Financial Analysis of the Solar PV Tariff Bids in India

Rajas P. Shah

IIT Gandhinagar

ABSTRACT

While technological progress and consolidation of manufacturing prowess in China continue to largely shape the volume as well as prices of solar PV modules across the world, India's governmental outlook and incentives, as well as indirect roadblocks imposed for purposes of taxation or for protection of Indian Solar industry continue to shape the prices and tariff bid s for grid-connected solar power plants.

This study establishes a basic understanding of the situation, the terms pertaining to solar power and financial analysis, and then analyses the trends in bids for solar power. Next, the erstwhile lowest bid of INR 2.44/kWh is analyzed Discounted Cash Flows, and a simulated bid value of INR 2.67/kWh is obtained with operational and financial decision assumptions. Linked in the study is the workbook to see how changes in inputs affect the LCOE and thereby the bid values, and also a deterministic sensitivity analysis showing impact of certain inputs upon the output, i.e., LCOE.

Next, the factors – Policy, Financial decisions, Technology are discussed briefly to understand the recent plateauing of lowest bids.

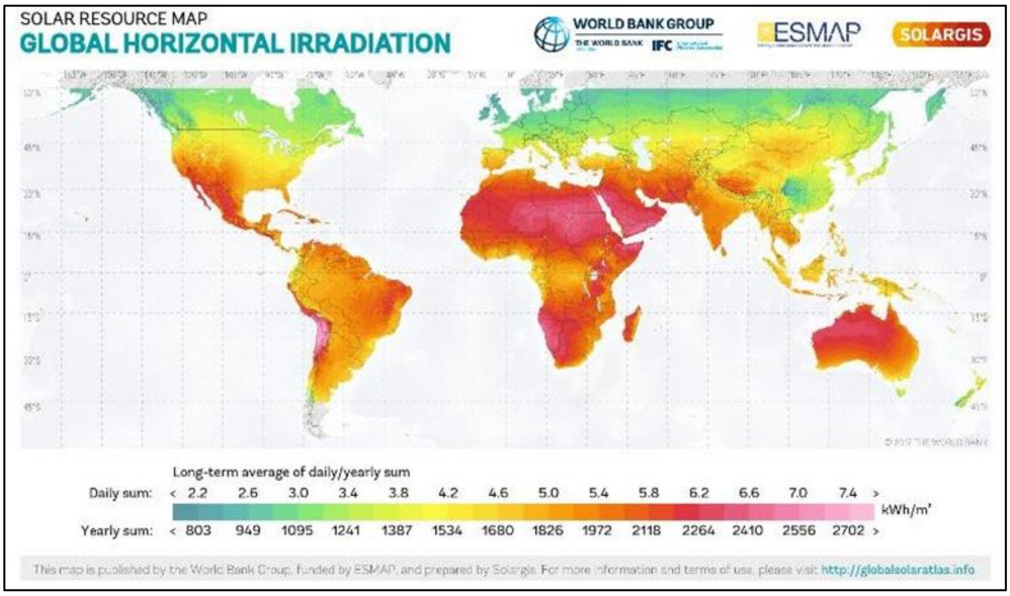
INTRODUCTION

Solar photovoltaic (PV) devices employ solid-state semiconductor devices to convert photon energy directly into electric energy. Incident photon energy modifying the intrinsic resistivity of a conductor is called *photoconductivity*. This phenomenon is utilized to produce devices called solar cells that convert photon energy directly into useful electrical energy. Solar PV began to gain attention as a clean, renewable energy source internationally after the oil crisis of 1973. Its performance reliability was proven in the previous two decades in space programs. Research began to explore the possibility of further developing this technology for its economic use on earth, the prime objective being to bring down the costs considerably, without sacrificing performance reliability.

In 1973, the US government initiated a large-scale R&D program for commercializing solar PV modules with an annual budget of US$ 20 million. By 1980, this figure reached US$ 150 million. By late 1970s, similar government-funded R&D commenced in many industrially advanced and developing countries, notably in India and Brazil. With this government interest came the participation of oil companies and business houses.

Today, major international companies are investing in the Indian solar market. Top Indian players include Tata Power Solar Systems Ltd., Vikram Solar, Azure, Emmvee, Kotak Urja, etc.

Solar power is an outstanding opportunity for India, mainly because of the ample solar resource India receives as a tropical country. The image given below shows the annual average horizontal irradiance for the globe.



IMG 01: Annual average GHI in the world.

The map demonstrates that India's location and solar resource is highly conducive for solar energy.

There is a huge scope due to the large prospective consumer base India has, thanks to the very high population density. Further, India's high energy requirements are creating a lot of economic burden, since the main sources of conventional energy are fossil fuels. Their decreasing reserves and ever-increasing prices mean India could save billions by shifting to non-renewable energy resources. The fact that in 2017-18, India spent $87.7 Bn on importing 220.43 million tonnes of crude oil alone exemplifies the issue.

Further, the potential to reach the thousands of remote places which are not on the grid due to their location is present in Solar PV. In addition, Solar PV represents an excellent opportunity to create jobs. 1GW of solar power generation generates approximately 4000 direct and indirect jobs.

As of 31 October 2019, India's installed solar capacity was 31.696 GW. The Indian Government has set a renewed target of achieving 100GW installed solar capacity (including 40GW rooftop installations) by 2022. The initial target, set in 2014, was to achieve 20GW capacity by 2022.

SOLAR PANELS

Solar panels are an arrangement of solar modules, which in turn are collections of solar cells. India's solar program is heavily dependent on Chinese imports. In 2017, Indian solar industry imported $4.12 billion worth of solar equipment. To protect local manufacturing and promote investments, the government imposed a *safeguard duty* (initially of 25%). The imports have fallen to $2.59 billion; However, there is also a slump in demand, meaning that the situation hasn't improved for Indian solar cell manufacturers. Even with the duty, an imported Chinese solar cell costs around 12 cents, which is still lower than what the Indian solar cell costs, 13.5 cents average.

The government had taken this step with a motive to increase investment in India's solar manufacturing industry and thus bring into effect the economies of scale due to increased production.

Indian domestic module manufacturers (using imported cells), though, have benefitted from the step, since a module produced in India now costs almost same as one imported including the duty, around 25 – 27 cents.

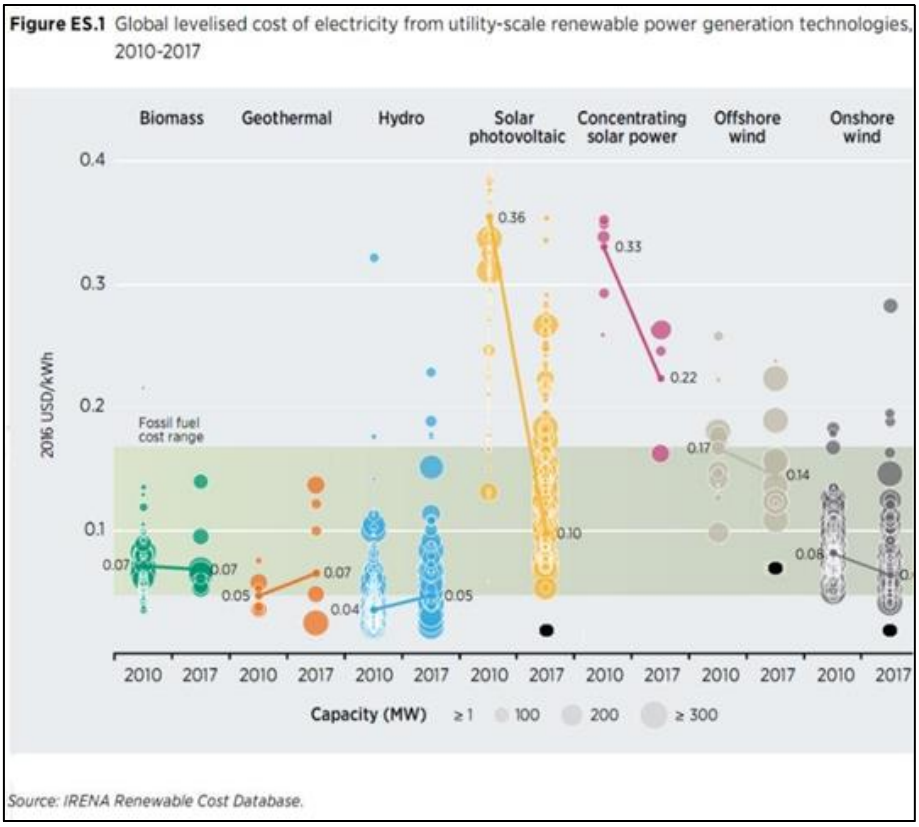
The top domestic solar manufacturers in India are Vikram Solar, Waaree Energies Ltd, Indo solar, Adani

Solar, Tata Power Solar Systems Ltd, Emmvee Group, Loom Solar, Moser Baer Solar Limited, Kotak Solar, Alpex Solar.

Major global players include Trina Solar, Renesola, Jinko Solar, Risen Energy, SunPower Corp, Axitec, Sharp, BOSCH, CSUN, Su Kam, Luminous and Microtek.

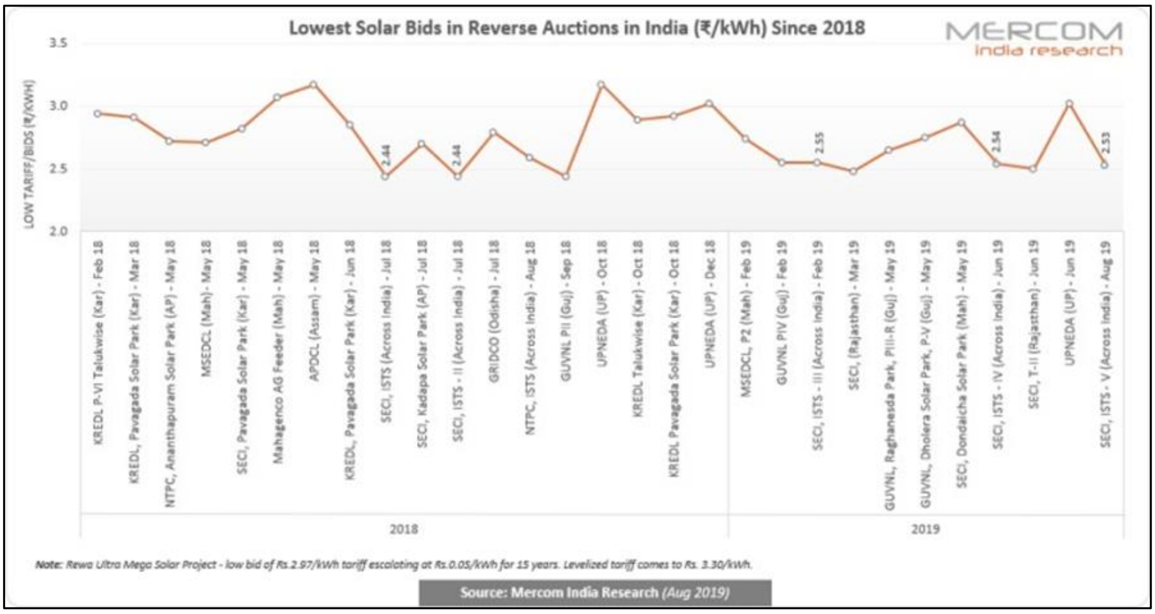
SOLAR TARIFF BIDS IN INDIA

Solar prices have fallen globally due to significant technological improvements, sharp fall in module prices, esp. Chinese and due to government focus and initiatives around the world. As the clipping below shows, the **highest fall in prices** has been achieved by solar of any renewable energy source.

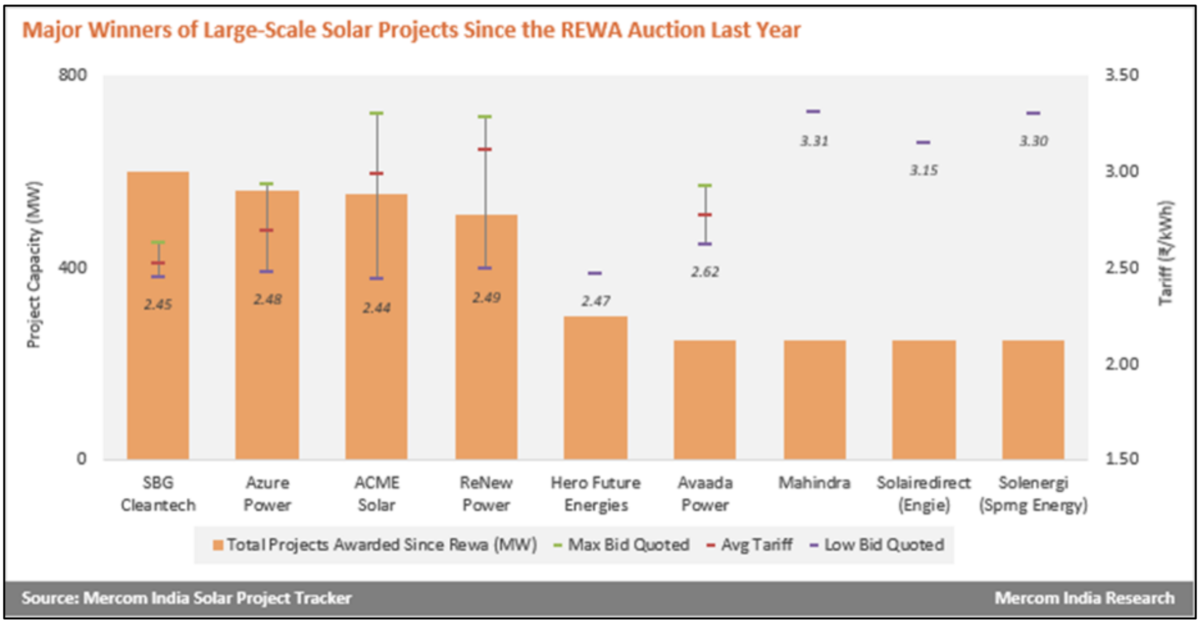


Since the launch of the Jawaharlal Nehru National Solar Mission on 11 January 2010, the solar tariff bids have fallen from the average of ₹12.16 in 2010 to the low solar bid of ₹2.44 by ACME in Bhadla Phase 3.

The chart below shows the trend in lowest solar bids in India in the last two years. Although the Chinese module prices have dropped, the lowest bids have not dropped below 2.44 ₹ recently. This could be attributed to uncertainties in the context of safeguard duty, which has also led to lesser participation from smaller developers.



Large players, who have the ability to take such risks are the ones bagging most of the projects recently. Moreover, this also means that lower interest of the smaller firms has reduced the cut-throat bids and hence the ₹2.44 figure remains the lowest, as even the bigplayers are playing it safe now. The next chart highlights these points.



Next, we will look at a case study to see how factors affect the solar power prices.

CASE STUDY: ACME BID IN BHADLA PHASE III SOLAR PARK

Here, we shall attempt to understand the finance behind the Rs. 2.44 /kWh bid at the auction carried out by SECI for 200 of the 500MW power plant being set up at Bhadla, Rajasthan.
The following are the inputs taken for calculation. For changing and analyzing their effects on LCOE, the calculator can be accessed here.

A. Inputs used for LCOE determination:

Tariff (₹/kWh)	2.44
Annual O&M expense/MW	150000
Capacity (MW)	200
CapEx/MW (lakh ₹)	425
Debt %	80
Debt maturity (Years)	12
Debt Interest rate (%)	8
Working capital Interest rate (%)	8.3
O&M Spare (%)	15
Depreciation pre-loan (%)	5.83
Depreciation post-loan (%)	1.54
ROE - Upto 10 years (%)	7
ROE - After 10 years (%)	8
$\mathbf{K_e}$ - Cost of equity (%)	12
Effective tax rate (%)	34.6
$\boldsymbol{\eta_p}$ - Module efficiency (%)	17.5
Modules depreciate to – (%)	80
$\boldsymbol{A_p}$ - Module Area (sq. m)	1.94
N - No. of modules	625000
$\boldsymbol{L_{AC/DC}}$ - AC-DC conversion losses (%)	20
ASR - Average Annual Solar Radiation (kWh/sq.m per year)	1743
O&M annual escalation rate (%)	5

Other facts and assumptions about the case are:
Bid corresponding to a tariff of ₹ 2.44/kWh for a capacity of 200MW won by ACME solar.[13] We assume that the module efficiency degrades linearly to 80% over their expected life, i.e., 25 years.

B. Units generated per year (kWh)

Year	Effective efficiency	Units generated
	%	kWh
1	17.5	295874250
2	17.36	293507256
3	17.22112	291159198
4	17.08335104	288829924.4
5	16.94668423	286519285
6	16.81111076	284227130.7
7	16.67662187	281953313.6
8	16.5432089	279697687.1
9	16.41086323	277460105.6
10	16.27957632	275240424.8
11	16.14933971	273038501.4
12	16.02014499	270854193.4
13	15.89198383	268687359.8
14	15.76484796	266537861
15	15.63872918	264405558.1
16	15.51361934	262290313.6
17	15.38951039	260191991.1
18	15.26639431	258110455.2
19	15.14426315	256045571.5
20	15.02310905	253997207
21	14.90292417	251965229.3
22	14.78370078	249949507.5
23	14.66543117	247949911.4
24	14.54810772	245966312.1
25	14.43172286	243998581.6

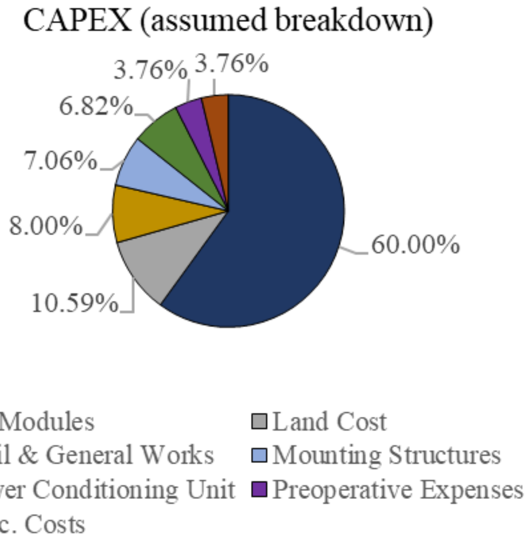
The output per year (not considering the degradation of the modules) is given by:

$$Units\ generated = \eta_p \left(1 - L_{\frac{AC}{DC}}\right)(ASR)NA_p\left(1 - \frac{100 - 80}{25 * 100}\right)^t$$

Here, the last factor accounts for linear degradation of the modules to 80% of their initialefficiency in 25 years, after *t* years.

C. Capital expenditure

We assume the capital expenditure to be 450 lakh ₹/MW.
The breakdown, is shown in the pie-chart below.



D. O&M expenditure

Year	O&M Expenses
	lakh ₹
1	300
2	315
3	330.75
4	347.29
5	364.65
6	382.88
7	402.03
8	422.13
9	443.24
10	465.40
11	488.67
12	513.10
13	538.76
14	565.69
15	593.98
16	623.68
17	654.86
18	687.61
19	721.99

20	758.09
21	795.99
22	835.79
23	877.58
24	921.46
25	967.53

O&M (Operation and Maintenance) expenditure is assumed to be 150000 ₹/MW. An *annual escalation rate* of 5% is taken. Also, *O&M spare* worth 15% of the O&M expenses is to be kept aside.

E. Interest on loan

Year	**Principal amount**	**Outstanding amount**	**Interest**
	lakh ₹	lakh ₹	**lakh ₹**
1	5666.67	62333.33	4986.67
2	5666.67	56666.67	4533.33
3	5666.67	51000.00	4080.00
4	5666.67	45333.33	3626.67
5	5666.67	39666.67	3173.33
6	5666.67	34000.00	2720.00
7	5666.67	28333.33	2266.67
8	5666.67	22666.67	1813.33
9	5666.67	17000.00	1360.00
10	5666.67	11333.33	906.67
11	5666.67	5666.67	453.33
12	5666.67	0	0
13	0	0	0
14	0	0	0
15	0	0	0
16	0	0	0
17	0	0	0
18	0	0	0
19	0	0	0
20	0	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0
25	0	0	0

Interest on loan is calculated using these: (after **t** years)

$$Principal\ instalment = \frac{Total\ debt}{Debt\ period}$$

$$OA_t(Outsdanding\ amount) = Total\ debt - \mathrm{t}(\mathbf{principal\ instalment})$$

$$Debt = OA_t * Debt\ interest\ rate$$

F. Interest on Working Capital

Year	Working Capital	Interest on WC
	lakh ₹	lakh ₹
1	1231.97	102.25
2	1223.78	101.57
3	1215.74	100.91
4	1207.86	100.25
5	1200.12	99.61
6	1192.55	98.98
7	1185.14	98.37
8	1177.89	97.76
9	1170.81	97.18
10	1163.91	96.60
11	1157.19	96.05
12	1150.65	95.50
13	1144.29	94.98
14	1138.13	94.47
15	1132.17	93.97
16	1126.42	93.49
17	1120.87	93.03
18	1115.54	92.59
19	1110.44	92.17
20	1105.57	91.76
21	1100.94	91.38
22	1096.56	91.01
23	1092.43	90.67
24	1088.57	90.35
25	1084.98	90.05

First, Working Capital is taken to be a sum of average monthly O&M expenses (*with spare*) along with average receivables for 2 months.

In our calculations, this means,

$$WC = \frac{O\&M\ expenses}{12} + \frac{Revenue}{6}$$

$$Interest\ on\ WC = WC * WC\ Interest\ rate$$

G. Depreciation

Year	Depreciation
	lakh ₹
1	4955.5
2	4955.5
3	4955.5
4	4955.5
5	4955.5
6	4955.5
7	4955.5
8	4955.5
9	4955.5
10	4955.5
11	4955.5
12	4955.5
13	1309
14	1309
15	1309
16	1309
17	1309
18	1309
19	1309
20	1309
21	1309
22	1309
23	1309
24	1309
25	1309

Here, we take into account the benefit of *accelerated depreciation* available for Renewable Energy projects as another Government step to promote investment in the Indian Renewable energy sector.

This method allows the user to post higher depreciation rates initially (instead of uniform linear depreciation throughout the project life), meaning more tax savings initially. This fact encourages investors over short-term cash flow issues, and also improves *projected ROI.*

$$\textbf{\textit{Depreciation}} = \textbf{Capital expenditure for 200 MW} * \textbf{Depreciation rate}$$

H. Return on Equity

Year	ROE
	lakh ₹
1	1190
2	1190
3	1190
4	1190
5	1190
6	1190
7	1190
8	1190
9	1190
10	1190
11	1360
12	1360
13	1360
14	1360
15	1360
16	1360
17	1360
18	1360
19	1360
20	1360
21	1360
22	1360
23	1360
24	1360
25	1360

Return on Equity is calculated using this formula:

$$ROE = \left(\frac{Capital\ Expenditure\ for\ 200MW}{1+\frac{Debt}{Equity}}\right) * (Equity\ rate\ of\ return)$$

The Equity rate of return is taken to be 7% for the first 10 years and 8% thereafter.

I. Cost of Debt (K_d), Cost of Equity (K_e) and Weighted Average cost of Capital (*WACC*)

$$\boldsymbol{K_d = Interest\ rate\ (1 - Effective\ tax\ rate)}$$

$$\boldsymbol{K_e = Risk\text{-}free\ rate\ of\ return + \beta(Risk\ premium)}$$

$$\boldsymbol{Risk\ premium = Market\ rate\ of\ return - Risk\text{-}free\ rate\ of\ return}$$

$$\boldsymbol{WACC = \left(\frac{1}{1+\frac{Debt}{Equity}}\right) * K_e + \left(\frac{\frac{Debt}{Equity}}{1+\frac{Debt}{Equity}}\right) * K_d}$$

Here, the terms in parentheses are Equity fraction and Debt fraction of the Capital expenditure respectively, expressed in terms of Debt: Equity ratio.

The following values are obtained:

Outputs - 1	
Cost of debt (%)	5.232
WACC (%)	6.586

J. Discount factor and Tariff

The discount factor is used to evaluate today's worth of a future transaction.

Year	**Discount factor**
1	1.0000
2	0.9382
3	0.8802
4	0.8259
5	0.7748

6	0.7270
7	0.6820
8	0.6399
9	0.6004
10	0.5633
11	0.5285
12	0.4958
13	0.4652
14	0.4364
15	0.4095
16	0.3842
17	0.3604
18	0.3382
19	0.3173
20	0.2977
21	0.2793
22	0.2620
23	0.2458
24	0.2306
25	0.2164

$$d_i = \frac{d_{i-1}}{1+WACC}, \text{ for } i = 2,3,..,25. \ d_0 = 1$$

So far, the values we calculated were for the annual capacity of the plant. For LCOE determination, we need to convert these values to per unit basis, i.e., divide them by that year's output. Once this is done, we evaluate the tariff T_i for the ith year using:

$$T_i = O\&M\ per\ unit + Interest\ on\ loan\ per\ unit + Interest\ on\ WC\ per\ unit + Depriciation\ per\ unit + ROE\ per\ unit \qquad (\text{for } i^{th} \text{ year})$$

The LCOE is given by:

$$LCOE = \frac{\sum_{i=1}^{25} T_i d_i}{\sum_{i=1}^{25} d_i}$$

Levelized Cost of Energy (₹/kWh)								
Year	**O&M costs**	**Interest on Loan**	**Interest on WC**	**Depreciation**	**Returns on Equity**	**Tarriff, Ti**	**Discount factor, di**	**Tidi**
	₹	₹	₹	₹	₹	₹	₹	₹
1	0.101	1.685	0.035	1.675	0.402	3.898	1.000	3.89842
2	0.107	1.545	0.035	1.688	0.405	3.780	0.938	3.54671
3	0.114	1.401	0.035	1.702	0.409	3.660	0.880	3.22191
4	0.120	1.256	0.035	1.716	0.412	3.538	0.826	2.92214
5	0.127	1.108	0.035	1.730	0.415	3.414	0.775	2.64563
6	0.135	0.957	0.035	1.743	0.419	3.289	0.727	2.39073
7	0.143	0.804	0.035	1.758	0.422	3.161	0.682	2.15593
8	0.151	0.648	0.035	1.772	0.425	3.031	0.640	1.93978
9	0.160	0.490	0.035	1.786	0.429	2.900	0.600	1.74095
10	0.169	0.329	0.035	1.800	0.432	2.766	0.563	1.55820
11	0.179	0.166	0.035	1.815	0.498	2.693	0.528	1.42327
12	0.189	0.000	0.035	1.830	0.502	2.556	0.496	1.26749
13	0.201	0.000	0.035	0.487	0.506	1.229	0.465	0.57180
14	0.212	0.000	0.035	0.491	0.510	1.249	0.436	0.54512
15	0.225	0.000	0.036	0.495	0.514	1.270	0.409	0.51987
16	0.238	0.000	0.036	0.499	0.519	1.291	0.384	0.49596
17	0.252	0.000	0.036	0.503	0.523	1.313	0.360	0.47333
18	0.266	0.000	0.036	0.507	0.527	1.336	0.338	0.45189
19	0.282	0.000	0.036	0.511	0.531	1.360	0.317	0.43160
20	0.298	0.000	0.036	0.515	0.535	1.385	0.298	0.41238
21	0.316	0.000	0.036	0.520	0.540	1.411	0.279	0.39418
22	0.334	0.000	0.036	0.524	0.544	1.439	0.262	0.37694
23	0.354	0.000	0.037	0.528	0.548	1.467	0.246	0.36061
24	0.375	0.000	0.037	0.532	0.553	1.496	0.231	0.34514
25	0.397	0.000	0.037	0.536	0.557	1.527	0.216	0.33049
LCOE *(₹/ kWh)*								**2.668**

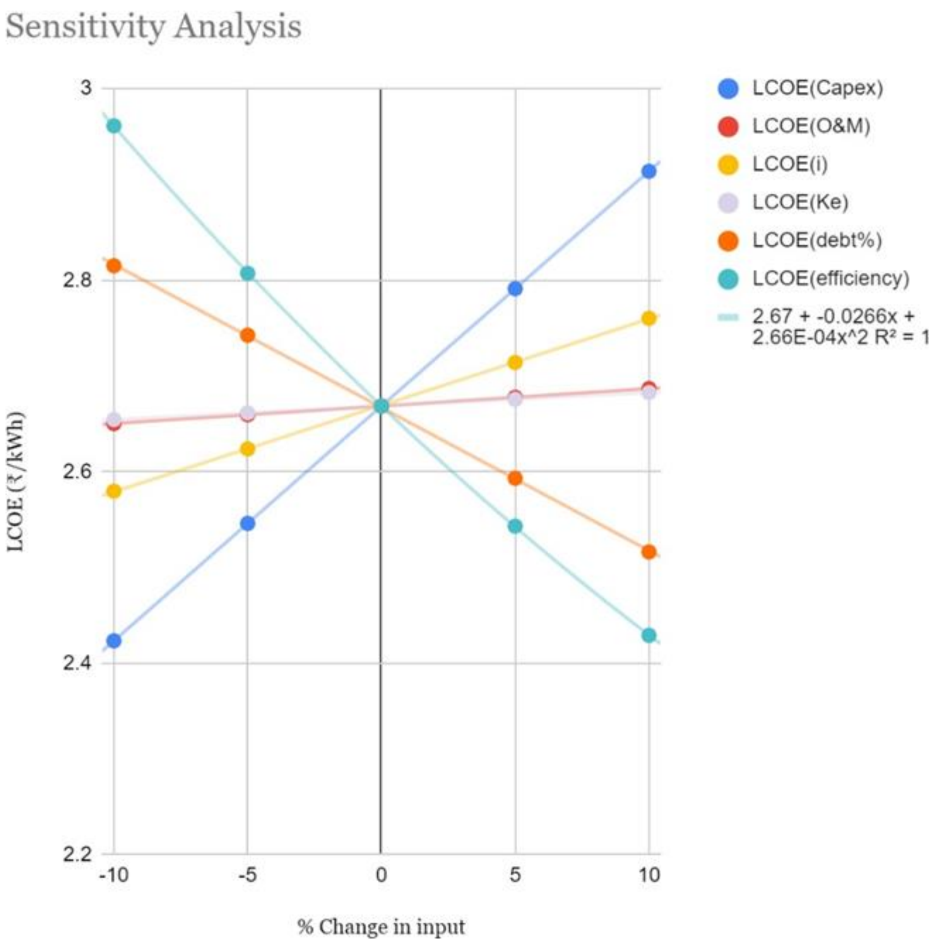
Thus, our analysis yields **LCOE** of **₹ 2.67/kWh**.

SENSITIVITY ANALYSIS OF THE CASE

Here, a deterministic sensitivity analysis of the changes in input factors of **Capital expenditure, O&M expenses, Rate of interest for debt, Cost of equity, Debt-to-equity ratio** and also **Module efficiency** (to get an idea of how much do technological improvements affect the LCOE) has been conducted manually.
The following chart shows the LCOE values after changing the resp. input factor by corresponding %, *while other factors are held constant at their originally assumed values*.

Factor \ % change	**0**	**5**	**-5**	**10**	**-10**
Capex/MW (lakh ₹)	425	446.25	403.75	467.5	382.5
LCOE	**2.668492**	**2.791106**	**2.545877**	**2.913721**	**2.423263**
Annual O&M expense/MW	150000	157500	142500	165000	135000
LCOE	**2.668492**	**2.677614**	**2.659369**	**2.686736**	**2.650247**
Debt Interest rate (%)	8	8.4	7.6	8.8	7.2
LCOE	**2.668492**	**2.713976**	**2.623685**	**2.760131**	**2.579562**
Cost of equity (%)	12	12.6	11.4	13.2	10.8
LCOE	**2.668492**	**2.675496**	**2.661461**	**2.682473**	**2.654404**
Debt %	80	84	76	88	72
LCOE	**2.668492**	**2.593026**	**2.742483**	**2.516078**	**2.815008**
Module efficiency (%)	17.5	18.375	16.625	19.25	15.75
LCOE	**2.668492**	**2.543028**	**2.807162**	**2.428970**	**2.961240**
Comments on Input:	Original assumption	Increased by 5%	Decreased by 5%	Increased by 10%	Decreased by 10%

The following plot illustrates this analysis graphically:



The LCOE calculator can be downloaded from here.

A. Remarks about the analysis:

It is clear that a decrease in capital expenditure significantly reduces the LCOE. In fact, for the LCOE to reach ₹2.44/kWh, the capital expenditure should fall to the tone of 382.5 lakh₹/MW. Assuming other things do not change and only module prices fall, that implies a 16.67% fall in the price of the modules.
Further, decrease in interest rate of debt, O&M expenses or cost of equity also decreases the LCOE. However, even for a 10% reduction in either of these, the LCOE does not touch the required ₹2.44/kWh value.
Increasing panel efficiency, as one would expect, decreases LCOE. As we can see, we could touch the ₹2.44/kWh value for a 10% increase in efficiency provided other factors remain constant. However, that would mean an efficiency of around 19.25%, which is very high for commercial solar modules.
In the years after, technological advancements have driven tariff bids to lower than ₹2.2/kWh [as of Q3 2022].
Also, a higher debt% decreases LCOE, driven by increased tax savings on interest and also by the lower cost of debt compared to equity financing.

Note: *The Excel Workbook containing the LCOE analysis as well as Deterministic Sensitivity Analysis of LCOE against key inputs can be found here*.

FACTORS AFFECTING TARIFF BIDS

The reason the bids fell as low as ₹2.44/kWh in 2017 is an overall conductive environment by the Government for solar PV. The government has introduced various subsidies and benefits for consumers as well as developers choosing solar, like the net metering benefits and accelerated depreciation. Further, it's ambitious target and humongous market base have attracted a lot of foreign investment. Many new players, backed by the financial strength of these large investments, submit extremely competitive bids, as initially gaining market share is more important than increasing profits. These foreign players and the firms under their financial support have a long-term strategy. A major reason behind the low bids, is the fall in solar module prices due to technological improvements, economics of scale and China's excess production. These investors think seriously about the prospect of investing in solar due to risk-minimizing approach followed by the Government. The procurement and preparation of land and infrastructure as well as the issue of uncertainty of selling the power produced have been taken care of by the Government. The latter is achieved through PPAs (Power purchase agreements) signed with the developers, thus giving them an assurance of demand.

However, as we did observe previously, the trend of lowering prices has plateaued recently. There are numerous factors behind this, one being government's imposition of the safeguard duty to promote Indian module manufactures, the introduction of the GST, increased uncertainty leading to disinterest among smaller, more competitive players.

As of 2023, technological changes as well as a renewed push towards solar module manufacturing have brought the lowest bids lower by ~10%. There is again a soft barrier of policy focus on developing solar cell manufacturing capabilities in India that might slow down the progress in short term, but will prove strategically crucial considering China's trade and geopolitical volatility and consolidation of mineral chains.

CONCLUDING REMARKS

Technological developments in Solar PV are the largest factor affecting the spread of Solar PV. If R&D goes on at a healthy pace and if investment into the sector from governments and private sector keep on flourishing, solar PV can achieve enough establishment to move away from conventional, exhaustive sources of energy.

Finance and technology go hand-in-hand in deciding what to risk on solar power, and a healthy atmosphere in India has led the investment to flourish over the decade. Recent hurdles must be sorted out to ensure this development goes on at a steady pace.

Although India has come a long way from being completely dependent on non-renewable energy, there is still a long way to go to achieve solar power potential to replace the conventional sources. It's large population and energy requirements, which are the biggest hurdles in moving away from non-renewable energy other than technological development, are also the ones India should leverage to produce a large consumer base for Solar PV.

India has used its ample solar resource well to be already among the top solar markets, but it needs to focus on independence in terms of imports. While doing that, it needs to keep a balance between pleasing investors and supporting Indian manufactures and work to achieve its ambitious, but still achievable goals.

TERMS & DEFINITIONS

I. SOLAR POWER TERMS

A. Balance of System (BoS)

BoS represents the components of a solar PV system other than the solar module. It includes the inverters, cables and connectors, mounts, etc. For off-grid PV, it also comprises of storage components like batteries and charge collectors.

B. Capacity Utilization Factor (CUF)

It is the ratio of the actual output from a Solar power plant to the maximum possible output from the plant.

$$CUF = \frac{\{Actual\ output\ (in\ kWh)\}}{Plant\ capacity(kW_p) * 24 * 365}$$

C. Days of Storage

Days of storage of a solar system gives us the number of days a given system could meet a defined load without solar input. Thus, it is a term related to the storage ability of a system.

D. Energy Payback Time (EPBT)

For an energy technology, EPBT is the amount of time that an energy technology takes to deliver the amount of energy required over its life cycle.

E. EPC company

EPC stands for engineering, procurement and construction. An EPC company takes up the entire job comprising of design, material procurement and construction of a project.

F. Feed-in-Tariff (FiT)

FiT is the special price paid by the electricity utility to the power generators for the power they feed into the grid. It is used as a financial incentive to encourage investment in renewable energy.

G. Grid parity

Grid parity is said to be achieved when the price of renewable power equals the price of conventional power (it aims to replace).

H. Irradiation and Irradiance

Irradiation (or insolation) is the solar energy received on a given surface area in a given time. It is the time integral of irradiance, which is a flux of incident solar radiation.

I. Levelized Cost of Energy (LCOE)

LCOE is a metric used to compare the cost of energy produced by two different types of sources by considering the plants' lifetime costs and production.

$$LCOE = \frac{\{Lifecycle\ cost\ of\ solar\ project\}}{Lifetime\ energy\ production\ of\ the\ project}$$

J. Net Metering

Net metering is the mechanism by which the utility meters the amount of excess electricity produced by the consumer and fed into the grid. It is advantageous for the consumer over gross metering since electricity rates increase as consumption increases. This is another measure taken by the government to promote use of solar PV.

K. On-grid and Off-grid

On-grid represents the connection of a PV system to the main electricity supply, so as to make the export of excess electricity generated possible in the day and draw electricity from the grid during shortfall in PV output.

Off-grid systems are decentralized and generally used in areas where grid extensions are expensive. They have a great potential, with the inclusion of right storage devices, to light up the remote parts of the country.

L. Peak capacity

Peak capacity represents the output power achieved by a solar cell under full solar radiation (under standard test conditions). The power generated is denoted using Wp (Watt peak), etc. Generally, the standard conditions assume a solar radiation of 1000 W/m2.

M. Performance Ratio (PR)

PR of a plant measures the effect of environment, solar conditions, etc. on the output. It is given by:

$$PR = \frac{\{Energy\ produced\}}{Irradiance * Active\ area\ of\ module * Module\ efficiency}$$

N. Power Purchase Agreement (PPA)

PPA is an incentive mechanism provided by the installer/developer/government agency to consumers for the installation of renewable energy generation systems. In case of a power plant, they help by reducing the risk of a private player, attracting competitive investments.

O. Solar Renewable Energy Certificate (SREC)

SRECs are tradable commodities representing proof that a certain amount of electricity was generated using solar PV. *Renewable Purchase Obligations* impose by law that some entities buy electricity generated by certain renewable sources or buy *Renewable Energy Certificates*.

II. FINANCIAL TERMS

A. Capital expenditure

Capital expenditure is the expenditure pertaining to assets that can benefit the organization for more than a year. It consists of the project cost before it gets operational, which includes design & engineering, procurement, construction, installation, etc.

B. Debt

Debt is a liability representing the money lent by financial institutions to a developer at some *interest* rate, to be paid back by a certain *maturity* period.

C. Cost of debt (K_d)

Cost of debt is *effective interest rate* paid on the debt.

$$K_d = Interest\ rate\ (1 - Effective\ tax\ rate)$$

D. Equity

Equity is the worth of owner's money in the venture.
(In the balance sheet equation, A = L + SE, SE (Shareholder's equity) represents what a firm owes to its owners.)

E. Cost of Equity (K_e)

Cost of Equity is the rate of return stockholders would expect from their investment in the project.
Using the Capital Asset Expenditure Model,

$$K_e = Risk\text{-}free\ rate\ of\ return + Q(Risk\ premium)$$

$$Risk\ premium = Market\ rate\ of\ return - Risk\text{-}free\ rate\ of\ return$$

β represents the degree of risk of the stock relative to the market.

F. Debt – Equity ratio

Debt – Equity ratio is an important metric to understand how much a firm depends on debt for its financing.

G. Discount factor

It is a factor used to estimate the present value of future transactions.

H. Depreciation

Depreciation is a financial tool to account for the wear & tear, degradation and loss in productivity or efficiency of long-term capital investments.

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