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# ANALYSIS OF THE KEY FACTORS AFFECTING LEVELIZED COST OF ELECTRICITY OF SOLAR PV IN INDIA

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**ABSTRACT:** The Central Government, as well as many State Governments of India, have introduced solar PV policies to promote solar PV technologies as India has a very high potential for solar energy with 300 clear sunny days with solar radiation ranging from 4 KWh/m2 to 7 KWh/m2. The key feature of these policies is a selection of through reverse auction process. Recently, it has been claimed that through a reverse auction process, the tariff of power from Solar PV has been brought down below Average Power Purchase Cost (APPC) However, such low tariff has raised doubt about the viability of solar PV project at such low tariff given the high cost of debt prevailing in India. The government has recently set a target of deployment of 100 GW of Solar PV by the year 2022 which accounts for around $100Bn investment. Under this condition, it is important to rationalize power tariff by analysing the impact of various sets of factors affecting the LCOE. The present paper intended to do the same. This analysis will be helpful to investors for avoiding the problem of underbidding and/or overbidding. This analysis is also helpful to policy makers for maintaining the competitive nature of markets as well as the sustainability of the market.

**KEYWORDS**

Levelised Cost of Electricity, Solar PV, India

## Introduction

India has a very high potential for solar energy with 300 clear sunny days with solar radiation ranging from 4 KWh/m2 to 7 KWh/m2. (Sharma et al., 2012) It has been that 12.5 % of India's total land mass or in other words, the area of around 43,000 Km2 can be used to generate solar energy. Currently, around 68 % of power is being produced through fossil fuel based conventional technologies (Shrimali et al., 2016). It has been estimated that for the next 5 years India's GDP would grow at 8% year to year basis. The energy demand would also grow at around 9 % year to year basis (Dawn et al., 2016). To meet this demand India has to import a massive amount of clean coal. However, from recent experience, it has been observed that sudden changes in royalty terms by coal exporting countries can increase power producing cost and make it uncompetitive resulting massive financial burden on energy producing companies. In such a situation, it is necessary for India to harvest its solar potential by introducing the favourable solar policy. On the other hand, being one of the most carbon polluting countries in the world, there is also international pressure building up for reducing carbon foot print by measures such as the deployment of clean energy technologies (Bloomberg New Energy Finance, 2016).

Since 2009, The central government of India, as well as many state government, has introduced Solar policy such as National Solar Mission as part of a broader framework called National Action Plan for Climate Change (NAPCC) (Government of India, 2008). To create energy market for renewable technologies, Central Government has set targets for Renewable Purchase Obligation (RPO), in which power utility companies and captive power consumers have to purchase a certain quantity of renewable energy. As per the direction is given by the Central Government under Electricity Act 2003, various State Electricity Regulatory Commissions (SERCs) have set their respective RPO targets specific different

renewable technologies such as bio gas, wind energy and solar technologies (Shrimali & Rohra, 2012).

As Solar PV was much expensive technology at that time, the central government as well as many state governments have introduced Feed in Tariff with long term contract of 25 years in which utility companies had to sign Power Purchase Agreement (PPA) with premium on Average Power Purchase Cost (APPC) to make Solar PV project viable (Dawn et al., 2016). However, as the financial health of most of the utility companies were already poor (Planing Comission, 2014) and there was a sharp decline in solar PV modules prices, the Central government, as well as many state government, have introduced reverse auction process in feed n tariff to let market forces decide the prices. Recently, to address the concern about bankability of Solar PV project, the central government have to change the policy with fixed Feed in tariff and capital subsidy (known as Value Gap Funding (VGF)) upto 30% of capital cost. The projects are being selected through a reverse auction process with the lowest requirement of VGF (Ministry of New & Renewable Energy, 2013). However, the state governments continue to select Solar PV project through a reverse auction process in Feed in Tariff (Umamaheswaran & Rajiv, 2015).

At present, the reverse auction process is a key driving policy instrument in the deployment of solar PV projects. This process has some inherent benefit. (Mayr et al., 2014) It has successfully brought down power purchase cost of Solar PV very near to APPC . In last year the bidder won the project in revers auction process, have quoted solar tariff in range of Rs. 2.50 to Rs. 2.70 per KWh (Ghosh & Prasad, 2017). These prices were below than APPC of Rs. 3 to 4/ KWh (Shrimali & Rohra, 2012). It has been claimed that the reverse auction process encapsulated the benefit of continuous decline of module prices and low cost of capital prevailing in the international market. However, some recent bids with very low tariff have raised the questions regarding the viability of solar PV projects and sustainability of market (Bhaskar, 2017; Sambit Basu, 2011). The government has recently set a target of deployment of 100 GW of Solar PV by the year 2022 which accounts for around $100Bn investment(Niti Ayog, 2015). Under such situation, it is important to rationalize power tariff by analysing the impact of various factors affecting the Levelized Cost of Electricity of solar PV and to analyze whether bidding with such low tariff is possible or not.

This study is carried out to identify and analyse the factors (if any) responsible for bringing down LCOE at such a low level. Such analysis will be helpful for policy makers to focus on such factors and co relate its effect on other macroeconomic parameters considering the massive projected investment of $100Bn in this sector. This analysis is also helpful for investors for determining the best combination various factors which will increase margins of LCOE during bidding.

## Literature Review

In this section, the financial parameters used for this feasibility analysis are explained.

**Levelised Cost of Electricity (LCOE):** The Levelised Cost of Electricity (LCOE) is the net present value of life cycle cost of the project divided by electricity production over the life time of the project. It can be seen as the production price of electricity adjusted over the life time of the project.

Branker et al., have described The levelized cost of electricity (LCOE) as benchmarking or ranking tool to assess the cost-effectiveness of different energy generation technologies. The LCOE methodology is designed to remove biases between the technologies. The method considers the lifetime generated energy and costs to estimate a price per unit energy generated (Branker et al., 2011).

In simple term, it is a measure of lifetime costs, divided by total lifetime energy production represented by following formula:

$$\text{LCOE} = \frac{\text{total life time cost}}{\text{total life time energy production}}$$

The less a system costs and the more energy it produces, the lower the LCOE. The LCOE represents the price point at which the energy is to be sold in order to achieve a zero NPV. LCOE can be affected by financial parameters such as capital cost, depreciation, cost of debt, cost of equity and annual operating cost (which also includes spare part replacement cost & fuel cost). While in the case of solar it is effected by technical parameters such as plant efficiency, plant capacity factor, and plant degradation rate.

It can be calculated based on the following formula (Mahmud & Prince, 2016):

$$LCOE = \frac{PCC - \sum_{n=1}^{N} \frac{DEP + INT}{(1+DR)^n} TR + \sum_{n=1}^{N} \frac{LP}{(1+DR)^n} \sum_{n=1}^{N} \frac{Aoc + In}{(1+DR)^n} (1 - TR) - \frac{RV}{(1+DR)^n}}{\sum_{n=1}^{N} \frac{Initial\ generation\ in\ KWh\ (1 - Degradradtion\ rate)^n}{(1+DR)^n}}$$

Where LCOE is Levelised Cost of Equity, DEP is annual applicable depreciation, INT is annually paid Interest, TR is Tax Rate, PCC is Project Capital Cost, LP is Annually paid Loan amt, Aoc is annual operation cost, In is annually paid insurance premium, RV is Residue value of the project after its life cycle, DR is discount rate n is nth year of project, N is total no of years of project life.

**Cost of Equity:** Cost of Equity is the rate of return which share holders ask as compensation for investing their capital. In this paper, the cost of equity is estimated using bond-yield -plus- risk premium approach. According to this approach, cost of equity is divided into two parts,

a) base rate of government bonds, which is also called risk free return and

b) risk premium asked by equity holders for investing their equity. It is represented by the following formula (Baker & Powell, 2009)

$$k_e = b_r + R_p \quad (1)$$

*Where ($k_e$) is the cost of equity, ($b_r$) is base ratthe e of government bond and($R_p$) is risk premiuma.*

The risk premium is linearly proportional to risk involved in the project in which equity is invested.

**Cost of Debt:** Cost of debt is the rate of interest expected for the lending money. Usually, the rate of interest on debt prevailing in the market is referred to as the cost of debt before tax. The rate of interest after adjusting tax is referred to as the effective cost of debt (Khan & Jain, 2007) represented by

$$k_{de} = k_d (1 - T) \quad (2)$$

*Where ($k_{de}$) is effective cost of debt, ($k_d$) is the cost of debt before tax and (T) is tax rate.*

In India, The debt is mainly financed by the domestic bank with a high interest rate of 12% and shorter debt tenure. Recently, many companies with good credit rating have started to finance their debt through corporate bonds. In addition to that, there is also an international financial institution which financed renewable energy project with the very low interest rate. However as these loans are in foreign currency, to negate the effect of fluctuating currency exchange rate, currency hedging is required. The open market the hedging cost adds 5 - 6% to the interest rate.

## Research Methodology

LCOE being benchmarking tool is highly sensitive to the assumptions made, especially when extrapolated several years into the future. Thus, if it is used to analyse policy initiatives, assumptions should be made as accurately as possible, with respective sensitivity analysis (e.g., Monte Carlo) and justifications(Branker et al., 2011)

As the main aim of this study is to analyze key factor affecting LCOE of solar PV in India under the present policy framework such as selection thorough reverse auction:-

The objectives of the present study are as follows:

- Analysis of variation in the cost of capital (cost of debt & cost of equity) on LCOE
- Analysis of variation in tenure of the cost of debt on LCOE
- Analysis of variation in Value Gap Funding (VGF) or in other words capital subsidy on LCOE
- Finally, to analyse upward margin and downward margin of LCOE with various combination of parameters such as the cost of capital, debt tenure and capital subsidy which will help to determine upward and downward limit of bidding price within which solar PV project become viable.

The scope of this study is limited to analyse the effect of below mentioned parameters on LCOE:

- Cost of Capital (Cost of equity & Cost of debt)
- Debt tenure
- Capital Subsidy provided as Value Gap Funding (VGF)

Now, the sensitivity of the Cost of Capital is analysed by Categorizing different possible combination of cost of debt and cost of equity into five groups of investors. The sensitivity of debt tenure is analysed with two levels, while the sensitivity of capital subsidy is analysed with four different levels of subsidy.

So, in the matrix of sensitivity analysis, different types of investors are classified in to different groups on the basis of their cost of capital. The effect of the cost of capital of different groups is analysed with two different scenarios on the basis of debt tenure against four different level of capital subsidy provided in the VGF scheme.

The classification of investors on the basis of the cost of capital is described as below.

**Group 1:** This group includes mainly domestic investors asking the low cost of equity at around 10%. (Ernst & Young, 2017) They have financed debt by acquiring a loan from a domestic bank with interest rate of 12% p.a. or from the international financial institution by hedging foreign currency. The landed cost of debt in such a situation is assumed to be 12% ( 5-6% interest rate in foreign currency + 5-6% market cost of hedging foreign currency (Farooquee & Shrimali, 2016)) .

**Group 2:** This group includes domestic investors having a good credit rating (AA or AAA) and the ability to finance their debt by issuing a bond with a coupon rate of 7%. However, they ask the cost of equity of 15% (Ernst & Young, 2017).

**Group 3:** These are foreign investors having low cost of equity of 10% and low interest rate of 6-7% in foreign currency without any type of hedging (mainly from Japan) (Ikeda, 2017; KPMG International, 2015) Also this group includes domestic public sector investors with high credit rating which can issue a bond with coupon rate of 6-7%.

**Group 4:** These are investors with the high cost of equity of 15% and the high cost of debt of 12% (small and medium scale domestic companies) (Ernst & Young, 2017).

**Group 5:** This group represents foreign investors who can finance their debt at a very low interest rate of 3.5% and low cost of equity of 7% (from EU and US) (KPMG International, 2015). However, in such cost of capital, the cost of currency hedging is not included. It is assumed that such investment come through 100% (Foreign Direct Investment) route.

The Scenarios on the basis of debt tenure are classified as below:

- Long term debt tenure of 15 years
- Short term debt tenure of 10 years

The VGF or capital subsidy is classified into four different levels with 0%, 10% of capital cost, 20% of the capital cost and 30% of capital cost.

The technical design and simulation of PV plant at Jodhpur Rajasthan are carried out using PV Syst software (PVSYST, 2013). The selected location has the highest level of solar radiation in the country. So, the results of this analysis are also applicable to all other locations of India due to a lower level of solar radiation than selected location. In the absence of any scientific publications in this area, input parameters for simulations are assumed on the basis of practices, followed by EPC (Engineering, Procurement, and Construction) service providers in India. Financial input parameters are assumed based on various regulatory orders and government documents.

For simulation, polycrystalline silicon based modules have been selected. Other technical specifications of solar PV plant assumed for simulation are mentioned in following Table 1.

| Technical specification | Data |
|---|---|
| Plant Capacity | 1 MW |
| Latitude & Longtitude | 26.3°N & 73.0°E |
| GHI | 2306 (kWh/sq. m annually) |
| Module life time | 25 Years |
| Inverter capacity/ total no. of inverter | 500KWac/ 2 |
| Inverter life time | 13 Years |

*TABLE 1. Technical specifications of Solar PV plant*

- The degradation rate is assumed at 1% per year.
- The tilt angle of the PV module w.r.t horizontal plane is assumed as the latitude of location and azimuth angle is assumed as zero (south facing).

Financial input parameters are assumed based on various regulatory orders and government documents. Input data assumed for this study are mentioned in the following Table 2.

| Financial Parameters | Values |
|---|---|
| Capital Cost | Rs. 5,64,00,000 (Niti Ayog, 2015) |
| O&M Cost | Rs. 2,82,000 (for first year) |
| Insurance Cost | Rs. 1,69,200 |
| Debt: Equity Ratio | 70% : 30% (Rajasthan Electricity Regulatory Commission, 2015) |
| Corporate tax | 34.00% (Rajasthan Electricity Regulatory Commission, 2015) |
| Depreciation | 6.00% for 10 years (Rajasthan Electricity Regulatory Commission, 2015)<br>2.00% for next 15 years |
| Residue Value | 10% of Capital Cost |

*TABLE 2. Financial inputs used for this study*

- Like any other democratic country, changing corporate tax drastically is a very politically sensitive issue and also has a major impact on the overall economy. So, it is assumed that corporate tax will remain stable throughout the project life cycle.
- The cost of land is included in the capital cost.
- The tax benefit due to accelerated depreciation is not included in this analysis.
- Administrative and other costs such as wheeling charges and transmission costs are included in O&M cost.
- It is assumed that O&M cost will escalate at the rate of 5.72% per year.
- Inverter life time is assumed as 13 years, and its replacement cost is added in O&M cost of the 13$^{th}$ year.
- The applicable discount rate equals the cost of equity of a selected group of investors.

## Result and Discussion

The analysis of the effect of selected parameters on LCOE is shown in Table 3. The interpretation and our opinion based on the present analysis are explained below:

- With the best combination of key factors such as lowest possible cost equity, lowest possible cost of debt, highest possible debt tenure and fully granted capital subsidy of 30%, the LCOE can be brought down to reported tariff between Rs. 2.00 to Rs. 3.00 due to extremely cost of capital prevailing in EU and US.
- From the present analysis, it can be observed that for most of the investors the debt tenure is not affecting their LCOE significantly as few previous studies reported (Shrimali et al., 2017).
- It can be observed from the results that the investors with low cost of equity (Group 1 and Group 3) may able to bring down LCOE at par with APPC provided they get a high level of capital subsidy (more than 20% of capital cost). However, due to the low cost of capital the investors of Group 5 can bring down LCOE without any requirement of capital subsidy.

| Group No. | Debt Tenure (Yrs.) | VGF (0%) | VGF (10%) | VGF (20%) | VGF (30%) |
|---|---|---|---|---|---|
| Group 1 | 10 | 5.71 | 5.11 | 4.51 | 3.91 |
| | 15 | 5.67 | 5.06 | 4.47 | 3.88 |
| Group 2 | 10 | 7.01 | 6.27 | 5.54 | 4.80 |
| | 15 | 6.73 | 6.02 | 5.32 | 4.61 |
| Group 3 | 10 | 5.32 | 4.76 | 4.20 | 3.64 |
| | 15 | 5.16 | 4.62 | 4.07 | 3.53 |
| Group 4 | 10 | 7.40 | 6.62 | 5.85 | 5.08 |
| | 15 | 7.21 | 6.45 | 5.70 | 4.95 |
| Group 5 | 10 | 3.95 | 3.54 | 3.04 | 2.70 |
| | 15 | 3.85 | 3.45 | 3.12 | 2.63 |

*TABLE 3. Effect of Selected Parameters on LCOE of Solar PV*

- Under a present reverse auction system, only investors with the overall low cost of capital (Group 5) will be able to bid below APPC provided they get a full capital subsidy. The dominance of these investors can be clearly observed from the results.
- The medium size and new start up EPC player (Group 4) who may have the only option to financed their debt by acquiring loan from domestic banks or from foreign banks with currency hedging has no chance to survive in this reverse auction system as their cost of capital is very high compare to foreign investors from US and EU.
- Under this reverse auction system, there is very little scope generating short term profit by discounting cash flow with the high cost of equity.
- The public sector investors with high credit rating (Group 3) will able to bring down LCOE of solar PV at par with APPC provided they financed their debt though issuing a bond. through without any subsidy due to their low cost of equity.
- The result shows the clear dominance of western investors from EU and US in reverse auction system due to their low cost of capital. The difference between western investors (Group 5) and Asian foreign investors as well as public sector investor with high credit rating is so, high (about Rs. 1.00) that it may create a monopoly of western investors in the market. However, in the flow of such capital without any hedging may create pressure on the exchange rate and impact on the macroeconomic condition of India.

## Conclusion

Under a present reverse auction system, the western investor will clearly dominate the market as they can bring down LCOE at the level of reported tariff between Rs. 2.00 to Rs. 3.00 while the medium scale and start-up companies will not have any chance of survival. However, the key group of investors is the domestic public sector investors with a high credit rating. They can bring down LCOE at par with APPC by financing their debt through the issuance of the bond. However, there is the high difference between their margins of LCOE with western investor due to the huge difference between their cost of capital. Under the present reverse auction system, there is the possibility of the creation of mono poly of western investors due to their extremely low cost of capital. However, the inflow of such capital through FDI route without any currency hedging may create huge pressure on the exchange rate, Forex, and other macroeconomic parameters. So, instead of focusing on a foreign investor with the lowest cost of capital which may bring down LCOE to a significant level, the policy makers should facilitate public sector investors with high credit rating though development of domestic currency dominated the bond market.

## Policy Implication

From the above analysis, the clear dominance of one particular type of investors is observed which may able to bid with the present level of aggression in bidding with a tariff of Rs. 2.00 to 3.00. There is fear of creation of a monopoly of such investors. The inflow of such foreign capital without any hedging will have a serious effect on the macroeconomic condition of country considering requirement of the huge investment of $100 bn in this sector. So, instead of introducing policy measures to attract Foreign Direct Investment in this sector, the government should focus on developing the domestic bond market with low coupon rate though will public sector investor or other domestic investors with low cost of equity can compete in the bidding process and competitive nature of the market. For the sustainable growth of the market and to avoid the problem of under bidding, the government must decide the floor price of bidding below which bidding should not be allowed. The floor price should be revised just like any other tariff by concern regulatory authority through a public hearing. From results it can be observed that in few cases, the government should introduce some fund to subsidize the cost of capital of medium scale and start-up companies in this sector so, they can compete in this market.

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