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Analysis of Feed-in Tariff and Net-Metering with respect to Residential Roof top Solar Photovoltaic Installation

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Abstract—The main objective of this paper is to understand the current Indian solar market and evaluate the growth of solar power in terms of installed solar power capacity. Also, to analyze the market trends for solar power plants and to investigate new incentive schemes for promotion of solar power against the present incentive schemes such as Capital Subsidies and Net Metering for solar power in India keeping in mind that India is trying to achieve the aggressive Solar Power target of 100 GW Installed capacity by year 2022.
The paper will try to analyze how Feed-in tariff will benefit the power generators via a mathematical model and how it can attract the mass population of India towards Environment friendly Solar Power. We will analyze the effective renumeration payable to an End user who chooses to install a roof top solar power plant at his house under present schemes along with the FiT Scheme and we will conclude why the FiT Scheme will be able to attract an average household to solar power.
The paper will also consider the Solar Irradiation profile of the locality of the household in question along with the Load profile as these two will also determine how beneficial it will be for the Owner to shift from present Incentive schemes to Feed-in Tariff Scheme.

Keywords:- Feed-in Tariff (FiT), Net-Metering(NM), Photovoltaic (PV), Return Of Investment (ROI), Levelized Cost Of Electricity(LCOE), Power Distribution Company (DISCOM), Ministry of New and Renewable Energy (MNRE), National Renewable Energy Laboratory (NREL).

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I. INTRODUCTION

SOLAR energy is a renewable source of electrical energy. The use of solar power has increased considerably in last few decades for generation of electricity as the non-renewable sources are limited and not environment friendly. In the list of renewable sources, wind and solar power lead as solar irradiance and wind is more easily available. Many techniques and methods are implemented on solar technology, making it stable and efficient.
The Total production of Renewable Energy has been increasing with a steady rate and by 2017-18 it has reached to 99,203GWh for the whole year. The Energy Yields from various Renewable Energy sources in India for last 4 Financial Years are shown in figure 1 [32].

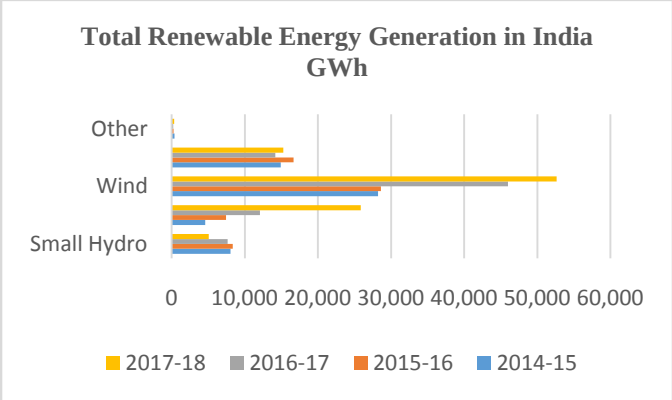

Figure 1 Total Renewable Energy Generation in India

Figure 2 shows the brake up of Total Renewable energy installed capacity in India. Solar energy contributes for 22% of the total installed capacity [32].

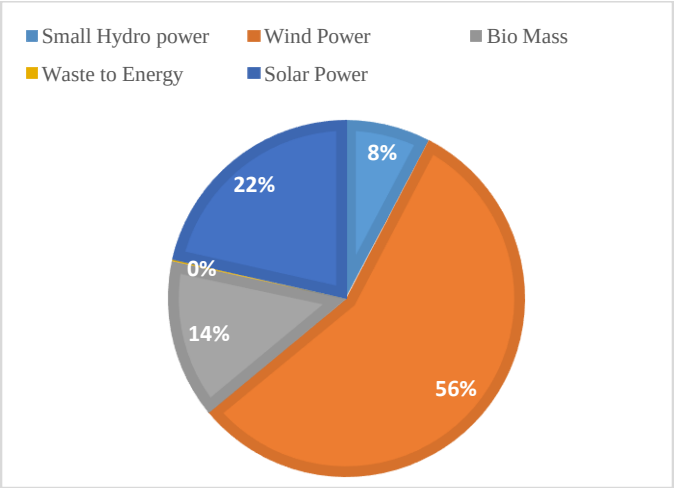

Figure 2 Renewable energy installed capacity

The Governmentof India has been committed to growth of solar power sector for quite some time now and good amount of tax payer's money is spent on development of solar power. The National Budget of 2018 has allocated INR 2.17 billion for the good cause[41]. The Department ofNonconventionalEnergy Sources, Government of India, which started in 1982, to promote the production of nonconventional power in India Further the Jawaharlal Nehru National Solar Mission (JNNSM) introduced on the 11th Jan 2010 focused mainly on solar power. The Central and state governments have avail attractive incentive schemes in order to promote investment in solar power sector.India is alsoplaying an Important role in the International Renewable Community with France in formation of International Solar Alliance (ISA) which has 121 members from the tropical regions.

II. INCENTIVE SCHEMES FOR SOLAR POWER PRODUCTION.

Various Nations all over the world use attractive incentive Schemes in order to promote Investments into solar power system in order to reduce their carbon emission and reduce dependability on fossil fuel. Following are few dominant schemes in India and world. [26][6].

A. Capital subsidies

This is one of the most basic incentive scheme which can cover both grid connected as well as stand-alone systems. Under this scheme the Government will subsidize a part of capital that is invested for the installation of a solar power plant. The Ministry of New and Renewable Energy in India subsidize 30% of the capital cost of solar installations while remaining is available in the form of a soft loan [39].

Major disadvantages with Capital Subsidies are that it puts entire financial burden on the tax payers. Capital subsidies are based only on the installation cost of the plant and they are independent of the actual energy yield over time or the capacity of the plant in question over all the Capital subsides can only ensure the installation of the plant not its efficient operation.

B. Net-metering

Net-metering applies only to the Grid Connected PV systems such systems may or may not have battery back-up installed according to Net-metering the power generated and injected back into the grid has the same economic value as the power supplied by the grid. A bi-directional Energy meter or two separate meters may be used to calculate the net flow of energy [1].

Net-metering is presently in use all over India for all grid connected Power Generators cum consumers with few exceptions, it is very simple and easy to implement [29] as the power supplied back to the grid is subtracted from the power supplied to the consumer and the billing is done over the net power supplied to the consumer. Although Net-metering is viable option for reduction in Net-payable bill [13] [17], but it is not very profitable from power generation prospective as buy back rates remains quite low in case the total generation of power is higher than the total consumption of electricity thus it is not able to attract too many investors especially at the house hold level as the installation cost remains very high and ROI period remains quite long.

*C. **Feed-in Tariff***

Under this scheme the DISCOM companies are under obligation to buy Solar Power generated at a tariff rate determined by the relevant authorities [23] which is normally higher than the average cost of power supplied to the end users, thus the financial burden of promoting solar power is no longer on the tax payers but on the end users of electricity [12].

The Feed-in tariff rate can be controlled via Power Purchase Agreement (PPA), normally it is kept higher for smaller installations in order to promote decentralization in power generation [16] and reduce transmission and distribution costs and reduce the effects of adverse weather conditions in total renewable energy production [3]. Feed-in tariff is successfully implemented in many countries like Germany, France, Italy, Spain, Japanetc [20].where it was utilized as an effective tool to increase investments into solar power [19]. The only drawback with Feed-in tariff is that it will result in increase of average electricity cost to the end users.

*D. **Other Schemes***

Apart from the above methods the government may use various other methods to lure investors into solar power like allocation of land at subsidized ratesfor development of solar parks and soft loan, accelerated depreciation and other incentives for roof top installations [8].

India is the home for the largest solar power parks in the world The Ministry of New and Renewable Energy lists 45 different solar power parks approved all over the country with a total capacity of nearly 26.5 GW till June 2018 power among with the GujratDholera Solar Park which has the highest capacity of 5 GW [39]. The problem with such parks are that they require massive amount of land and infrastructure and cause centralization in power production.

Apart from this The Government of India has started few other schemes which promote the installation of roof top plants like subsidies for Roof top grid connected plants by Solar Energy Corporation of India such plants do not require massive land or infrastructure as they are already connected to the grid further such installations improve the decentralization of power, reducing the transmission and distribution cost and losses maintaining stable grid operation [21].

III. TARIFFS AND BIDS

Tariffs are the amount that utilities are charging consumers and not their procurement price from the developers.whereas bids are the prices agreed upon by the utility and the power producer as per a power purchase agreement (PPA) [22].

Bid price = LCOE + profit margin (developer)
Tariff to Consumer = LCOE + profit margin (developer) + margin by DISCOM
Tariff to Consumer = Bid price + margin by DISCOM

Despite (weighted average) prices having declined from INR 12.16/ kWh when the National Solar Mission (NSM Batch 1) started in December 2010 to INR 6.72/kWh in November 2014, shortly after the new targets were announced, solar power was seen as being a long way off from cost competitiveness.However, the optimism around the potential of solar power is not unanimous, with concerns being raised around the sustainability of the aggressively low solar bids, especially as bids went as low as USD 3 cent (INR 1.99)/kWh in Dubai and Chile. Recently ACME Solar India has made bid of 2.44 INR/kWh Bhadla Solar park in Jodhpur, Rajasthan [33].
Figure3 below shows the declining trend in solar bids in India, comparing the lowest solar bids from the beginning of the National Solar Mission, till now.

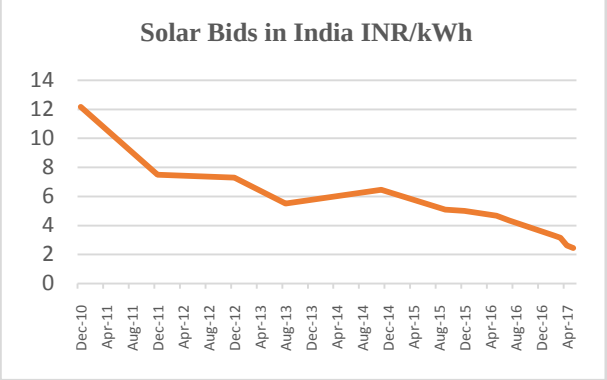

Figure 3 Solar Bids in India.

*A. **Levelized Cost of Electricity***

The Levelized Cost of Electricity (LCOE), also known as Levelized Energy Cost (LEC), is the net present value of the unit-cost of electricity over the lifetime of a generating asset. Following are the factors affecting LCOE.

a) Material cost
b) Balance of system
c) Land
d) Transmission and evacuation infrastructure
e) Financing
f) Operation and maintenance

*B. **Small scale rooftop power plant***

Small Roof top Grid Connected Installations can help the End users in reduction of their Net Payable Electrical bills also it can result in earnings in case the power produced exceed the total consumption. Such Installation do not require land and other infrastructure as the Household is already connected to the Grid and Panels can directly be mounted on the roof tops, only major obstacle is the Financial Cost and unsecure Electrical power market for small scale power generators.

In India all such Installations are covered under the scheme "Grid Connected Rooftop and Small Solar Power Plant Programme" [39].

On Paper such installations are subsidized up to 30% of total capital cost but there are certain conditions [9].

a. The Installation and Equipment purchase to be done only by companies listed with Ministry of New and Renewable Energy, this restrict the buyer from choosing the more efficient and cheaper equipment.
b. The subsidy claim will be processed as per the priority list and the claim will receive the subsidy only if sufficient funds are available.
c. The Red tape and long procedural delay in India makes it very difficult for an average Citizen to get his subsidy claim.

Renumeration for domestic rooftop Plants are under Net-Metering scheme. In case they generate excess power compared to their consumption the buyback rates for such excess is not fixed as the Electrical Power market is under the open market scheme as per the Electricity Act of 2003, so the DISCOM companies [31] are not under any legal obligation to buy such power. The power generator may sell it to any other commercial or domestic customer, but it is very difficult for an average household with such low production.

It is due to such uncertainties Roof top solar installation in residential sector are not very common India, if provided with proper Feed-in Tariff and legal assurance for buyback the solar roof tops can be a major game changer [10].

IV. MATHMATICAL MODELING

The Peak Power Rating (kWp) which is a standard term used with respected solar installation is given by the power generated at standard test conditions at solar irradiance of 1000 watt/ meters^2. The Peak power ratings of a module can all be expressed in terms of Imp and Vmp.

P_{kWp} = Imp x Vmp. /1000

Power output of a solar panel array can be defined as [7].

$$PV_{array}(t) = [\{(I_{mp} \times N_{string)} \times (V_{mp} \times N_{module})\}/1000] \times G(t)$$

Power Output from Photovoltaic system will be the product of inverter efficiency with total DC power generated from the panel.

$$PV_{out}(t) = PV_{array}(t) \times \eta_{inv}$$

Total Renewable Energy Generation.

$$RE_{kWh} = \sum (PV_{out}(t) \times \text{time interval}/1000)$$

Where

P_{kWp} = Peak Power ratings in kWp.
$PV_{array}(t)$ = PV array power output (watts)
I_{mp} = Rated current (Amp.)
V_{mp} = Rated voltage (Volt.)

N_{string} = No. of panels in the string
N_{module} = No. of panels in the module
G(t) = Solar irradiance (watt/$m^{2)}$
$PV_{out}(t)$ = Power generated through Solar panel (watts)
η_{jnv} = Inverter efficiency
RE_{kWh} = Total Renewable Energy generation (kWh)

Table 1 Domestic tariff rates in Rajasthan

Energy consumption (kWh) per month	Applicable charges Per unit (INR)		Fixed monthly charges (INR)
	Tariff rate	Electrical charges	
First 50 units	3.85	0.4	100/-
51 - 150 units	6.1	0.4	200/-
151 - 300 units	6.4	0.4	220/-
301 - 500 units	6.7	0.4	265/-
More than 500 units	7.15	0.4	285/-

Computation of Total Bill as per the domestic tariff rateswhich are given at the website of Rajasthan Electricity Regulatory Commission [37].
Electricity charges (E) = total consumption (kWh) x applicable tariff rates
Fixed electrical charges (F) = total consumption (kWh) x 0.40
Fixed monthly charges (S) = applicable as per consumption slab
Total bill (T) = Electricity charges (E) + Fixed electrical charges (F) + Fixed monthly charges (S)

$$\mathbf{T = E + F + S}$$

Feed-in Tariff Renumeration

$$FiT = RE_{kWh} \times FiT_{rate}$$

Where
FiT = Feed-in Tariff renumeration (INR)
RE_{kWh} = Photovoltaic energy generation (kWh)
FiT_{rate} = Feed-in Tariff rate applicable (INR/kWh)

A Simulink model is designed based on above equations and billing structure to calculate the FiT and Net-Metering Benefits for four different locations the solar irradiation profile for these places is taken from National Renewable Energy Laboratory [38] website.

Figure4 shows MATLAB/Simulink model designed for solar power generation, Feed in Tariff calculations, load input and Net metering system. PV system outputs are taken as input for both Feed-in Tariff and Net-Metering system and load data is considered from Indian Solar Energy department website [36], average of that is taken for calculations. This structure measures the tariff income of PV generation.

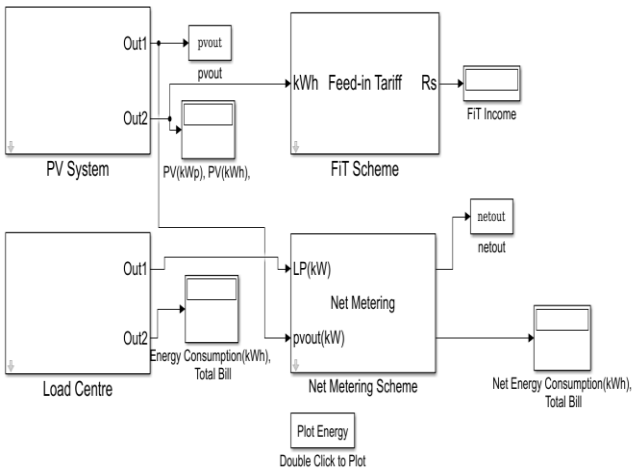

Figure 4 Model to Calculate total electricity charges FiT income and Net-Metering income

The PV System calls the Variable Radiation data from the workspace tocalculates the PV Out from the panel and gives out put in kW. It also generates the kWp i.e. the max rating of the power plant installed along with the total Energy generation from the PV rooftop panel.

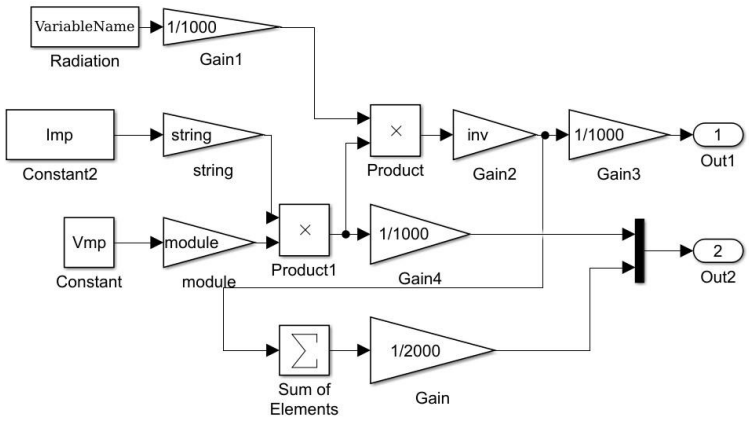

Figure 5 Model for PV power generation

The Fit System uses the Output Energy generation from the PV block and calculates the FiTrenumeration under different Fit Rates for four different cities Jaipur, Jaiselmer, Kota, Barmer.

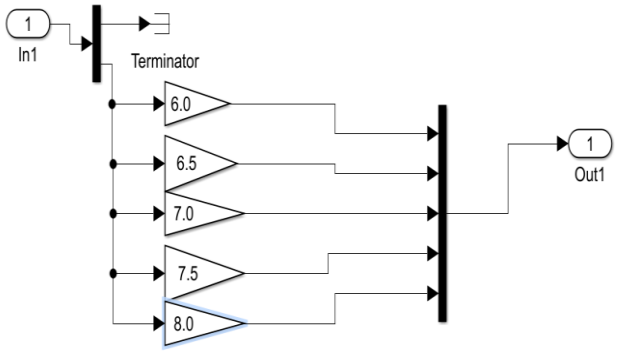

Figure 6 Model of Feed-in Tariff in MATLAB

The Load Centre calls the Load Data from the workspace and use the same for calculation of total Energy consumption. It also calculates the total amount of bill payable for the consumption.

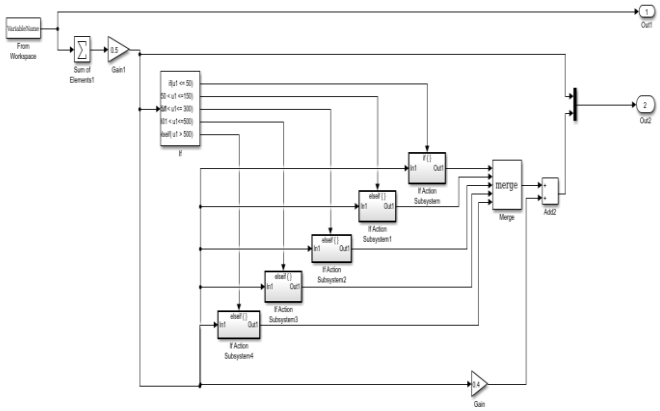

Figure 6 Model of load center in MATLAB

The Net Metering system takes PV out data and the Load Data as input in the form of Matrix in order to calculate the shaved power out, net energy consumption and the total bill amount payable for the net energy consumption.

Figure 7 Model for Net-Metering in MATLAB

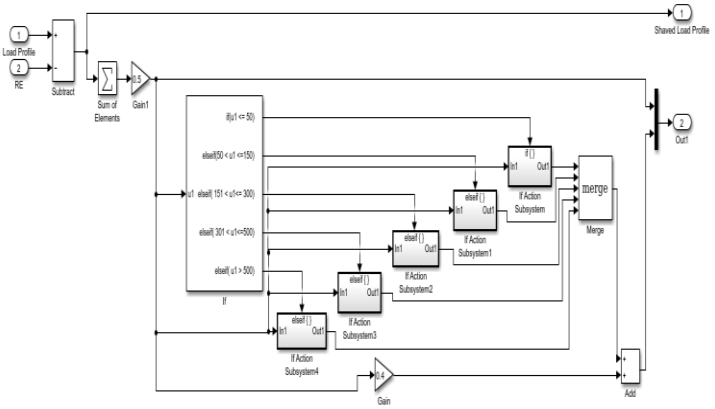

Figure 7 Model for Net-Metering in MATLAB

V. RESULT AND ANALYSIS

Using the MATLAB Simulink Model as described above the Load profile, PV power profile is plotted for all four locations to show the resultant flow of power over the period of time.

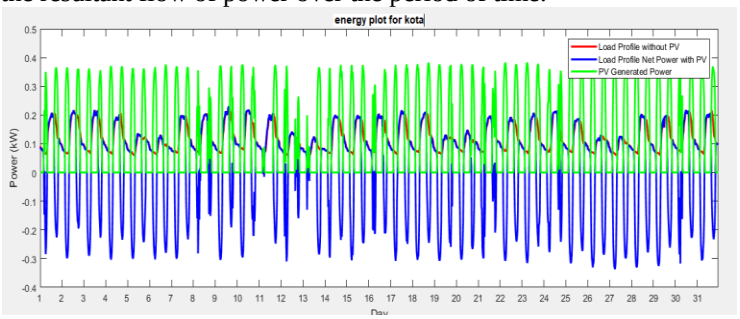

Figure 8 Plots Load, PV generated and Shaved Load for Kota Region.

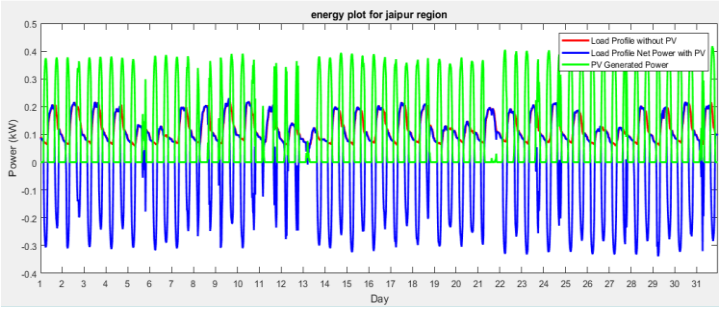

Figure 9 Plots Load, PV generated and Shaved Load for Jaipur Region

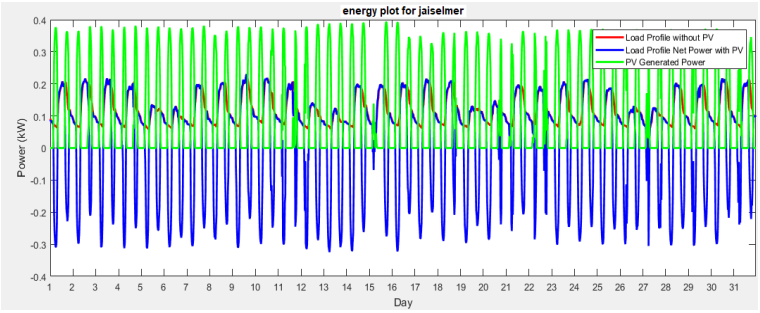

Figure 10 Plots Load, PV generated and Shaved Load for Jaisalmer Region

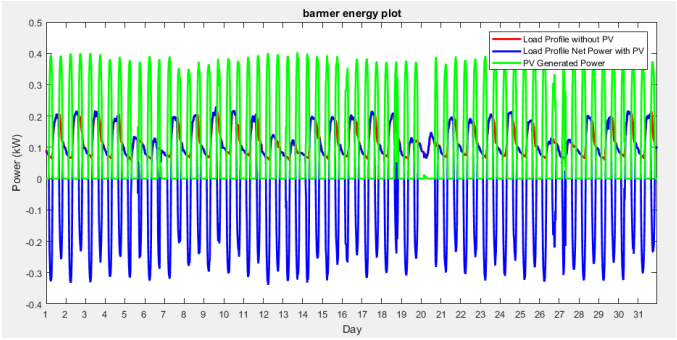

Figure 11 Plots Load, PV generated and Shaved Load for Barmer Region

Comparison of load profiles with and without PV inclusion and total power generated from PV is represented in figure 8 to 11 respectively. It shows that PV generation fulfills the extra demand of load and add-on to current supply effectively supplying power back to the grid during the peak sun shine hours of the day.

Table 2 Total payable bill amount under Net-metering and various FiT rates.

Net payable bill amount (INR)				
City	Jaipur	Barmer	Kota	Jaisalmer
Without PV	672.2	672.2	672.2	672.2
Net-metering	143.47	109.61	144.53	158.73
FiT Rate 6.0 INR/kWh	193.84	146.04	195.33	215.39
FiT Rate 6.5 INR/kWh	153.98	102.19	155.59	177.32
FiT Rate 7.0 INR/kWh	114.12	58.35	115.85	139.26
FiT Rate 7.5 INR/kWh	74.25	14.5	76.12	101.19
FiT Rate 8.0 INR/kWh	34.39	-29.35	36.38	63.12

Table 2 shows the Net Payable bill amount for the Domestic roof top solar installation where the row 1 shows the total Payable in case the consumer does not have a PV Installation at all. The negative billing amount indicate that the consumer cum generator will receive money back from the DISCOM.

Table 3 Total Net Metering and Fit Earnings

Total Benefits (INR)				
City	Jaipur	Barmer	Kota	Jaisalmer
Net-metering	528.73	562.59	527.67	513.47
FiT Rate 6.0 INR/kWh	478.36	526.16	476.87	456.81
FiTRate 6.5 INR/kWh	518.22	570.01	516.61	494.88
FiTRate 7.0 INR/kWh	558.08	613.85	556.35	532.94
FiTRate 7.5 INR/kWh	597.95	657.7	596.08	571.01
FiTRate 8.0 INR/kWh	637.81	701.55	635.82	609.08

Table 3 shows the total benefits achieved by the household under various Feed-in Tariff rates and Net-Metering due to the solar roof-top installation.

Table 4 Difference in Benefits

Difference in Benefits FiT and Net-metering (INR)				
City	Jaipur	Barmer	Kota	Jaisalmer
FiT Rate 6.0 INR/kWh	-50.37	-36.43	-50.8	-56.66
FiT Rate 6.5 INR/kWh	-10.51	7.42	-11.06	-18.59
FiT Rate 7.0 INR/kWh	29.35	51.26	28.68	19.47
FiT Rate 7.5 INR/kWh	69.22	95.11	68.41	57.54
FiT Rate 8.0 INR/kWh	109.08	138.96	108.15	95.61

Table 4 shows a comparative analysis of the FiT and Net-metering scheme negative amount imply that Net-metering is more beneficial under that particular condition. A clear trend is visible of higher benefit with higher FiT rates.

Figure 12 gives a graphical representation of difference between Feed-in Tariff and Net-metering benefits it shows that the Barmer region is benefited the most by FiT scheme as the region has higher solar irradiance during the month.

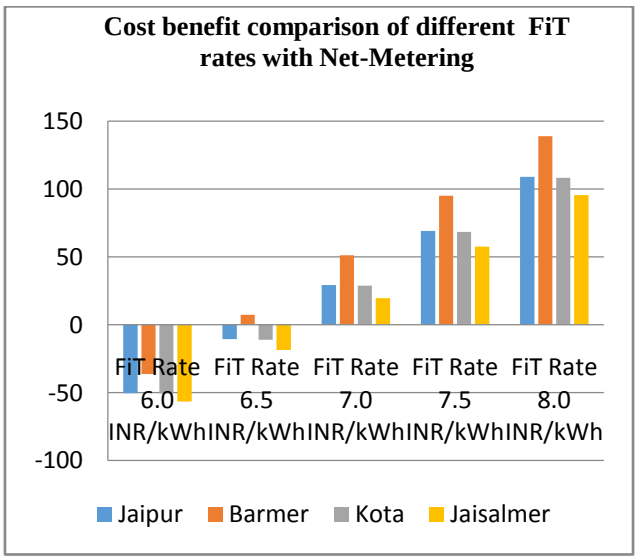

Figure 12 Graphical representation of Cost benefit comparison of different FiT rates with Net-Metering

A. ***Future Roadmap for India***

The aggressive target of 100 GW of solar capacity by 2022 requires the installed solar capacity to increase with an average rate if 1.5 GW every month between now and 2022 with the current solar installed capacity standing at 12.3 GW (31st March 2017). The government intends to tender 21 GW of additional capacity in the next few months, to stay on course on its targets.

For future capacity and the price curve of solar tariffs will be well supplemented with a further expected decline in module and balance of system costs. Costs of panels are expected to decline from USD 48 cent/W to USD 28 cent/W i.e., from the current INR 32.64/W to INR 19.04/W by 2025. This would translate into the LCOE declining to INR 3.45/kWh, if everything else remains unchanged.

Government policy is aimed at attracting private players to execute most of renewable energy projects in India. But it cannot accept the lower ROE that government sponsored organizations in Dubai can afford. It should also be noted that the tax benefit offered in the form of tax holiday to developers has expired in 2017[18] [31]. However, the government would need to play an important role in reducing the cost of capital by mitigating risks and directing public money into innovative financing mechanisms pertaining to hedging costs and reduction in cost of capital discussed above. As the world economy is expected to grow at lower rates in the

future, there is a chance that investors recalibrate their returns on investment, and in turn, target lower returns. This would further bring down the cost of financing.

VI. CONCLUSION

As the resultsshows that if the Feed-in Tariff rates are higher than average electricity cost the consumers will be benefitted more if he choose to install roof top PV systems. Consumers living in cities/locations with higher solar irradiance will be benefitted more and thus can survive with lower Feed-in Tariff rates compare to other cities.

Higher Feed-in Tariff rates for smaller installations can attract average population to opt for Roof top solar installations thus covering the gap between the target set for 2022 and the total installed capacity till date.

The Policy makers need to understand the strength of mass population of India. Proposed Feed-in Tariff rates and buyback assurances for small roof top installations can be the game changer for solar power India.

As per the Census of 2001 and 2011 [38] if 25% of Indian population decides to install solar power at their homes with average power capacity of just 1 kWp India will be able to meet the 2022 targets without installing a single large-scale power plant.

A. Scope for Further Studies

Further studies may be carried out to investigate the problems associated with generation of intermittent power, installation of smart meters and load management according to energy generation, energy management using storage batteries according to peak demand, dynamic tariffing systems and their implications in India, use of bifacial solar panels to optimize the energy yield.

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