# Comparison of Different Incentive Schemes For Exploring Profit In Residential Rooftop Photo-Voltaic Installation

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***Abstract***- *In this paper, we will understand the need of developing and promoting the generation of renewable energy (solar energy) in the state of Rajasthan. We will also get to know the management and working of the electricity board in Rajasthan, as to how electricity is provided in the state.*

*In order to understand the need of renewable energy, and how solar energy will benefit the state of Rajasthan, we will investigate the present incentive schemes. We will also make a cost benefit analysis according to the plant size, radiation data of particular location and different incentive schemes, and hence find how these schemes can be optimize to give maximum profit to the consumer as well as the distribution companies.*

***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).

Nomenclature

| | | |
|---|---|---|
| $PV_{array(t)}$ | = | Instantaneous PV array output power |
| $I_{mp}$ | = | Rated current |
| $V_{mp}$ | = | Rated voltage |
| $G(t)$ | = | Solar irradiance |
| $N_{string}$ | = | Number of panel in a string |
| $N_{module}$ | = | Number of panel in a module |
| $PV_{out}(t)$ | = | Instantaneous Power Generated |
| $\eta_{inv}$ | = | Inverter efficiency |
| $RE_{kwh}$ | = | Renewable Energy Generation |

## I. INTRODUCTION

SOLAR energy is a renewable source of electrical energy. The use of solar powerfor the generation of electricity has increased considerably in the last few decades as the non-renewable sources are limited and not environment friendly. In the list of renewable sources, wind and solar power are more prominent as solar irradiationand wind are more easily available. Many techniques and methods are implemented on solar power technology, making it stable and efficient.

Solar energy is the most attractive, exploitable non-conventional source of energy in Rajasthan as it hasapproximately 325 days per year of full sunshine, there is very low rainfall. Solar radiation received by Rajasthan is 6.0 – 7.0 $kWh/m^2$.

In Rajasthan,using only fossil fuels is not enough as the demand of electrical energy is more than the energy generated. Also, the reserves of fossil fuels in Rajathan are not sufficient for the energy need of the state and both fuel and energy have to be imported from the neighbouring states and country.

## II. RAJASTHAN STATE ELECTRICITY BOARD

As per the notification of Rajasthan Power Sector Reforms Transfer Scheme 2000, on 19 July, 2000, the assets, liabilities and personnel of the RSEB have been transferred to the newly formed five companies.

### *A. Generation Company*

In order to operate and maintain the existing state-owned power stations, a generation company was established with the name Rajasthan RajyaVidyutUtpadan Nigam Limited (RRVUNL).

### *B. Transmission Company*

To undertake thetransmission and bulk supply of electricity in Rajasthan and also to share the rights of inter-state partnerships, this unit is established and named as Rajasthan RajyaVidyutPrasaaran Nigam Limited (RRVPNL).

### *C. Distribution Company*

The distribution in the state is done by three DISCOMs, registered under the Companies Act namely,

a) Jaipur VidyutVitaran Nigam Limited
b) Ajmer VidyutVitaran Nigam Limited
c) Jodhpur VidyutVitaran Nigam Limited.

## III. INCENTIVE SCHEMES FOR SOLAR POWER PRODUCTION.

Various incentive schemes are being used in various countries all around the world to attract investors into the solar power market. These schemes promote solar power production, thus enabling a reduction in carbon emission and reducing dependability on non-renewable energy sources. Following are a few dominant schemes in India and other countries in the world [26][6].

### *A. Capital subsidies*

Under this scheme, up to 30% of the cost of installation is provided as a subsidy by the central government to the consumer. The remaining amount is paid by the consumer and is available as a loan at low interest rate[11-16].

### *B. Net-metering*

A specialized meter is used for the calculation of both inflow and outflow of energy; however two separate meters can also be used for calculating the net flow of energy [21-23]. Accordingly, the bill is generated for the net flow of energy [7].

### *C. Feed-in Tariff*

To boost solar power production, this scheme was globally accepted. Under this scheme, an obligation is on the DISCOMs to purchase solar energy from the solar power generators at a pre-determined tariff rate. This tariff rate can be controlled by the relevant authorities through an agreement called Power Purchase Agreement (PPA) [17-19].

### *D. Others*

Accelerated depreciation is a method of depreciation, mainly used for income tax purposes. It allows greater deductions in the initial years of an asset's life. The increase in deduction taken during the initial years of business can lower the overall tax burden.

Renewable Purchase Obligation (RPO) is a mechanism by which the distribution companies are obligated to purchase either a certain percentage of power from renewable energy sources or Renewable Energy Certificate (REC). RPO is implemented to create a demand for renewable energy.

A Renewable Energy Certificate is a tradable proof of generation of energy from renewable energy sources. Each REC represents a generation of 1 MWh of renewable energy.

## IV. TARIFF AND BIDS

Tariff: - per unit cost of electricity that a consumer is charged with, by a utility.

Bids: - power procurement price agreed upon by the power producerand theutility as per a Power Purchase Agreement (PPA).

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

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/- |

The tariff rate for Rajasthan is shown in the table 1 which is common for all the three DISCOMs.

### *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) Financing
b) Operation and maintenance
c) Material cost

d) Land
e) Balance of system
f) Transmission and evacuation infrastructure

***B.** Residential rooftop power plant*

Residential rooftop solar PV installations help an average household to reduce their net energy consumption and also can help as an earning source if the power generation exceeds the total consumption of the household. All such installations in India are promoted under the scheme of "grid connected rooftop and small scale power plant programme". As these plants do not require land and other infrastructure, only the initial installation cost and unsecure power market are the major obstacles for a small scale power generator.

In India, Remuneration for domestic rooftop Plants is mainly availableunder Net-Metering scheme. In cases wherea power producer generatesmoreenergy as compared to their consumption, the buyback rates for such excess power generated is not fixed. As the Electrical Power market is under the open market scheme as per the Electricity Act of 2003, the DISCOM companies [31] are not under any legal obligation to buy any excess power. The power producer may also sell it to any other domestic or commercialconsumer, but it is quite difficult for an average household to generate a significant amount of excess energy, and with low power production, it is difficult to find interested customers.

Due to such uncertainties, residential rooftop solar installations are not very common in Rajasthan. However, if proper Feed-in Tariff and legal assurance for buyback is provided, the number of residential solar rooftop installations can be drastically increased which can highly reduce dependency on non-renewable sources of energy in Rajasthan. [10].

## V. MATHMATICAL MODELING

The Peak Power Rating (kWp) is a standard term used for solar PV plant installations. It is given by the power generated at standard test conditions forsolar irradiance of 1000 watt/meters$^2$. The Peak power ratings of a module can also be expressed in terms of $I_{mp}$and $V_{mp}$.

$$P_{kWp} = I_{mp} \text{ x } V_{mp} /1000$$

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

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

Power Output from PV system is calculated by multiplying inverter efficiency with total DC power generated from the panel.

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

Total Renewable Energy Generation.

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

Computation of Total Bill is done as per the domestic tariff rateswhich are available 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 Remuneration

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

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

A Simulink model is designed based on the above equations and billing structure to calculate the benefits of FiT and Net-Metering schemes. For further analysis, these benefits are calculated for four different locations.The solar irradiation profile for these places is taken from National Renewable Energy Laboratory [38] website.

Figure1 shows the MATLAB/Simulink model designed for solar power generation, Feed-in Tariff calculations, load input and Net-metering system. The PV system outputs are taken to be the input for both Feed-in Tariff and Net-Metering systems and load data is considered from Indian Solar Energy department website [36]. The average of that is taken for calculations. This structure measures the tariff income of PV generation.

The PV System calls the Variable Radiation data from the workspace to calculate the PV Out from the panel and gives the output 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.

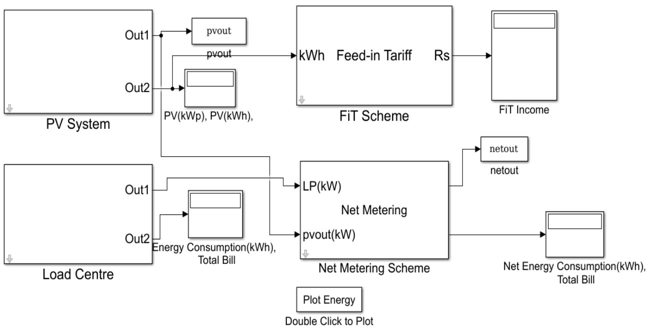


Figure 1- Model to Calculate total electricity charges FiT income and Net-Metering income

## VI. RESULT AND ANALYSIS

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

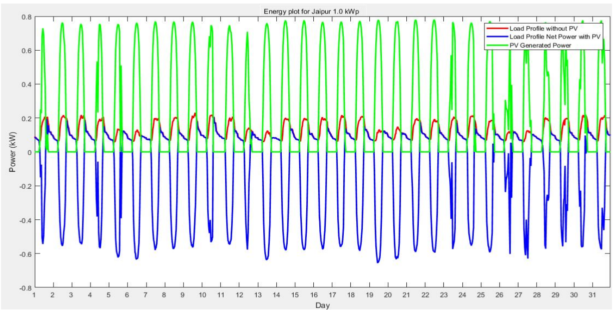


Figure 2 - Load, PV generated and Shaved Load forJaipur

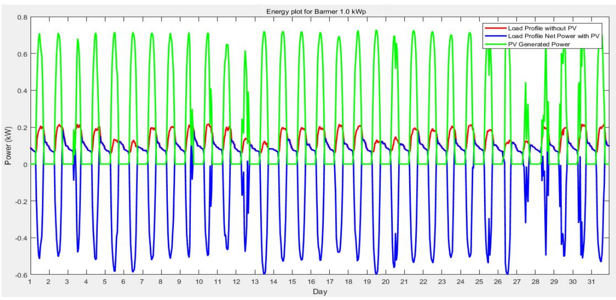


Figure 3 -Load, PV generated and Shaved Load for Barmer

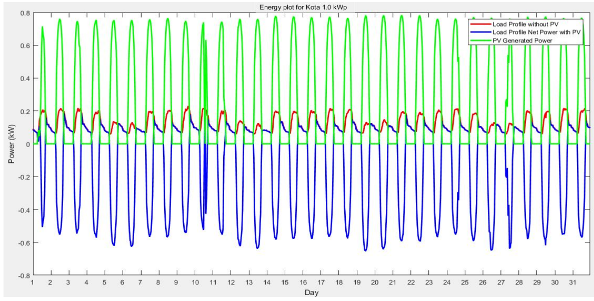


Figure 4- Load, PV generated and Shaved Load for Kota

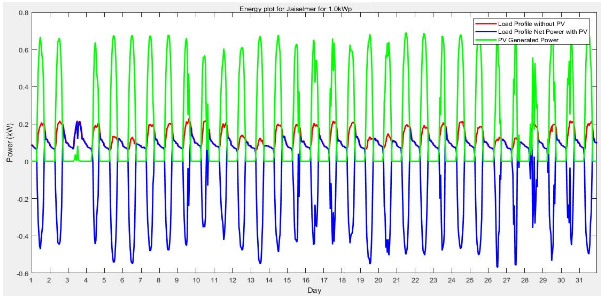


Figure 5 Plots Load, PV generated and Shaved Load for Jaisalmer Region

Comparison of load profiles with and without PV inclusion and total power generated from PV is represented in figure 2 to 5 respectively. It shows that solar power generation helps to fulfill the extra demand of load and adds-on to current supply,in some cases, effectively supplying electrical energy back into the grid during the peak sunshine hours of the day.

Figures 6, 7, 8 and 9 show the graphical representation of Net Payable billed amount for all the different sizes of Domestic rooftop Solar PV installations. First set of bars in each figure representsthe total payable amount when there is no Solar PV Installation. All negative amounts indicate that the consumer/generator will inject excess generated Solar Energy into the grid and hence will receive money from the DISCOM.
Data was also generated for the benefits from FiT income and the benefits from Net-Metering Scheme. Data was tabulated for better analysis and comparison.

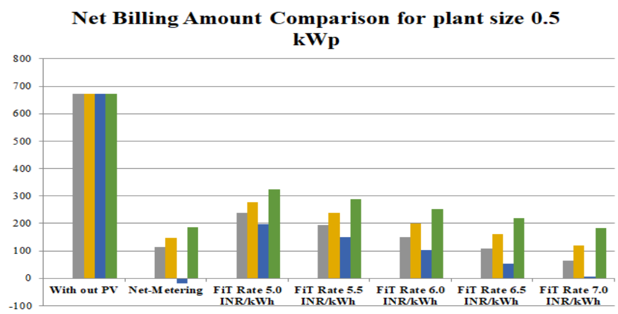


Figure 6- Net billing amount for plant size 0.5 kWp

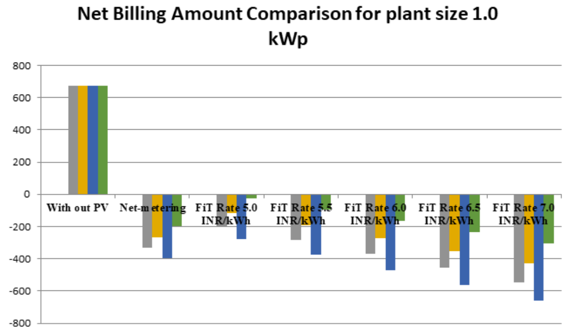


Figure 7 - Net billing amount for plant size 1.0 kWp

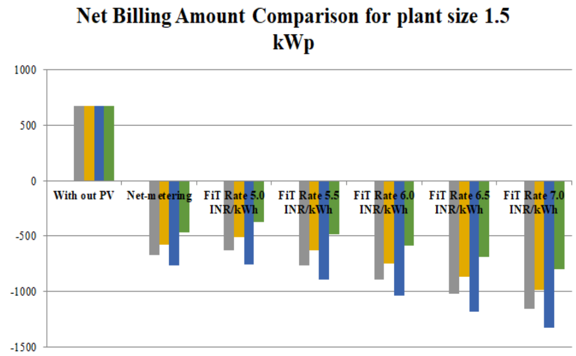


Figure 8 - Net billing amount for plant size 1.5 kWp

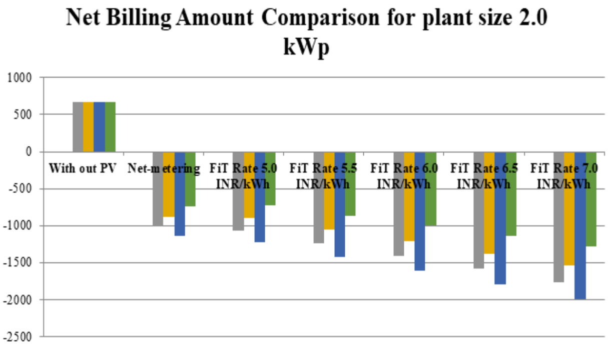


Figure 9 - Net billing amount for plant size 2.0 kWp

Tables 2, 3, 4 and 5 show a comprehensive comparative analysis of the FiT and Net-Metering schemes. The negative amounts show that payable bill is reducedto zero and additional amount is available as buybackunder that particular condition. A clear trend is visible of higher benefits with lower FiT rates

Table 2- Difference Between Net-Metering and FIT (INR) for 0.5kWp

| Difference Between Net-Metering and FIT (INR) for 0.5 kWp | | | | | |
|---|---|---|---|---|---|
| Region | FiT Rate 5.0 INR/kWh | FiT Rate 5.5 INR/kWh | FiT Rate 6.0 INR/kWh | FiT Rate 6.5 INR/kWh | FiT Rate 7.0 INR/kWh |
| Jaipur | -124.71 | -81.25 | -37.8 | 5.65 | 49.11 |
| Barmer | -130.81 | -91.42 | -52.03 | -12.64 | 26.75 |
| Kota | -216.96 | -169.42 | -121.89 | -74.35 | -26.82 |
| Jaisalmer | -137.49 | -102.55 | -67.62 | -32.68 | 2.26 |

Table 3- Difference Between Net-Metering and FIT (INR) for 1.0kWp

| Difference Between Net-Metering and FIT (INR) for 1.0 kWp | | | | | |
|---|---|---|---|---|---|
| Region | FiT Rate 5.0 INR/kWh | FiT Rate 5.5 INR/kWh | FiT Rate 6.0 INR/kWh | FiT Rate 6.5 INR/kWh | FiT Rate 7.0 INR/kWh |
| Jaipur | -132.7 | -45.79 | 41.12 | 128.03 | 214.94 |
| Barmer | -150.09 | -71.31 | 7.47 | 86.25 | 165.03 |
| Kota | -115.23 | -20.16 | 74.91 | 169.97 | 265.04 |
| Jaisalmer | -169.15 | -99.28 | -29.4 | 40.47 | 110.35 |

Table 4- Difference Between Net-Metering and FIT (INR) for 1.5kWp

| Difference Between Net-Metering and FIT (INR) for 1.5 kWp | | | | | |
|---|---|---|---|---|---|
| Region | FiT Rate 5.0 INR/kWh | FiT Rate 5.5 INR/kWh | FiT Rate 6.0 INR/kWh | FiT Rate 6.5 INR/kWh | FiT Rate 7.0 INR/kWh |
| Jaipur | -39.71 | 90.66 | 221.02 | 351.38 | 481.74 |
| Barmer | -65.8 | 52.37 | 170.55 | 288.72 | 406.89 |
| Kota | -13.51 | 129.09 | 271.7 | 414.3 | 556.9 |
| Jaisalmer | -94.38 | 10.43 | 115.24 | 220.05 | 324.86 |

Table 5-Difference Between Net-Metering and FIT (INR) for 2.0kWp

| Difference Between Net-Metering and FIT (INR) for 2.0 kWp | | | | | |
|---|---|---|---|---|---|
| Region | FiT Rate 5.0 INR/kWh | FiT Rate 5.5 INR/kWh | FiT Rate 6.0 INR/kWh | FiT Rate 6.5 INR/kWh | FiT Rate 7.0 INR/kWh |
| Jaipur | 53.29 | 227.1 | 400.92 | 574.73 | 748.55 |
| Barmer | 18.51 | 176.07 | 333.63 | 491.19 | 648.75 |
| Kota | 88.22 | 278.35 | 468.49 | 658.63 | 848.77 |
| Jaisalmer | -19.62 | 120.13 | 259.88 | 399.62 | 539.37 |

It is evident from the above tables that Kota Reign is benefited the most by FiT scheme as the region has higher solar irradiance during the month.

## VII. CONCLUSION

From the result and analysis, we can conclude that due to the difference in irradiance in different regions, the cost benefit changes. At some places, Feed-in Tariff scheme is beneficial and at other locations, Net-Metering will give more benefits. Regions like Jaipur and Kota are more populated and have more intense radiation than regions likeBarmer and Jaisalmer. Thus, we have concluded thatFiT scheme performs better for JVVNL while Net-Metering is beneficial for Jodhpur DISCOM.

As the resultsshow, it is evident that if the Feed-in Tariff rates are higher than the average electricity cost in any region, the consumers will be benefitted more if theychooseto install roof top PV systems. Also, consumers living in cities/locations with higher solar irradiance will be benefitted more and thus can get benefitted even with lower Feed-in Tariff rates, as compared to other cities. On the other hand, higher Feed-in Tariff rates for smaller installations can attract average population to opt for rooftop solar PV installations.

The strength of mass population of Indianeeds to be understood by the policy makers. Proposed Feed-in Tariff rates and buyback assurances for small roof top installations can be the game changer for solar power production inIndia.
The result tables show that as the size of PV plant is increased, the benefits also shift from Net-Metering to Feed-in Tariff. A 2.0KWp plant is a moderate sized plant that can be easily adopted bya nuclear family and thus the consumers can get benefits by participating like power producers.

Implementing these schemes properly will definitely help the state of Rajasthan to become self-dependent for its energy demands, and will in turn also help in the reduction in the overall import of electrical energy in India.

The global trends show that implementing FiT smartly enables the power industry to lower the energy production costs and helps to attain grid parity.

Keeping in mind India’s population, implementing FiT properly will surely give strength to our local utilities such as DISCOM, as well as to cover their debt and improve their efficiency.

### *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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