Trend of Solar tariff and its effect on Renewable energy sector in India.

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Abstract

India needs to considerably accelerate its solar energy capacity addition in order to meet its renewable energy (RE) capacity deployment targets. Besides policy commitments, the cost-competitiveness of RE tariffs is a major determinant of capacity addition. This paper focuses on the major determinants of RE tariffs, disaggregating the impact of equipment-related factors and financing costs (costs of debt and equity). The Project finds that financing costs account for the largest component—over 50% of RE tariffs. Further, equipment-related factors have been the major drivers of tariff reduction historically, accounting for 73% of the solar tariff reduction between January 2016 and May 2017. However, the Project demonstrates that there could be a role reversal—changes in financing costs could drive future decreases in solar tariffs. This necessitates the de-risking of Renewable sectors through suitable policy- and market-led interventions in order to lower financing costs.

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Chapter 1

Introduction

1.1 Overview

India has committed itself to rapid and large-scale renewable energy (RE) capacity addition. As part of its nationally determined contributions (NDCs) under the Paris Agreement, India intends to achieve a 40% share of installed power generation capacity from non-fossil fuel sources by 2030 (UNFCCC NDC Registry 2017). In terms of megawatt capacity, this translates into around 450 GW of RE installed capacity by 2030 (The Hindu Business Line 2019). As a stepping stone to the longer-term target, the country has a shorter-term target of setting up 175 GW of RE installed capacity by the end of fiscal year (FY) 2022, including 100 GW of solar, 40 GW is expected to be achieved through deployment of decentralized rooftop projects, 40 GW through utility-scale solar plants, and 20 GW through ultra-mega solar parks. and 60 GW of wind energy capacity (Press Information Bureau, Government of India 2018a). While India's RE generation capacity had grown rapidly to 75.8 GW by the end of December 2018, including 35.3 GW of wind and 26 GW of solar (both utility scale and rooftop), the country still has a long way to go to meet both the short-term and long-term targets (Ministry of New and Renewable Energy, Government of India 2019a). Considering these targets, renewables (solar, wind and hydro) will account for ~10% of the total energy mix, by 2022 (IESS 2047).

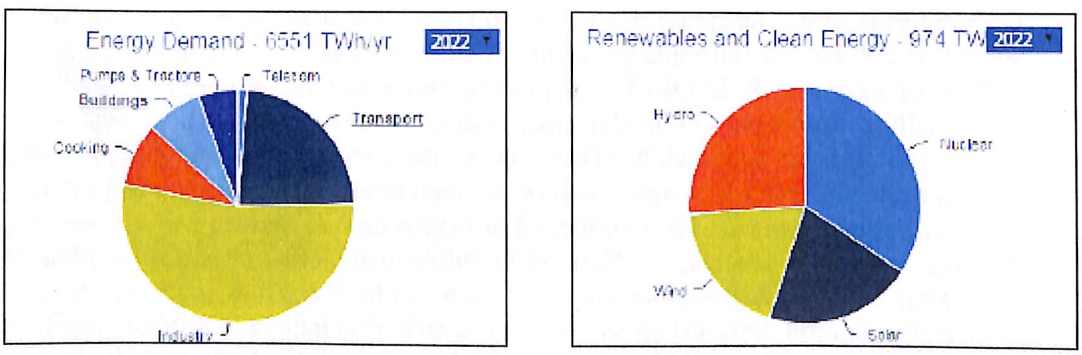

Fig 1: Possible share of RE in India's Energy Mix in 2022 (NITI Aayog)

While the policy ecosystem in India has both supported deployment and created demand for renewable power, the increasing competitiveness of RE tariffs can greatly facilitate the uptake of RE in the Indian context. Further, since affordable energy access is crucial for economic development, it is essential that India's future RE capacity additions occur in a cost-effective manner compared to new and existing thermal capacity.

1.2 Back ground

India has a very high potential for solar energy with 300 clear sunny days with solar radiation ranging from4 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 favorable 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 (Planning Commission, 2014) and there was a sharp decline in solar PV modules prices, the Central government, as well as many state governments, 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)) up to 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 (Uma Maheswaran & 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.

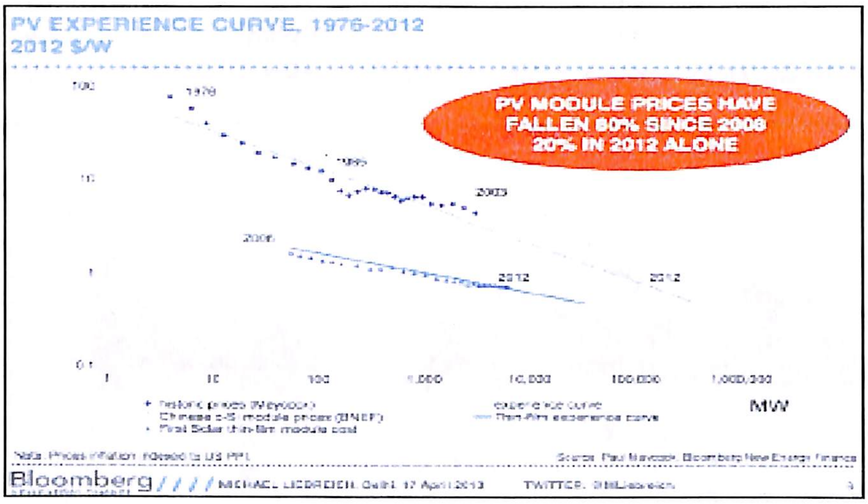

Fig 2 : Falling prices of solar PV Module cost (NITI Aayog)

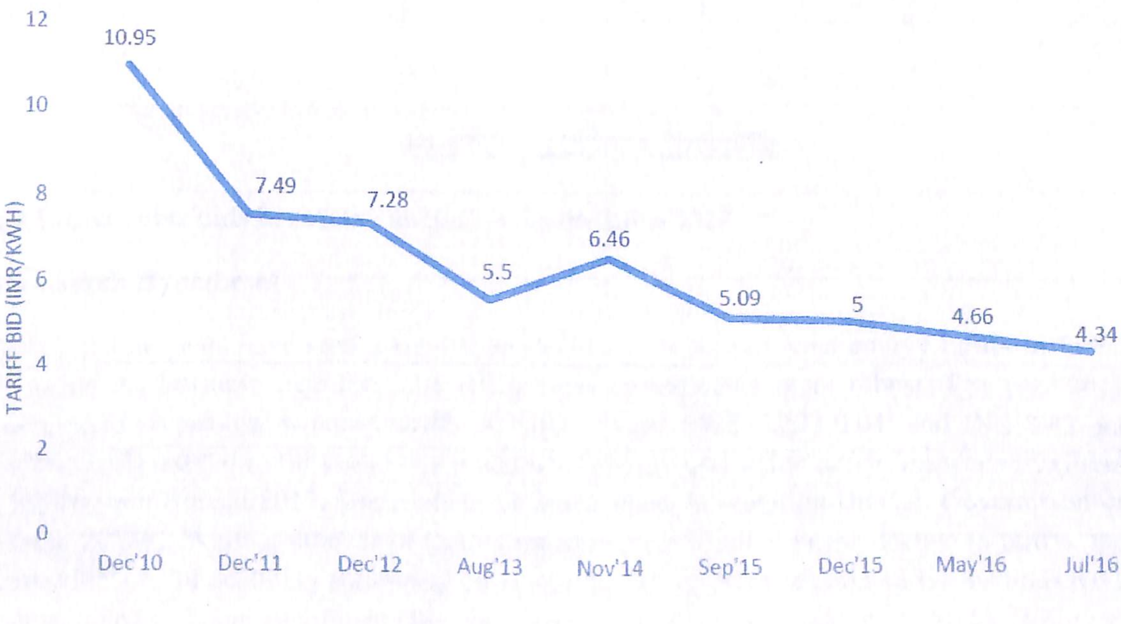

Fig 3 Declining Solar Bids in India

1.3 Purpose of study

Focusing on evidence from India, this paper is geared towards quantifying the major constituents of RE tariffs and identifying drivers of future tariff reduction. By dissecting specific examples of Indian solar —the record-low solar tariff, this paper illustrates the magnitudes of the relative contributions of these components to overall RE tariffs. Further, reasons for the recent decline in RE tariffs are also analyzed through a comparative analysis of tariffs pertaining to the Solar Parks in order to estimate the extent of the contributions of changes in equipment- and non-equipment-related factors to the decline in tariffs. Lastly, the paper highlights areas that represent opportunities to increase the competitiveness of RE tariffs in the years to come and discusses the policy measures that could accelerate future tariff reduction and their effect on Renewable Energy sector.

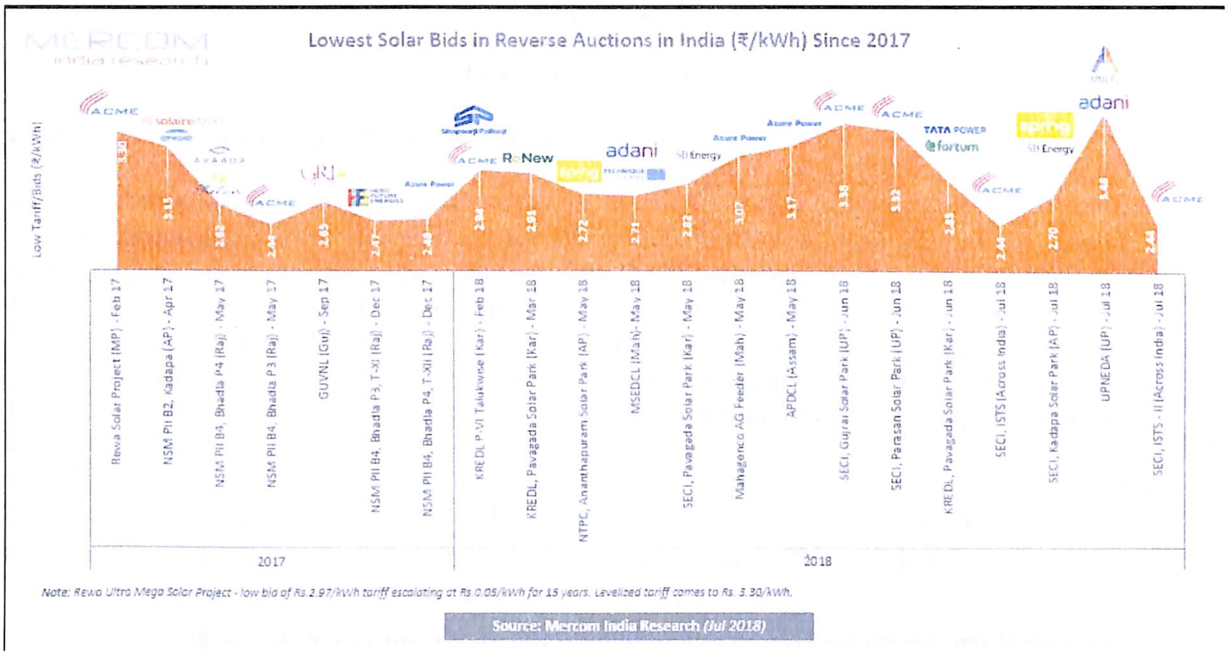

Fig 4 Lower solar bids in reverse auction in India Since 2017

1.4 Research Hypotheses

The last few years have seen a significant decline in solar and wind energy tariffs in India, making the business case for these RE sources considerably more robust. The year 2017 witnessed record-low winning tariffs of INR 2.44 per kWh (USD 0.04) and INR 2.43 per kWh (USD 0.04) for utility-scale solar and wind energy generation tariffs, respectively (Press Information Bureau 2017, Government of India; Press Information Bureau, Government of India 2018b). While a number of factors together have resulted in the decline in tariffs, the contributions of declining equipment costs and the introduction of competitive auctions have been noted as being significant (IRENA 2016; Crisil 2017; Shrimali et al. 2015). However, besides equipment costs, tariffs are a composite of a number of constituents including financing costs, operations and maintenance expenses, and the impact of government incentives. In order to accelerate future tariff reduction, understanding key drivers of RE tariffs can help focus and thereby maximize the impact of policy efforts geared towards tariff reduction.

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Chapter 2

Literature Review

2.1 Review of Elements govern Solar Tariff

A number of elements govern the magnitudes of solar energy tariffs, which can broadly be classified into equipment-related factors (those pertaining to PV modules) and non-equipment-related factors. The decline in unit equipment costs (USD per W) has been reflected in the declines in unit project costs (USD per MW) and thereby declines in RE tariffs. The rate of decline in costs (measured as either unit project costs or equipment costs) pertaining to electricity generation technologies has been widely studied in terms of learning rates (Rubin et al. 2015). The learning rate refers to the reduction in cost for each doubling of cumulative production or capacity (Rubin et al. 2015).

Most learning rate studies pertaining to solar PV technology have selected PV module prices as the dependent variable. The eighth edition of the International Technology Roadmap for Photovoltaic (ITRPV) estimated a 22.5% learning rate for solar PV module prices (in USD per Wp) over a period spanning 1979 to 2016 (International Technology Roadmap for Photovoltaic 2017). According to IRENA estimates, solar PV module prices have demonstrated learning rates of 18%–22% historically (IRENA 2016). While there have been wide variations in learning rates over periods of shorter duration, as noted by Rubin et al. (2015), module prices are expected to continue to track long-term learning rates going forward (International Technology Roadmap for Photovoltaic 2017; IRENA 2016). However, according to the World Energy Council, given the relatively low prevailing levels of PV module prices, learning rates of 18%–22% will not translate into large price reductions in absolute terms, unlike in the past (World Energy Council 2016). Figure 5 shown below illustrates this point—at the current level of module prices, the scope for reduction in unit module prices in absolute terms is limited. Thus, though declines in module prices are likely to continue to play a role in solar tariff reduction going forward, their impact on future tariff reduction is likely to be less than that seen in years gone by.

Note:

- Prices for 2007 to 2017 refer to annual averages, while those for 2018 and 2019 refer to values for December 2018 and April 2019, respectively.

Sources:

- Prices from 2007 to 2015: Harvesting Solar Power in India Working Paper August 2016, ICRIER.
- Prices for 2016 and 2017: Based on Mercom Quarterly Solar Market Update reports.
- Prices for 2018 and 2019: Refer to price for Chinese modules, sourced from PV Insights.

Figure 5: Limited Scope for Absolute Price Reduction at Current PV Module Pricing Levels

2.2 Effect of Financial cost on RE Tariff

Financing costs have been cited as another important determinant of RE tariffs. Ondraczek, Komendatova, and Patt (2014) identified lower financing costs as the primary reason for the prevalence of lower solar tariffs in developed solar PV markets in high-latitude countries vis-à-vis solar resource-rich countries where developers did not have access to low-cost capital (Ondraczek, Komendatova, and Patt 2014). They identified lowering financing costs through de-risking the RE ecosystem in these underdeveloped solar markets as an important means of increasing the adoption of solar PV installation. Though Ondraczek Komendatova, and Patt's work talks of the importance of financing costs as a determinant of solar tariffs, it does not quantify the extent of the contribution of financing costs in determining these tariffs. In the Indian context, industry reports have noted that the costs of debt and equity for RE projects in India are much higher than in developed markets (PWC and Mytrah 2015). Nelson et al. estimated that higher finance costs typically added 22%–28% to the LCOE in India vis-à-vis similar solar and wind energy projects in the US (Nelson et al. 2012). IRENA identified declines in financing costs as an important driver of future RE tariff reduction (IRENA 2016). Given the prevalence of substantially higher financing costs for RE developers in India vis-à-vis developed markets, the lowering of financing costs is potentially an important avenue of future RE tariff reduction in India.

Besides the factors mentioned earlier in this section, other determinants of RE tariffs include operations and maintenance expenses, land costs, evacuation infrastructure costs, and balance of system costs (Central Electricity Regulatory Commission 2016a). Based on the analysis, as outlined later in this paper, these costs taken together account for only around 20%–30% of wind and solar LCOEs in India. Given the relatively low contributions of these cost variables in the overall LCOE, the analysis in this paper focuses on other components of the LCOE, particularly financing costs and equipment costs, which play a much more significant role in the determination of RE tariffs in India.

2.4 Summery

Through this literature review, it becomes clear that there is extensive commentary on the major determinants of solar and wind energy tariffs. However, most of the existing literature focuses on a qualitative description of these determinants. A quantitative description of the relative contributions of various components to overall solar tariffs, particularly in the Indian context, has not been covered in great detail. In addition, quantitative analyses examining the reasons for the decline in RE tariffs in India in recent years are largely absent in existing literature. Similarly, quantitative analyses of the major drivers of future RE tariff reduction in India are largely absent. This paper intends to fill these gaps in existing literature. Chapter 1 presents a brief overview of the process and policies supporting RE procurement in India. Chapter 3 outlines the methodology adopted for the analysis while Chapter 4 presents the data and assumptions upon which the analysis is based. Chapter 5 presents the results of the analysis, including a discussion of the same, while Chapter 6 discusses the policy implications of the findings.

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Chapter 3

METHODOLOGY

3.1 Outline for Analysis

The levelized cost of electricity (LCOE) of an electricity generation asset is the net present value of the unit cost of electricity over the lifetime of the asset (Lee et al. 2019). Section 4.2 specifies the various input variables that are used in the estimation of the LCOE of an RE project. Costs per MW of generation capacity, including depreciation pertaining to project capital expenditure, operations and maintenance expenses, and financing expenses (required return on equity, expenses pertaining to the servicing of both long-term and working capital debt), are estimated over the life of the generating asset. The estimated values for every cost head for each year of the asset's life are discounted to their present values at the weighted average cost of capital (WACC) for the project. For each cost head, the summation of discounted costs for each year divided by the summation of the estimated levelized electricity generation (estimated electricity generation discounted at the WACC) over the life of the generation asset represents the contribution of that particular cost variable to the overall LCOE. The actual LCOE is the sum total of the individual contributions of each cost variable.

In order to understand the composition of RE tariffs, the record-low winning tariff of INR 2.44 per kWh at the Bhadla Solar Park Phase 3 auctions held in May 2017 (hereafter referred to as the "May 2017 Solar Tariff" in this paper) and the first competitively determined tariff for wind-based electricity generation (hereafter referred to as the "February 2017 Wind Tariff" in this paper) are dissected into their constituent parts using the discounted cash flow methodology outlined earlier in this section. These tariffs are representative examples of solar and wind tariffs in the reverse-auction regime of tariff determination. Further, both the solar and wind tariffs analyzed correspond to projects with central government offtakers, which also helps to control for the impact of the offtaker on financing costs (refer to Section 3 for understanding the differences in the credit profile of different categories of offtakers). This ensures that the changes in financing cost assumptions between the two bids reflect changes in the general level of interest rates and risk perceptions for the solar and wind sectors and are not skewed by differences in the type of offtaker.

While the dissection of a tariff into its constituent parts is helpful in order to understand its composition, a comparative analysis of two specific tariffs at different points in time is useful in order to determine the key reasons for their decline. The comparative analysis of tariffs is restricted to the solar energy space only in this paper. However, given the similarity in the compositions of their respective project costs and LCOEs (as illustrated further in this paper), arguments similar to those applicable for solar tariffs can be made for wind tariffs as well.

The purpose of the comparative analysis is to get a sense of the extent of the impact of changes in key input variables, particularly equipment-related factors and financing costs, on tariff reduction. Therefore, two tariffs pertaining to projects located in different phases of the Bhadla Solar Park—the winning tariff of INR 4.34 per kWh at the Phase 2 auctions held in January 2016 (hereafter referred to as the "January 2016 Solar

Tariff" in this paper) and the May 2017 Solar Tariff—were selected for the purpose of the analysis. Selecting projects on sites that are closely located helps clearly identify the impact of the aforementioned key input variables in lowering tariffs since it helps control for the variations in other variables such as resource availability and some cost variables, as described in the following lines. Though solar park projects are subject to the specific solar park charges pertaining to the park that they are located in, balance of system costs (see Section 4.2) for these projects have become reasonably standardized under the MNRE's solar park scheme. Under this scheme, the solar park developer is responsible for providing standardized supporting infrastructure for projects in return for solar park charges (Ministry of New and Renewable Energy, Government of India 2017). Thus, for the purpose of the analysis, it is assumed that balance of system costs remain at the same level for both the January 2016 and May 2017 solar tariffs. Further, both the January 2016 and May 2017 solar tariffs correspond to projects with central government offtakers, which also helps to control for the impact of the offtaker on financing costs (refer to Section 3 for understanding the differences in the credit profile of different categories of offtakers). This ensures that the changes in financing cost assumptions between the two bids reflect changes in the general level of interest rates and risk perceptions for solar energy only and are not skewed by the type of offtaker.

In order to understand the impact of changes in key input variables on overall tariff reduction, a modified January 2016 tariff (with upfront solar park charges corresponding to those of the May 2017 tariff and the same accelerated depreciation rates) was first created. Module and financing costs are the only input variables that differentiate the modified January 2016 tariff from the May 2017 tariff. In order to get a sense of the extent of the impact of changes in equipment costs in lowering tariffs, a modified May 2017 solar tariff was created that factored in financing cost assumptions pertaining to the January 2016 solar tariff. This modified May 2017 tariff is indicative of what the actual tariff would have looked like had financing costs not changed between the two rounds of bidding. The difference between the modified January 2016 tariff and the modified May 2017 tariff is the impact of equipment-related factors on tariff reduction.

Apart from analyzing the impact of the two key input variables on solar tariff reduction in recent times, this paper also attempts to identify the major drivers of potential declines in tariffs going forward, specifically focusing on how changes in module costs and financing costs could affect tariffs. This is done by taking the May 2017 tariff as a baseline, and projecting the trajectory of tariffs pertaining to a hypothetical project located at the same site over a five-year period beginning mid-2017 (around the time of the May 2017 solar tariff) and culminating in mid-2022. This time frame roughly coincides with the Indian government's plans for achieving 175 GW of cumulative RE installed capacity by the end of FY2022. A five-year time horizon is also arguably sufficient to assess the impact of potential policy interventions aimed at de-risking the RE sector. This exercise consists of two steps. The first is the estimation of the potential trajectory of the tariff if only module costs were to change over the five-year forecast horizon. The second step is the potential trajectory of the tariff driven by changes in both module costs as well as changes in financing costs. This exercise highlights the potential role of declines in financing costs in lowering RE tariffs going forward.

3.2 Input Variables

Based on the literature review, it was found that several factors determine the LCOE of grid-connected solar and wind power plants. These include costs of PV modules or wind turbine generator, balance of system (BOS), land, evacuation infrastructure, operations and maintenance, and finance, as well as government incentives (if any) such as accelerated depreciation benefits. The variables mentioned in this section have been used for performing the analysis outlined in Section 4.1.

- **Wind turbine generator/PV modules**

A wind turbine generator is the element of a wind energy generating system that converts wind energy to electrical energy. Corresponding to wind turbine generators in wind energy installations, solar PV modules are the analogous components used in solar PV energy generation systems.

- **Solar park charges**

Solar park charges are paid by developers of solar projects to the solar park developers in exchange for the facilities provided by the park developer. These include solar park charges consist of one-time and recurring components, the setting up of evacuation infrastructure (pooling substations within solar parks and connecting them to the transmission system of the state or central transmission utility), and other supporting infrastructure such as road connectivity to each plot of land, water availability, etc. Though the specific cost heads vary, solar park charges consist of one-time and recurring components. Both the one-time and recurring solar park charges corresponding to the two projects considered are different as they are located in different phases of the Bhadla Solar Park. Phase 2 of the Bhadla Solar Park, corresponding to the January 2016 project, was developed by a subsidiary of the Rajasthan Renewable Energy Corporation, while Phase 3 of the Bhadla Solar Park, corresponding to the May 2017 project, was developed by a JV of the Government of Rajasthan and IL&FS Energy (Government of Rajasthan Energy Department 2018).

- **Land**

This refers to the cost of acquiring or leasing land for the installation of wind turbines/PV modules, and associated infrastructure. Given the challenges involved in land acquisition, the leasing model is preferred by developers, including the solar park model for solar projects. The analysis in this paper factors in the land leasing model for the analysis of wind tariffs and the solar park model in the analysis of solar tariffs.

- **Balance of system (BOS) costs**

BOS costs include those pertaining to civil works, mounting structures, evacuation infrastructure (in the case of solar parks, the portion that is borne by developers), the power conditioning unit, and preliminary and preoperative expenses.

• **Financing costs**

Given the huge upfront capital expenditure in renewable power projects, financing is one of the major factors that affects the LCOE and in turn the price at which discoms purchase power from producers. The capital raised for financing RE projects is debt-heavy. Average debt-to-equity ratios for financing these projects stood at around 75:25 in India in 2017, though more debt-heavy capital structures have been observed in recent times (Dutt, Arboleya, and Mahadevan 2019). Based on inputs from market participants, the costs of debt and equity (ROE) for utility-scale solar and wind projects have been in the range of 9%–14% and 14%–16%, respectively, in recent years.

• Operations and maintenance expenses (O&M)

O&M expenses include the recurring expenses incurred throughout the life of the project such as labor costs pertaining to the upkeep of the equipment, insurance, etc.

Automation in O&M activities through the deployment of robots has enabled the reduction of O&M expenses for large-scale solar projects.

• Accelerated depreciation benefits

Accelerated depreciation benefits help lower the burden of taxation in the early years of a project, translating into higher cash flows and improved project viability. The applicable rates for accelerated depreciation benefits were 80% pertaining to the January 2016 solar tariff and 40% pertaining to the February 2017 wind tariff and May 2017 solar tariff.

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Chapter 4

DATA AND ASSUMPTIONS

This section presents the data and assumptions used in performing the analysis in the succeeding sections of this paper, as per the methodology outlined in Section 3. No energy yield data for projects pertaining to either the January 2016 or the May 2017 solar tariffs were publicly available. Therefore, the capacity utilization factor (CUF) pertaining to the January 2016 and May 2017 solar tariffs was estimated by considering the CUF for a comparable solar project—a 20 MW utility-scale solar project located in Jodhpur, Rajasthan (UNFCCC 2017). The analysis in this paper assumes no changes in technology between the two tariffs, thereby factoring in the same CUFs for the geographically proximate projects characterized by similar resource availability.

Module costs in INR for the January 2016 and May 2017 projects were estimated based on industry reports, using INR/USD exchange rates of 66 and 64, respectively (Mercom Capital Group 2016; Mercom Capital Group 2017). In order to account for module degradation, the net present value of module degradation costs was accounted for as additions to the capital cost as per the Central Electricity Regulatory Commission's (CERC) recommendations (Central Electricity Regulatory Commission 2016b). This equates to an addition in capital cost of INR 1 million/MW. The estimates for solar park charges and BOS costs are based on industry reports and inputs from market participants (Bridge To India 2015). Further, inputs for the February 2017 wind tariff were sourced from CERC guidelines on capital costs for wind energy projects and inputs from market participants. An annual degradation in output of 1.6% has been factored in for the estimation of wind tariffs (Staffell and Green 2014).

Data on the terms of debt and the required return on equity for the solar and wind projects under consideration were sourced from interactions with market participants. The estimates for the debt-to-equity ratio are also based on interactions with market participants. The discount rate for each project was estimated based on the estimates for costs of capital and the debt-to-equity ratio and the prevailing tax rates. Table 1 below summarizes the data and assumptions for the three projects. In addition, the analysis also factors in the impact of government incentives offered in the form of accelerated depreciation benefits, as applicable to the respective projects. Given that the offtakers for each of the bids analyzed in this paper have central government offtakers, working capital assumptions are based on CERC recommendations, which factor in minimal delays in payment from discoms to RE developers (refer to Section 7 for a discussion on how longer payment delays can affect tariff bids).

(All Costs in INR million/MW)	January 2016 Solar Tariff	May 2017 Solar Tariff	February 2017 Wind Tariff
CUF	20.52%	20.52%	35.00%
Annual electricity generation per MW in first year (in kWh)	1.80 million units	1.80 million units	3.07 million units
Performance degradation	Addition of 1 million/MW to capital cost	Addition of 1 million/MW to capital cost	Annual degradation in generation of 1.6%
Wind turbine cost/solar PV module cost	34.3	17.9	42.5
Land lease cost	–	–	0.095 million per annum with an annual escalation of 5%
One-time solar park charges	2.6	5	–
Recurring solar park charges	Land lease: 0.03 million per annum for the first two years with a 5% escalation thereafter Solar park O&M charges: 0.1 million per annum with an escalation of 10% Other annual charges: 0.1 million	Land Lease: 0.027 million per annum in the first year, 0.048 million per annum for the second year, with a 5% escalation thereafter Solar park O&M charges: 0.15 million per annum with an escalation of 5% Local area development fee: 0.1 million per annum for first five years	–
Operations and maintenance costs	1.5% of initial capex with 5% increase per year	1.5% of initial capex with 5% increase per year	1 million per annum with an annual escalation of 5%
Balance of system costs	9	9	17.5
Working capital	1 month of O&M charges Maintenance spares at 15% of annual O&M expenses 2 months of receivables Interest on working capital: 13.26%	1 month of O&M charges Maintenance spares at 15% of annual O&M expenses 2 months of receivables Interest on working capital: 13.26%	1 month of O&M charges Maintenance spares at 15% of annual O&M expenses 2 months of receivables Interest on working capital: 13.26%
Terms of debt (interest rate and tenor)	14% (12 years)	9% (12 years)	10% (16 years)
Required return on equity	16%	14%	16%
Taxes	34.61% (30% income tax + 12% surcharge + 3% education cess)	34.61%	34.61%
Debt: equity ratio	70:30	80:20	70:30
Discount rate	11.21%	8.32%	9.38%
Accelerated depreciation benefit	80%	40%	40%

Table 1: Data and Assumptions for Estimating Breakdown of Wind and Solar Tariffs

the LCOE. Based on the literature review, unit module prices are expected to track historical learning rates of around 20% in the long term. However, since module prices have declined faster than historical rates in recent times due to a supply glut (International Technology Roadmap for Photovoltaic 2017), the decline in module prices should be less rapid than historical rates over the next few years as the overall decline trajectory reverts to historical rates. Thus, this paper adopted a learning rate of 15% for the period from mid-2017 to mid-2022 for estimating the decline in unit module prices for the purpose of the analysis. This implies a 15% decline in unit module prices with the doubling of cumulative installed capacity. It is important to note that this analysis does not account for any technology disruption over this period. The time period over which a 15% decline in prices is likely to occur was estimated based on cumulative installed PV

capacity data and the expected rate of additions going forward. Global cumulative installed PV capacity stood at 303 GW at the end of 2016 (International Energy Agency 2017). According to projections by the International Energy Agency (IEA), it would take around four years for the doubling of global cumulative installed capacity (International Energy Agency 2018). There could be considerable downside risks to the pace of global PV capacity addition as a result of lower electricity demand resulting from the rising energy efficiency of demand sources. This paper factors into the analysis a conservative four-year period for the doubling of cumulative installed capacity and a 15% decline in unit module costs over the same period. This translates into a compounded annual rate of decline of approximately 4%.

Table 2 below lists the module-related assumptions for the projections of the future trajectory of the baseline May 2017 solar tariff (hereafter referred to as the "Baseline LCOE"), based on changes in module costs alone

Year-wise Module Cost	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Module cost (in INR million/MW)	17.9	17.2	16.5	15.8	15.2	14.6

Table :2_Module-related Assumptions for Baseline LCOE Projections

Besides module costs, as discussed in Section 2, reductions in financing costs are another avenue for achieving tariff reduction. The cost of debt for RE projects in India could decrease either as a consequence of a reduction in the base rate on borrowings or through a fall in risk premium on borrowings for this sector. RE projects in India are highly dependent on bank debt, in the absence of other sources of domestic debt. The trajectory of short-term interest rates in India is determined by the monetary policy imperative of inflation targeting. A number of factors, including subdued outlooks for commodity prices and food inflation, are likely to keep inflation rates within the RBI's target range, translating into lower benchmark rates over the next few years than in years gone by (Bhandari 2017). In addition, potential improvements in India's sovereign credit rating driven by fiscal and institutional reforms initiated by the government could make the country a more attractive destination for low-risk long-term investors such as pension funds, which only invest in financial assets with high credit ratings (Crisil 2019). The government's reform agenda was recognized in a sovereign credit rating upgrade for India in November 2017 (Moody's Investors Service 2017), and there could be further improvements in the country's credit rating should the government stay the course of institutional reforms and fiscal consolidation, as per its stated intention (Press Information Bureau, Government of India 2017b).

In addition to a fall in benchmark lending rates, the lowering of investors' risk perceptions could lower risk premiums factored into the cost of debt and equity. These risk premiums have declined over the years; however, further reduction in risk perceptions can be achieved if policy and market interventions address major existing and emerging risks facing the sector (Section 7).

For the purpose of estimating the impact of the decline in financing costs on the baseline LCOE, in combination with changes in module costs over the five-year forecast period, the analysis factors in a 200 basis points decline in the cost of debt and a 400 basis points decline in the required return on equity Such a decline in financing costs could be achieved through a combination of the factors mentioned earlier. The projections for the decline in LCOE shown in Section 6 illustrate the extent of the impact of such a decline in financing costs on tariffs.

Year-wise Assumptions	Cost of debt	Cost of equity
2017	9.00%	14.00%
2018	8.60%	13.20%
2019	8.20%	12.40%
2020	7.80%	11.60%
2021	7.40%	10.80%
2022	7.00%	10.00%

Table 3: Financing Cost Assumptions for Baseline LCOE Projections

The assumptions pertaining to declines in financing costs, as shown in Table 3, over a five-year period are fairly conservative compared to the 500 basis point reduction in the cost of debt and the 200 basis point reduction in the cost of equity witnessed between the January 2016 and May 2019 tariffs. The surge in liquidity experienced by Indian banks as a result of the withdrawal of old high-denomination currency notes from circulation towards the end of 2016 partly explains the decline in the base rate on borrowings and consequently the cost of debt for RE developers. However, the decline in the cost of debt between the January 2016 and May 2019 tariffs is greater than the decline in base rates over the intervening time period. This is indicative of improved investor confidence in the maturing RE sector in India, alongside rapidly declining unit capital costs (as a result of sharp declines in module costs). In line with such a development, the analysis factors in a more debt-heavy capital mix for the future LCOE projections, with a debt-to-equity ratio assumption of 80:20.

For the projections of future LCOE, cost variables along with module costs and financing costs are maintained at base case levels. This is for ease of comparison and also bears in mind that the forecast is being made for the same site as the base case.

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Chapter 5

RESULTS AND DISCUSSION

5.1 Deconstructing the Tariffs

Based on the data and assumptions stated in the previous section, this section presents the results of the deconstruction of the February 2019 wind tariff and the May 2019 solar tariff. Table 4 and Figures 2 and 3 shown below illustrate the component-wise breakdowns of these tariffs.
As is evident from Table 4 and Figures 2 and 3, financing costs account for the largest chunk of the overall LCOE for solar and wind-based generation. Financing costs accounted for 53% and 62% of the LCOE for the respective solar and wind tariffs under consideration. Higher finance costs pertaining to the wind tariff are a reflection of the inferior terms of finance vis-à-vis those for the solar tariff, as borne out by the cost of debt and equity assumptions stated in Table 1. This could be a reflection of the highly competitive nature of solar energy auctions, translating into lower returns on equity pertaining to the solar tariff, with prevailing interest rates affecting the cost of debt. This was only the first competitively determined wind auction and subsequent auctions have been characterized by more competition.

(All Costs are in INR/kWh)		
	Feb 2019 Wind Tariff	May 2019 Solar Tariff
Operations and Maintenance	0.56	0.44
Wind Turbine/PV Module	0.74	0.47
Land Lease/Solar Park Charges	0.05	0.32
Balance of System	0.3	0.22
Financing Costs	2.14	1.38
Accelerated Depreciation Benefit	–0.32	–0.21
Total	3.47	2.62
Tariff (actual)	3.46	2.44
Model Error	0.01	0.18

Table 4: Component-Wise Breakdown of February 2019 Wind Tariff and May 2019 Solar Tariff

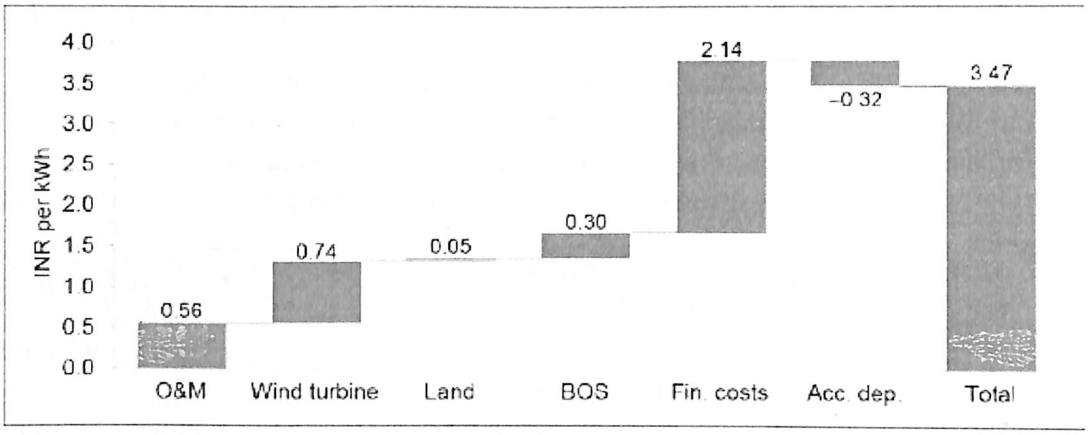

Figure 6: Financing Costs Constitute the Largest Component of Indian Wind Energy Tariffs

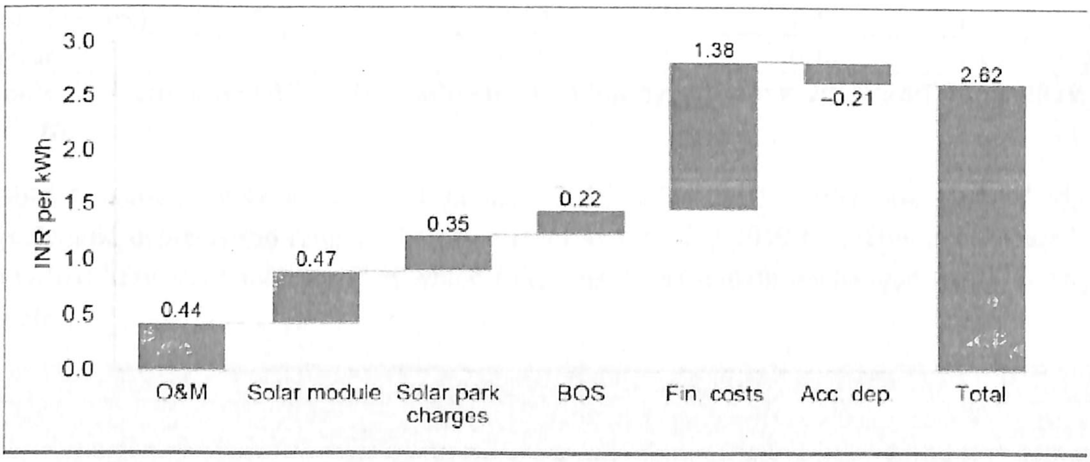

Figure 7: Financing Costs Constitute the Largest Component of Indian Solar Energy Tariffs

Interestingly, module costs and wind turbine costs, the second largest components of the two tariffs discussed above, account for only around 20% of the overall LCOE for the respective solar and wind tariffs. This clearly illustrates that financing costs are the largest components of wind and solar energy tariffs.

5.2 Estimating the Impacts of Changes in Module- and Nonmodule-Related Factors on the LCOE

While the preceding section demonstrated the predominance of financing costs in the composition of solar and wind energy tariffs, this section examines the extent of the impact of changes in key inputs on changes in overall tariffs. Table 5 presents the deconstruction of the January 2016 solar tariff and May 2019 solar tariff for comparison.

All Costs are in INR/kWh)		
	Jan 2016 Solar Tariff	May 2019 Solar Tariff
Operations and Maintenance	0.58	0.44
Modules	0.96	0.47
Solar Park Charges	0.28	0.32
Balance of System	0.24	0.22
Financing Costs	2.82	1.38
Accelerated Depreciation	–0.55	–0.21
Total	4.33	2.62
Tariff (actual)	4.34	2.44
Error	–0.01	0.18

Table 5: Component-Wise Breakdown of Winning January 2016 and May 2019 Solar Tariffs

Table 6 below shows a modified January 2016 solar tariff, with solar park charges and accelerated depreciation rates at the same level as the May 2019 bid. This is compared with a modified May 2019 solar tariff in which financing terms remain unchanged from January 2016 levels.

Decline in LCOE Due to Module Costs		
	Modified Jan 2016 Solar Tariff with Bhadla Phase 3 Solar Park Charges Assumptions	Modified May 2019 Solar Tariff with Jan 2016 Financing Assumptions
Operations and Maintenance	0.61	0.41
Modules	0.96	0.51
Solar Park Charges	0.32	0.32
Balance of System	0.24	0.24
Financing Costs	2.96	1.99
Accelerated Depreciation	–0.49	–0.32
Total	4.6	3.15

Table 6: Decline in LCOE Due to Module Costs

Since input variables besides module costs remain unchanged between the two modified tariffs, this exercise reveals that had only module costs changed between the two tariffs, the actual decline in tariffs would have been around 73% of the actual decline in tariffs witnessed. However, the actual LCOE of INR 2.44 per kWh (INR 2.62 per kWh with the error) was achieved as a result of a decline in financing costs in addition to changes in module costs, as illustrated in the previous section. Thus, though module costs certainly drove the majority of the decline in tariffs between the January 2016 and May 2019 tariffs, the decline in financing costs played a significant role in tariff reduction as well, accounting for roughly 27% of the decline in tariffs.

The maturing of RE technologies, particularly solar and wind, and growing familiarity with these technologies has lowered risk perceptions among financiers in the Indian context. This has lowered the risk premiums that financiers attach to the financing of solar and wind projects, translating into improved terms, and thereby costs of finance. Moreover, favorable policy support has helped lower the business risk for project developers. In addition, intense competition at these auctions has prompted equity investors to recalibrate their return expectations as well. These factors taken together translated into lower financing costs pertaining to the May 2019 tariff than for the January 2016 tariff.

5.3 Estimating the Impact of Changes in Module Costs and Financing Costs on the Future Trajectory of the LCOE

While the preceding section gave a sense of the relative contributions of module costs and the financing costs in tariff reduction between the January 2016 and May 2019 tariffs, this section examines how changes in these factors could affect the trajectory of the baseline LCOE going forward. Table 7 shows the projected declines in the LCOE as a result of changes in module costs only.

Year-wise Estimated LCOE	2017	2018	2019	2020	2021	2022
LCOE (INR/kWh)	2.62	2.57	2.52	2.47	2.43	2.38

Table 7: Projected Decline in Baseline LCOE as a Result of Changes in Module Costs

Table 8 shows the projected trajectory of the baseline LCOE as a result of changes in both module costs and financing costs due to improved terms of finance.

Year-wise Estimated LCOE	2017	2018	2019	2020	2021	2022
LCOE (INR/kWh)	2.62	2.50	2.38	2.27	2.17	2.07

Table 8: Projected Decline in Baseline LCOE Due to Changes in Module Costs and Financing Costs

Tables 7 and 8 show that changes in only module costs along the trajectory specified in Section 5 result in a 9% decline in the LCOE by the end of the five-year forecast horizon as compared to the baseline figure. However, if, in addition to changes in module costs, financing costs were to decline along the trajectory specified in Section 5, it would result in an additional 12% decline in the LCOE from the baseline figure, translating into a 21% reduction in the overall tariff from the baseline figure. Thus, should financing costs decline as per the trajectory specified in Section 5 along with changes in module costs, it would more than double the tariff reduction achieved from module costs alone.

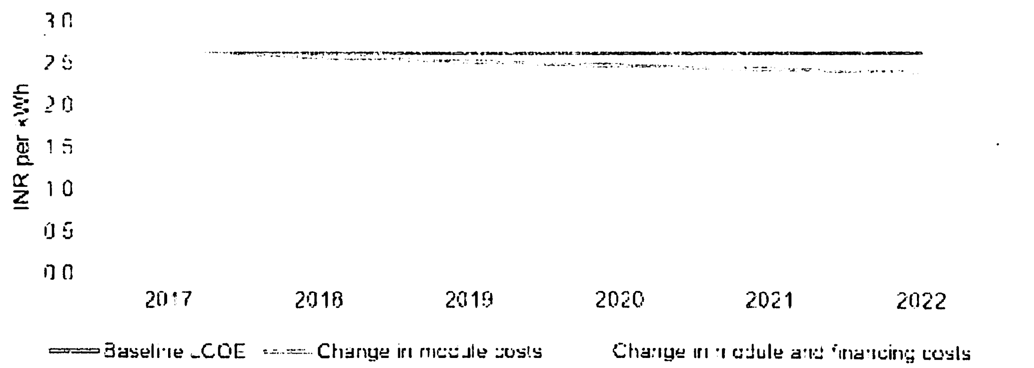

Figure 4: Financing Costs Increasingly Important in Order to Lower LCOE Going Forward

This clearly shows that changes in financing costs are likely to be much more important in tariff reduction going forward than in years gone by, should a trajectory of declining costs as envisioned be realized. Moreover, the divergence between the trajectories of the LCOE based on changes in module costs alone and that accomplished by changes in both module and financing costs shows that the importance of financing costs in realizing tariff reductions is likely to increase going forward. While the analysis performed in this section focused on a specific case, the inferences are equally valid not only for other utility-scale solar projects but also for wind energy projects, given the similarity in the composition of solar and wind energy tariffs (as demonstrated by Section 6.1).

Module costs or wind turbine generator costs are largely exogenous factors from the point of view of the Indian RE ecosystem, given that they are dependent on technological changes and supply-demand dynamics at a global level, along with supply chain changes and efficiency improvements in manufacturing hubs like the PRC. In addition, trade barriers such as safeguard duties could mitigate the declines in tariffs realized through lower module prices in the short to medium term. Based on petitions by domestic Indian module manufacturers, the Directorate General of Trade Remedies (DGTR) has imposed safeguard duties on module imports, which collectively account for around 90% of modules used in India (Ministry of Commerce & Industry, Government of India 2018). Duties of 25% are applicable for a year beginning 30 July 2018 before being lowered to 20% in the first six months of the second year and 15% for the following six months (Ministry of Commerce & Industry, Government of India 2018). The imposition of duties will mitigate the impact of declines in module prices on the LCOE. Thus, changes in module prices are not likely to be as impactful in LCOE reduction going forward as in years gone by. This leaves policy makers only with influencing financing costs as a driver for lowering tariffs. This is discussed in the next section.

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Chapter 6

CONCLUSION & POLICY IMPLICATIONS

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

The lowering of financing costs for RE projects can be achieved in a number of ways. These include explicit subsidies or measures geared towards the de-risking of the RE sector, translating into lower return expectations for investors. Given that utility-scale RE tariffs in India are now competitive with those for thermal generation, explicit subsidy support through measures such as capital subsidies and interest rate subvention are not desirable (Josey, Mandal, and Dixit 2017). However, mitigating risks either by de-risking RE projects or covering for the risks through de-risking financial instruments can help lower return expectations and thereby financing costs pertaining to RE projects. This section describes the major existing and emerging risks for utility-scale RE projects in the Indian context and measures that could mitigate these risks:

Offtaker risk: This refers to the risk of noncompliance by the offtaker with the terms of the PPA. This may be categorized into two major subtypes:

• Payment delays: While delays of 30–60 days between developers raising invoices and receiving payments are usually permitted, data reported on India's Ministry of Power's (MOP) PRAAPTI portal indicate that average payment delays to RE developers are of the order of 12 months.1 Expectations of long payment delays could translate into higher working capital assumptions factored in by RE developers into tariff bids, translating into higher tariffs.

• Renegotiation of PPAs: Financiers compensate for additional risk by demanding higher returns. Uncertainty generated by instances of renegotiation of PPAs could translate into higher return expectations for RE financiers and thereby financing costs. The planned renegotiation of PPAs by the state of Andhra Pradesh in the middle of 2019 is one such instance. If unchecked, such instances can translate into higher financing cost assumptions factored into RE tariff bids and thereby higher tariffs.

Mitigating off taker risk requires strict enforcement of contractual provisions by state electricity regulators to minimize instances of payment delays or PPA renegotiation. Alternatively, payment security mechanisms safeguarding RE developers against long payment delays could also help mitigate this risk. A recent order by the MOP mandating the maintenance of letters of credit for payments by Discom could constitute part of the solution for payment delays, provided that it is implemented effectively (Ministry of Power, Government of India 2019).

Land acquisition/evacuation infrastructure risk: Delays in land acquisition and the setting up of evacuation infrastructure have translated into delays in the setting up of solar parks, with the share of solar park projects in overall solar project capacity awarded declining to 24% in 2018 from 54% in 2017 (Dutt, Arboleya, and Mahadevan 2019). These challenges have mostly been faced by private sector developers of solar park infrastructure.
In order to mitigate this risk, a greater role of government entities in facilitating timely land acquisition can help streamline the process of solar park development. The recent introduction of a new scheme of solar park development, in which SECI assumes the responsibility of land acquisition, could help facilitate the process of solar park development (Ministry of New and Renewable Energy, Government of India 2019b).

Curtailment risk: With rising penetration of RE in India's electricity mix, curtailment risks could become more significant going forward. While current evidence of curtailment is limited, anecdotal evidence suggests rising instances of RE curtailment in India (Tongia 2018). Managing this risk could be based on a two-pronged approach:

- Contractual provisions that safeguard against curtailment risk by guaranteeing a minimum level of offtake of RE generation (Viswamohanan and Aggarwal 2018).
- Design of financial instruments such as guarantees that mitigate curtailment risks for developers (Aggarwal and Chawla 2019).

Glossary of Terms:

RE	Renewable Energy
NDC	Nationally determined contribution
NAPCC	Natinal Action plan for climate change
RPO	Renewable purchase obligation
SERC	State Electricity regulation commission
VGF	Value Gap finding
ITRPV	International Technology Roadmap for Photovoltic
LCOE	Leverage cost of Energy
WACC	Weighted Average Cost of Captital
BOS	Balance of system
O&M	Operation & Maintenance
CUF	Capacity utilization factor
CERC	Central Electricity Regulation Commission

Bibliography:

1. BRIDGE TO INDIA

2. Ministry of power, Govt. of India. *24X7 POWER FOR ALL, A Joint Initiative of Government of India and Government of Kerala.* Ministry of Power, Govt of India, 2016. Print.

3. Analyzing the falling solar and wind tariffs.

4. The Hindu Business Line. 2019. *PM Modi pledges to more than double India's non-fossil fuel target to 450 GW.* 23 September. Accessed 18 November 2019. https://www.thehindubusinessline.com/news/world/president-trump-makes-unscheduled-appearance-at-un-climate-summit-to-listen-to-modi/ article29492629.ece. https://www.forbes.com/sites/christopherhelman/2014/04/24/solar-is-booming-but-will-never-replace-coal/#5a9ca46a6ebb

5. Ministry of Power, Government of India. 2019. "Clarification on Order related to Opening and maintaining of adequate Letter of Credit (LC) as Payment Security Mechanism under PPAs by Discoms." *Ministry of Power.* August 9. Accessed 19 November 2019. https://powermin.nic.in/sites/default/files/webform/notices/ Clarification_on_Order_related_to_Opening_and_maintaining_of_adequate _Letter_of_Credit.pdf

6. Evaluating the Future of Indian Solar Industry by ***Faculty Contributor** : Ganesh N. Prabhu, Professor **Student Contributors** : Sreejith Narayanan E. and Ashin Mathew*

7. http://economictimes.indiatimes.com/industry/energy/power/price-of-solar-power-may-fall-further-in-fy18/articleshow/57565592.cms

8. Power Plus Solar - www.indiapowersector.com

9. https://www.telegraphindia.com/1170313/jsp/business/story_/ Falling tariff fillip to solar power

10. http://www.atimes.com/article/boom-time-indias-renewable-energy-sector/

Appendix

a. Wikipedia Data - Electrical Sector of India

b. IRENA - Renewable energy

c. Exploring Solar Power - NEED Solar short

d. Mission document - JNNSM

e. Tata Power in-house Magazine with Special edition on Renewal Energy

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