.63%	₹ 881	1.61	2.25	(111)	16	32	50	69	90	112	136	161	189	218	249	282	318	356	397	440	487	536	589	645	706	769	838	910	987
13.0%	7,692	13,986	3.46	106.70	1.40	9.49	51.08%	₹ 913	1.46	2.07	(109)	16	33	52	72	93	116	141	167	195	225	257	291	328	367	409	454	501	552	606	664	725	790	860	934	1,013
14.5%	6,897	12,539	3.10	106.63	1.42	9.75	52.23%	₹ 947	1.31	1.86	(108)	17	35	54	75	97	121	146	173	202	233	266	301	339	379	422	468	516	568	624	683	745	812	883	959	1,039
18.0%	5,556	10,101	2.50	121.58	1.47	8.93	50.31%	₹ 990	1.20	1.50	(123)	18	37	58	79	103	128	155	183	213	246	280	317	357	399	443	491	542	596	654	715	780	850	924	1,002	1,086
19.0%	5,263	9,569	2.36	131.63	1.49	8.39	48.71%	₹ 1,001	1.23	1.42	(133)	18	38	59	81	105	130	157	186	217	250	286	323	363	406	451	500	552	607	665	728	794	864	939	1,019	1,104
20.0%	5,000	9,091	2.25	135.07	1.51	8.32	48.61%	₹ 1,020	1.20	1.35	(136)	19	39	60	83	107	133	161	190	222	255	291	330	370	414	460	510	562	618	678	741	809	880	957	1,038	1,124
Modules Placed on Fixed Structurere but better performing thei						Degradatio	Lowest -->					0.0%	0.3%	0.5%	0.8%	1.0%	1.3%	1.5%	1.8%	2.0%	2.3%	2.5%	2.8%	3.0%	3.3%	3.5%	3.8%	4.0%	4.3%	4.5%	4.8%	5.00%	5.25%	5.50%	5.75%	6.00%
19.0%	5,263	9,569	2.36	131.63	1.42	9.03	49.28%	₹ 1,040	1.23	1.42	(133)	19	39	59	82	106	132	160	189	221	256	293	332	374	420	468	520	576	636	700	768	841	920	1,003	1,093	1,188
20.0%	5,000	9,091	2.25	135.07	1.47	9.10	49.60%	₹ 1,080	1.20	1.35	(136)	20	40	62	85	110	137	166	197	230	265	304	344	388	435	486	539	597	659	725	795	871	952	1,038	1,131	1,230
Modules Placed on Fixed Structurere but better performing feat						Degradatio	Lowest -->					0.0%	0.3%	0.5%	0.8%	1.0%	1.3%	1.5%	1.8%	2.0%	2.3%	2.5%	2.8%	3.0%	3.3%	3.5%	3.8%	4.0%	4.3%	4.5%	4.8%	5.00%	5.25%	5.50%	5.75%	6.00%
19.0%	5,263	9,569	2.36	131.63	1.54	9.82	51.71%	₹ 1,144	1.23	1.42	(133)	21	42	65	89	116	144	174	207	242	279	319	362	408	458	510	567	628	693	762	836	916	1,001	1,091	1,188	1,292
20.0%	5,000	9,091	2.25	135.07	1.56	9.73	51.55%	₹ 1,165	1.20	1.35	(136)	21	43	66	91	118	147	178	211	246	284	325	369	416	466	520	578	639	705	776	851	932	1,018	1,111	1,209	1,315
Best Case : Modules Placed on Single Axis Tracking Structurere						Degradatio	Lowest -->					0.0%	0.3%	0.5%	0.8%	1.0%	1.3%	1.5%	1.8%	2.0%	2.3%	2.5%	2.8%	3.0%	3.3%	3.5%	3.8%	4.0%	4.3%	4.5%	4.8%	5.00%	5.25%	5.50%	5.75%	6.00%
19.0%	5,263	9,569	2.36	134.01	1.82	11.44	55.90%	₹ 1,375	1.35	1.42	(135)	24	49	76	105	137	170	206	245	287	331	379	430	485	543	606	673	745	822	904	992	1,086	1,187	1,295	1,410	1,532
20.0%	5,000	9,091	2.25	137.40	1.85	11.34	55.77%	₹ 1,400	1.31	1.35	(139)	24	50	78	107	139	174	210	250	292	338	386	438	494	554	617	686	759	837	921	1,010	1,106	1,208	1,317	1,434	1,559

Module Effeciency	Area			roject Co	Generati	Enrichment Ratio (Revenue / Capex) in 25	IRR in 25 Years	NPV of Cash Flow @	O&M / Annum
	Module Surface / Per	Ground /MW		Cost / MWp	Units / Annum (Avg)				
	SqM	SqM	Acre	MINR	Milion KWh			14.50%	MINR
Modules Placed on Fixed Structurere and performing on St						Degradation	Standrad / Gurranteed -->		
7.0%	14,286	25,974	6.42	111.92	1.34	8.72	49.66%	₹ 881	2.85
10.0%	10,000	18,182	4.49	112.22	1.36	9.05	51.40%	₹ 936	2.00
12.0%	8,333	15,152	3.74	108.27	1.38	9.64	53.56%	₹ 974	1.61
13.0%	7,692	13,986	3.46	106.70	1.40	9.98	54.74%	₹ 1,000	1.46
14.5%	6,897	12,539	3.10	106.63	1.42	10.18	55.51%	₹ 1,025	1.31
18.0%	5,556	10,101	2.50	121.58	1.47	9.24	52.66%	₹ 1,052	1.20
19.0%	5,263	9,569	2.36	131.63	1.49	8.66	50.78%	₹ 1,060	1.23
20.0%	5,000	9,091	2.25	135.07	1.51	8.57	50.53%	₹ 1,077	1.20
Modules Placed on Fixed Structurere but better performing						Degradation	Lowest -->		
19.0%	5,263	9,569	2.36	131.63	1.49	9.73	52.10%	₹ 1,149	1.23
20.0%	5,000	9,091	2.25	135.07	1.51	9.63	51.84%	₹ 1,167	1.20
Modules Placed on Fixed Structurere but better performing						Degradation	Lowest -->		
19.0%	5,263	9,569	2.36	131.63	1.54	10.08	53.16%	₹ 1,195	1.23
20.0%	5,000	9,091	2.25	135.07	1.56	9.97	52.89%	₹ 1,214	1.20
Best Case : Modules Placed on Single Axis Tracking Structu						Degradation	Lowest -->		
19.0%	5,263	9,569	2.36	134.01	1.82	11.70	57.87%	₹ 1,434	1.35
20.0%	5,000	9,091	2.25	137.40	1.85	11.59	57.59%	₹ 1,456	1.31

Module Effeciency	Cash Flow (Years) ROI (Cum MINR) compared with power purchased from DG (with O&M Cost Considered)																									
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
		3.0%	3.8%	4.6%	5.3%	6.1%	6.9%	7.7%	8.4%	9.2%	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	17.3%	18.0%	18.7%	19.3%	20.0%
7.0%	(112)	16	33	51	70	91	113	137	163	190	219	250	283	318	356	396	439	485	534	586	641	700	763	829	900	976
10.0%	(112)	17	35	55	75	97	121	146	173	201	232	264	299	336	375	417	462	509	560	613	671	731	796	865	938	1,016
12.0%	(108)	18	37	57	78	101	126	152	179	209	240	274	309	347	388	431	476	525	577	632	690	753	819	889	964	1,044
13.0%	(107)	18	38	58	80	104	129	155	184	214	246	280	316	355	396	440	487	536	589	645	705	768	836	908	984	1,065
14.5%	(107)	19	39	60	82	106	132	159	188	219	252	286	323	363	405	450	497	548	602	659	720	784	853	926	1,004	1,086
18.0%	(122)	19	40	62	85	110	137	165	195	227	261	297	335	376	420	466	515	567	623	682	745	812	883	958	1,038	1,123
19.0%	(132)	20	41	63	87	112	139	167	198	230	265	301	340	382	426	473	523	576	632	692	756	824	896	972	1,053	1,140
20.0%	(135)	20	41	64	88	114	141	170	201	234	269	306	346	388	433	480	531	585	642	703	768	837	910	988	1,070	1,158
		0.0%	0.3%	0.5%	0.8%	1.0%	1.3%	1.5%	1.8%	2.0%	2.3%	2.5%	2.8%	3.0%	3.3%	3.5%	3.8%	4.0%	4.3%	4.5%	4.8%	5.00%	5.25%	5.50%	5.75%	6.00%
19.0%	(132)	20	42	65	90	117	146	176	209	244	281	322	364	410	459	512	568	628	692	760	833	911	995	1,084	1,179	1,280
20.0%	(135)	21	43	66	92	119	148	179	212	248	286	327	370	417	467	520	577	638	703	772	846	926	1,010	1,101	1,197	1,301
		0.0%	0.3%	0.5%	0.8%	1.0%	1.3%	1.5%	1.8%	2.0%	2.3%	2.5%	2.8%	3.0%	3.3%	3.5%	3.8%	4.0%	4.3%	4.5%	4.8%	5.00%	5.25%	5.50%	5.75%	6.00%
19.0%	(132)	21	44	68	94	121	151	183	217	253	292	333	378	425	476	530	588	650	717	787	863	944	1,030	1,123	1,221	1,326
20.0%	(135)	21	44	69	95	123	153	186	220	257	297	339	384	432	484	539	598	661	728	800	877	959	1,047	1,140	1,240	1,347
		0.0%	0.3%	0.5%	0.8%	1.0%	1.3%	1.5%	1.8%	2.0%	2.3%	2.5%	2.8%	3.0%	3.3%	3.5%	3.8%	4.0%	4.3%	4.5%	4.8%	5.00%	5.25%	5.50%	5.75%	6.00%
19.0%	(134)	25	52	80	111	144	179	216	257	299	345	395	447	503	563	627	696	769	848	931	1,021	1,116	1,218	1,327	1,444	1,568
20.0%	(137)	25	53	82	113	146	182	220	261	304	351	401	454	511	572	638	707	782	861	946	###	1,134	1,237	1,348	1,466	1,592

Module Effeciency	Area: Module Surface / Per MW SqM	Area: Ground /MW SqM	Area: Ground /MW Acre	roject Co Cost / MWp MINR	Generati Units / Annum (Avg) Milion KWh	Enrichment Ratio (Revenue / Capex) in 25	IRR in 25 Years	NPV of Cash Flow @ 14.50%
Modules Placed on Fixed Structurere and performing on S						Degradation	Standrad / Gurranteed -->	
7.0%	14,286	25,974	6.42	111.92	1.34	9.40	53.99%	₹ 1,004
10.0%	10,000	18,182	4.49	112.22	1.36	9.53	54.41%	₹ 1,022
12.0%	8,333	15,152	3.74	108.27	1.38	10.03	56.03%	₹ 1,044
13.0%	7,692	13,986	3.46	106.70	1.40	10.34	57.00%	₹ 1,063
14.5%	6,897	12,539	3.10	106.63	1.42	10.51	57.53%	₹ 1,081
18.0%	5,556	10,101	2.50	121.58	1.47	9.50	54.33%	₹ 1,104
19.0%	5,263	9,569	2.36	131.63	1.49	8.91	52.39%	₹ 1,114
20.0%	5,000	9,091	2.25	135.07	1.51	8.81	52.06%	₹ 1,129
Modules Placed on Fixed Structurere but better performing						Degradation	Lowest -->	
19.0%	5,263	9,569	2.36	131.63	1.49	9.98	53.67%	₹ 1,203
20.0%	5,000	9,091	2.25	135.07	1.51	9.87	53.34%	₹ 1,219
Modules Placed on Fixed Structurere but better performing						Degradation	Lowest -->	
19.0%	5,263	9,569	2.36	131.63	1.54	10.33	54.72%	₹ 1,249
20.0%	5,000	9,091	2.25	135.07	1.56	10.21	54.38%	₹ 1,266
Best Case : Modules Placed on Single Axis Tracking Struct						Degradation	Lowest -->	
19.0%	5,263	9,569	2.36	134.01	1.82	11.97	59.48%	₹ 1,492
20.0%	5,000	9,091	2.25	137.40	1.85	11.84	59.13%	₹ 1,513

Cash Flow (Years)

ROI (Cum MINR) compared with power purchased from DG

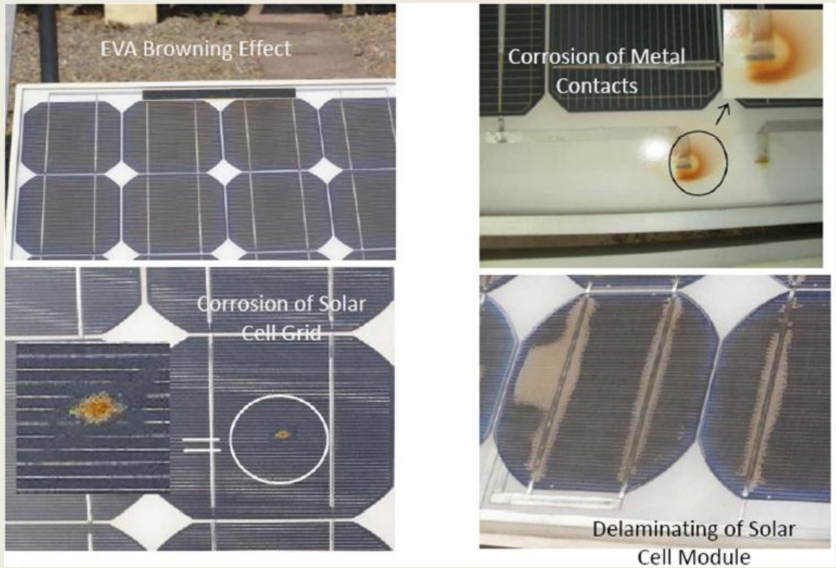
Module Effeciency	0	1	2	3	4	5	6	7	8	9	10	11	12
Degradation (Standrad / Gurranteed)		3.00%	3.78%	4.56%	5.33%	6.11%	6.89%	7.67%	8.44%	9.22%	10.0%	10.7%	11.3%
7.0%	(112)	19	39	60	82	106	131	158	187	217	249	283	319
10.0%	(112)	19	39	61	84	108	134	161	190	221	253	288	325
12.0%	(108)	19	40	62	85	110	136	164	193	224	257	292	330
13.0%	(107)	20	41	63	86	111	138	166	196	228	261	297	335
14.5%	(107)	20	41	64	88	113	140	169	199	231	265	302	340
18.0%	(122)	21	43	66	90	117	144	174	205	238	274	311	351
19.0%	(132)	21	43	67	92	118	147	177	208	242	278	316	356
20.0%	(135)	21	44	68	93	120	149	179	211	245	282	320	361
Degradation (Lowest)		0.00%	0.25%	0.50%	0.75%	1.00%	1.25%	1.50%	1.75%	2.00%	2.25%	2.50%	2.75%
19.0%	(132)	22	45	69	95	124	153	185	219	256	295	336	380
20.0%	(135)	22	45	70	97	125	156	188	223	260	299	341	386
Degradation (Lowest)		0.00%	0.25%	0.50%	0.75%	1.00%	1.25%	1.50%	1.75%	2.00%	2.25%	2.50%	2.75%
19.0%	(132)	22	46	72	99	128	159	192	227	265	305	348	393
20.0%	(135)	23	47	73	100	130	161	195	230	269	309	353	399
Degradation (Lowest)		0.00%	0.25%	0.50%	0.75%	1.00%	1.25%	1.50%	1.75%	2.00%	2.25%	2.50%	2.75%
19.0%	(134)	26	55	85	117	151	187	226	268	312	360	410	464
20.0%	(137)	27	55	86	118	153	190	230	272	317	365	416	471

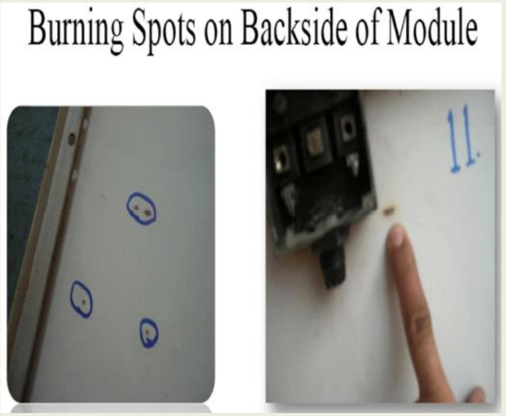
Module Effeciency	13	14	15	16	17	18	19	20	21	22	23	24	25
Degradation (Standrad / Gurranteed)	12.0%	12.7%	13.3%	14.0%	14.7%	15.3%	16.0%	16.7%	17.3%	18.0%	18.7%	19.3%	20.0%
7.0%	358	398	442	488	536	588	643	702	764	829	899	973	1,052
10.0%	364	405	449	496	545	598	654	713	776	843	914	989	1,069
12.0%	369	411	456	504	554	608	664	725	789	857	929	1,005	1,086
13.0%	375	418	463	512	563	617	675	736	801	870	943	1,021	1,104
14.5%	381	425	471	520	572	627	685	748	814	884	958	1,037	1,121
18.0%	393	438	485	536	589	646	707	771	839	911	988	1,069	1,155
19.0%	399	444	492	544	598	656	717	782	851	925	1,002	1,085	1,173
20.0%	405	451	500	552	607	665	728	794	864	938	1,017	1,101	1,190
Degradation (Lowest)	3.00%	3.25%	3.50%	3.75%	4.00%	4.25%	4.50%	4.75%	5.00%	5.25%	5.50%	5.75%	6.00%
19.0%	427	478	531	589	650	715	785	859	939	1,023	1,114	1,210	1,313
20.0%	434	485	539	597	660	726	797	872	953	1,039	1,130	1,228	1,333
Degradation (Lowest)	3.00%	3.25%	3.50%	3.75%	4.00%	4.25%	4.50%	4.75%	5.00%	5.25%	5.50%	5.75%	6.00%
19.0%	442	494	550	609	673	740	812	889	972	1,059	1,153	1,253	1,359
20.0%	449	502	558	618	683	751	824	903	986	1,075	1,170	1,271	1,379
Degradation (Lowest)	3.00%	3.25%	3.50%	3.75%	4.00%	4.25%	4.50%	4.75%	5.00%	5.25%	5.50%	5.75%	6.00%
19.0%	522	583	649	719	794	874	959	1,050	1,146	1,250	1,360	1,478	1,604
20.0%	530	592	659	730	805	886	973	1,065	1,163	1,268	1,380	1,500	1,628

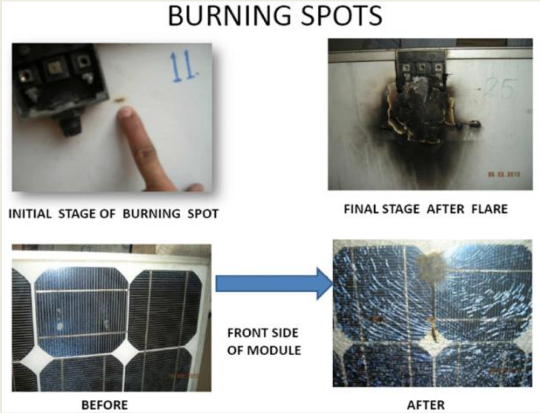
Annexure 1B: Sample comparison of projects expected yearly generation with respect to various PV technologies

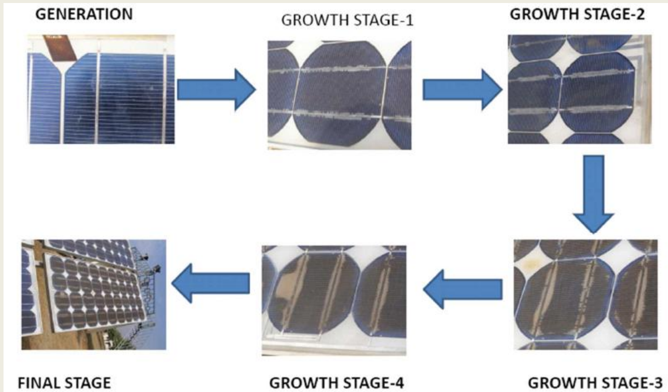
Module Effeciency	Area			Project Cos		Generatio	Generation	Generation --> kWH / Annum, Cum Years																								
	Module Surface / Per MW	Ground /MW		Cost / MWp	Cost / kWh	Comparision to lowest	Units / Annum (Avg)	Million Units (M kWh / Annum) cumulative																								
	SqM	SqM	Acre	MINR	Capex / Units		Milion KWh	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Modules Placed on Fixed Structurere and performing on Standard warranted effeciencies / Deger								3.00%	3.78%	4.56%	5.33%	6.11%	6.89%	7.67%	8.44%	9.22%	10.0%	10.7%	11.3%	12.0%	12.7%	13.3%	14.0%	14.7%	15.3%	16.0%	16.7%	17.3%	18.0%	18.7%	19.3%	20.0%
7.0%	14,286	25,974	6.42	111.92	3.80	100%	1.34	1.30	2.58	3.86	5.12	6.38	7.62	8.85	10.08	11.29	12.49	13.68	14.87	16.04	17.21	18.37	19.52	20.66	21.79	22.91	24.02	25.13	26.22	27.31	28.39	29.46
10.0%	10,000	18,182	4.49	112.22	3.75	102%	1.36	1.32	2.62	3.92	5.20	6.48	7.74	9.00	10.24	11.47	12.70	13.91	15.11	16.31	17.49	18.67	19.84	21.00	22.15	23.29	24.42	25.54	26.65	27.76	28.85	29.94
12.0%	8,333	15,152	3.74	108.27	3.56	103%	1.38	1.34	2.67	3.98	5.29	6.58	7.87	9.14	10.41	11.66	12.90	14.13	15.36	16.57	17.78	18.97	20.16	21.33	22.50	23.66	24.81	25.95	27.08	28.21	29.32	30.42
13.0%	7,692	13,986	3.46	106.70	3.45	105%	1.40	1.36	2.71	4.05	5.37	6.69	7.99	9.29	10.57	11.84	13.10	14.36	15.60	16.83	18.06	19.27	20.48	21.67	22.86	24.04	25.21	26.36	27.51	28.65	29.78	30.91
14.5%	6,897	12,539	3.10	106.63	3.40	107%	1.42	1.38	2.75	4.11	5.46	6.79	8.12	9.43	10.74	12.03	13.31	14.58	15.84	17.10	18.34	19.57	20.80	22.01	23.22	24.41	25.60	26.78	27.94	29.10	30.25	31.39
18.0%	5,556	10,101	2.50	121.58	3.76	110%	1.47	1.42	2.84	4.24	5.62	7.00	8.37	9.72	11.07	12.40	13.72	15.03	16.33	17.62	18.90	20.18	21.44	22.69	23.93	25.16	26.39	27.60	28.80	30.00	31.18	32.35
19.0%	5,263	9,569	2.36	131.63	4.01	111%	1.49	1.44	2.88	4.30	5.71	7.11	8.49	9.87	11.23	12.58	13.92	15.25	16.57	17.89	19.19	20.48	21.76	23.03	24.29	25.54	26.78	28.01	29.23	30.44	31.65	32.84
20.0%	5,000	9,091	2.25	135.07	4.05	113%	1.51	1.47	2.92	4.36	5.79	7.21	8.62	10.01	11.40	12.77	14.13	15.48	16.82	18.15	19.47	20.78	22.08	23.37	24.65	25.92	27.17	28.42	29.66	30.89	32.11	33.32
Modules Placed on Fixed Structurere but better performing then Standard warranted effeciencies								0.00%	0.25%	0.50%	0.75%	1.00%	1.25%	1.50%	1.75%	2.00%	2.25%	2.50%	2.75%	3.00%	3.25%	3.50%	3.75%	4.00%	4.25%	4.50%	4.75%	5.00%	5.25%	5.50%	5.75%	6.00%
19.0%	5,263	9,569	2.36	131.63	3.64	123%	1.49	1.49	2.97	4.46	5.93	7.41	8.88	10.35	11.81	13.27	14.72	16.18	17.62	19.07	20.51	21.95	23.38	24.81	26.24	27.66	29.08	30.49	31.90	33.31	34.71	36.11
20.0%	5,000	9,091	2.25	135.07	3.69	124%	1.51	1.51	3.02	4.52	6.02	7.52	9.01	10.50	11.98	13.46	14.94	16.41	17.88	19.35	20.81	22.27	23.72	25.17	26.62	28.06	29.50	30.94	32.37	33.80	35.22	36.64
Modules Placed on Fixed Structurere but better performing features & lowest Degeradation								0.00%	0.25%	0.50%	0.75%	1.00%	1.25%	1.50%	1.75%	2.00%	2.25%	2.50%	2.75%	3.00%	3.25%	3.50%	3.75%	4.00%	4.25%	4.50%	4.75%	5.00%	5.25%	5.50%	5.75%	6.00%
19.0%	5,263	9,569	2.36	131.63	3.52	127%	1.54	1.54	3.08	4.61	6.14	7.67	9.19	10.71	12.22	13.73	15.24	16.74	18.24	19.74	21.23	22.72	24.20	25.68	27.15	28.63	30.09	31.56	33.02	34.48	35.93	37.38
20.0%	5,000	9,091	2.25	135.07	3.56	129%	1.56	1.56	3.12	4.68	6.23	7.78	9.33	10.87	12.40	13.93	15.46	16.99	18.51	20.03	21.54	23.05	24.55	26.06	27.55	29.05	30.54	32.02	33.50	34.98	36.46	37.93
Best Case : Modules Placed on Single Axis Tracking Structurere but better performing features &								0.00%	0.25%	0.50%	0.75%	1.00%	1.25%	1.50%	1.75%	2.00%	2.25%	2.50%	2.75%	3.00%	3.25%	3.50%	3.75%	4.00%	4.25%	4.50%	4.75%	5.00%	5.25%	5.50%	5.75%	6.00%
19.0%	5,263	9,569	2.36	134.01	3.04	150%	1.82	1.82	3.63	5.44	7.25	9.05	10.84	12.64	14.42	16.20	17.98	19.76	21.52	23.29	25.05	26.80	28.55	30.30	32.04	33.78	35.51	37.24	38.96	40.68	42.39	44.10
20.0%	5,000	9,091	2.25	137.40	3.07	152%	1.85	1.85	3.69	5.52	7.35	9.18	11.00	12.82	14.63	16.44	18.25	20.05	21.84	23.63	25.42	27.20	28.97	30.75	32.51	34.28	36.03	37.79	39.53	41.28	43.02	44.75

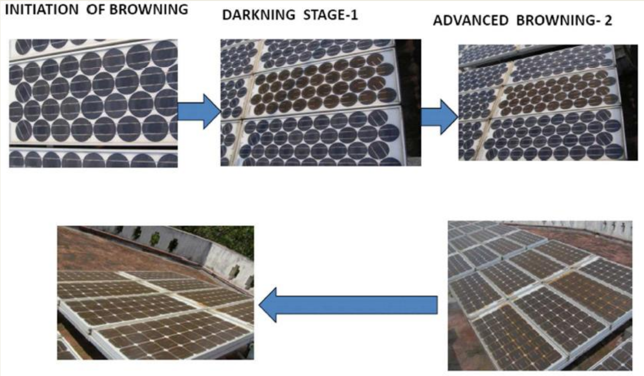
Annexure 2: Examples of performances issues faced at site on executed projects

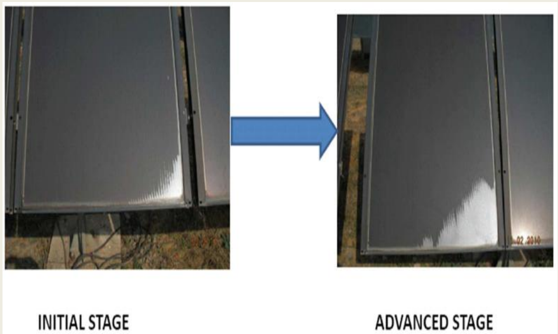


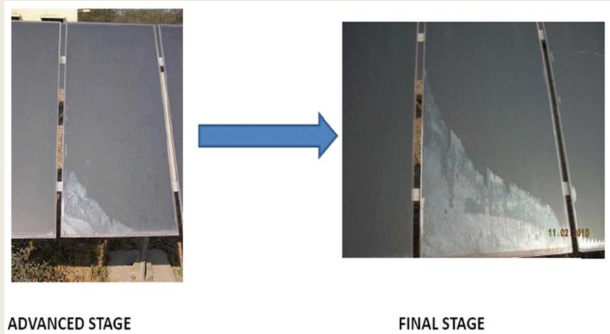




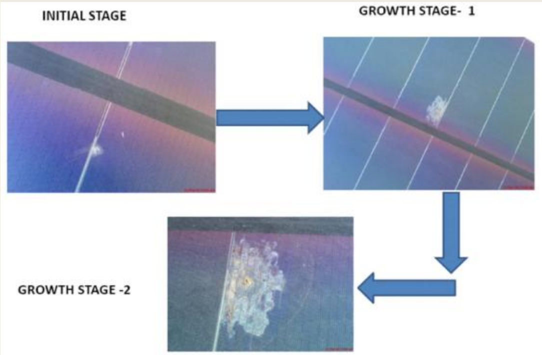


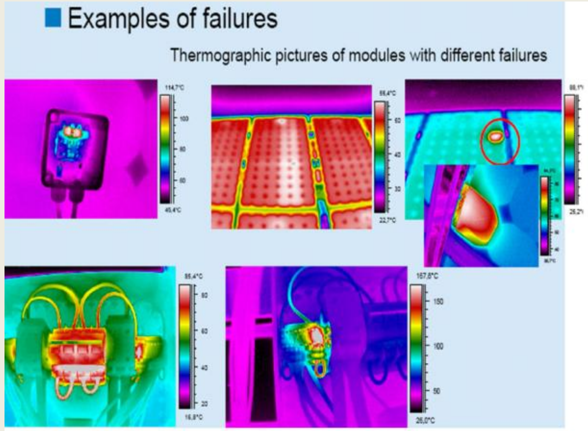


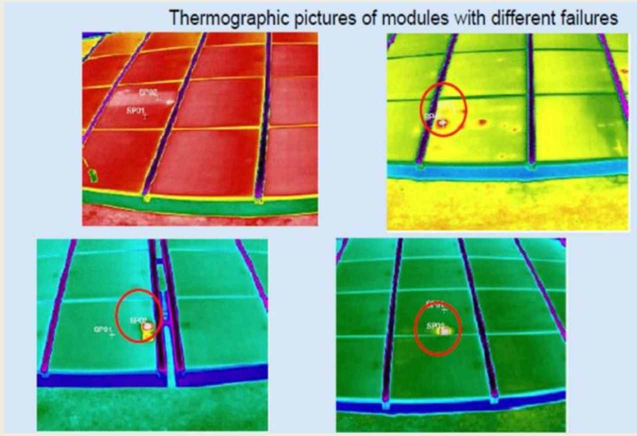


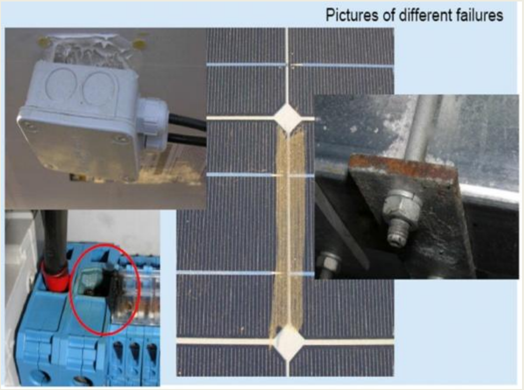


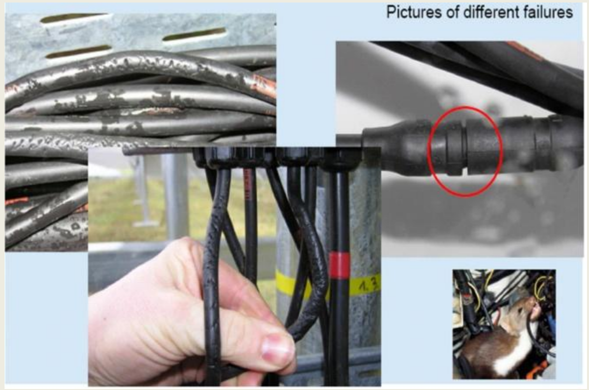
Module Browning








Pictures of different failures


Pictures of different failures