LEARNING FROM EXPERIENCE – IMPERATIVES OF NTPC IN SOLAR PV

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Abstract

With serious climate concern, India pledges to bring 40% of the electricity generation from non-fossil fuel by 2030. The country has revised its target of renewables too and plans to achieve 175 GW of renewable power by 2022, of which 100 GW will come from solar. India has adopted a strategy to deploy large scale solar PV power plants in order to achieve this huge solar energy target, through economy of scale.

A substantial share of country's intended solar capacity installation has been assigned to NTPC, the leading power generator of India. The company faces a challenge to attain the target of 25 GW as developer and facilitator, in an adolescent solar market and within a still evolving regulatory framework. For large scale utility based solar power in India, there is a need to achieve grid parity in a competitive energy market.

Principle of experience curve states that for every doubling of cumulative production capacity of a technology, the cost of production declines at a fixed percentage called learning rate. The present work has attempted to determine the contribution of learning phenomenon in cost development of solar PV installation in the context of development of Indian solar PV carried out by developer like NTPC. Then, the result of experience curve analysis with historical data has been used to predict future cost of solar PV power project by extrapolation and trending.

The study opens up the possibility of using experience curve approach in future monitoring and cost optimization for solar PV in order to devise course correction as and when necessary. This also shows how developers like NTPC can decide on their strategies using learning as a quantitative tool to determine economic implications of a future when more renewables like solar PV plays a larger role in the energy basket of the country as we make progress towards fulfilling our objective on emission reduction and climate concern.

The approach of Learning by doing may provide NTPC a mechanism to build a strategic roadmap to evolve its solar PV power towards declining production cost to attain grid parity in a competitive energy market.

Keywords: Solar PV, Experience curve, Learning by doing, NTPC, cost

INTRODUCTION:

Solar PV is a commercially available and reliable technology for direct conversion of sunlight into electric energy. PV systems are comprised of PV modules and set of associated components like inverters, electrical connections, mounting structure etc. which are together called balance of system (BOS).

Grid connected solar PV has been successfully deployed as an alternative to fossil fuel in many countries of the world, pioneers being Japan, Germany and USA. India geared up to its solar journey with national solar mission in 2010. Since then the solar development has seen a rapid growth, mostly due to favourable policy initiatives and reduction of cost of solar installation worldwide.

In 2015, the renewable target of India was revisited and revised. Out of 175 GW of renewable energy targeted to be achieved by 2022, 60 GW will come from grid connected utility based solar PV projects. India's current solar PV installation is 8.7 GW. But the cost of large scale solar project is declining at a fast rate thus reducing cost of solar power which probably has raised the confidence of the authority to target an economy of scale, to reach grid parity of solar by 2020-22.

NTPC has been assigned to bring 25 GW of grid connected solar power as developer and implementing agency (MNRE-REP, 2016), by 2022. Till date, NTPC's installed capacity of grid connected solar PV is 360 MW. Most of the target power is planned to be installed as large scale solar PV projects (NTPC-AR, 2016).

After the COP21 in Paris, Indian government is more determined on its NDC pledge of 40% electricity through non fossil fuel by 2030 (INDC-IN, 2015). The solar potential of India is very high and much of it remains untapped yet (WEO-IN, 2015). With an uncertain nuclear future due to factors like public opinion, environmental clearance issues in Hydro, and the favourable fact of decreasing cost of PV modules, solar PV projects are becoming more and more viable. Hence, beyond 2022, there is a possibility of further revision in country's solar target and NTPC's share too can increase to meet the national target.

International energy agency, IEA, has questioned the solar PV target of India, in their energy outlook and has predicted that solar PV in India will attain grid parity only after 2040 (WEO-IN, 2015).

This paper uses experience curve based analysis to determine the learning by doing and related cost trend of solar PV in India and in NTPC. Cost reduction through learning can be utilized in planning overall strategies of solar development by the company. It will help the organization to make strategic roadmap for the solar development in a cost controlled manner, eventually to replace fossil fuel based energy technologies by renewable, which is a likely scenario in long term.

MODEL AND METHOD

For years, strategists and researchers have used theory of experience curve for strategy and policy determination of energy technologies.

Learning phenomena, the predecessor to experience curve theory, was first established by T P Wright (1936), in aircraft manufacturing process, indicating a definitive relation of labour cost reduction with increase in cumulative production. As more units are produced, due to experience or better learning, performance of the technology improves, reducing the cost.

Later on Boston Consultancy group extended the theory to cover entire gamut of production costs for a technology. There is a decline of cost with every doubling of production, at a fixed percentage called learning rate and the resulting curve is called "experience curve" (BCG, 1968). The decline of cost in experience curve however reflects combined effect of learning, specialization, investment and scale (BCG, 1968, Henderson, 1974).

Experience curve concept:

The cost decline of a product or technology is a function of cumulative production and when plotted in a log-log scale, results commonly in a linear experience curve (Junginger, 2012). The cumulative production is seen as an approximation of accumulated experience for employing a technology. The feedback of experience is shown schematically in Fig. 1. As the product output increases, the experience in making the product acts as a feedback to enable the system to produce a better product at a lower cost.

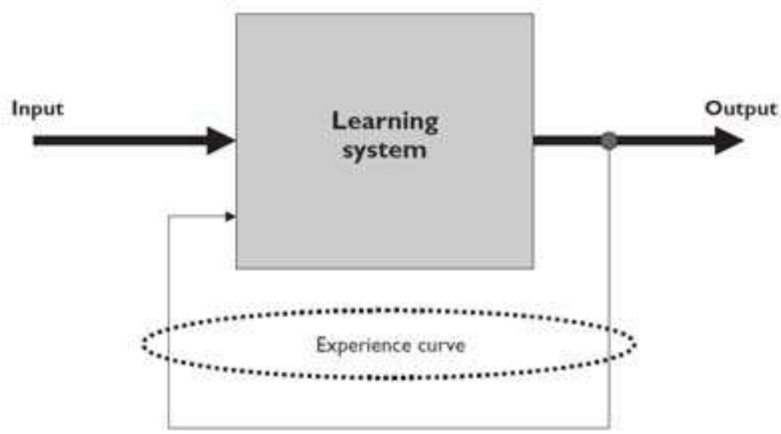

Fig 1: Experience curve is a measure of efficiency of the feedback or learning loop of the system (IEA, 2000)

If C_{Cum} is the cost per unit production, then, the equation for the experience curve is (Junginger, 2012):

$$C_{Cum} = C_0 Cum^m \qquad (1)$$

Where, C_0 is the cost of first unit produced, Cum is cumulative (unit) production, and m is an indicative parameter for experience.

$$logC_{Cum} = logC_0 + mlogCum \qquad (2)$$

The linearity of log-log plot or the experience curve is seen here. The slope of this curve gives the parameter m.

For every doubling of production, $Cum = 2Cum1, \frac{C_{Cum}}{C_{Cum1}} = 2^m$,which is termed as progress ratio (PR).

$$PR = 2^m$$

It gives the fractional cost reduction in a period, when cumulative production is doubled. Another measurement parameter involving experience curve is learning rate (LR), which gives extent of cost decrease,

$$LR = 1 - 2^m$$

As progress ratio increases, learning rate decreases, thus, indicating a lesser technology development (Junginger, 2008, Junginger, 2012).

A typical experience curve for solar PV module is shown in fig 2.

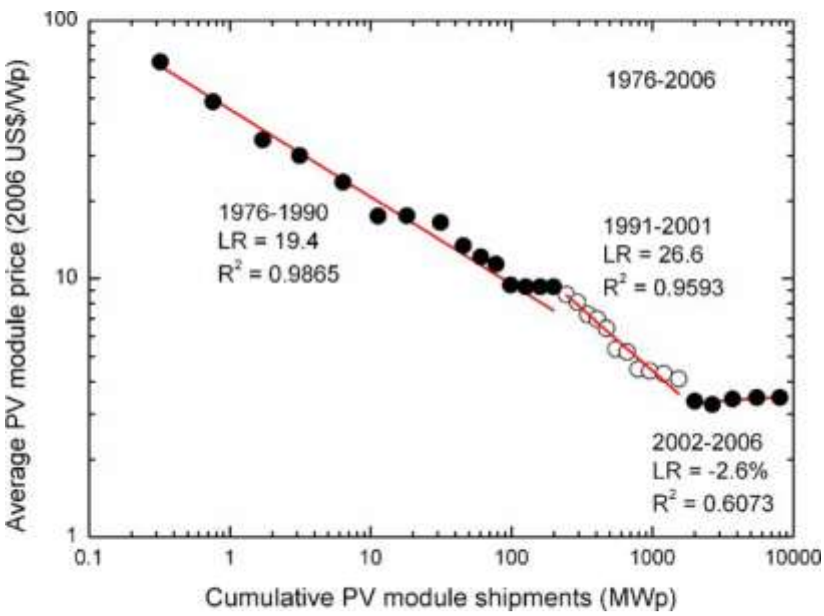

Fig.2: Experience curve for the production of solar PV modules; 1976-2001 (strategies unlimited, 2003), 2002-2006 (Swanson, 2006)

The data used in this curve is for a very long period and there has been variation in learning rates, over the time. Usually, learning rate has been seen to vary depending on the time period of data and nature of data.

The experience curve phenomenon was first used by International energy agency (IEA, 2000) to apply in policy making in energy technologies, and most impressive result in cost reduction was seen for solar PV technology. One reason for that may be due to availability of long term data, starting from 100 KW of global capacity through early developmental phase to a substantial steady growth as seen in current years.

The majority of studies so far have been on learning in PV modules. Modules are global product and data used is global price and shipment data. Few studies like PHOTEX in Europe and study on

California Solar policy have considered country level learning or local learning for BOS (Schaffer et al, 2004, Van Betham et al, 2010).

Mostly learning in solar PV is a combined learning, global for PV modules and local for BOS (Schaeffer et al, 2004, Van betham et al). In PHOTEX study, for the PV system of Germany, cumulative capacity is plotted against system price for overall learning.

In this study, first a country based analysis is done for complete PV system and then a firm level analysis for NTPC, where overall learning is considered. Cumulative installed capacity of NTPC is plotted against EPC cost per MW for solar PV projects. It is assumed that EPC cost reflects both cost of modules and BOS, thus projecting cost of unit solar PV power generation.

Global and Local learning for Solar PV:

Fig 3a. PV Module

Fig 3b. BOS

Experience curve analysis of solar PV has been unique in a way as it involves two components of learning, global and local. Global learning is mostly due to PV module for which global module price and global shipment volume are considered. Studies like PHOTEX have attributed local learning to BOS (Schaeffer et al, 2004).

Learning rate of different global studies on PV module has been compiled and average learning rate is 20.2% with standard error of 3.2% to 7.6%. The difference is attributed to country level versus global study, knowledge spill over, economics of scale effect, and product standardization reducing the transaction cost (Arnaud et al, 2013, p.7).

Main constraint in component wise study of learning is availability of local data for BOS.

METHOD:

The experience curve developed from the data of past could be projected to future to determine the cumulative production volume that should be attained to reach the level of cost required for commercial viability.

Data from sources like MNRE website and CERC site has been used for analysis in a country perspective. Global shipment data and module price data of EIA have been used to calculate global learning.

Cost data (Tariff per generation/Capital Cost per capacity) and production data (Cumulative capacity) were plotted in double logarithmic scale (equation 1) and a power trend line was added to obtain slope or the learning parameter.

Log of data on cost and cumulative capacity was analysed using regression analysis in excel to determine correlation, standard error, 95% confidence interval associated with data trend.

Available EPC cost / MW data of NTPC's solar PV project with respective cumulative installed capacity were plotted in a logarithmic scale and a power trend line was added to obtain slope which gives the learning parameter. Data was analysed using regression analysis to determine standard error, coefficient of correlation, 95% confidence interval etc. for estimating the uncertainties due to modelling calculation method.

RESULT & DISCUSSION

Data used for the experience curve

Recent 2016 tariff calculation details has been consulted for benchmark data on large scale solar PV, from review document of Central electricity regulatory commission (CERC) (CERC-SO17, 2016). Yearly capital cost data of project has also been extracted from CERC source, to estimate BOS price. As capital cost comprises mainly of PV module price and BOS price, the cost trend with time and capacity, this helped to study component level learning.

Experience curve for Indian large scale solar PV system:

Annual benchmark tariff data of CERC is taken in place of cost and cumulative installed capacity is the dependent variable here.

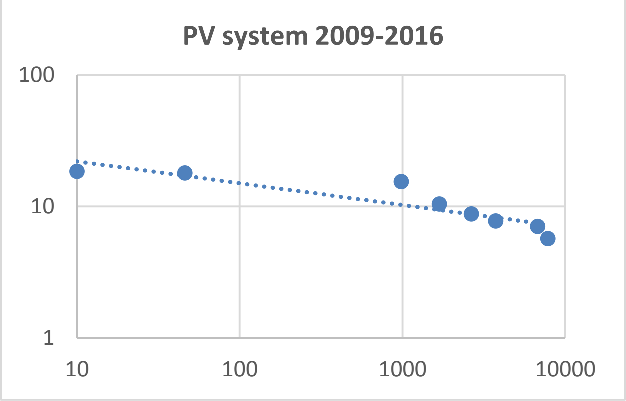

Fig 4a: Experience curve for Indian solar PV system (2009-2016) for tariff data

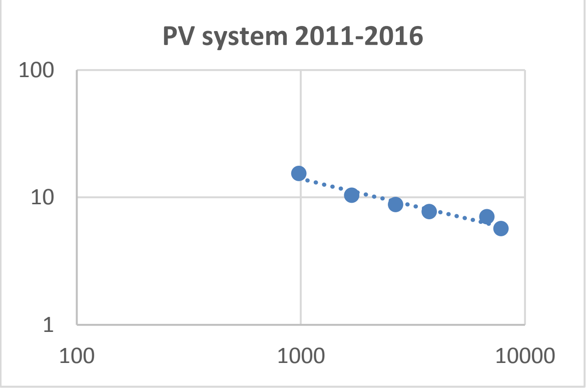

Fig 4b: Experience curve for Indian solar PV system (2011-2016) for tariff data

A linear regression fit has been carried out to determine learning parameter and to examine the level of correlation. In view of the observed scatter in the data for initial two years as revealed by Fig.4a, these data has been taken out and the remaining data for the period between 2011 and 2016 have been plotted separately in Fig. 4b.

Global learning & Local learning:

The data on global average price of PV module as well as those on cumulative shipping and global cumulative capacity are available for the period from 2004 t0 2014. The experience curves for PV module have been plotted in excel for both cumulative shipping and for BOS as country level learning, as shown in Figs. 5a and b (Ray Sarbani, 2016).

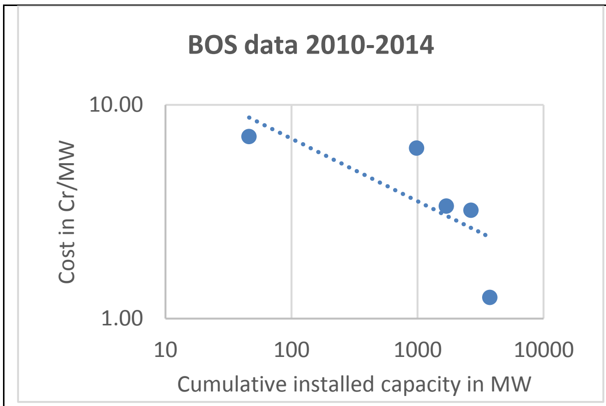

Fig 5a: Experience curve of BOS, Indian Solar PV

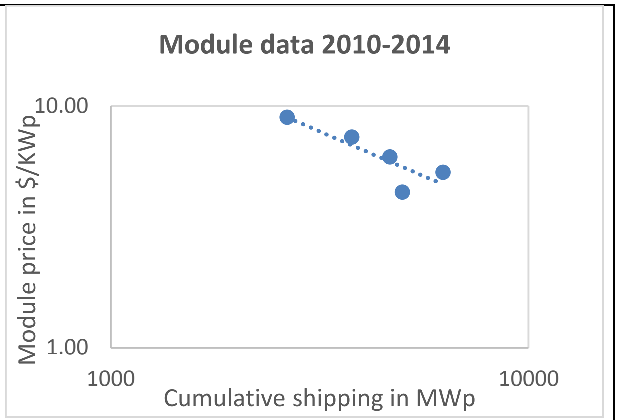

Fig 5b: Experience curve of PV module, Global

The broad trend of variation in price for module shows an increase till 2008 and then again in 2014. The increase has been attributed to increase in price of raw materials like silicon and silver during 2004 to 2008 (Arnaud et al, 2013).

Firm level learning from Experience Curve – Case of NTPC

NTPC limited, has a target to develop 10 GW large scale solar PV capacity on their own and facilitate 15 GW of large scale solar PV through others. Data of EPC (Engineering, procurement and construction) cost of NTPC and their cumulative capacity addition is available. The experience curve for NTPC is plotted with EPC cost and cumulative installed capacity at NTPC as shown in Fig.6.

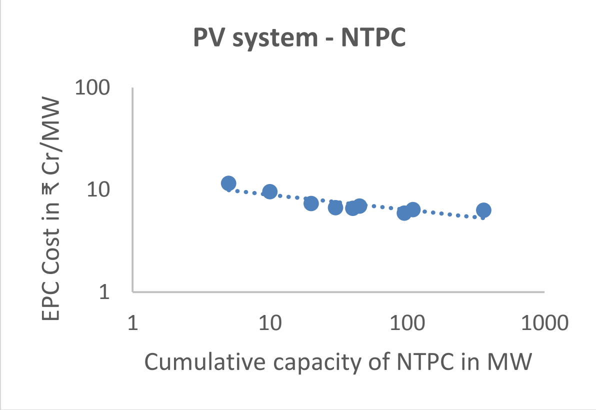

Fig 6a Experience curve for compound learning at NTPC

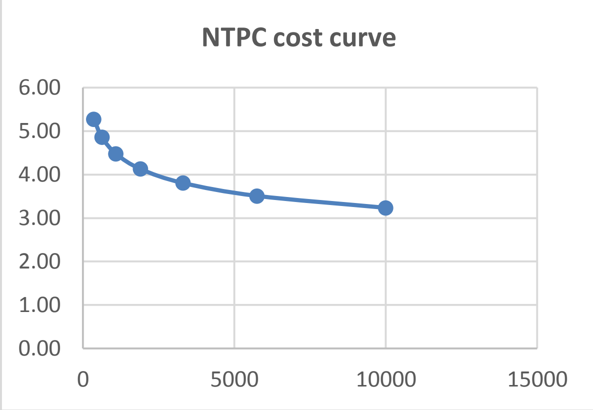

Fig 6b Predicted Cost curve for EPC cost and capacity of NTPC

EPC cost includes project cost with all the cost components like module cost, BOS cost etc. but land cost and other incidental costs are not included. Thus, EPC cost reflects cost of project to a great extent. But in this case, the data is not annual data.

In a span of four years (2012-2016), a total of 360 MW has been added starting from 5 MW. Progress ratio is 90.3%, implying a low learning, which presumably may be due to the initial phase of rapid firm level growth, when learning may have been segmented as has been seen in the Indian context also.

More capacity addition of large PV plant, will lead to more experience, resulting in improvement on installation, commissioning, operation and operational procedures. At the firm level, it will be easier for NTPC to devise strategies to disseminate learning of one project to other projects more effectively in order to utilize the full benefit of cost reduction from learning.

From the above curve, it is predicted that future cost of EPC, when NTPC's target of 10 GW solar PV capacity is installed will reduce by 40% from today's cost, if present learning rate and growth is maintained (Fig 6b).

Analysis:

Table 1: Concluding features after comparing experience curve parameters of large scale solar PV in India from this study and previous studies on different component of solar PV

Component	Present study (India)	Previous study (various countries and global)	Remarks /Conclusion
PV system – Compound Learning	Progress ratio varies for different timeframe (2009-2016 and 2011-2016)	In case of Germany Progress ratio is 86.2%	Much study records on compound PV system is not there. But variation of PR with timeframe is

	Progress ratio varies from 73.36 to 89.13% for different timeframe		established
PV Module – Global learning	Progress ratio varies for different timeframe (2009-2016 and 2011-2016) Progress ratio varies from 73.76 to 88.82% for different timeframe	Progress ratio varies for different timeframe Even for same timeframe in different studies, Progress ratio are 80%, 83% and 79.4% Largest estimated progress ratio is 83.4% during 1981 to 1990.	It is seen that result for global learning of PV module is similar to compound learning in case of large scale Indian solar PV. It can be due to global learning being major contributing factor.
BOS – Local learning	Progress ratio for Indian large scale solar PV is 87.1% Coefficient of correlation for BOS learning, R2 = 0.7145	Progress ratios with same timeframe of countries for small scale solar PV are, Netherland – 81%, Germany – 77.3% and US – 82.5% For large scale solar PV, Coefficient of correlation R2 = 0.44 (Schaeffer et al) is too scattered.	Range of progress ratio in BOS learning of India is similar to previous studies. Coefficient of correlation is much better in Indian case
PV System – Compound learning for NTPC	Progress ratio is 90.3% and Learning rate is 9.7%	The period is very short and occurrence of doubling of production is five times	But similarity is seen with learning rate country wide

If the experience curve of Indian utility scale solar PV, is seen (Fig. 4), growth appears to be mostly driven by policy and whatever learning has taken place is probably due to factors related to global learning reflected in the reduction of module price globally. Later, it is observed that learning increases at a steady rate, and becomes almost constant at around 10%, which is similar to the learning rate from the experience curve over data from 2009-2016.

As the initial frenzy over policy is over, learning by doing starts occurring naturally, and cost declines at a constant rate.

The variation in learning rate as observed by Nemet (2011) is statistical, primarily due to poor correlation in data. In PHOTEX study also, learning shows a trend of variation when different periods are considered and the rate is constant only over a limited period (Schaeffer et al, 2004, p.22).

From fig.4, it is seen that for the same period as considered in Indian solar PV system curve, there is a significant increase in the global learning rate of PV module. Ren21 in their ten years overview, reports a very high learning rate between 2010 to 2014, causing cost decline of about 50% in module price (Ren21, 2015a, p.19), which is also noticed in the experience curves in Figs.4a and b.

In Indian solar PV, the major cost component of BOS is materials for mounting structure, cabling and evacuation system (Madhavan, 2012). Due to economic fallout of global recession, demand went low and price of the price of BOS was abnormally low in 2009. By 2010, India recovered fast and price went up, before eventually settling to a relatively stable level in subsequent years.

All the different experience curves drawn in the present study for Indian solar PV system and NTPC show similar progress ratios and learning rates as in other studies related to solar PV systems in different geographical contexts.

Thus, it is evident that these data are consistent for determining learning parameter from experience curve.

RECOMMENDATION:

NTPC is going to have a substantial share of utility scale solar PV capacity installed in near future. Competition is high here with more and more developers joining in due to growing market and favourable policies.

Cost reduction due to learning helps to strategize on economics of scale which eventually is responsible for reduction of cost in the long run. Then prices continue to fall even if incentives are withdrawn.

Development of utility based solar PV in India is still largely policy dependent. With a learning rate of 10% or so, NTPC should adjust its growth rate in such a way so that in the long term, its cost of generation reduces and parity is achieved even without policy support.

There is a scope of improvement in BOS at firm level which is local learning and will have substantial impact on cost reduction. PV module and storage is a global learning. In the field of BOS, NTPC can do handholding in this market. Hence, NTPC should promote R&D and knowledge dissemination in BOS area, to benefit from experience curve.

Data capturing and analysis of data for renewable generation need to be done in a structured manner so as to promote theoretical and analytical studies aiding the strategic roadmap for renewable. Since, the organization is still in early stages of development, there is a huge scope of directing the course of renewable growth scientifically by registering data precisely. Learning curve is a good indicator if firm is on the right road towards target and needs to be monitored continuously and can have feel or hint of other factors which are affecting the experience curve prediction.

Rooftop small scale solar PV development for internal requirement as well as customer specific decentralized installation can be attempted as a company strategy. This will help to increase learning rate especially the local learning rate and would help to reduce cost in overall solar PV generation. Capacity building cost would then be shared with Decentralized solar energy installation by numerous domestic user.

CONCLUSION

The application of learning curve model has been widely used in predicting technology change, forming policies and guiding firm strategy. With data quality and reduction in uncertainties, impact of learning in cost can be accurately predicted.

It is a simplistic model and hence can be adopted easily. This gives a variation from the usual prediction based on time dependent change to a more certain data dependent trend in the solar PV generation. Since experience curve analysis is a predictive model, continuous strategy evaluation and incorporation of updated data is necessary for effective utilization of the model.

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