

Impact Investing: a techno-commercial study aimed at promoting solar investing in India

Seemal Malpani

Student, The Cathedral and John Connon School.

Abstract- This paper is a study about the different aspects involved in successfully setting up a solar-based technology. It's important to dwell on the industry dynamics regarding the key players, challenges and results. With a detailed secondary research, to really catch the right pulse of the sector I elected to conduct a study of few commissioned projects attempting to cover the gamut of Solar industry focusing on key sector characteristics: feasibility studies, technology, execution, and operational and financial aspects. My first study was a 5.75 Solar PV project located in Osiyan, Rajasthan. Having heard about Solar PV from team Osiyan, I wanted to understand the other technologies used in the solar industry. The Government in Phase-1 had given equal emphasis to Solar PV and Concentrated Solar Power (CSP) projects. My choice was, therefore, a CSP project awarded in Phase-1 – a 50MW Solar Thermal project in Jaisalmer, Rajasthan

Index Terms- Irradiation, Concentrated solar power (CSP), Capacity Utilization Factor (CUF);

I. INTRODUCTION

Even as the world's hunger for more energy grows, the mix of installed energy capacities remains skewed towards conventional energy sources with renewables contributing less than 1% of the total consumption. Further, even within renewables the contribution from solar – perhaps the most reliable and exploitable source of energy – is far lesser. Consider the Indian scenario - as of April 2016, India had a total installed capacity of 302.8GW – ~70% of which is from Thermal i.e. Coal, Gas and Diesel, followed by 14% from Hydro and Renewable each, and balance from Nuclear. Within renewable, Solar contributes only 2% of the total installed capacity. However, through my industry interactions I understand that the scenario is brightening rapidly. The current Government has increased its focus on providing affordable and sustainable power to all, and in-line to achieving this has significantly increased the target for renewable energy installations - **175GW of renewable energy by 2022!**

The pace was slow in the initial phases, with the industry learning the tricks of the trade – understanding the technology, emphasizing on local manufacturing, studying successful case studies around the globe, but 2015 has been the breakthrough year when the industry saw new capacity additions of ~3GW – that's a stunning 80% growth in a year. The industry saw this leap for several reasons - Government push & support, increased local manufacturing, maturing of Solar PV technology brought down the production costs significantly, and lately with Solar power edging towards grid parity - price of solar power has come down from Rs 17.91/kWh in 2010 to ~INR5/kWh currently.

2015 is just the beginning though and the sector needs to witness more such leaps to reach the ambitious target of 100MW. It is estimated that the fulfillment of this vision calls for an investment of ~US\$100bn in the sector. The dwindling cost of producing energy from the sun has made a compelling case for big companies to enter solar business. Some big names including Adani, Bharti, and Reliance have already placed their bet on the sector. Thus, solar energy has transitioned from being merely corporate social responsibility to opening up a sea of opportunities within a span of four to five years. Along with big corporates, VCs, Private Equity players are also investing heavily – PE investments in solar sector for 2014 were ~US\$216m

Japan's SoftBank, along with telecommunication major, Bharati Enterprises, and Taiwan's electronic goods manufacturer, Foxconn, announced plans to invest US\$20 billion for setting up 20GW of solar power

Adani Power, Reliance Power have also committed investments worth more than US\$5 billion for setting up solar power plants in India

According to data from India's socio-economic and caste census collected between 2011 and 2013, 70% of India's population lives in villages. Of all the countries in Asia, India has the largest population with no access to electricity – a staggering 304 million people! While 94% of Indians living in Urban areas have electricity, only 67% living in rural area has access to power. That's anomalous considering India has about 300 sunny days a year, and there is a huge potential for generating solar electricity annually - ~ 5,000 trillion kilowatt-hours (kWh) per year. Solar resource if effectively exploited could ensure electrification of maximum population including even the remotest & smallest villages.

So, it's fairly straight:

**India
needs
Solar**

Solar is probably the most effective, reliable, fast-turnaround solution India can have to its electrification problems of covering even the remote villages. Small-scale solar projects / rooftop solutions can be set-up fairly quickly to provide small villages' access to electricity, with connecting them to country grid eventually.

**Solar
needs
India**

Foreign and local players across the solar sector value chain are gearing up to exploit the huge potential that solar has to offer in India. Solar panel manufacturing companies are largely US / Canada / Germany & emergence of Chinese players, however, key consumption markets being India and China where there are ample solar farms being constructed. The cost per mw of Solar panels has a downward bias, partly due to technological advancement & partly due to over supply.

MY OBJECTIVE: For my study I have focused on Rajasthan – the state with the highest solar potential in the country. Both the projects were awarded under the Jawaharlal Nehru National Solar Mission (JNNSM) Phase-1, and are currently commissioned. My analysis and observations described here are result of my several interactions with the plant teams including Heads, workers, operational teams, and finance & strategy teams. They not only helped me get a macro perspective of the sector but also helped me understand the finer aspects of project implementation, operation and maintenance.

My first study was a 5.75 Solar PV project located in Osiyan, Rajasthan. Here I dwelled on 2 things – how to choose the project site, and the technology? I learned that there are various technical analyses performed including simulations on satellite and ground data, land topography, Wind / Precipitation / Temperature analysis – all these mostly conducted through expert third party companies. The feasibility studies and their interpretation form the basis of site feasibility analysis. This project was picked up during the nascent stages of solar development in India. Technology then, though widely known through documentation of success stories abroad, was fairly new for Indian troughs. Detailed comparative studies were therefore a must to know the merits and demerits of each. The Osiyan project selected the widely adopted Solar PV technology, roping in expert local and foreign panel manufacturers, equipment makers, and turnkey contractors.

Solar Thermal compared to Solar PV is not very widely documented mainly as it is costlier, requires ample water, needs skilled manpower, and accurate irradiation data (as output depends on direct sunlight received). There are however numerous other benefits – higher capacity utilization, storage capability, flexibility of output, grid connection, and the ability to combine with another thermal or renewable plant. In India, so far there is only about 120MW of commissioned projects – across just 4 projects! The technology is viable and future will depend on the sustainability of these current commissioned projects.

III. IDENTIFY, RESEARCH AND COLLECT IDEA

Before visiting the sites, I did some background research regarding the Current Scenario in the Indian Solar Power Industry.

INDIAN SOLAR INDUSTRY: Current Scenario and Outlook: Key Players in the Value chain:

<p>PROJECT DEVELOPERS</p>	
<p>EPC CONTRACTORS</p>	
<p>EQUIPMENT / PANEL MANUFACTURERS</p>	

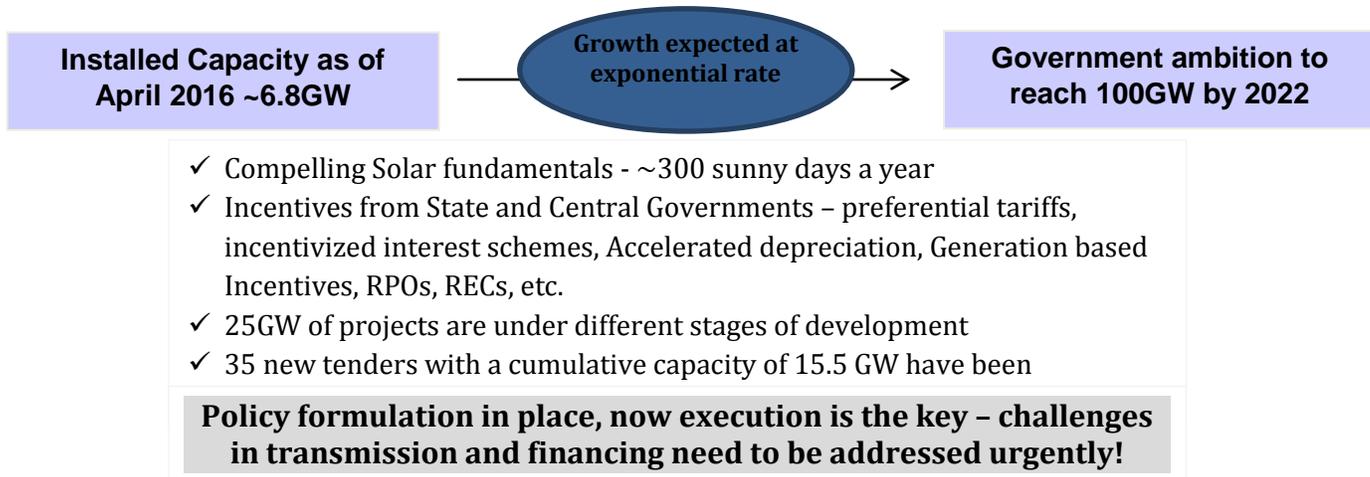
Indian Solar Power Industry- Government policy support

The thrust on renewable / solar power generation started with a number of State Governments announcing policies to aid development of solar plants in the country.

<p>Electricity Act 2003</p>	<ul style="list-style-type: none"> ✓ Mandated State Electricity Regulatory Commissions (SERCs) to promote generation of electricity from renewable sources ✓ Fix certain minimum percentages for purchase of renewable power
<p>National Electricity Policy 2005</p>	<ul style="list-style-type: none"> ✓ Further provided for progressive increase in generation of electricity from renewable sources and supported purchases by distribution companies through competitive bidding process
<p>Tariff Policy 2006</p>	<ul style="list-style-type: none"> ✓ Provided for fixation by SERCs of a minimum percentage of Renewable Purchase Obligation (RPO) taking into account availability of such resources in the region and its impact on retail tariffs and procurement by distribution companies at preferential tariffs determined by SERCs
<p>National Action Plan on Climate Change 2008</p>	<ul style="list-style-type: none"> ✓ Outlined existing and future policies and programs addressing climate mitigation and adaptation - NAPCC has advised that starting 2009-10, RPOs be set at 5% of total grids purchase, and be increased by 1% each year for 10 years

The broader sector policy reforms through amendments in the Electricity Act 2003, is still awaiting parliamentary approval, however the Government has formalized policies like UDAY and Solar Parks Policy which have been largely hailed as successful.

Indian Solar Power Industry – heading towards a ‘brighter’ future?



Bridge to India 2016 report estimates, with capacity additions of ~5.4GW in coming years, India is all set to become the 4th largest solar market globally - behind only China, US and Japan. Though there is enough policy support to meet the ambitious targets for capacity addition, but ensuring grid connectivity and investment / lending appetite at the current tariff levels of ~INR5/kWh (tariffs have fallen by almost 33% over last 2 years) will remain the main challenges

IV. FIRST PROJECT STUDY: 5.75MW LOCATED IN OSIYAN RAJASTHAN

The Osiyan 5.75MW project was among of the early solar projects executed in India. The Sponsor is a very reputed industrialist group (Videocon) and this project was their first foray in solar power sector. It was interesting to study this project since solar sector in India was still in nascent stages then. There were a very few PV projects being developed in India, and the Sponsor faced numerous challenges such as high capital costs, land procurement, lack of transmission capacity in remote areas, etc.

I had several interactions with the project team and site visits to understand in detail some of the key aspects of the project including:

- ✓ **Selection of Project Site – Feasibility study**
- ✓ **Selection of Right Technology**
- ✓ **Selection of Right Technical Partners**
- ✓ **Power evacuation system**
- ✓ **Financial assessment**

1. Key Project Metrics

a) **Plant Capacity:** 5.75MW

b) **Location:** Betwasiya site situated approximately 12km to the East of tehsil Osiyan and approximately 50km from the city of Jodhpur. The site is well connected by MDR37 from Osiyan and can be accessed by State Highway (SHW61) from the city of Jodhpur. The Company had entered into land lease agreement with the Rajasthan Government for 37.5 acres



c) **PPA:** NTPC VidhyutVyapar Nigam (NVTN) under the feed in tariff policy of Jawaharlal Nehru National Solar Mission (JNNSM) at Feed-in tariff of INR17.91/Kwh for 25 years

d) **Technology:** Multi Crystalline Silicon Photovoltaic Technology

e) **Project Cost:** INR860mio; D/E – 70:30; Debt tied up with Infrastructure Development & Finance Corporation (IDFC)

2. Selection of Project Site

Rajasthan is one the Indian states with highest solar irradiation, and thus is most ideal location for Solar PV.

The basic checklist that the Sponsor considered includes the following –

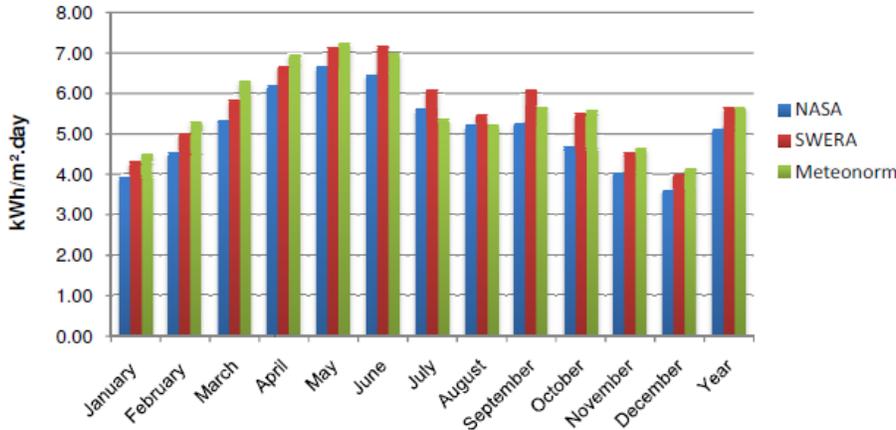
a) **Irradiation Analysis :** Irradiation study / simulation analysis is extremely important as the annual energy yield of a PV plant is heavily dependent on the solar resource at the site. There are a variety of possible solar irradiation data sources that may be accessed. The datasets either make use of ground based measurements at well controlled meteorological stations or use processed satellite imagery.

The Sponsor sourced monthly horizontal plane irradiation data for the proposed site from below mentioned sources:

- **NASA's** Surface Meteorology and Solar Energy data set; holds satellite derived monthly data for a grid of $1^{\circ} \times 1^{\circ}$ covering the globe for a 22 period (1983- 2005). The data are suitable for feasibility studies of solar energy projects
- **SWERA;** obtains primary inputs into its models from geostationary satellites. The satellites provide information on reflection of the earth-atmosphere system and surface and atmosphere temperature, which is useful in determining cloud cover. SWERA also uses data such as elevation, ozone, water vapour, snow cover, etc. to attain results. Model outputs are verified with ground-based data to ensure quality of the measurements.
- The **METEONORM** global climatological database and synthetic weather generator; contains a database of ground station measurements of irradiation and temperature. Where a site is over 20km from the nearest measurement station it outputs climatologic averages estimated using interpolation algorithms. Where no radiation measurement station is within 300km from the site, satellite information is used. If the site is between 50 and 300km from a measurement station, a mixture of ground and satellite information is used.

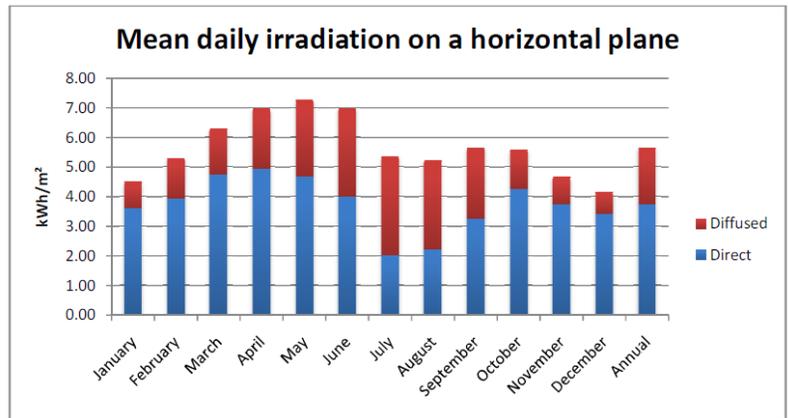
Comparison of data obtained for all the 3 above sources was studied and the results obtained as follows:

Mean global daily irradiation on a horizontal plane



Since METEONORM provides a combination of ground and satellite data and the measurement include temperature data as well which is important for PV projects, the Sponsor used the METEONORM data for energy yield prediction. The comparative study and the detailed data from METEONORM are shown below:

Month	Mean global daily irradiation on a horizontal plane kWh/m ²
January	4.49
February	5.30
March	6.29
April	6.96
May	7.25
June	6.98
July	5.35
August	5.21
September	5.66
October	5.59
November	4.66
December	4.15
Annual Mean	5.66



Direct and Diffuse Daily Irradiation on a Horizontal Plane at Betwasiya.

Land topography

As understood from technical due-diligence reports, the proposed site located at Village Betwasiya, Tehsil Osian in District Jodhpur of Rajasthan was a barren patch with negligible vegetation and approximately 36 acres in area. The area was undulating, and it is understood that the Sponsor considered blasting and leveling to eliminate the risk of inter-row shading. Interestingly, I noticed that there is a large wind farm adjacent to the project, and was keen to know how this would impact the output at the site. On Q&A I it came to my highlight that this wind project was commissioned just before COD of the solar plant, and due to shadow from this adjacent plant, the project efficiency was hampered. The Sponsor had filed a petition against the same, and recovered the losses

b) Water availability

The Sponsor has conducted a hydro-geological study which indicated presence of fresh and potable underground water, between 80-85m below ground level. For maintaining plant efficiency, these could be used for cleaning during long dry spells.

c) Electrical Infrastructure

There was no local electrical infrastructure available on site for power evacuation. The Sponsor had entered into an agreement on a grid connection infrastructure with the Rajasthan VidyutPrasaran Nigam Limited (RVPNL). The power from the plant was to be evacuated through 33kV lines to the 132kV substation owned and operated by RVPNL.

3. Selection of Right Technology

Three key elements in a solar cell form the basis of their manufacturing technology

1. Semiconductor, which absorbs light and converts it into electron-hole pairs
Choice: either crystalline silicon in a wafer form (mono-crystalline or multi-crystalline) or thin films of other materials – Amorphous Silicon, Cadmium Telluride, & Copper Indium (gallium) Diselenide (CIS or CIGS).
2. Semiconductor junction, which separates the photo-generated carrier (electrons and holes)
3. Contacts on the front and back of the cell that allow the current to flow to the external circuit

Comparison of the technologies is as below-

#	PARAMETER	CRYSTALLINE	THIN FILM	CPV
1	Type of Material	Polycrystalline	Amorphous Silicon, CdS, CdTe, CIGS etc.	Triple Junction GaAs Cell & lens, tracker
2	Power Efficiency	12-16%	6-8%	20-25%
3	Technology credentials at the time of COD	Well developed	Under development	Under development
4	Module Weight	Light	Heavier	Heaviest
5	Area utilization	Higher power generated per unit area due to high efficiency	Less power per unit area	Highest power per unit area
6	Temperature effects	Temperature variations affect output	Lesser impact of temperature variation	High variation
7	Irradiance	Used particularly for normal radiations	Better performance with Diffuse radiations	Works only for normal radiations
8	Module quantity	Lesser nos required due to high efficiency	More modules required	Lowest nos. of modules required
9	Output per MW installed	High	Varies as per sunlight condition and various locations	Very High (due to tracking)
10	Transportation Cost	Low	Highest	High
11	Mounting Structure required per KW power	Fewer	More	Sophisticated mounting required
12	Land Requirement required per MW	Lesser space required	Largest space required	Lowest space required
13	Inverter	High inverter flexibility	Limited inverter flexibility	Limited inverter flexibility
14	Cost	High cost per Watt	Lower cost per Watt	Highest cost per Watt
15	Environment Effects	Less Sensitive	Sensitive	Sensitive
16	Stabilization	Stable power output from at initial stages	Stability achieved after 4-6 months	Unknown
17	Health hazards	Made from non toxic material(Si)	Toxic materials used for thin films(CdS, CdTe)	Unknown
18	Power Degradation	Less degradation	Highest degradation for initial 5-7 years	High Degradation
19	Plant Maintenance	Less maintenance required after installation so lower cost	Highest maintenance required, so highest maintenance cost	High maintenance required, so high maintenance cost
20	Repair	Relatively easy	Difficult due to complex structure	Difficult due to complex structure
21	Cooling Requirement	Not required	Not required	Requires active or passive cooling which could increase cost
22	Cabling	Well known, and lower cabling losses	Well Understood but yet difficult due to higher number of arrays, along with high cabling losses	Complex and under development.Cabling losses expected to be high
23	Suitability for Grid Technology	Good	Good	Good

The Sponsor decided to use multi-crystalline silicon photovoltaic technology as preferred technology. The advantages and disadvantages in addition with their market availability and costing were the key parameters on basis of the technological decision were finalized.

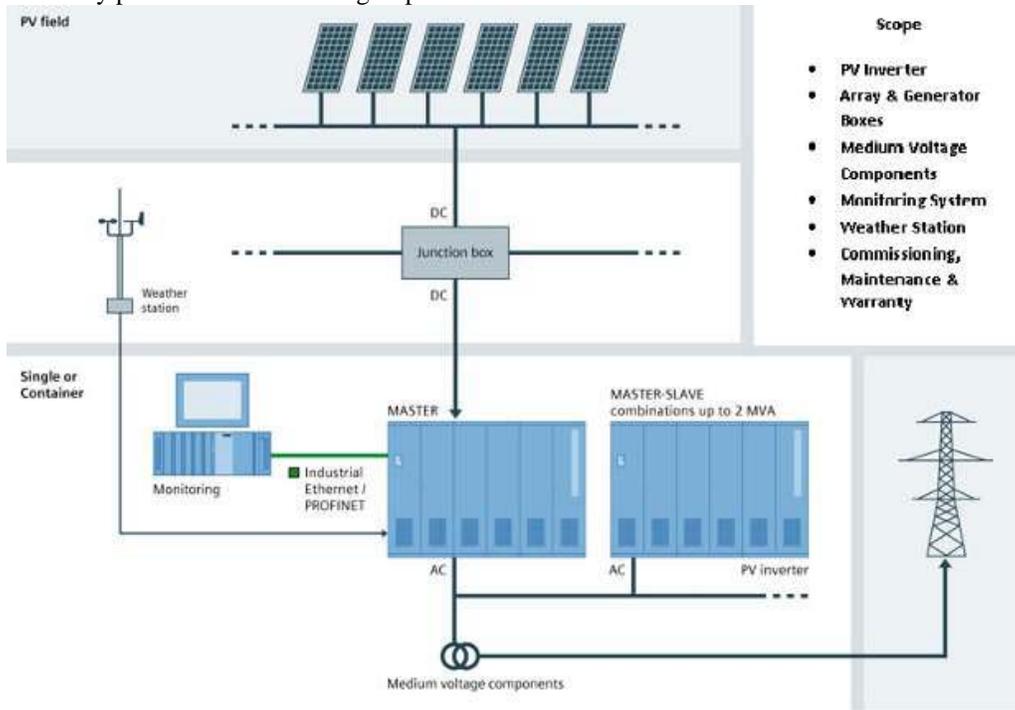
4. Selection of Right Technology Partners

In line with their vision and strategy of developing Solar Farms, the Sponsor has roped in the best technology partners in the solar energy sector -

	China-based producer of solar panels		India based Solar EPC Company – qualified turnkey contractor
	Germany-based specialist for Solar PV technology		One of the leading solar panel manufacturers in India
	Germany based photovoltaic specialist – leader in Solar PV		Japanese company specializing in thin-film silicon technology

5. Power evacuation system

The biggest challenge for solar plants during the initial phase of the sector was connecting the remote areas to grid. To mitigate this risk, the Sponsor entered into agreement with the State distribution company – RVPNL to ensure connection to the grid with all necessary protection and metering as per relevant standards



Power evacuation was considered by drawing 33 KV S/C overhead line strung on Panther Conductor from Solar Plant to RVPNL's 132 KV Osayan Grid Sub-Station, located approximately 7 kms from plant site

6. Financial assessment

The estimated project cost for the project was ~INR860m i.e. ~150m per MW, and majority of the cost ~ 80% was towards EPC. The Sponsor's equity contribution was ~30% of the project cost and for the balance debt was tied-up. One of the best infrastructure company IDFC appraised the project and took an entrepreneurial call to finance the project.

Conclusion

This being an early stage project the commercial aspect was quite different from some of the current ongoing projects / bids. The capital costs for solar PV projects have come down significantly and solar power has already reached grid parity for some industrial users – cost per unit for solar stabilizing ~INR5/kWh.

Also, the Sponsor was a new entrant in the solar sector, and it was thought provoking how they successfully achieved project commissioning mitigating all the challenges in the way, The project gave me a good insight on the technical as well commercial aspects of a Solar PV project. It also gave me enough confidence of getting it replicated elsewhere.

V. SECOND PROJECT STUDY: 50 MW SOLAR THERMAL PROJECT AT JAISALMER, RAJASTHAN

Over my interactions with the project team of Osayan, I realized that there are number of ways to exploit the solar energy resource. While Solar PV was the widely adopted technology then, there were a number of other projects exploiting the other technology i.e. Solar Thermal.

With an aim to explore the potential of other established solar power technologies, I selected another project in Rajasthan, which used Solar Thermal as a technology to produce energy. This project was India's first Concentrated Solar Power (CSP) project under JNNSM, Phase 1 to be commissioned and connected to the Grid. From the Sponsor I learned that in 2010, with an idea of giving equal emphasis to Solar PV and CSP technologies, 7 CSP projects totaling 470MW were allocated under JNNSM-Phase 1, and these had a May 2013 deadline for commissioning. The Jaisalmer project was the only one among the 7 projects, which was commissioned around this deadline (with a couple of months of delay) while for the other projects the Government announced an extended deadline. These interactions raised several questions – How is CSP technology different than the widely adopted Solar PV technology? Does the choice depend on the capacity of the project? Which one fares better in terms of plant efficiencies, capital costs, maintenance, etc. Considering only a fraction of the allotted CSP projects from JNNSM Phase-1 have been commissioned, is CSP a viable technology in India?

Q&A with the project team helped me understand a number of these questions. My key observations are as presented in following paragraphs –

1. Key Project Metrics

Plant Capacity: 50 MW

Location: Jaisalmer, Rajasthan

PPA: 25 years with NTPC VidyutVyapar Nigam Limited (NVVN), Feed-in Tariff of INR12.2/kWh

Technology: Grid-Connected Parabolic Trough Solar Thermal on the base of EuroTrough design

Project Cost: INR8,000m, D:E (%) – 70:30

2. Solar Thermal (CSP) vs Solar PV

CSP vs PV – Basic Principle

CSP technology uses reflective mirrors to concentrate the solar radiation at a particular point to produce heat and convert water into steam. Solar PV uses solar panels to directly convert the solar radiation into electricity.

Critical Parameters to compare and evaluate these technologies:

- ✓ **Capacity utilization factor (CUF):** CERC tariff order in November 2010 considered a CUF of 23% for CSP technology (without thermal storage) as against 19% for solar PV.
The Jaisalmer project has achieved on an average CUF of 24% and a peak of 29%. Further, the technical team also highlighted that the biggest advantage of CSP installation is that they can store the heat using different technologies like molten salt technology to further improve the CUF. Using storage, the team suggested that the CUF can improve 40-50% for every 6-8 hours of storage.
The project has however not implemented any storage technology currently. But the plant heads confirmed that given that the time of operation per day is less than 12 hours, they are positively contemplating towards adding thermal storage
- ✓ **Flexibility of usage during nights / cloudy days:** Since heat generated from CSP can be stored, the project can produce electricity all day, as against Solar PV technologies dependence on the sun for producing electricity.
- ✓ **Grid Flexibility:** Another important advantage that the project team highlighted was the flexibility to ramp up or down electricity generation in line with the demand, thus minimizing the risks for grid shocks.

✓ **Hybridization:** As CSP basically uses sun to generate thermal energy, I further questioned the team if it can be used in combination with thermal projects. The team asserted that they can have a hybridized CSP & Thermal plants, and also emphasized that theoretically, hybridization can lead to improvement in CUF and can help in significant capital cost savings.

The above points definitely suggested that CSP was a viable and may be a more efficient technology for solar power. So my obvious question was why there have been such few installations so far. What are the key challenges in implementation?

1.Lack of reliable DNI data: The team elaborated that at the time of bidding they had relied on the satellite data for Direct Normal Irradiance (DNI), which considered the DNI of 1,825 kWh/m²/year. However, when the technical team measured DNI data at the ground at the time of project execution they actually received DNI of 1,753 kWh/m²/year. So to maintain the output from the plant to 50MW, they had to reengineer the project – increase the loops (the mirrors are arranged in a circular manner) from 80 to 120.

2.Project implementation costs: The costs of implementing Solar PV projects have come down significantly ~INR50-60m per MW while costs for Solar Thermal implementation is ~INR120m per MW (Source: CERC, 2015-16 guidelines). The costs for CSP are higher given the fact that critical components including reflective mirrors, tracking devices, etc. have to be imported, as there is no local manufacturing. The Company sourced its solar collectors from EuroTrough, Reflective Mirrors from Flabeg, Germany, Heat Transfer Chemicals from Dow Chemicals, USA, etc. Further, O&M costs are also high – the project team said they face a major issue with sandstorms in Jaisalmer due to which the mirrors require frequent cleaning. Currently they have ~80 people to clean the mirrors at the plant.

3.Need for skilled manpower: The team also discussed how they faced execution delays as the EPC contractor Lauren-Jyoti took more time for fabricating the mounting structure than anticipated. Technical know-how and skill availability is much more in Solar PV than CSP

Selected site need ample water: Water requirement for CSP per unit of electricity generated is much more than Solar PV

4.Financial tie-up: On interactions with the finance team I learned that convincing debt investors for a new technology with no documented successful case was a mammoth task. However, they did not face any major hiccups and were able to tie-up with Bank of Baroda, which conducted an extensive evaluation of the project before disbursing the loan.

Conclusion

I had very informative discussions with the team about the advantages and the challenges faced by the team while commissioning a CSP Solar project. CSP technology has a long ground to cover with only about 120MW of successful installations till now, but is definitely a viable technology for harnessing the solar resource potential. My study formed the basis on which I pitched the commercial and environmental benefits of investing in Solar. This led to the company making two solar investments in Pune, India.

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I would like to thank Mr. Saurabh Dhoot, Director and Promoter Videocon Group, for providing me with a very informative overview and answering the innumerable questions an inquisitive mind posed before him. I'd also like to express my gratitude towards Mr. Amit Patel, CEO Sintex Ltd., for considering the research of a sixteen year old and drawing on it to make investments in Solar. My sincere acknowledgment to the employees at both the organisations without whom the detailed aspects of the technology wouldn't be half as easy to get at. Finally I'd like to thank my father who helped me brainstorm on how to go about the research.

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