SHAKTI SUSTAINABLE ENERGY FOUNDATION

Deloitte.

Rooftop Solar

Garnering Support from Distribution Utilities

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Foreword

Increasing energy demand, rising environmental concerns and falling cost of solar technology are making solar power increasingly popular globally. Recognizing benefits of our solar energy resources, Government of India has set an ambitious target of achieving 100 GW by 2022. Out of this 100 GW, 40 GW has been allocated for grid connected solar rooftops. In support of this, 31 states/union territories have notified regulations for net/gross-metering.

Globally, rooftop solar installations have been driven by incentives offered through various schemes leading to faster tariff parity with utility supply. These incentives have been in the form of direct capital subsidy, tax credits, net metering, solar specific RPOs, etc. Similarly, in India various schemes have been launched by central and state governments to realize the full potential of rooftop solar projects.

Solar rooftop sector has proliferated globally and is now growing in India. However, increase in the capacity has also given rise to debates in many countries about its impacts on utility shareholders and ratepayers, and such debates will likely become more pronounced and widespread as solar costs continue to decline and deployment accelerates. In India too, it is possible that distribution utilities in India may face similar commercial and operational challenges.

Distribution utilities have an important role to play in promotion of rooftop solar projects. Financial health of distribution utilities in India has persistently been an area of concern – partly attributed to high levels of Aggregate Technical and Commercial (AT&C) losses as well as inability of power tariffs to recover the cost of supply.

Rooftop solar projects offer multiple benefits including savings in T&D losses, environmental benefits, and avoided capacity during peak solar generation. However, given the financial and operational capabilities of Indian utilities, it is important to understand the implications of rooftop solar on the utilities, to develop a framework that incentivizes utilities to support large-scale deployment.

Shakti Sustainable Energy Foundation is pleased to support this report, which provides critical insights on the implications of solar rooftop for Indian utilities. We hope that this report will be of interest to policy makers, regulators, utilities, solar rooftop developers and other stakeholders, and that it will help inform policy action in the solar rooftop sector.

Abbreviations

Abbreviation	Description	Abbreviation	Description
ABR	Average Billing Rate	FY	Financial Year
AC	Alternating Current	GBI	Generation Based Incentive
AP	Andhra Pradesh	GHG	Green House Gases
APPC	Average Power Purchase Cost	GHI	Global Horizontal Irradiation
AT&C	Aggregate Technical & Commercial loss	GM	Gross Metering
CAGR	Compound Annual Growth Rate	GoI	Government of India
CEA	Central Electricity Authority	GSM	Global System for Mobile
CERC	Central Electricity Regulatory Commission	GW	Giga Watt
CFA	Central Financial Assistance	HV / HT	High Voltage/ tension
CIL	Coal India Limited	IEEE	Institute of Electrical and Electronics Engineers
CO2	Carbon Dioxide	IEGC	Indian Electricity Grid Code
COS	Cost of Supply	IPP	Independent Power Producers
CPUC	California Public Utility Commission	IREA	Intermountain Rural Electric Association
Cr	Crore	IREDA	Indian Renewable Energy Development Agency
CSR	Corporate Social Responsibility	IRENA	International Renewable Energy Agency
CSS	Cross Subsidy Surcharge	IRR	Internal Rate of Return
CUF	Capacity Utilization Factor	ITC	Investment tax Credit
DC	Direct Current	JNNSM	Jawaharlal Nehru National Solar Mission
DER	Distributed Energy Resource	JPAC	Japan Photovoltaic Expansion Center
DG	Distributed Generation	kVA	Kilo Volt Ampere
DOE	Department of Energy	kW	Kilo Watt
DT	Distribution Transformer	kWp	Kilo Watt Peak
EEG	Erneuerbare-Energien-Gesetz	LCOE	Levelized Cost of Energy
EMI	Equated Monthly Installments	LV /LT	Low Voltage/ Tension
EPA	Environmental Protection Agency	METI	Japan’s Ministry of Economy, Trade, and Industry
EPC	Energy Performance Certificate	MNRE	Ministry of New and Renewable Energy, India
EPS	Electric Power Survey	MP	Madhya Pradesh
FDI	Foreign Direct Investment	NAPCC	National Action Plan on Climate Change
FERC	Federal Electricity regulatory commission	NASA	National Aeronautics and Space Administration
FiT	Feed in Tariff	NERC	North American Electric Reliability Corporation

Abbreviation	Description	Abbreviation	Description
NISE	National Institute of Solar Energy	ROE	Return on Equity
NM	Net Metering	RPO/RPS	Renewable Purchase Obligation/Standard
NPV	Net Present Value	RPSSGP	Rooftop PV & Small Solar Power Generation Program
NREL	National Renewable Energy laboratory	SDG&E	San Diego Gas and Electric
NTPC	National Thermal Power Corporation	SERC	State Electricity Regulatory Commission
O&M	Operation and Maintenance	SNA	State Nodal Agency
PFA	Power for All	StrEG	Stromeinspeisungsgesetz
PFC	Power Finance Corporation	SW/NW	South West/ North East
PG&E	Pacific Gas and Electric Company	T&D	Transmission and Distribution
PPA	Power Purchase Agreement	TL	Telangana
PSU	Public Sector Utilities	TOD	Time of Day
PTC	Production Tax Credit	TOU	Time of Utilization
PUC	Public Utilities Commission	TSO	Transmission Service Operator
PV	Photovoltaics	UK	United Kingdom
R&D	Research and Development	UP	Uttar Pradesh
RE	Renewable Energy	USA	United States of America
REC	Renewable Energy Certificate	VGF	Viability gap Funding
RESCO	Renewable Energy Service Company	WACC	Weighted Average Cost of Capital

Executive Summary

With energy security and climate change concerns taking center stage in the policy arena, Renewable Energy (RE) has become an important part of the agenda in India's energy planning process. To this effect the government has set aggressive renewable energy targets and has put in place several policy initiatives at the Central and State levels for both grid connected & off-grid renewable energy.

Solar energy is fast becoming the preferred options in the development of renewable energy resources in the country. With about 250–300 sunny days in a year, around 5,000 trillion kWh of energy is incident on an annual basis over India's land area, with most parts receiving 4-7 kWh per sq. m per day. A study carried out by the National Institute of Solar Energy (NISE) estimated that India has a potential of 748.9 GW of solar capacity.

To tap the solar potential in the country, India had embarked on an ambitious program under the Jawaharlal Nehru National Solar Mission (JNNSM), targeting to achieve an installed capacity of 20,000 MW of solar power by 2022. However, realizing the vast potential and fast technology growth, this target has been revised to 100 GW to be achieved by 2022. This target is proposed to be achieved through deployment of 40 GW of rooftop solar projects and 60 GW of large and medium scale projects.

Rooftop solar installations across the globe have been driven by incentives offered through various schemes leading to faster tariff parity with utility supply. These incentives have been in the form of direct capital subsidy, tax credits, net metering, solar specific RPOs, etc. In India, various schemes have been launched to realize the full potential of rooftop solar projects. To support rooftop solar projects, many states are incentivizing rooftop solar systems through net metering regulations.

To achieve such ambitious target of 40 GW rooftop capacity within a span of six years, it is necessary that all the key stakeholders such as distribution utilities, consumers, solar system installers, Regulatory Commissions etc. work together and create the ecosystem for development of solar rooftop projects in the country. Distribution utilities have an important role to play in the proliferation of rooftop solar projects as they will be responsible for technical interconnections and creating the framework for various business models to allow banking and/ or off-take of surplus power.

Globally, deployment of customer-sited rooftop solar PV projects have expanded rapidly in recent years, driven in part by public policies premised on a range of societal benefits that PV may provide. Table below is showing the implementation models and key drivers for solar rooftop across the solar rich countries

Country	Implementation Model	Key Drivers	Ownership of assets	Contracting mechanism
Germany	Gross metered	Feed in Tariff (FiT)	Self-Owned	-
Japan	Net metered	Capital Subsidy	Self-Owned	-
United States	Net metered	Tax rebates (ITC/ PTC) – RECs	Self-Owned	Lease
United States	Net metered	Tax rebates (ITC/ PTC/ Depreciation)	Third Party Owned	PPA
India (Gujarat)	Gross metered	Feed in Tariff/ Generation Based Incentive (GBI)	Third Party Owned	Rooftop Lease Agreement
India (Odisha)	Net metered	Feed in tariff/ GBI	Third Party Owned	Rooftop Lease Agreement

The solar rooftop segment has seen rapid proliferation in countries like USA, Germany, United Kingdom, Japan etc. because of the factors outlined in the table above. However, the increase in the rooftop solar capacities has also given rise to debate on its impact on utility shareholders and ratepayers, etc. Some of the common issues faced by utilities globally due to proliferation of solar rooftops are summarized below

- Significant reduction in sales volume due to large procurement from solar rooftops
- Difficulty in recovery of fixed cost because of distribution infrastructure and long term purchase agreements
- Difficulty in recovery of cross-subsidy charges due to migration of high paying consumers from the utilities to solar rooftop
- Managing variability in generation of solar rooftop for variable load
- Injection of solar power during off-peak periods and withdrawal by the consumers during peak periods
- Treating utility grid as a backup power source by rooftop consumers
- Technical issues like phase imbalance due to solar rooftop projects, quality of utility power, etc.
- Increase in administration burden (application processing, inspection, connectivity, metering and billing etc.)
- Safety and security issues during operation and maintenance of grid

Impact of solar rooftop on Utility business in India

Rooftop solar development in India is currently at the initial phases of development. The steep capacity targets would require accelerated growth in the solar rooftop projects and it can be expected that distribution utilities in India would face several commercial and operational challenges as has been indicated above.

Rooftop solar project offers multiple benefits in the form of savings in T&D losses, environmental benefits (reduced GHG emission, lower water requirement & no land requirement), and avoided capacity during peak solar generation. Depending upon the State regulatory framework, Discoms will also be eligible for deemed Solar RPO benefit for the solar power consumed under net-metering framework by the consumer. Given the financial & operational capabilities of Indian utilities, it is important to understand the extent of impact rooftop solar will make on the utilities. Some of the key issues that will impact utilities under net metering framework are:

1. **Revenue loss to Utility**

The net metering model of solar rooftop development provides the consumer with an option to self-generate & consume the solar power from the rooftop solar project. The consumers adopting rooftop solar for self-consumption will have lower dependence on utilities for meeting their electricity requirement, thereby reducing the electricity consumed from utility. This shift will result in reduced sales for utilities to the solar consumers, resulting in the revenue loss.

It can be argued that the revenue loss to utility is limited to the loss in cross-subsidy (over and above the cost of supply). The utility will stand to lose the cross-subsidy it was getting from the subsidizing consumers who were paying more than the cost of supply if they chose to switch to solar. Utilities would also benefit if subsidized category of consumers (those having tariffs below the cost of supply) adopt the rooftop solar systems.

2. **Recovery of fixed costs**

In India, the tariff rate design relies heavily on the volumetric sales to recover a portion of the fixed costs. With the reduction in sales to consumers, the utilities would not be able to recover a part of fixed cost as the rooftop solar consumer will be paying energy charges for a lower consumption levels.

Currently, the rooftop solar capacity is at a lower level and utilities have not felt the revenue impact & related aspects. However, with increase in penetration & reduced revenue, there can be demand from utilities to impose additional charges on net metered rooftop solar consumers as experienced globally. Globally utility have proposed to increase the fixed charges in the consumer bill to safeguard against the revenue drop on account on net metering.

3. **High number of tariff slabs within a consumer category**

Many states have multiple tariff slabs (even up to 5) within a consumer category and depending upon the consumption levels of the consumer, the tariff rate is applicable. The consumers adopting the rooftop solar will be able to save on the utility electricity bill. The impact (revenue loss) for utilities will be high in consumer categories having high number of consumption slabs.

4. **Loss in banking charges**

Banking charges are not applicable on rooftop solar projects in general. However, for net metered rooftop solar project, the gird is providing the banking facility. With the increase in rooftop solar capacity (with target of 40GW), it can be expected that utilities need to plan accordingly to manage high capacity under this banking arrangement. In such a scenario, not imposing any banking charge can be considered a loss to utility. However, it needs to be considered that only a partial amount of energy generated (which consumer is not able to utilize) will be banked with the utility.

5. **Solar consumers not covered under TOD framework**

Consumers not covered under TOD have the benefit of utilizing off-peak injected solar power during peak power. The utility is required to arrange adequate power to such consumers during the peak time, which will get settled with the off-peak solar power injected. With increased rooftop solar capacity addition in future, this may pose operational/commercial challenge to utilities.

- Operational Challenges due to small & distributed nature

With proliferation of solar rooftops operational challenges such as demand balancing, variability etc. will come in picture. Rooftop solar projects are not under the purview of generation forecasting and given the small & distributed nature, it will be difficult of utilities to have real time visibility on these distributed generation sources, especially at LT levels.

- Loss is fixed charges because of consumer reducing sanctioned load.

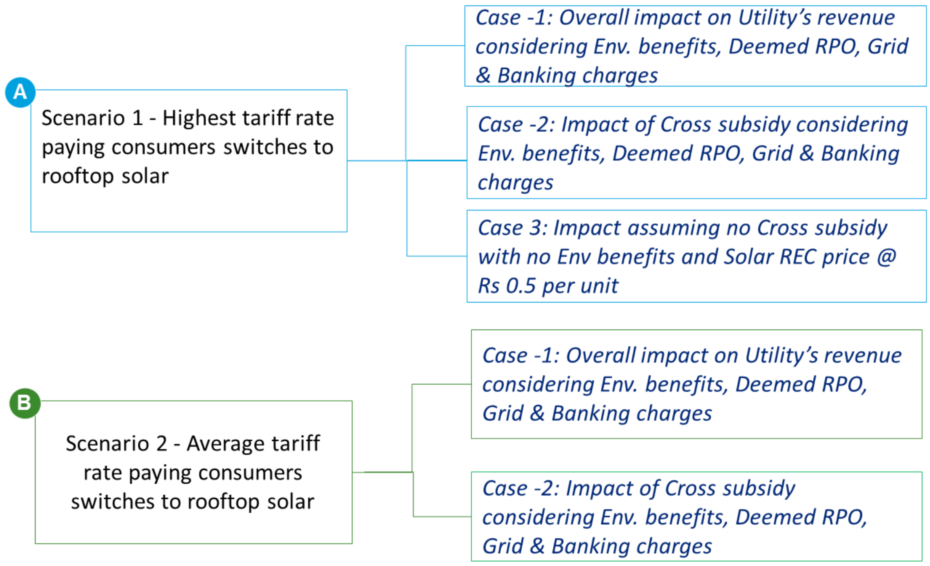
Utilities may suffer loss in fixed charges, in cases where consumers reduce their sanctioned load because of rooftop solar capacity addition. This will also result in loss of fixed charges which utilities were expected to recover from consumers. This case is expected to occur only for limited capacity.

Quantification of the benefits & impact on the utilities

Net metering is considered to be important for the rooftop solar consumers to safeguard their investments, by the solar industry as self-replication model for the retail consumers, and by policy makers to achieve the clean energy targets. However, the utilities have a concern about revenue erosion and reduced shareholder returns when customers with net-metered rooftop solar systems can avoid charges for fixed infrastructure costs, as well as potential cost-shifting between solar and non-solar customers.

This study has analyzed the commercial parameters of 17 state utilities in eight selected states covering energy requirement, rooftop penetration, utility revenue, retail tariff, RPO expense, environmental benefits etc. to understand the impact of solar rooftop on Indian utilities by 2022. Several scenarios have been simulated and reviewed to understand the impact on utilities as well as benefits from rooftop solar in case the utilities achieve the rooftop solar capacity targets for FY 2022 proposed by MNRE. The utilities wise targets are mapped based on the projected energy requirement of the respective utility in year FY 2022.

To analyze the impact on Utility, different cases and scenarios have been developed, which are shown in the figure



A. Scenerio-1: Highest tariff Paying Consumers Switch to Rooftop Solar

The Scenario 1 considers that rooftop solar power will replace the consumer consumption mapped at highest tariff slab in a consumer category. The analysis below covers three cases under Scenario 1.

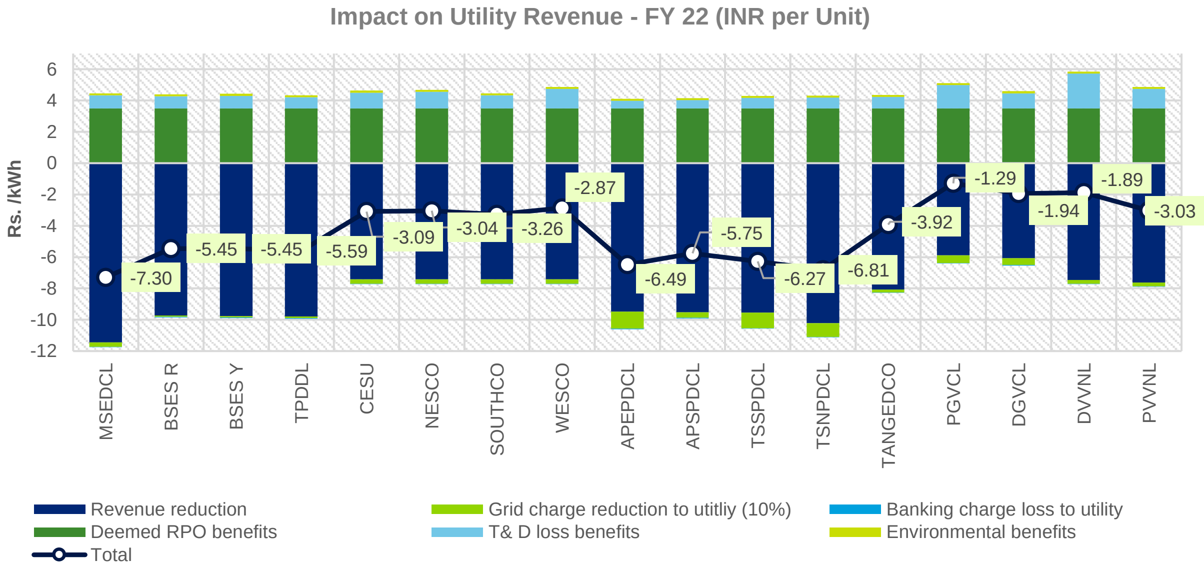
- ***Case-1: Impact of solar Rooftop on Utility Revenue***

Case 1: This assumes the highest tariff paying consumer's switch to rooftop solar. The impact on utility is in terms of: revenue loss, loss in fixed charges (assuming 10% of the solar capacity will result in sanctioned load reduction), loss in banking charges (assuming 30% of energy generated from rooftop solar is banked and do not pay 2% banking charge @ APPC price). The benefits for utility is Deemed RPO (@ Solar REC price of INR 3.5/kWh), environmental benefit and savings in T&D losses.

Proliferation of Solar Rooftops will have both positive and negative impact on the Utilities' revenue, this case explains the impact of solar rooftops on utility revenue for FY 2022 assuming that the capacity addition in rooftop segment will be as per MNRE's target. With increase in the retail tariff, higher number of consumers will shift to rooftop, this will result in the reduction of sales volume and hence reduction in utility revenue. As the rooftop capacity is expected to increase with time in view of increase in retail tariff and falling cost of rooftop system, the loss of revenue is expected to increase with time. However, Rooftop capacity will also have positive impact on utility revenue due to deemed RPO benefit, environmental benefit, saving in infrastructure and reduction of technical losses etc., which will also increase with increase in rooftop capacity.

As per the analysis the overall impact under this case for utilities will be negative. Revenue loss to selected utilities due to solar rooftops will be in the range Rs. 7.3/kWh to 1.2/kWh depending upon the retail supply tariff and energy requirement to be met through solar rooftops.

The overall impact (Rs/kWh) of rooftop on utility revenue in FY 2022 is shown in the following graph. The graph also depicts the impact of rooftop on various factors of utility revenue:



Utilities with low energy charge have lower negative impact. Utilities having high T&D losses will gain from rooftop solar

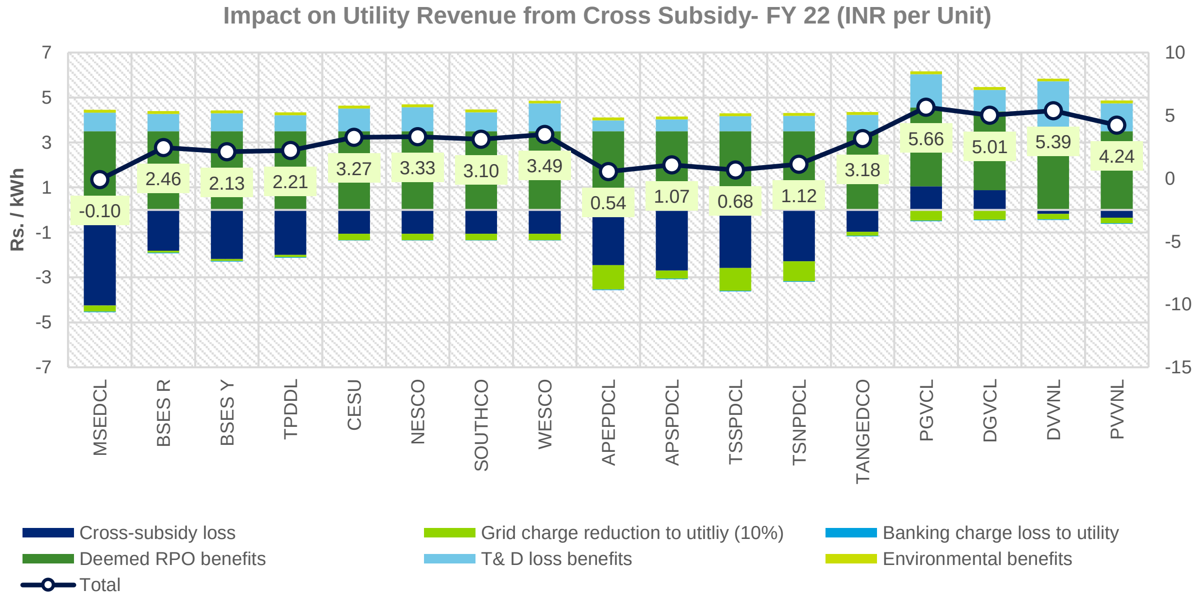
- ***Case-2: Impact of solar rooftop on Cross Subsidy***

Case 2: This Case assumes that the highest tariff paying consumer's will switch to rooftop solar. The impact on utility is in terms of: cross subsidy loss, loss in fixed charges (assuming 10% of the solar capacity will result in sanctioned load reduction), loss in banking charges (assuming 30% of energy generated from rooftop solar is banked and do not pay 2% banking charge @ APPC price). The benefits for utility is environmental benefits, Deemed RPO (@ Solar REC price of INR 3.5/kWh) and savings in T&D losses.

This case explains the impact of solar rooftops on utilities from the perspective that the loss utility is linked with loss of cross subsidy (and not complete energy charge). With increase in the affordability of solar rooftop system and rising retail tariff, utility consumers are expected to go for solar rooftop. As the high tariff paying consumers will start shifting to solar rooftop, the utility sales will start falling. This will also impact the collection of cross-subsidy, which utility was collecting from consumer.

In addition to this utility will also lose revenue through exemption in banking charges for solar rooftops and reduction in demand charges. However, it will also earn though deemed RPO benefit and reduction in technical losses.

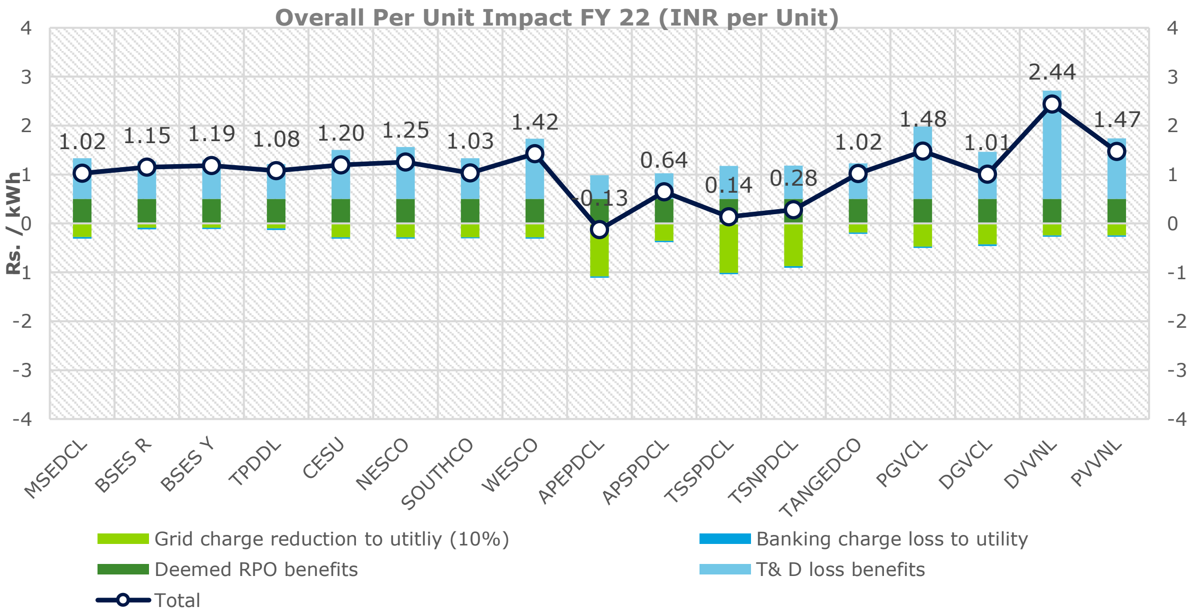
In this case, the overall impact on the revenue is positive. The impact of all the parameters including the cross subsidy for utilities for FY 2022 is shown in the following graph. As per the analysis, except MSEDCL, all utilities other are having positive impact of solar rooftop.



Utilities with low cross subsidy levels will have lower impact. Consumer categories having energy charge lower than COS & adopting rooftop solar will benefit utilities.

- ***Impact of Solar Rooftop in progressive scenario***

Case 3: This assumes the highest tariff paying consumer's switch to rooftop solar. It is assumed that the Cross subsidy will become zero in FY 2022 and no environmental benefits is considered to analyze the impact. The impact on utility is in terms of: loss in fixed charges (assuming 10% of the solar capacity will result in sanctioned load reduction), loss in banking charges (assuming 30% of energy generated from rooftop solar is banked and do not pay 2% banking charge @ APPC price). The benefits for utility is only Deemed RPO (@ Solar REC price of INR 0.5/kWh) and savings in T&D losses.



This is assumed to be a progressive case where it is assumed that the cross subsidy component from retail tariff will become zero and utility consumers will charge consumers as per the cost of supplying to that particular consumer. Recognizing the falling cost trend, it is also assumed that the floor price of solar REC will drop down to Rs. 0.50/kWh from Rs. 3.50/kWh in 2022.

In this case the impact on utility due to solar rooftop will be on the revenue loss from fixed charges, banking charges, and benefits from deemed RPO & reduction in technical losses. As per the analysis, the overall impact of solar rooftop on utilities will be positive in this case.

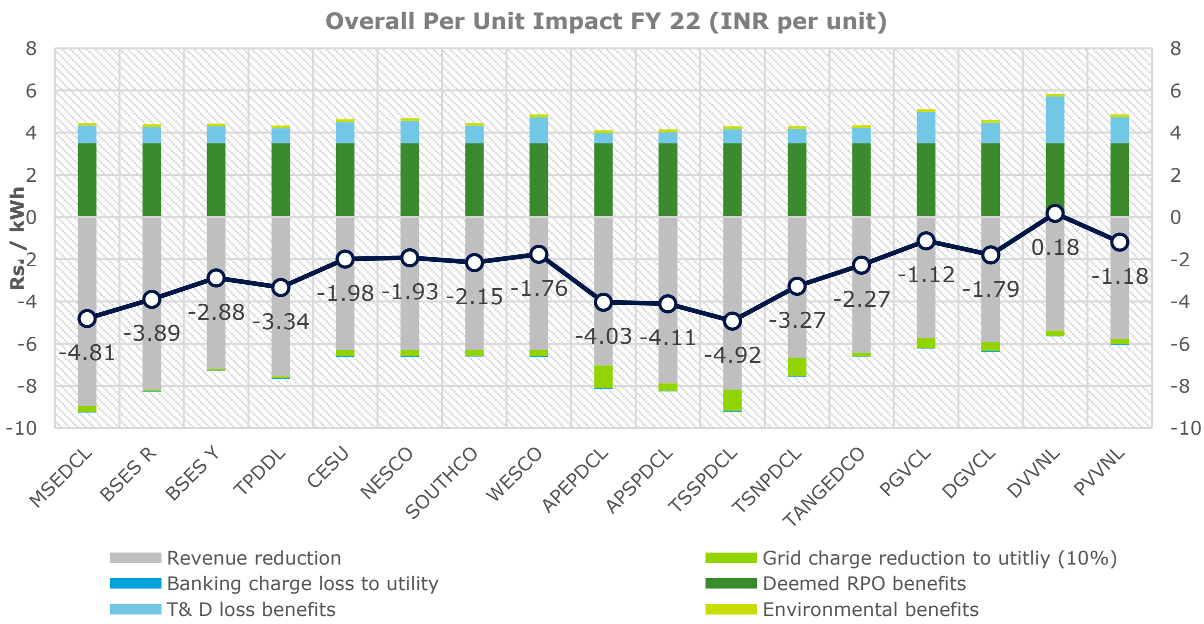
As the reduction in power purchase cost because of reduction in technical losses will have dominating impact on the utility revenue as compared to revenue loss on account of reduction in demand and waiver of banking charges. The graph above is depicting the impact of solar rooftop on utility revenue in progressive scenario.

B. Scenerio-2: Average tariff paying Consumers switch to Rooftop Solar

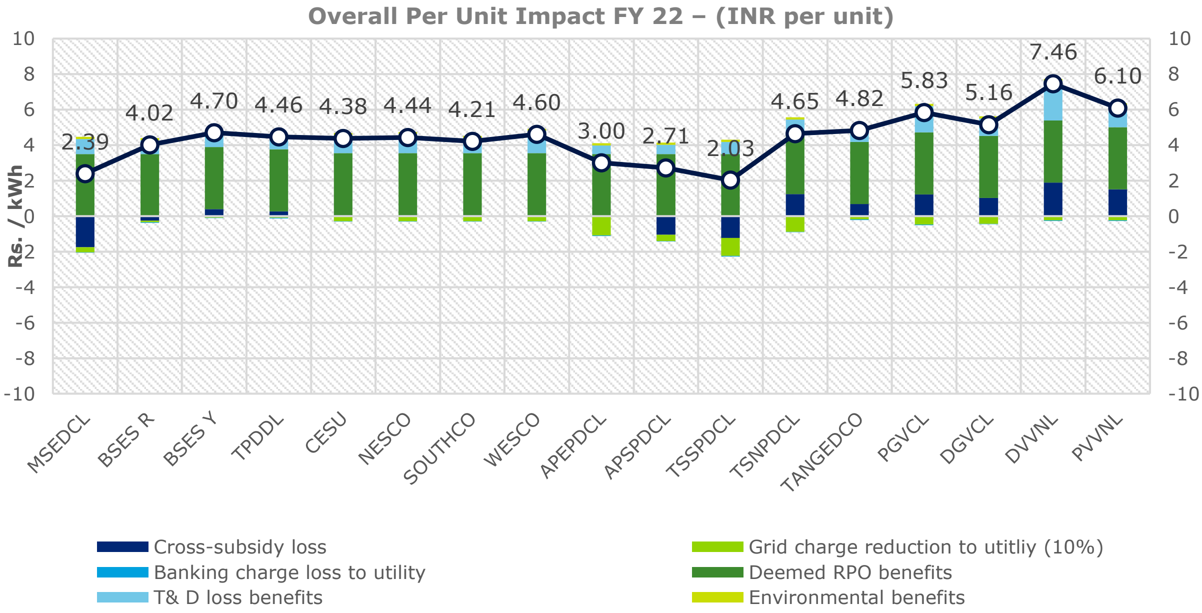
The Scenario 2 considers that rooftop solar power will replace the consumer consumption mapped at average tariff slab in a particular consumer category. The analysis below covers two cases under Scenario 2.

Case 1: This assumes the Average tariff paying consumer's switch to rooftop solar. The impact on utility is in terms of: revenue loss, loss in fixed charges (assuming 10% of the solar capacity will result in sanctioned load reduction), loss in banking charges (assuming 30% of energy generated from rooftop solar is banked and do not pay 2% banking charge @ APPC price). The benefits for utility is Deemed RPO (@ Solar REC price of INR 3.5/kWh) and savings in T&D losses.

The result of the analysis is shown with the help of above graph, which represents the behaviors of various parameters of utility revenue to be impacted due to installed solar rooftop capacity for year FY 2022. The analysis shows that utilities will have negative impact on revenue due to solar rooftop as due to solar rooftop, utility sales volume will decrease and so as its revenue. However, Utility will also have saving in expenses due to deemed RPO benefit and reduction of technical losses but the impact of sales on revenue will be much higher than the benefits accrued from solar rooftops.



Case 2: This Case assumes that the average tariff paying consumer's will switch to rooftop solar. The impact on utility is in terms of: cross subsidy loss, loss in fixed charges (assuming 10% of the solar capacity will result in sanctioned load reduction), loss in banking charges (assuming 30% of energy generated from rooftop solar is banked and do not pay 2% banking charge @ APPC price). The benefits for utility is environmental benefits, Deemed RPO (@ Solar REC price of INR 3.5/kWh) and savings in T&D losses.



This case explains the impact of solar rooftops on utilities from the perspective that the loss utility is linked with loss of cross subsidy (and not complete energy charge). With increase in the capacity of solar rooftops utility sales will decrease and with decrease in the sales utility cross subsidy collections will be impacted. However, at the same time utility will also save revenue from other benefits such as deemed RPO and reduction in technical losses, thus the overall impact on cross subsidy will be positive in this case.

Key recommendations

Based on the analysis of the commercial and operational parameters for the utilities and learnings from the international experience, the study has identified certain initiatives which would support the long-term development of rooftop solar segment in India and provide a win-win situation for both consumer and distribution utilities.

The key initiatives which could be implemented include:

Suggested Initiative	Description
Rationalization of consumer category wise consumption slabs	• Slab rationalization should be adopted by SERCs to protect utility interest (Short term initiative)
TOD framework on net-metered consumers	• Rooftop solar net metered consumers can be mandated to come under TOD framework (long term initiative)
Allow surplus solar power injection during peak time	• Allow surplus power injection during peak time in an accounting year by a net metered consumer. Limits for surplus power injection can defined by SERCs (Short term initiative)

Suggested Initiative	Description
Promote peak-time solar injection through attractive tariffs/ incentives	• Providing higher level of tariff/incentive will also encourage rooftop solar based storage options (Short term initiative).
De-Coupling of Import and Export tariff under Net Metering	• As utility is providing grid infrastructure to rooftop solar projects, to protect interest of Utility, segregation of the import and export tariffs for net-metered rooftop solar consumers can be considered. • Import tariff will be energy charge and export tariff can be capped at rooftop solar FIT, linked as % of energy charge indicated by SERC (Long term initiative)
Active power control on rooftop solar systems	• Regulations to enable active power function of advance inverter • Utility command regulatory framework for control & Instrumentation functions to enable advance inverter regulations in Indian context need to be prepared and framed. • Compensation mechanism for loss on account of active power curtailment (Long term Initiative)
Reactive tariff & standards	• Advance Inverters can be used to provide voltage regulation for improvement of tail end voltage profiles. • Regulations for enabling reactive power function of advance inverter • Incentive/tariff mechanism and level of incentives for adopting advance inverter functionality (Short term Initiative)
Explore utility driven rooftop solar models	• Utilities need to play an active role in rooftop solar capacity addition and promote utility owned/driven models. • Consumer should get additional incentive to participate in utility driven models. MNRE can provide incentive to utilities to encourage such models
Dedicated rooftop aggregation program	• Apart of initiatives at Discom level, achieving large capacity addition will require dedicated program from MNRE for aggregation of rooftops. The objective of this shall be to assist Discoms in meeting their rooftop solar targets. – Standard documents (Contract, leasing agreement) – this will reduce the risk of RESCOs – Consumer will get benefit from competitive bidding & scale – Provisions for robust O&M and performance in RESCO selection to benefit consumer

Suggested Initiative	Description
Support to Discoms to facilitate implementation of rooftop solar	• Given the low level of rooftop solar capacity, it is important to improve the capacity of utilities, MNRE can provide support to utilities: • Developing web-portal for online processing of application • Setting up consumer helpline center; Consumer grievance cell • Procurement & installation of net meters • Organizing consumer awareness; • Training for utility – energy accounting & billing software, business models & net metering • Upgradation of distribution transformers (DT) to accommodate higher solar penetration; • Training to ensure quality installation and O&M • Online consumer feedback/rating for RTPV installers
Incentive scheme for distribution utilities	• Need to develop scheme to encourage distribution utilities to accelerate the growth of solar rooftop in the country. The MNRE can devise a dedicated scheme for incentivizing distribution utilities. • Under this framework, all the distribution utilities shall be eligible for incentive based on the rooftop solar capacity added in their jurisdictions. • Performance linked incentives, based on ▪ Meeting rooftop solar targets on yearly basis ▪ Number of consumers connected under net metering arrangement • Initiate regulatory reforms for rooftop solar capacity addition

Conclusion

Solar rooftop is going to play an important role in meeting India's growing energy demand and its ambition towards becoming a global leader in solar power. With declining cost of solar PV systems, electricity generation from rooftop solar installation is already economically viable and, in some markets, cheaper than conventional sources of energy. Solar rooftop has already reached grid parity in some states, for certain consumer categories in the country.

The study indicates that solar rooftop provides several benefits to distribution utilities in terms of meeting the day time peak demand, curbing technical losses, reducing power purchase cost etc. While in some cases, it also affects utility business through reduction in sales volume, reducing demand etc. Given the huge potential and limited installed capacity of solar rooftop in the country, solar rooftop segment requires nurturing support from key stakeholders such as policy makers, regulators, distribution licensees etc.

To achieve India's ambitious target of 40 GW of rooftop capacity by 2022, there is a need to devise a dedicated scheme to improve the capacity of distribution utilities by Central or State Government. In view of this, MNRE must introduce a programme to build capacity of discoms in specific areas such as establishing solar rooftop cell, developing interconnection framework, consumer awareness, developing web portal for online processing, establishing consumer helpline/grievance cell, developing capacity of Discom, SNA, SERC and Chief Electrical Inspector, Upgradation of distribution transformers etc.

Such an initiative will be a good step in the direction of bringing utilities on board. Going forward, policy makers with support from electricity regulators will also have to devise schemes for adoption of market models, wherein utilities plays an active role and utility concerns associated with implementation of solar rooftops can be mitigated. Through such measures, India will be able to meet its desired targets and meet its objective to reduce carbon emission.

About the study

The study has been supported by Shakti Sustainable Energy Foundation and carried out by Deloitte Touche Tohmatsu India LLP.

About Shakti Sustainable Energy Foundation

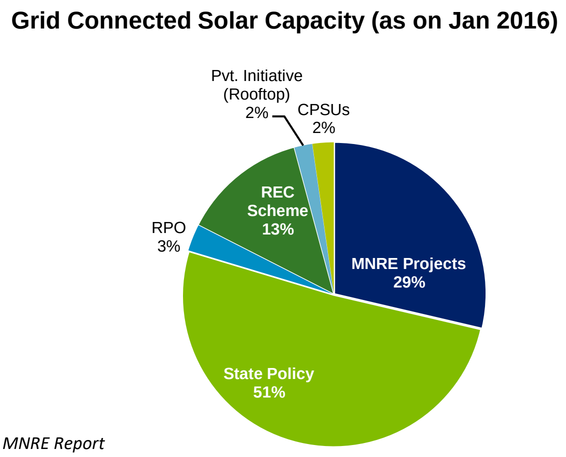
Shakti Sustainable Energy Foundation works to strengthen the energy security of the country by aiding the design and implementation of policies that encourage energy efficiency, renewable energy and sustainable transport solutions, with an emphasis on sub sectors with the most energy saving potential. Working together with policy makers, civil society, academia, industry and other partners, we take concerted action to help chart out a sustainable energy future for India (www.shaktifoundation.in).

1 Introduction

1.1 Solar sector in India

With 250–300 sunny days in a year, about 5,000 trillion kWh of energy is incident on an annual basis over India's land area with most parts receiving 4-7 kWh per sq. m per day. Recently a study carried by National Institute of Solar Energy (NISE) estimated that the country has a total solar power generation potential of 748.9 GW.

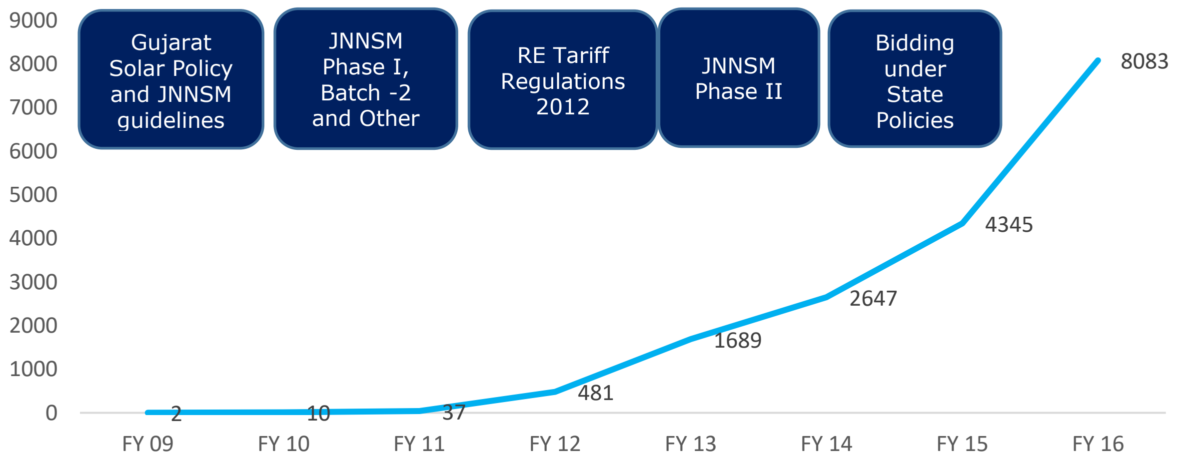
In comparison, the total installed capacity of solar energy as on end of July 2016 was 8,062 MW[1] – a mere 1% of the overall potential. To tap the huge solar potential, MNRE launched the JNNSM with a capacity addition target of 20GW solar power by 2022. The targets have been further revised by five times to 100GW by 2022.



Source: MNRE Report

Figure 1: Grid connected solar projects capacity

The sector had a slow start post the launch of JNSSM, but the growth has picked up in a short span of time. The capacity has risen significantly in the last five years, reaching to ~8 GW (by July, 2016) from just 38 MW in 2011. Incentives programs like Generation Based Incentive (GBI), Viability Gap funding mechanism (VGF) and Capital subsidy program have provided significant financial incentive to invest in solar energy. Apart from JNNSM, almost all state governments have introduced solar specific state policies and have notified Feed-in-Tariffs to promote solar generation.



Source: MNRE (August, 2016)

Figure 2: Solar Growth trend in India (MW)

With technology innovations and reducing module prices, solar PV tariffs are fast reaching grid parity. Since the launch of JNNSM in 2010, Solar PV capital costs and tariffs have decreased by approximately 65%, from Rs. 17 Crore per MW in 2010 to Rs. 6.06 Crore per MW in FY16. Further reduction in the solar costs and increase in generation tariffs from conventional fuels in India is likely to see the solar achieve grid parity sooner than

[1] *Ministry of New and Renewable Energy, Commissioning Status of Grid Connected Solar Power Projects, as on 31th July 2016*

anticipated earlier. The trends in Solar Power benchmark Capital Cost and Tariff is indicated below:

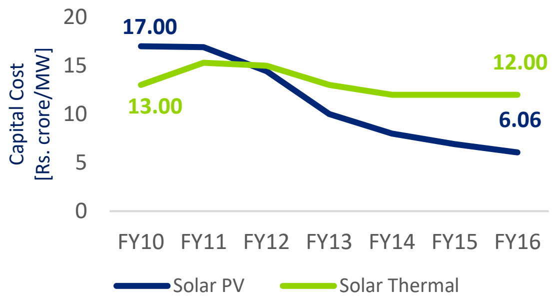


Figure 3: Solar Capital Cost Trend

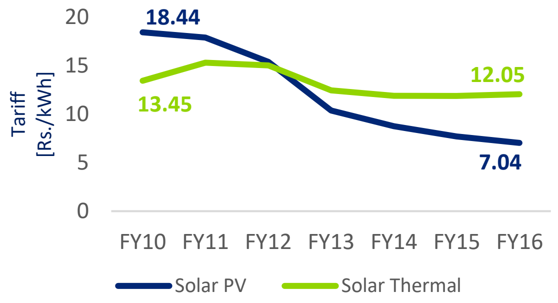


Figure 4: Solar Tariff Trend

*Tariffs shown are for projects which are not availing accelerated depreciation benefit.

Source: Central Electricity Regulatory Commission

1.2 Rooftop Solar in India

The unutilized space on rooftops provides a large potential for generating solar power. Small quantities of power generated by each individual household, industrial building, commercial buildings or any other type of building can be used to fully / partially fulfil the requirement of the building occupants and surplus, if any, can be fed into the grid. Rooftop solar PV systems have the advantage of low installation time, providing clean, quiet and visually unobtrusive source of energy. They can also improve the reliability of power supply for rooftop owners, eliminate the need for long-distance transmission lines associated with large-scale solar generation plants and save on network losses associated with large-scale plants wheeling power to load centers.

Realizing the potential and advantages, MNRE launched a program for Generation-Based Incentives (GBI) to incentivize the installation of Rooftop PV and Small Solar Power Plants connected to the distribution network (at or below 33 kV level). The scheme was part of JNNSM tail end projects under GBI scheme which is referred to as "Rooftop PV & Small Solar Power Generation Program" (RPSSGP). A generation based incentive (GBI) was given to the utilities to cover the difference between the tariff determined by Central Electricity Regulatory Commission (CERC) and the base price of Rs.5.50 /kWh (FY 2010-11) with 3% escalation per annum. In all, 71 projects have been commissioned across 12 states under the RPSSGP scheme with total installed capacity of 90.8 MW[2]. However, it was observed that this scheme garnered enthusiastic responses primarily in the ground-mounted segment, while it received almost negligible interest in the rooftop segment.

MNRE also launched a national level 'Grid Connected Rooftop and Small Solar Power Plants Program' on June 2014 which provides Central Financial Assistance (CFA) of up to 30% of the capital cost for plants ranging from 1 kWp to 500 kWp in residential, commercial and institutional sectors.

As per the new ambitious target of 100 GW set under the JNNSM program, MNRE has allocated 40 GW for solar rooftops and is making concerted efforts to promote grid connected solar rooftop projects. In a bid to achieve the same, MNRE has allocated the targets to different states as per their energy demand and approached PSUs and other government institutions to invest in renewable energy. Supporting the mandate, PSUs like NTPC, CIL have already taken steps towards investments. The ministry has also introduced a scheme for setting up of 1000 MW of Grid-connected solar PV projects by CPSUs and Govt. of India organizations with Viability Gap funding under Batch-V of JNNSM[3]. The graph

[2] *Ministry of New and Renewable Energy, Annual Report 2014-15*

[3] Ministry of New & Renewable Energy, http://mnre.gov.in/file-manager/UserFiles/Scheme-1000MW-grid-connected-SPV-batch_V-phase_II-JNNSM.pdf

below is presenting the roadmap of MNRE for achieving the 40 GW of rooftop target by 2022

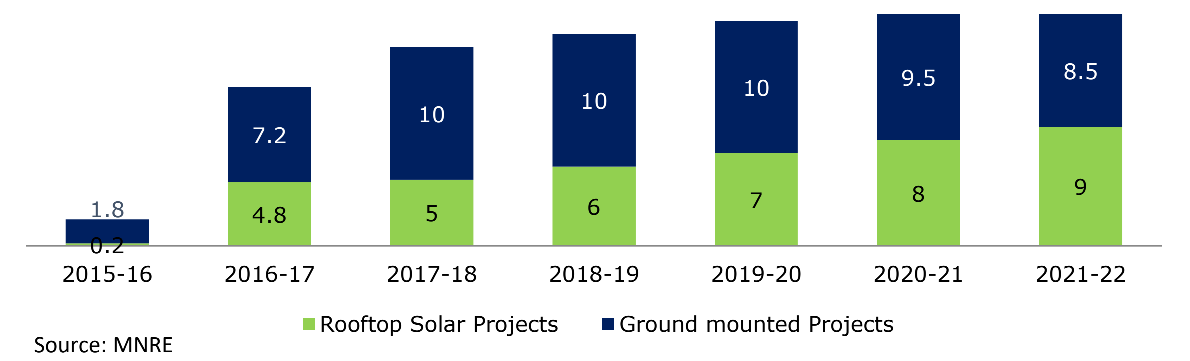


Figure 5: Capacity additions under JNNSM (in GW)

Large government institutions which have large space availability can play a pivotal role in achieving these targets. Such institutions have high power demand and rooftop space available with these can be utilized to meet their captive needs through a clean source. In addition, this shall also contribute towards achieving their CSR mandate. The figure below is presenting the targets allocated to different States by MNRE to achieve 40 GW rooftop capacity by 2022

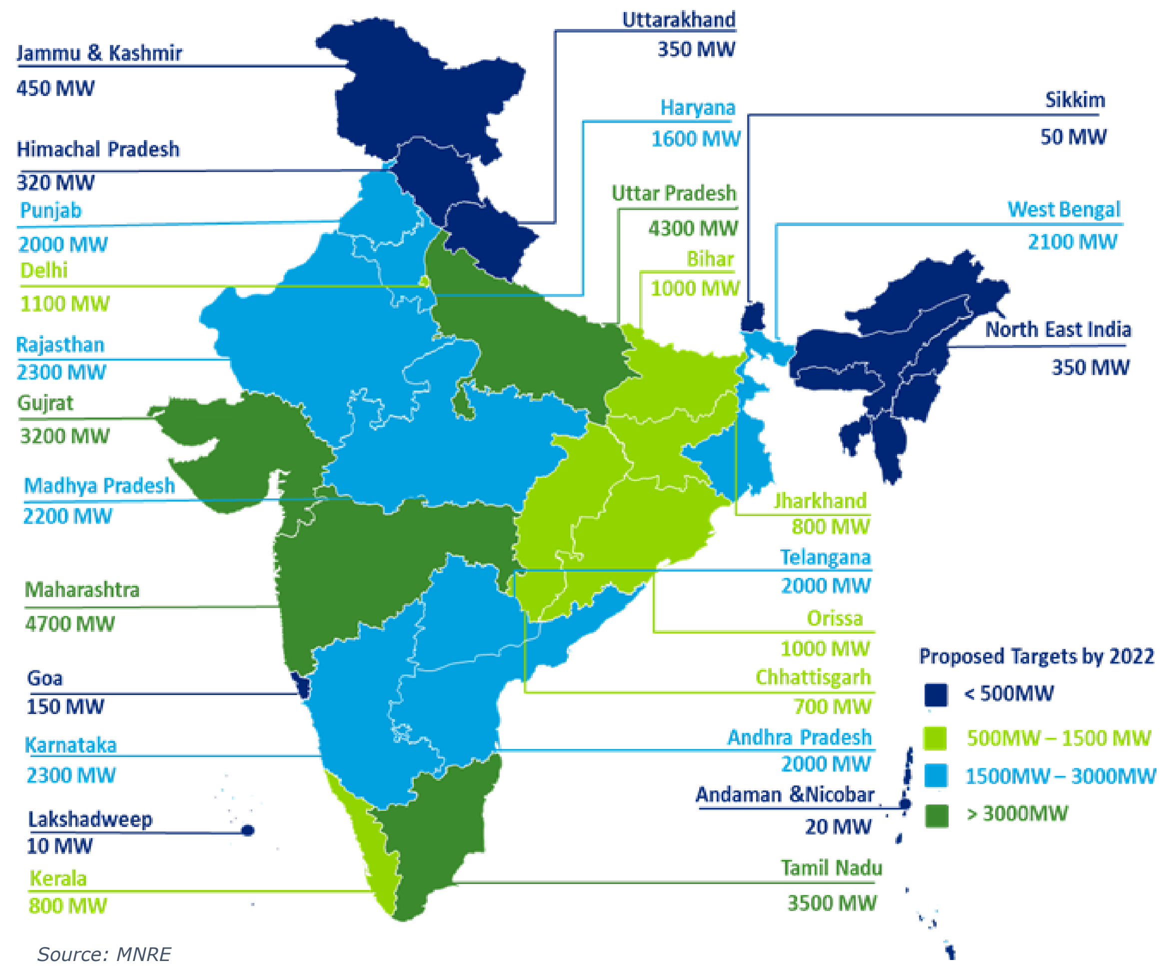


Figure 6: MNRE state-wise targets for Solar Rooftops

While there have been some attempts under the existing policies and regulations to promote rooftop solar PV projects, there are several barriers which continue to exist for achieving a large-scale proliferation. A number of states are yet to specify tariff for rooftop solar projects. Given the cost differential between MW scale solar PV projects and small scale rooftop projects, a preferential tariff for rooftop solar PV projects needs to be considered for the gross-metered systems. Though several states have released net-metering regulations, there still are limiting challenges in the form of capacity and grid integration restrictions under these regulations. In addition, there is a need to define the technical standards for rooftop systems to ensure quality installations and operational efficiency.

The technical limitations for the distribution networks can be one of the biggest barriers to rooftop installations which have high potential to proliferate quickly in a favorable policy environment. This limitation is reflected in net-metering regulations which have set project capacity limits depending on DTR capacity. Apart from this, with increasing penetration of rooftop solar PV, commercial interests of the utilities will need to be recognized and managed in the choice of implementation models.

1.3 Objective of the study

India has an ambitious target to deploy 40 GW of grid-connected rooftop PV systems by 2022. However, unless the concerns of distribution utilities are addressed, a situation similar to Tamil Nadu’s wind sector, where utility is opposing any additional wind installations, can hit the solar rooftop sector as well. These debates have been rising even in other countries.

Thus, with a view to bring solutions to the table, it is necessary to analyze the actual local and aggregate impacts of rooftop systems on utilities considering actual demand and supply profiles of the distribution areas, and tariff and cost structures. Amongst other solutions, cost-reflective and transparent tariff design mechanisms can ensure a healthy equation between prosumers, utilities and consumers, thus facilitating a sustained growth of the sector.

Based on the understanding from the international experience in issues related to rooftop solar proliferation, adoption of different market models & impact on utilities, this study aims at devising solutions from Indian context (after considering distribution utility specific aspects) and recommendation on changes in existing models & identifying regulatory requirements.

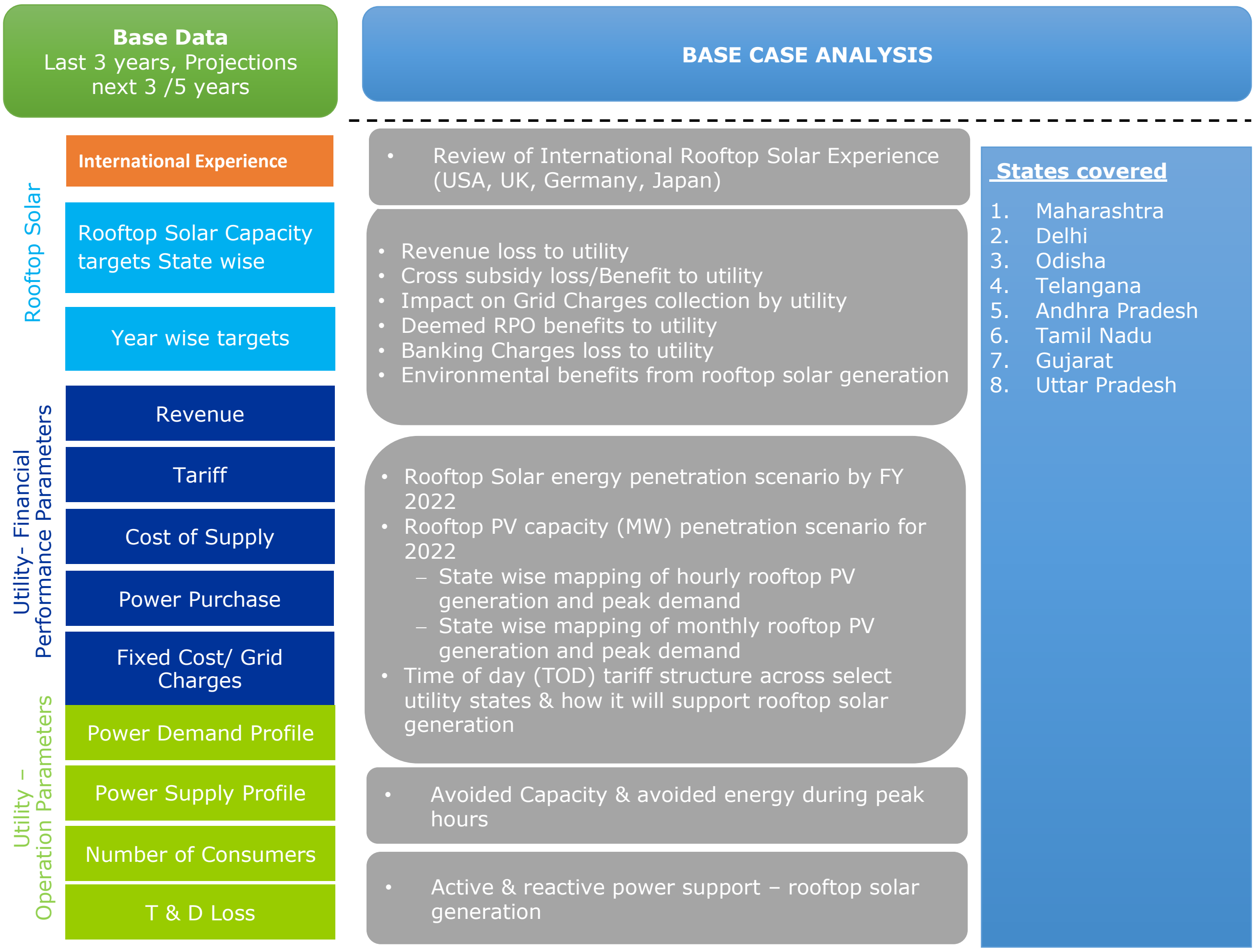
The detailed scope of work is included in Annexure 1

2 Overall approach for the study

To assess the impact of solar rooftop on utility business, in-depth analysis of state utilities of eight states is carried out. Utilities Performance and Operational parameters are analyzed based on data of past three years and projection of next five years have been taken to analyze the future scenario. The capacity addition in rooftop segment is taken as per MNRE's target allocated to different states to achieve 40 GW target to analyze various business cases in view of utility business in India.

The approach adopted for analysis and devising recommendation is shown in the following figure

Figure 7: Overall approach



In total 17 utilities from eight (8) states have been covered for the analysis viz. Maharashtra, Odisha, Delhi, Tamil Nadu, Andhra Pradesh, Telangana, Gujarat and Uttar Pradesh. The utilities analysed as a part of this study are shown in the following table

Table 1: Distribution utilities covered

S No	State	Utility
1	Maharashtra	Maharashtra State Electricity Distribution Company Limited (MSEDCL)
2	Delhi	BSES Rajdhani Power Ltd (BRPL)
3		BSES Yamuna Power Limited (BYPL)

S No	State	Utility
4		Tata Power Delhi Distribution Limited (TPDDL)
5	Odisha	Central Electricity Supply Utility (CESU)
6		North Eastern Electricity Supply Company of Odisha Limited (NESCO)
7		Southern Electricity Supply Company Of Odisha Limited (SOUTHCO)
8		Western Electricity Supply Company Of Odisha Limited (WESCO)
9	Andhra Pradesh	Eastern Power Distribution Company of Andhra Pradesh Limited (APEPDCL)
10		Southern Power Distribution Company of Andhra Pradesh Limited (APSPDCL)
11	Telangana	Telangana State Southern Power Distribution Company Limited (TSSPDCL)
12		Telangana State Northern Power Distribution Company of Limited (TSNPDCL)
13	Tamil Nadu	Tamil Nadu Generation and Distribution Corporation (TANGEDCO)
14	Gujarat	Paschim Gujarat Vij Company Ltd. (PGVCL)
15		Dakshin Gujarat Vij Company Ltd. (DGVCL)
16	Uttar Pradesh	Dakshinanchal Vidyut Vitran Nigam Ltd (DVVNL)
17		Paschimanchal Vidyut Vitaran Nigam Limited (PVVNL)

Various published sources of information have been relied on for collating and analyzing the data for respective utilities. These data sources include 18th EPS report (CEA), Performance of State Power Utilities for the years 2011-12 to 2013-14 (PFC), Tariff orders by the State Regulatory Commissions, Power for All (PFA) reports for different states. In addition to this data from other sources like World Bank, Asian Development Bank, IRENA, NREL, National and International Reports have also been taken to develop the business cases for utilities.

In the following section, the relevant international experience in the context of evolution of rooftop solar segment has been provided.

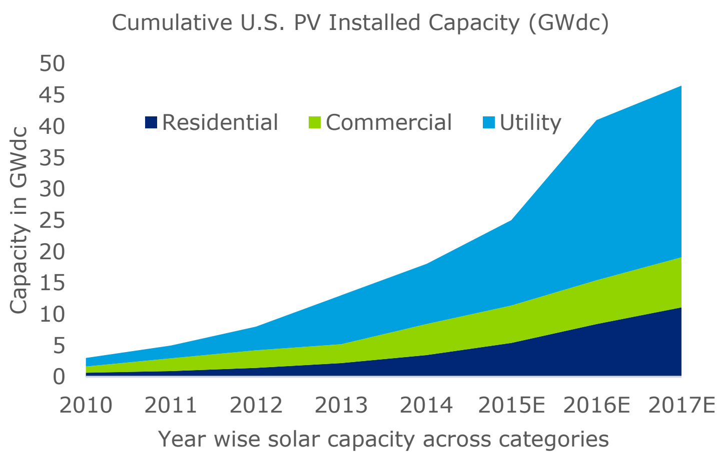
3 International Experience

3.1 United States of America

In last few years, Solar PV has seen phenomenal growth in United States and it is expected to grow to cumulative capacity of 41 GWdc by 2016. Till Q3 2015, US solar has witnessed addition of 1 GWdc or more in the last 8 consecutive quarters. Q3 2015 alone has 1,361 MWdc installed, bringing the market up to 4.1 GWdc through the first three quarters of 2015.

Growth of solar installation is attributed to falling solar PV prices. It is observed that average solar PV price ($/watt) has fallen from $8 in 2005 to around $3 in 2014 i.e. 62.5 % decline in prices over a decade. Resulted in proliferation of solar PV installation in all the segments i.e. Residential, Commercial and Utility Scale. Following figure illustrates growth in cumulative US PV installations from 2007 to 2016[4] in different segments:

Figure 8: Cumulative U.S. PV Installed Capacity, 2007-2017E



While the prices have fallen, the total installed cost ($/Wdc) has been different for each of the market segments ranging from the highest of around $3.55 for residential to lowest of around $1.38 for utility fixed tilt.

The cost of residential rooftop is highest mainly due to miscellaneous site, supply chain, logistics, taxes and overhead costs, as well as margins. PV inverter and AC subsystem costs are also higher for the residential rooftops.

Source: SEIA & GTM research

Due to reduced cost, the utility owned solar installations has outgrown other segments. It is predicted that during the period from 2017 to 2020, the residential solar installations would be more than utility owned installations mainly due to lower LCOE as compared to utility tariff. In many states, solar is already reaching towards grid parity where existing prices of electricity is high. Majority of states in USA (45 in 2015) out of total 50 have adopted net metering policies.

3.1.1 US Initiatives to promote solar

US Solar market started has grown rapidly in past few years, this is primarily due to the initiatives taken by US state governments to promote solar. Realizing the benefits of solar rooftops, there was equal focus on promotion of solar rooftops with utility scale solar projects. To promote solar for de-centralized distributed generation some of the major initiatives taken in different states of US are Go Solar California, New York Sun, Sunshot Initiative etc.

In "Go Solar California" initiative, around 3,000 MW of solar capacity additions were envisaged in California. The California Solar Initiative (CSI) program has a total budget of $2.167 billion between 2007 and 2016 and a goal to install approximately 1,940 MW of new solar generation capacity. California Solar Initiative pays solar consumers their

[4] *http://www.seia.org/research-resources/solar-market-insight-2015-q3*

incentive either all-at-once for smaller systems, or over the course of five years for larger systems.

New York-Sun was also launched in 2012 to increase solar electric installations in the State. In April 2014, commitment of nearly $1 billion was made to NY-Sun for expanding deployment of solar capacity throughout the State and transform New York's solar industry to a sustainable, subsidy-free sector. New York State Energy Research and Development Authority (NYSERDA) has begun transitioning to the statewide NY-Sun Incentive Program, using a Megawatt (MW) Block system, starting in August 2014 for solar electric systems up to 200kW in capacity and in early 2015 for systems larger than 200kW in solar capacity.

In 2011, The U.S. Department of Energy (DOE) SunShot Initiative was launched with the goal to make solar energy fully cost competitive with traditional energy sources before the end of the decade. The SunShot works with private companies, universities, non-profit organizations, state and local governments, and national laboratories to drive down the cost of solar electricity to $0.06 per kilowatt-hour, without incentives, by the year 2020. The SunShot initiative is designed to re-establish American technological leadership, strengthen U.S. economic competitiveness in the global clean energy race, help cut carbon pollution to combat climate change, and secure energy future.

3.1.2 Financing Mechanism

In addition to the promotional programs, there is focus also on providing finance to the end consumers through different routes. To fund these rooftop models, there are several financing models that emerged out in US, three broad categories to fund rooftop projects are depicted in following figure

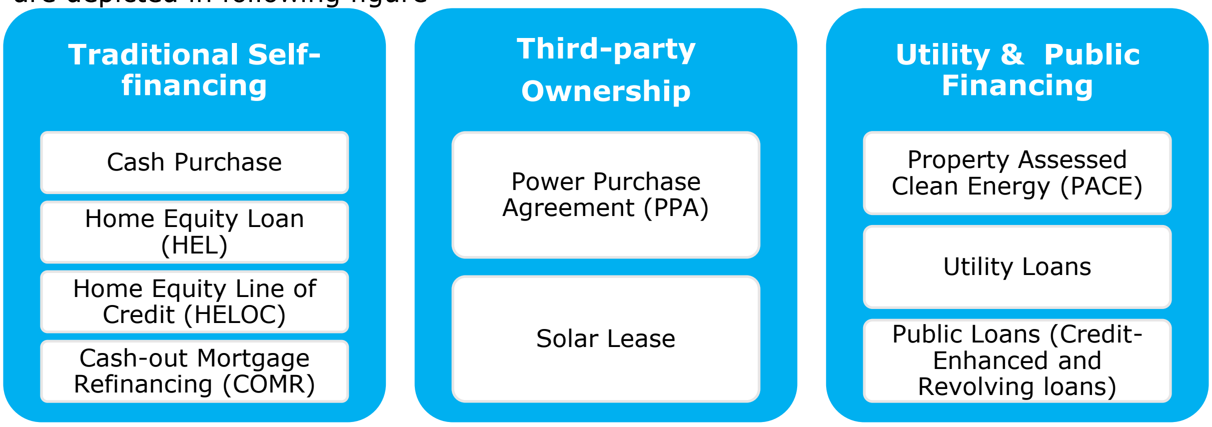


Figure 9: Financing mechanism for solar projects in USA

Under these financing mechanism, traditional financing scheme is the most common form of solar financing wherein Cash purchase is the least expensive option in terms of total dollars spent to acquire PV as no financing costs or solar finance company fees are incurred. However, the upfront cost of a PV system is significant and likely a barrier for most households. There are several financing options available to homeowners who choose not to (or cannot) purchase a PV system with cash. The options include Home Equity Loans or HELs (also known as second mortgages), Home Equity Line of Credit (HELOCs), and Cash-out Mortgage Refinancing (COMRs). They are provided by banks and credit unions across the country and therefore are likely the most available options for homeowners. Interest rates for HELs and COMR are compound whereas HELOC interest rates are simple. There are generally no fees (upfront or yearly) or very low fees for HELs. HELOCs and COMR loan contracts often require upfront or yearly fees with non-interest costs tending to be the highest for COMRs (akin to first mortgages).

Traditional self-financing tools provide homeowners with a means of purchasing a PV system outright. However, some homeowners have additional options for procuring solar energy via third-party ownership models, such as PPAs or solar leases, offered by multiple local, regional, and national solar finance companies. Third party ownership enable homeowners to benefit from commercial tax incentives available for solar—the ITC and the Modified Accelerated Cost Recovery System (MACRS)—by partnering with a third-party solar provider. By making efficient use of tax incentives, third-party ownership can be cost competitive with local retail electricity rates.

In addition to third parties, several utilities, states, and local governments also have solar PV system financing programs for eligible residents in US. These utilities fund rooftop systems under different schemes such as Property Assessed Clean Energy (PACE) which is a public financing mechanism used by local governments. Similarly, utility financing is also available to some residential and commercial customers. Utility loans are a low-cost financing option that can either be an on-bill loan or meter-attached (i.e., secured to the meter/electric service). However, only homeowners who are customers of utilities that provide or participate in financing programs can access these loans. In addition to this public loans were also available for consumers, it uses third-party capital (i.e., that of banks or credit unions) to support lending for all or a portion of a loan. The state or local government either provides a loan for the remaining portion of the principal or a credit enhancement for the private-lender portion of the loan.

3.1.3 Prevalent Business Models

There are broadly three structure based on the ownership of the system relevant in US, the first one is Self-owned wherein the rooftop system is owned and used by the end consumer. While in case the consumer wants to go away from high initial investment, it goes for third party or utility owned system, wherein third party or utility invests in the rooftop system to be used by the end consumer and in return consumer pays it either in the form of EMI for using the system or it procures the energy generated from the system at a mutually agreed price. However, under these ownership structure there could be difference in terms of the energy accounting and settlement. It could either be in the form of Gross Metering, wherein the complete energy generated from the system is sold to the grid or it could be Net Metering, wherein only the excess generation left after consumption from solar rooftop is injected to the grid. End consumers can also choose to setup rooftop system in off-grid mode for captive use only.

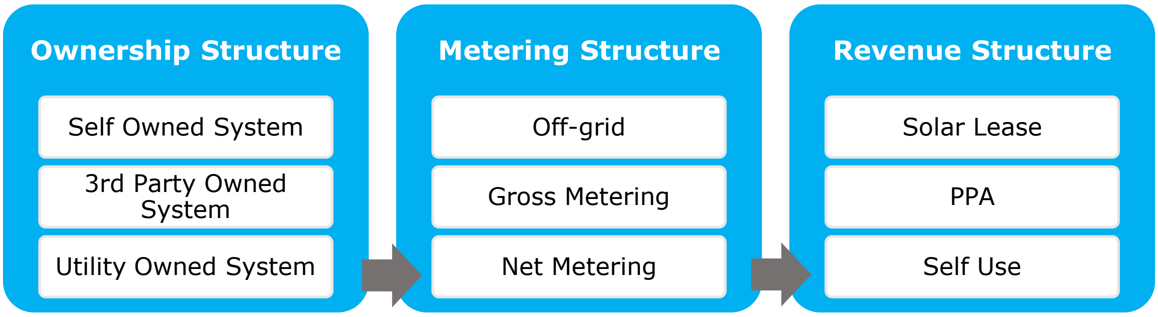


Figure 10: Popular rooftop solar business models in USA

3.2 Germany

The annual capacity installation for solar PV in Germany peaked around 7 GW during the period 2010 - 2012. Germany had the world's highest installed solar capacity by 2015, with more than 39 GW, ahead of US, China, Italy, UK and Japan. The capacity has grown at a CAGR of 45.6% in the last 13 years. There has been a decline in the capacity additions since 2013 due to changes in governmental policies.

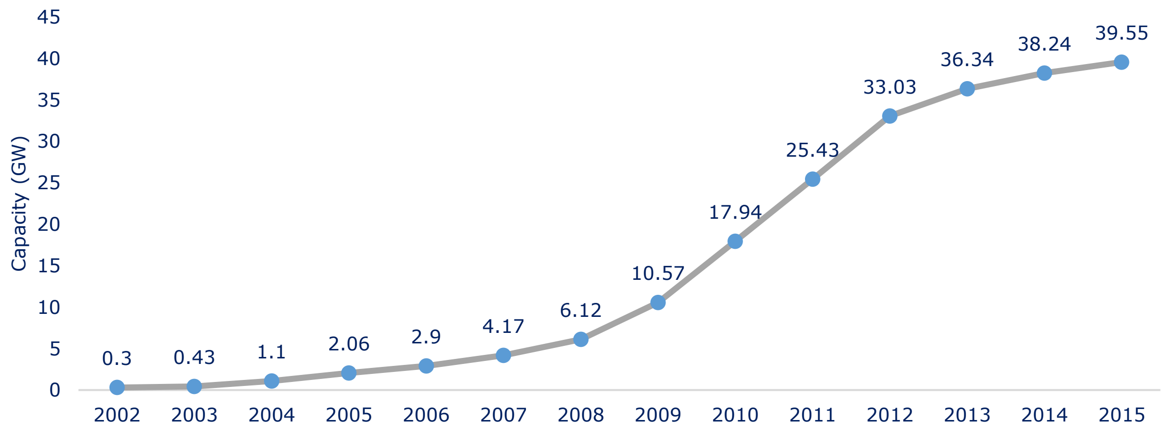


Figure 11: Growth of Solar Installed Capacity in Germany

Source: AGEE, BMWi, Bundesnetzagentur

The amendments in the German Renewable Energy Act (EEG) has reduced the feed-in tariffs and also set constraints on utility-scaled installations by limiting their size to 10 MW. The current version of the EEG only guarantees financial assistance as long as the overall PV capacity reaches 52 GW. It also foresees to regulate annual PV growth within a range of 2.5 GW to 3.5 GW by adjusting the guaranteed fees accordingly. The legislative reforms in Germany stipulates a 40 to 45 percent share from renewable energy sources by 2025 and a 55 to 60 percent share by 2035.

Germany's FIT regime has been essential to the country's successful drive to meet and exceed its aggressive renewable electricity goals. The FIT policies have been designed to support market rapid scale-up, and stand out as a policy that has delivered transparency, longevity, and certainty to investors in German renewable energy projects.

3.2.1 Evolution of Germany's solar sector

Germany is widely considered to be the country most successful at rapidly transitioning toward renewable energy systems through feed-in tariffs. Under FIT regime, the tariff is set so that a modest profit is ensured, thereby unleashing the collective capital resources of the country to be part of the transition to renewable energy. Any incremental cost of purchasing the renewable energy is shared among all consumers of that energy.

Germany adopted FIT in 1990 and since than there has been several amendments taken to improve the effectiveness of the program. The following figure depicts changes in the FIT program since 1990 to 2014 and subsequent amendments/Improvements introduced their off to check the growth of the sector as per prevailing market conditions.

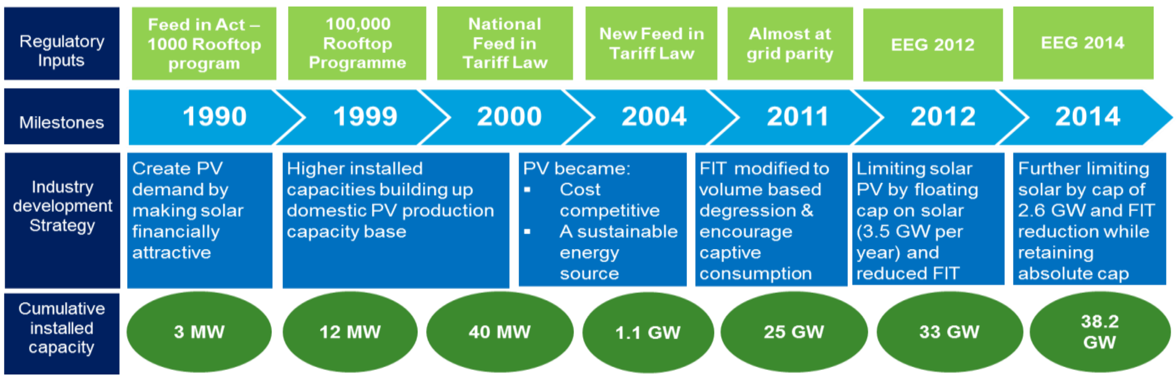


Figure 12: Modification in German FIT Program

During 1990 to 1999, the StrEG, or "Electricity Feed-in Law", was Germany's first feed-in tariff and did not have rates high enough to support PV installations. This scheme has caps on generation and cost. Under the StrEG, both PV and wind generators were eligible for a feed-in tariff payment set at 90% of the retail electricity rate, which meant that the FiT rate fluctuated between 8.45-8.84 €cent/kWh over the course of the decade. Although this rate was insufficient to drive PV markets on its own, PV generators were eligible for rebates equal to 70% of system cost (starting in 1990) and low-interest financing under the 100,000 roof-top program (1999). By the end of year 1999, 67 MW of PV were installed due in large part to capital cost subsidies.

The volume management strategy during this period consisted of caps triggered by the amount of renewable energy in each utility service area. Under the StrEG, policy costs were recovered regionally, rather than distributed nationally. Initially, local utilities were only required to recover policy costs from within their service territories, up to a 5% renewable energy penetration level. Above that level, the costs would be socialized more broadly among ratepayers served by the regional transmission system. In addition to the generation caps, utilities were exempt from renewable energy purchases if the purchases substantially impacted ratepayers.

In 2000, Germany passed the EEG, or "Renewable Energy Law," which first introduced national rates that approximated the generation cost of PV systems and proved more effective than a direct linkage of incentives to retail rates. This program was an effort to set cap on program and projects to control impact on ratepayers. In combination with the 100,000 Roofs Program (which offered zero-interest loans starting in 1999), the EEG drove cumulative capacity to 435 MW by the end of 2003, or an average annual capacity addition of ~120 MW. The EEG initially specified that a hard cap would be implemented once 350 MW of capacity was reached in order to limit policy costs. In June, 2002, however, the law was amended to increase the capacity that would trigger the cap to 1,000 MW.

In 2003, the EEG rates were revised one year ahead of schedule when the 100,000 Roofs Program ran out of funds. Main feature of this module was to remove the caps. The new rates, which were established and went into effect in January 2004, were differentiated by system size and by application type (façade mounted, roof-mounted, or free-standing), and ranged from 46-62 €cent/kWh. Market growth accelerated under the amended EEG, with cumulative capacity expanding to 5,979 MW by the end of 2008, or an average annual capacity addition of ~1,100 MW. The revised EEG removed the 1000 MW program cap, as well as the system size caps, creating the first uncapped PV market in the world.

In July 2008, the EEG was revised, and new rates went into effect in 2009. First time, the corridor system was introduces. The new law removed rates for façade integrated PV but introduced payments on top of the retail electricity rate for PV electricity consumed onsite. The amendment established a "corridor" or "flexible" digression system for PV whereby the rate would decrease each year based on the volume of MW installed during the previous year (defined as October 2008-October 2009). The 2009 amendment projected that 1500 MW would be installed in 2009, 1700 MW in 2010, and 1900 MW in 2011. If the actual installations matched the projections, then the next year's digression would be 6.5%. If actual installations were below or above the projections, the digression would decrease or increase by an additional 1%.

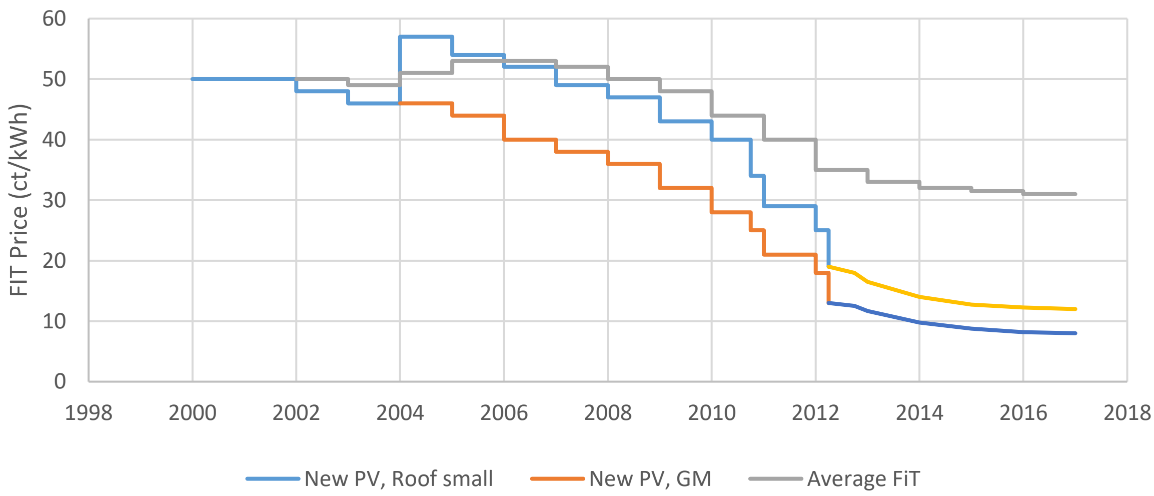
In 2010, the Government introduced two "non-scheduled" decreases to reflect PV component price declines and altered the corridor digression schedule. The rates decreased from 2009 to 2010 by 7.5% since the amount of capacity installed exceeded the projected 1,500 MW projection. In order to account for rapid declines in PV module prices, the government called for additional cuts beyond the digression introduced in 2009. In July 2010, a law was passed that immediately decreased rates for building-mounted systems by 13%, and rates for ground mounted systems by 8-12%. The law further decreased rates on all systems by an additional 3% in October 2010. The law also set out a revised corridor digression system with a 3,500 MW annual installation projection. Each GW installed in excess of the 3,500 MW baseline in 2010 would result in an additional 1% digression in 2011, up to a maximum digression of 13%. In 2012, each GW of excess capacity would result in a 3% decrease, for a maximum digression of 21%.

In February, 2011, the German government issued a revised corridor degression schedule. In anticipation of continued robust growth enabled by additional system cost reductions, the revision split the potential degression for 2012 into two parts: one that would occur in July 2011 and one that would occur on January 1, 2012. Both adjustments are to be based on the amount of capacity installed. The total degression for 2011-2012 could be as low as 1.5% or as high as 24%, depending on the actual PV market growth.

In 2012, the German government set a "floating cap" on solar power, limiting it to 2.5 to 3.5 gigawatt per year and reducing the feed-in remuneration of small rooftop panels (under 10 kilowatt) from 24.43 cents per kilowatt-hour to 19.5 ct/KWh. The degression schedules that are proposed for 2011 and between 2011-2012 can already be projected, based on the proposals made in January.

In 2014, the new EEG retains the absolute cap of 52 gigawatt for the installed capacity of solar power in Germany (first introduced in 2012). Installations beyond this target will not receive any funding under the EEG. Depending on the size of the installation, new photovoltaics will receive 9.2 to 13.1 ct/KWh. This tariff is generally set to be reduced monthly; by how much and if at all depends on whether the addition of new solar capacity exceeds or falls short of the prescribed target. The graph below is showing the FIT price trend for rooftop and ground mounted solar PV from 2000 to 2016

Figure 13: FIT price trend for Rooftop and ground Mounted PV in Germany



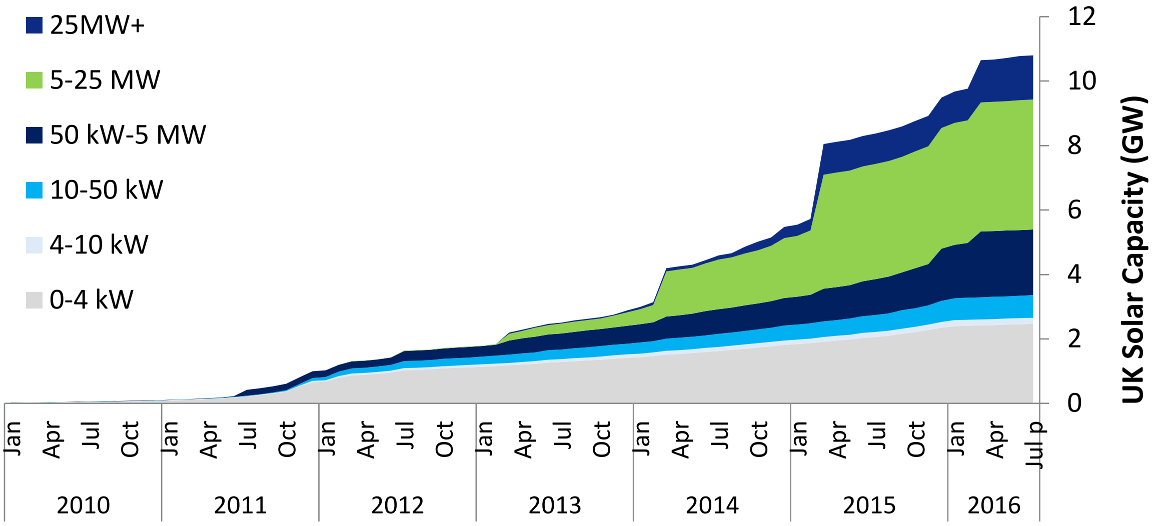
Source: Fraunhofer Institute for Solar Energy Systems

3.3 United Kingdom

In United Kingdom, Solar PV has witnessed tremendous growth in the past 6 years. It has reached 10,799 MW (till 2nd quarter 2016) from 32 MW installed capacity in 2010 across 892,817 installations. This is an increase of 29% (2,423 MW) compared to July 2015.

Rooftop solar industry in the UK is centered primarily in two key markets viz. small scale and mid-size. Small scale is typically smaller than 4 kWp and up to 50 kWp in housing, small commercial premises and community buildings. Mid-size deployment are larger than 50 kWp and up to 1 MWp, particularly on commercial and industrial buildings but also on larger public and community buildings.

Following graph indicates year wise growth of solar PV installation and share of different size of PV projects in the overall capacity.



Source: Department for Business, Energy & Industrial Strategy

Figure 14: Growth of Solar PV in UK

To date, 50% (5,403 MW) of total installed solar PV capacity comes from large scale installations greater than 5 MW, with 23% (2,450 MW) coming from small scale 0 to 4 kW installations.

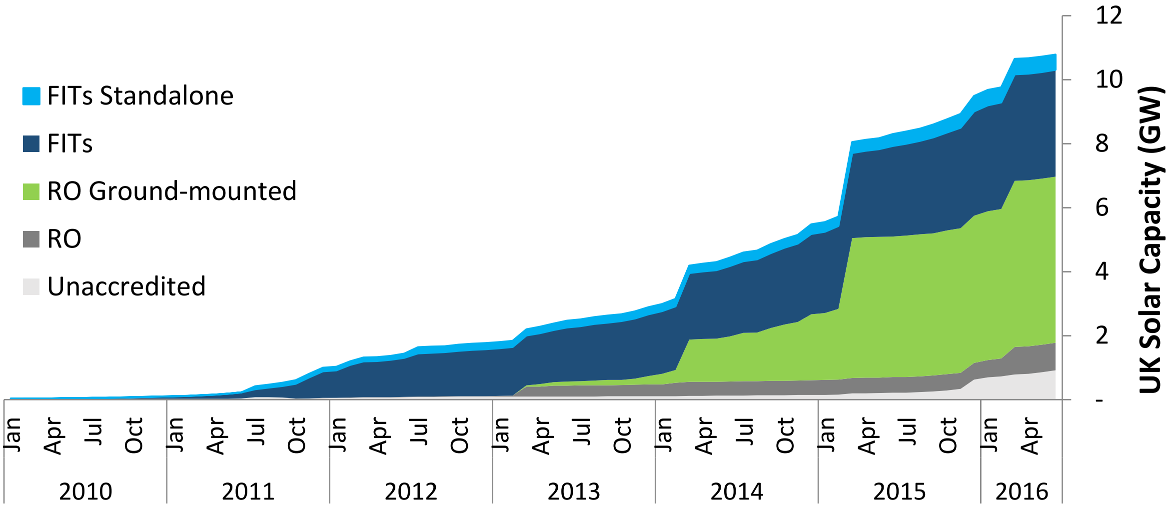
3.3.1 FIT Model

The introduction of the Feed-in-Tariff (FiT) in 2010 saw rapid growth of the UK photovoltaic market, with many thousands of domestic installations along with numerous commercial, community and industrial projects. By 2014, more than 650,000 solar installations had a total capacity of over 5400 MW of solar power. In 2012, government had said that 4 million homes across UK will be powered by sunlight, representing 22,000 MW of installed solar power capacity by 2020.

If a household, business or community has a PV installation with a total installed capacity of 5 MW or less, FITs pays them a tariff for the electricity they generate, and electricity they export back to the grid. Tariff for FIT change as often as every 3 months. Once an installation is registered for FIT, it will keep getting generation and export tariffs as long as its installation is eligible. They will be adjusted annually for inflation based on the retail prices index.

These installations must demonstrate that the building which they are wired to provide electricity to has achieved an Energy Performance Certificate (EPC) rating of level D or above in order to receive the higher tariff rate. A registered assessor can issue an EPC indicating how energy efficient the building is. The rating band varies from A (the highest rating) to G (the lowest rating). The energy efficiency requirement applies to solar PV installation, with the exception of stand-alone and capacity up to 250kW.

The following graph is showing the share of different schemes in the total installed solar PV capacity of UK



Source: Department for Business, Energy & Industrial Strategy

Figure 15: Growth and Share of different schemes in total solar Capacity

3.3.2 FIT Rates

FIT rates in UK compensate for generation and export of power to grid at certain rates. These rates are dependent on the size of the solar installment along with the energy efficiency requirement of the buildings. Depending upon the category of the building, FIT rates are assigned as low, medium and high to each of the building type. Export FIT is same for all the building types but generation FIT differ depending upon the identified class of building as low, medium or high.

Corresponding rates for each of the category is mentioned in the following table.

Table 2: FIT rates for January 2016 to April 2016

	PV Installed Capacity (other than stand-alone)	For eligible installations (1 Oct 2015 to 1 Jan 2016) (p/kWh)			For eligible installations (1 Jan 2016 to 1 Apr 2016) (p/kWh)		
Building type	System Capacity	Low	Medium	High	Low	Medium	High
Generation tariff	0 – 4 kW	5.94	11.22	12.47	5.73	10.83	12.03
	4 – 10 kW	5.94	10.17	11.30	5.73	9.81	10.90
	10 – 50 kW	5.94	10.17	11.30	5.73	9.81	10.90
	50 – 100 kW	5.94	8.67	9.63	5.73	8.36	9.29
	100 – 150 kW	5.94	8.67	9.63	5.73	8.36	9.29
	150 – 250 kW	5.94	8.29	9.21	5.73	8.00	8.89
	More than 250 kW	5.94			5.73		
	Stand-alone	4.28			3.08		
Export FIT		4.85			4.85		

3.4 Japan

3.4.1 Evolution of Solar PV in Japan

Japan for long trusted on capital subsidy mode to encourage investment in solar PV sector and later on it introduced RPS but the actual growth in Solar PV market was seen with the introduction of FITs. In 1994 subsidies started at 50% of the system costs, and were then gradually reduced to 33% in 1999. Market support on the national level, however, had been terminated afterwards, leading to a decline in FY 2007 and 2008. Subsequently, the government re-launched a subsidy program in 2009. In November 2009, the government also initiated Solar FiT under which residential PV systems as well as non-residential systems (up to 500 kW) were eligible for preferential purchasing tariffs. This led also to a moderate growth in the non-residential solar PV market.

The Japanese Photovoltaic (PV) market has gained speed after introduction of Feed-in Tariff (FiT) in July 2012. Prior to the start of the FiT in July 2012, the accumulated Japanese PV capacity was 5.6 GW, 84% of which had been added by small-scale PV systems for residential purposes. From July 2012 to June 2014 a total of 10.5 GW of new PV capacity has been installed, 30 percent of which is residential installations. Japan Photovoltaic Energy Association, predicts that Japan is going to install 49 GW by 2020 and 102 GW by 2030 - a capacity that would account for roughly 10 percent of Japan's annual electricity consumption.

The graph below is representing the growth of solar PV in Japan with change in policy framework from 1992 to 2014.

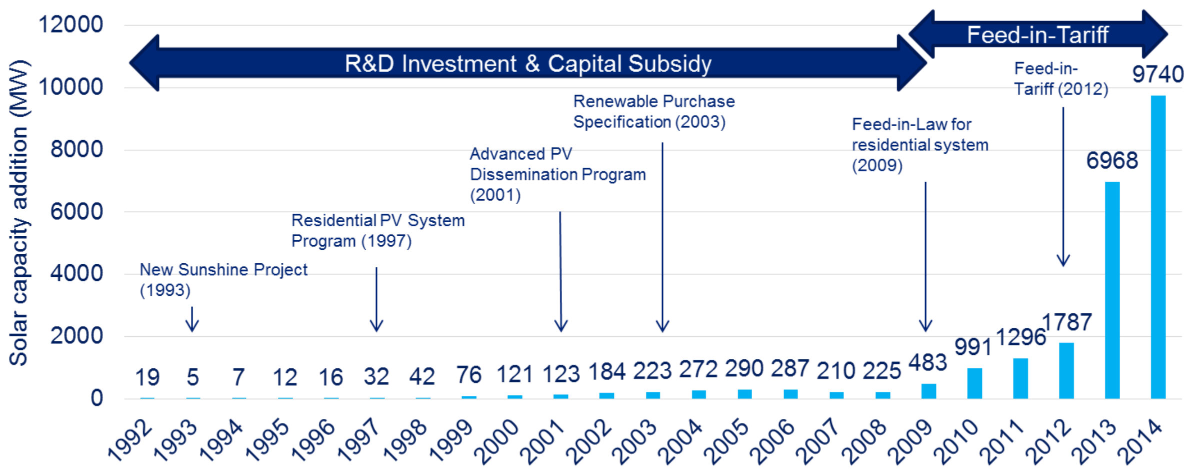


Figure 16: Growth trend in Solar Capacity with change in Policy environment

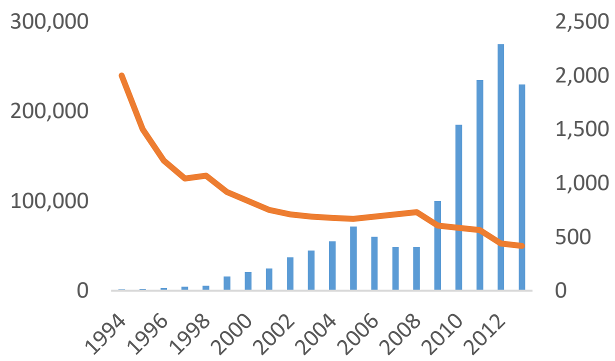
As of now, Solar PV accounted for 10% of Japan's electricity demand on some of the hottest summer days, and represented 3% of total power generation in 2015[5]. Large volume of Capacity addition in Solar PV projects exceeded the capacity of the grid in Japan that leads the government to revise regulation and causing utilities to refuse new interconnection and curtail the output of existing projects without compensation.

3.4.2 Key initiatives to promote solar PV

Evolution of Japanese Solar PV market started way back in 1974 with the launch of "Sun Shine Project". Sun Shine project is a long term, large scale project scheduled to run from 1974 to 2000 with a goal of developing sufficient alternative energy sources to meet considerable energy needs of Japan by 2000's. It includes research and development programs for solar, geothermal, coal, hydrogen energy technologies. In 1993 a re-organization of national program was done by combining sun-shine and moon-light

[5] *REN 21-2016*

projects with the environmental issue new projects to give rise to new program called "New Sun-Shine projects" which is scheduled up to 2020 with the estimated budget of 1.5 trillion yen[6].



Source: National Energy Foundation and J-PAC

As a part of Sun-shine program, the government launched Residential PV System Program. The program was launched in 1994 and laid a strong foundation for the world's largest residential PV market. The program ended in March, 2014 and till that time the program is expected to solarized over 1.5 million residential roofs and added about 6 GW of solar PV capacity in Japan

Between 1994 and 2005, the program funded close to 300,000 residential PV systems. In this period, Japan dominated the global Solar PV market both in terms of installation and production. The cost of average residential PV system was greatly reduced to ¥661 per watt with an incentive rate of just ¥20 per watt (or 3% of the system cost). During this point, the Japanese government concluded that the domestic PV market became self-sufficient and discontinued the residential incentive program[7].

During 2006 to 2008, Japan solar market faced its first market contraction due to the inability of domestic module manufacturers to provide models. Since domestic module makers shifted their focus to Europe for huge demand and better profits. Recognizing this, the federal government brought back the residential PV incentive program in January 2009 with an incentive rate of ¥70 per watt. The domestic PV market was revitalized and Japan celebrated its one million solar-roof installations in April 2012. According to data published by the Japan Photovoltaic Expansion Center (J-PAC), the program supported 276,051 residential PV system installations during fiscal year 2012 (April 2012 to March 2013).

In order to accelerate the growth in solar PV installation, Japan shifted its focus from the traditional residential segment to the non-residential segment with the launch of the national FIT program in July 2012. Before the new FIT program started, Japan's Ministry of Economy, Trade, and Industry (METI) implemented the Purchase Program for Surplus PV Power in November 2009.

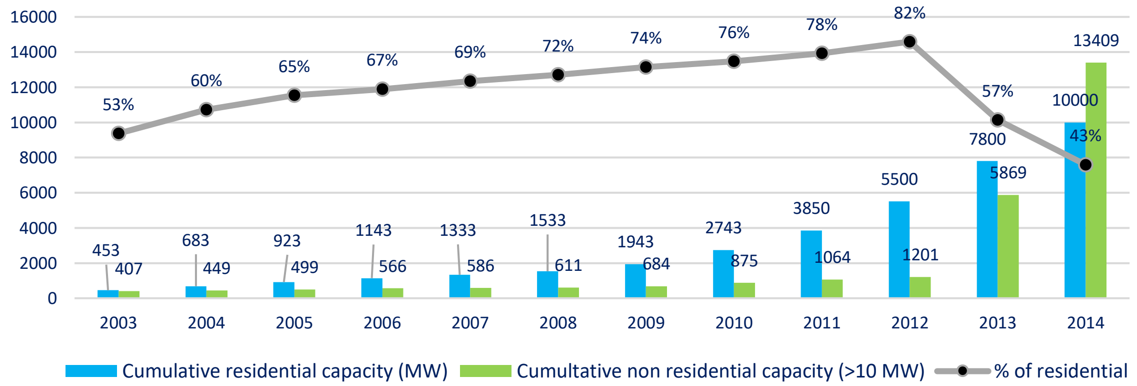


Figure 17: Solar PV Capacity (MW) in Residential and Non Residential Segment

6 *http://unesdoc.unesco.org/images/0009/000948/094830eb.pdf*

7 *Renewable Energy World - Japan FIT Changes Reflect End of Residential PV Program*

Under this law, electric utilities were obliged to purchase surplus PV power. In the case, all the generated power from solar PV can be sold if the installed capacity of the PV system is 10 kW as shown in the table below.

Table 3: FIT Scheme Details

		Residential	Non-residential
Capacity		Below 10 kW	Above 10 kW
Duration (in years)		10	20
Scheme		Excess electricity only	Total electricity produced
Purchase price (Yen/ kWh)	**2012**	42	40 + tax
	2013	38	36 + tax
	2014	37	32 + tax
IRR		3.2%	6%

Source: METI, 2014

In order to fund FIT, Japanese government introduced Renewable Energy Surcharge per kWh on customers with some exceptions keeping in view industry competiveness and earthquake hit citizens. Government allowed exemption to earthquake hit customers and 80% reduction to heavy electricity consumers industries (consumption higher than higher 1,000,000 kWh) considering adverse business impact.

Table 4: FiT surcharge rate for 2014

	2012	2013	2014
FiT surcharge (Yen/ kWh)	0.24	0.35	0.75
Cost accrued with the purchase of renewably produced electricity (billion Yen) (A)	250	480	900
Administrative costs (billion Yen) (B)	1.7	2.5	2.7
Avoided costs (billion Yen) (C)	120	167	248
D = A+B-C (billion Yen)	130.3	313.3	654.7

Source: JREF, RTS 2014

FIT provided incentives for non-residential categories and as a result the solar capacity in non-residential category took off very quickly. The start of the FIT generated an immediate surge of PV applications to METI and within 2 years the total capacity applied for increased to 68.7 GW. Around 55 percent of the approved capacity after FIT introduction had been added by large-scale projects, 41 percent by mid-size projects and only 4 percent by residential PV projects (below 10 kW).

Thus, Japan presents a successful case for solar PV deployment by using combination of Investment/Capital subsidy, R&D investments and RPS (2003) to promote the solar PV industry till around 2005. Post 2005 the capital subsidy was withdrawn which led to the fall in the market, In 2009 Japan again renewed its interest in solar PV promotion through introduction of a FIT.

3.5 Case Studies - Impact of Rooftop Solar on Utility Business

Case-1: Impact on Tariff Structure

In Net Metering framework, rooftop consumers meets part of their energy requirement through solar rooftop and remaining though grid. This makes grid to act as a backup power for consumers. Further, rooftop consumers are generally exempted from wheeling and transmission charges for the energy they procure from rooftop solar. Thus utilities sales and revenue suffers with increase in the capacity of Distributed Generation/rooftop solar.

Due to the same reason, UniSource Energy Services (UNS), a utility serving in Arizona saw a reduction of 8% in its annual sales. The decline in sales is due to several factors, including:

- The shutdown or curtailment of operations by certain large customers
- The commission's EE and Distributed Generation (DG) requirements
- The slow pace of economic recovery.

UNS electric's current rate design relies heavily on volumetric sales to recover a majority of fixed costs. And Utility feels that this model requires adjustment at a time when usage per customer is expected to decline, driven by increasingly successful EE programs and growing DG usage. Moreover, without changing the current tariff structure, utilities will not be able to recover its costs and earn an appropriate return on its investments.

In view of this, UNS proposed to increase its fixed monthly rate from $10 to $20 in its application to Arizona Corporation Commission. The Company's proposed to include a mandatory three-part rate design for new residential DG users and new small commercial DG users. The proposed rate design will allow utilities more equitable cost recovery in an environment where overall electricity sales are declining yet the requirement of the grid has increased. The rate design changes proposed by the company is as follows:

a) **Basic Service Charge:** A basic service charge to recover some fixed costs, such as the meter, service lines, customer service and billing function, and minimum distribution system costs.
b) **Demand Charge:** A demand charge to send appropriate cost-of-service price signals and allow for recovery of fixed transmission and generation costs necessary to satisfy a customer's maximum electric demand over a specific period of time.
c) **Rate Tiers:** UNS Electric is proposing to eliminate certain upper tiers to reduce this cost shift and enhance company's ability to recover its fixed costs.

Moreover, the company also proposed that the three-part rate design would be mandatory for all new DG and other partial requirements customers and would be available as an option for non-DG customers.

Case-2: Impact on Cross Subsidy

Net Metering mechanism helps the market to grow itself but it may also burden the non-solar consumers with rise in retail tariffs. As due to high retail tariff, cross subsiding consumers are expected to switch to rooftop solar and leaving the burden of cross subsidy on lower consumer bases. In order to recover the cross subsidy, utilities will be forced to increase the tariff, thus to avoid high rates more consumers will switch to solar.

To counter this, Utilities in USA have proposed new fees and interconnection charges for solar users. The companies say that as more customers adopt rooftop solar, fewer will be left to pay for the upkeep of the power plants, transmission lines and substations, which solar customers still rely on when their panels aren't generating power. Hence Utilities have also proposed lowering the rate at which solar customers are compensated for the surplus electricity they generate and don't use.

Utility's suggestion

In view of this, Edison, which serves 130,000 homes with rooftop solar, wants to charge future solar customers $3 per kilowatt of capacity they've installed on their roofs. If new net metering rules aren't enacted, Edison estimates non-solar customers would pay an additional $16 billion for grid maintenance over the next decade because of cost shifting from solar to non-solar customers. Other utilities also feel the same and meditating similar solutions:

i) PG&E, which serves northern and central California, also has proposed a $3 per kilowatt fee.

ii) SDG&E, wants to offer two options: Either homeowners pay a fixed, monthly curb-to-meter fee or they opt into a system where they sell all the electricity to the utility and buy all the electricity they need from the utility, at rates SDG&E did not specify.

Recent changes

The CPUC approved a rate reform package that cuts the number of electric tiers from four to two by 2019. That change will effectively raise electricity rates for people who use less and lower them for people who use more. That rate-flattening makes solar less attractive for heavy consumers of electricity, who are more likely to adopt it in the first place.

The rate reform will also stick all electrical customers with a $10 minimum bill – meaning that no matter how little electricity a homeowner consumes, he or she will pay at least $10 a month. (Additionally, time-of-use rates, in which electricity is more expensive when demand is high, will become the default, though customers will be able to opt out.)

The CPUC is in process of drafting and finalizing new set of rules. The commission will implement the new rules on July 1, 2017, or when the proportion of utilities' generating capacity from net metered sources hits 5 percent, whichever comes first. San Diego Gas & Electric is expected to hit that 5 percent cap in early 2016, while Edison and Pacific Gas & Electric are expected to hit it in late 2016.

Case-3: Impact on Utility Cash-flow/ Sales

Net Metering mechanism allows consumers to meet part of their energy requirements from solar rooftop, thus consumption from grid comes down. Which means that the more kilowatt-hours generated by rooftop solar, the fewer kilowatt-hours sold by utilities. And with fewer kilowatt-hours sold, utilities have a harder time justifying investments in new power stations, transformers and other types of capital investments that utilities earn money from.

The loss of revenue from solar PV is not only happening in sunny states such as California and Arizona but also in less-sunny New Jersey and others states with solar incentive programs. PVs, electricity storage such as lithium-ion batteries, electrification of heating and transport, energy efficiency, energy conservation and demand response, are all poised to reduce utility revenue.

In a study carried out by Lawrence Berkley National Labs "Financial Impacts of Net-Metered PV on Utilities and Ratepayers" revenue of utilities declines with PV penetration. Two utilities were studied i.e. South West Utility and North East Utility. As per the study Customer-sited PV reduces both utility revenues and costs (i.e., revenue requirements).

In the case of the SW Utility, the impacts on revenues and costs are roughly equivalent under the 2.5% PV penetration scenario. At higher PV penetration levels, however, revenue reductions exceed cost reductions, in part because of a declining marginal value of PV. In the case of the NE Utility, revenue reductions exceed cost reductions across all of the future PV penetration levels considered, and the divergence is considerably wider than for the SW Utility. This occurs because the NE Utility has higher assumed growth in certain fixed costs that customer-sited PV does not reduce. Following table illustrates the impacts of customer sited PV on revenue.

Table 5: Impact of PV penetration on Utility Earnings

	Earnings Impacts (NPV 20-yr)			
PV Penetration	***2.5%***	***5%***	***7.5%***	***10%***
Southwest Utility	-4%	-4%	-8%	-8%
Northeast Utility	-4%	-9%	-12%	-15%

Source: Lawrence Berkley National Labs

Thus, PV reduces earnings as a result of both revenue erosion and also deferred capital investments ("lost earnings opportunity effect").

Case-4: Impact on Market Models and Pricing Framework

Solar Rooftop generates electricity during day time, however in State's where peak demand occurs during evening could promote storage solutions to manage the day time excess generation by meeting peak demand during evening. In current regulatory and policy framework, such market models do not have any provisions which otherwise could support utility at times of evening or morning peaks.

As per the California ISO (CAISO) increase in the availability of solar generation in the early afternoons have resulted in the creation of a great deal of potential for oversupply at some times of day during specific seasons. Based on this analysis, CAISO expects an increasing mismatch between current design of time of utilization (TOU) rates, which encourage a reduction in demand during afternoons in favor of evening usage, and the likely availability of electricity over the coming years.

According to CAISO, this mismatch, in which high energy demand persists at a time when fewer renewables are available, could threaten reliability. As a result, CAISO has proposed to change the existing TOU periods in order to discourage electricity use during those periods when supplies may be lower, such as weekday late afternoons in the spring and to encourage the use of renewable distributed generation at those times. Based on its analysis, CAISO recommends a TOU rate structure with seasonal variations in the times for peak rates. Specifically CAISO proposes the TOU period structure as show in the following figure:

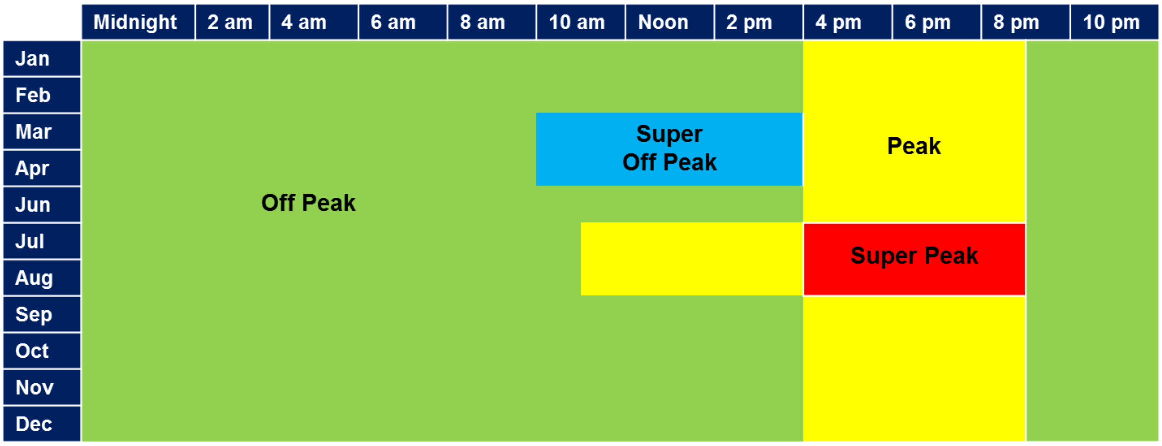


Figure 18: Weekdays Peak Hour

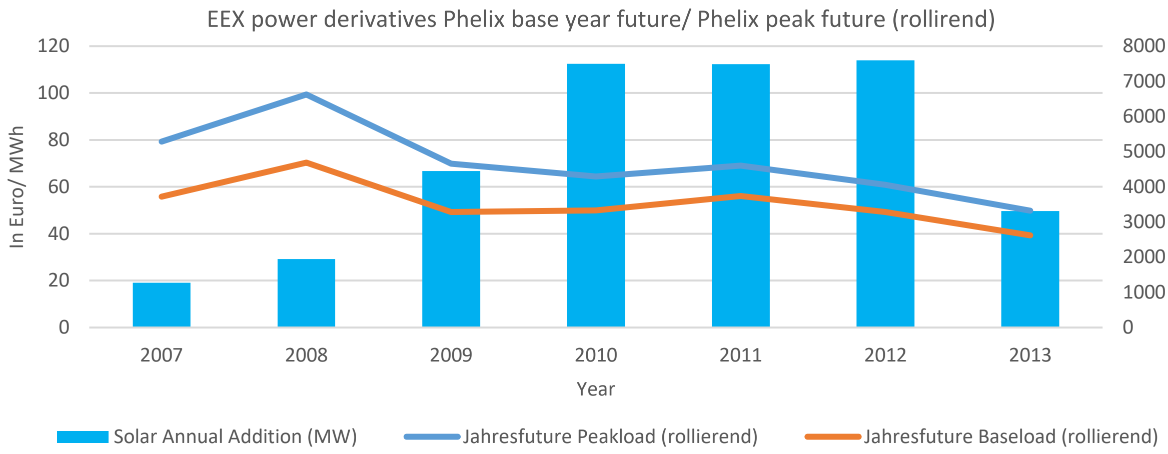
Under this proposed TOU period structure, the daily peak period on both weekdays and weekends would be from 4 p.m. to 9 p.m. daily. In summer months, July and August only, electricity during these hours on weekdays would be at an even higher, "super- peak" rate, with the peak rate charged for usage between 11 a.m. and 4 p.m. weekdays during those months. The remaining time would be split between an off-peak rate applicable during nights and mornings, and a super-off-peak rate available during weekend and certain spring weekday afternoon. This would result in relatively lower rates during early afternoons, with higher rates during late afternoon and early evening hours.

In general, these CAISO recommendations are consistent with recent utility proposals to modify TOU periods. The SCE and PG&E RDW cases, in which new, later peak periods have been approved, differ from the SDG&E RDW in at least two respects:

1) SDG&E proposed changes applicable to all customers, whereas the SCE and PG&E proposals were limited only to some customer classes, and
2) The SCE and PG&E RDWs resulted in unopposed settlements, which are subject to a different standard of approval than fully litigated cases.

Case-5: Impact on Power procurement cost

Germany presents a case where increase in solar installations has resulted in falling wholesale prices. As solar tends to replace costlier source of power production. There has been consistent falling wholesale prices with addition of solar generation. As the renewables levy reflects the difference between FIT payments to renewable energy producers and the market value of the produced electricity when sold on wholesale markets.



Source: EEX, reproduced from BDEW, Strompreisanalyse November 2013

Figure 19: Impact of Solar on Wholesale price (base and Peak Load)

The German Transmission system operators (TSOs) are either required to pay renewable energy producers the FIT price and sell the energy produced on the wholesale market or pay a market premium if the producer choses to sell the generated electricity directly on the market. The TSOs are then compensated for all expenses (FIT + market premium) exceeding the revenues from his sales via the renewable levy.

Thus, wholesale price reductions are having some of this effect in Germany today. As a result of significantly reduced operating hours and lower wholesale prices, much of the existing fossil generation fleet does not cover its operating costs. The big German utilities (E.On, RWE, EnBW and Vattenfall) owning the bulk of fossil generation have seen their share prices fall sharply, and have been suggesting that the operating losses suffered by its fossil generation are not sustainable and will likely lead to significant plant retirements, absent some major adjustments to market mechanisms.

Key observation: The increasing power generation from renewable energy sources is a major contributor to falling wholesale market prices in Germany as is evident from table below

Description	2007	2013	% Decline
Average Base load Price	€55.83/MWh	€39.31/MWh	30%
Average Peak load Price	€79.36/MWh	€49.83/MWh	37%

Conclusion: Residential and commercial customers benefit since their suppliers pay less for acquiring power in the wholesale market, assuming that the wholesale price decline is passed on to final consumers. Industrial customers may benefit even more if they can access the wholesale market directly.

Case-6: Quantifying environmental benefits of rooftop solar

In addition to meet the energy requirement, solar rooftops also contributed towards the environment by producing clean energy. Sierra Club worked with Berkeley consulting firm Cross border Energy conducted a study to quantify benefits of rooftop solar in a way that could be used in the cost/benefit model the PUC is relying on for its decision, called the "Public Tool." Their analysis concluded that rooftop solar provided about 10 cents of societal and environmental benefits for every kilowatt hour of generation. Table is showing the contribution of various environmental benefits from solar rooftops

Table 6: Environmental benefits from rooftop solar

S. No.	Benefit	Quantified benefit
1.	Reduced Climate Impacts	3¢/kWh
2.	Cleaner Air	2¢/kWh
3.	Conserved Water	1¢/kWh
4.	Preserved Open Space	2¢/kWh
5.	More Resilient Energy System	2¢/kWh
	Total	**10¢/kWh**

Source: Sierra Club (Non Energy benefits of distributed generation)

As per their white paper Non-Energy Benefits of Distributed Generation, that ten cents includes the value of each of these benefits:

1. **Reduced climate impacts -** The EPA's Social Cost of Carbon estimates that each metric ton of carbon dioxide will cost society up to $120 in 2015 -- equivalent to $0.03 per kilowatt hour of rooftop solar generation from avoided carbon emissions.
2. **Cleaner air -** Less pollution means fewer health costs borne by society in the form of emergency room admissions, lost work days, and premature deaths. The EPA estimates that these costs total $24 for each pound of particulate matter, and $184 for each pound of nitrous oxide, equivalent to $0.02 per kilowatt hour of rooftop solar generation from avoided air pollution.
3. **Water conservation -** Generating electricity from natural gas requires a lot of water. Analysis base estimate on the value of water on what it would cost to retrofit existing gas plants to convert to cooling technology that uses no water, or to desalinate ocean water. The estimate comes to about $1,600 for each acre-foot of water saved, adding about $0.01 to the value of each kilowatt hour of renewable generation.
4. **Open space preservation** - When we use the existing built environment for energy production, we protect California's open spaces and priceless natural heritage. Analysis base estimate on the value of agricultural land, leading us to conservative value of $0.02 saved for each kilowatt hour of rooftop solar generation.
5. **A more resilient power system** - Rooftop solar insulates against the energy security threats to reliability by siting generation close to load. When paired with storage and smart inverters, it will increasingly be able to provide a host of grid services to help stabilize power flow and keep power on during grid outages. By our estimates, this security is worth $0.02 for each kilowatt hour of rooftop solar generation.

Case-7: Operational Initiatives

Increasing capacity of solar distributed generation will also have an impact on operational parameters such as voltage, frequency, phase imbalance etc. of distribution utility. In order to compensate utilities for the same, the Intermountain Rural Electric Association (IREA) proposed a new Load Factor Adjustment Rider that would apply to new residential customers or those installing solar after December 30, 2015 in Colorado. The charge would apply to any residential customer who has a load factor less than or equal to the Load Factor Threshold (9% or 10%) in a billing period.

<u>Key observations</u>

- The Association will measure the consumer's load factor percentage by dividing the energy (kWh) consumed in a full billing cycle by the product of the maximum demand (kW) and the number of hours in the billing period (kWh/kW x days x hours). For each billing period in which the calculated load factor is less than or equal to the Load Factor Threshold, the consumer's bill will be adjusted by an amount equal to the peak demand times Load Factor Adjustment applicable for the rate.

- Proposed Load Factor Adjustment Rate

Rate Description	Load Factor Adjustment/kW	Load Factor Threshold
Residential Service (A)	$4.04	9%
Residential Incorporated City or Town Service (CS)	$4.13	10%

The utility (IREA) wants to ensure that the load on DT level should not fall below 10% and proposed a penalty for customers breaching the limit thus impacting rooftop solar customers adversely.

Case-8: Impact on T&D cost

Solar rooftops helps consumers to generate and consumer power locally, thus reduced burden on distribution or transmission system. With increase in the capacity of these system, utilities could avoid the cost of developing new transmission or distribution lines for evacuating power from large utility scale projects to the end consumers.

To evaluate the saving in the cost of T&D due to solar rooftop, Cross border Energy conducted a study "The Benefits and Costs of Solar Distributed Generation for Arizona Public Service[8]". The study pointed out the case studies which results in avoided cost in transmission as approx. 2 cents/ kWh while for distribution the avoided cost came out to be approximate 0.2 cents/ kWh. The Study reported that Arizona Public Service (APS) incurs $125 million in high-voltage transmission costs for every 400 MW increase in peak demand, and $7 million in lower-voltage sub-transmission costs per 30 MW of load growth. It also shows $29.5 million in deferrable sub-transmission costs for a 130 MW decrease in peak demand.

In the long-run, solar DG combines with EE and demand response (DR) resources to defer such costs even if, over a short-term period such as a three-year transmission planning cycle, none of these small-scale resources individually amounts to 400 MW or to the smaller amounts in specific areas that is required to defer sub transmission projects. Given that EE, DR, and DG resources will combine to reduce APS's peak demands by 1,150 MW in 2017, it seems clear that, in aggregate, these resources will avoid significant transmission costs on the APS system.

The Study concluded that distribution capacity cost savings are possible if demand reductions from DG exceed load growth on distribution feeders or substations, and if solar DG can be targeted to specific locations where circuits would otherwise need an upgrade. The study valued these reductions using a distribution avoided cost of $133,000 per MW of DG ($133 per kW). Moreover, even on a circuit whose loading is below the 90% threshold today, PV can reduce the peak loading and defer the future date when that circuit's loads exceed the 90% threshold, a date that may be beyond the current distribution planning period but well within the lives of the installed PV systems.

[8] *Thomas Beach et al*

4 Impact of rooftop solar on Indian utilities

Deployment of customer-sited photovoltaics (rooftop solar) in countries like United States has expanded rapidly in recent years, driven in part by public policies premised on a range of societal benefits that PV may provide. With the success of these efforts, heated debates have surfaced in a number of countries about the impacts of customer-sited PV on utility shareholders and ratepayers, and such debates will likely become only more pronounced and widespread as solar costs continue to decline and deployment accelerates.

Rooftop solar development in India is currently in a nascent phase of development. However, with GOI targeting 40 GW of rooftop solar capacity addition and with expected increase in rooftop solar penetration levels, it can be expected to face issues from distribution utilities in India.

Rooftop solar project offers multiple benefits in the form of savings in T&D losses, environmental benefits (reduced GHG emission, lower water requirement & no land requirement), and avoided capacity during peak solar generation. Depending upon the State regulatory framework, Discoms will also be eligible for deemed Solar RPO benefit for the solar power consumed under net-metering framework by the consumer. Given the financial & operational capabilities of Indian utilities, it is important to understand the extent of impact rooftop solar will make on the utilities.

4.1 Impact on Utility – key parameters

To develop and analysis various cases and scenarios, the parameter accessed and key assumptions taken are as follows:

- Capacity addition target for Rooftop solar (FY 2022) has been taken from MNRE in MW. For computation of energy produced by rooftops a CUF of 16% is considered.
- State wise, year-wise Capacity addition in selected States considered as below :

State-wise MNRE Rooftop solar annual addition targets (MWp)							
State	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Delhi	5	132	138	165	190	220	250
Gujarat	15	385	400	480	560	640	720
Odisha	5	120	125	150	175	200	225
Tamil Nadu	15	420	438	524	613	700	790
Maharashtra	20	565	588	704	823	940	1060
Andhra Pradesh	10	240	250	300	350	400	450
Telangana	10	240	250	300	350	400	450
Uttar Pradesh	20	510	538	650	752	860	970

- Rooftop solar capacity across category
  - Total state-wise solar rooftop target is divided into utilities' in proportion of respective energy requirement
  - Utility's solar addition is further divided into residential, commercial and industrial categories in ratio of their respective energy consumption assuming all capacity addition will come under Net Metering mechanism and energy produced from rooftops shall be consumed within these three categories

- **Revenue loss to utility** - Revenue loss to utility is calculated assuming that all solar MUs would be replacing the energy sold by utility to customers in the 2 scenarios (Scenario-I and Scenario – II).

- **Scenario - 1:** If the rooftop solar replaces the energy MUs consumed by the existing customers and that customer falls in the highest energy slab tariff paying category.
- **Scenario -2:** If the rooftop solar replaces the energy MUs consumed by the existing customers and that customer falls in the average tariff paying category.

- **Loss of Cross Subsidy** - The impact on cross subsidy is calculated as difference b/w avg. COS (Cost of Supply) and Energy Charge/Avg. Energy Charge considered and depending on quantum of energy replaced.

- **Loss of grid Charges** - Grid charges loss to utility is calculated assuming reduction in contract demand by rooftop consumer by 10%.

- **Loss of Banking Charges** - Loss for utility is calculated assuming 30% of energy generated from rooftop solar is banked and do not pay 2% banking charge (assumed in-kind i.e. MU). Price for calculating the impact has been taken as APPC price.

- **RPO Benefit to utility** - The impact of getting deemed RPO for utility is calculated assuming Solar REC price as alternative option for meeting Solar RPO compliance.

- **Benefit in T&D losses** – Rooftop solar power as is generated in consumer premises will result in utilities benefit from savings in T&D losses. The MU saved in T&D losses due to rooftop solar is quantified using the APPC rate.

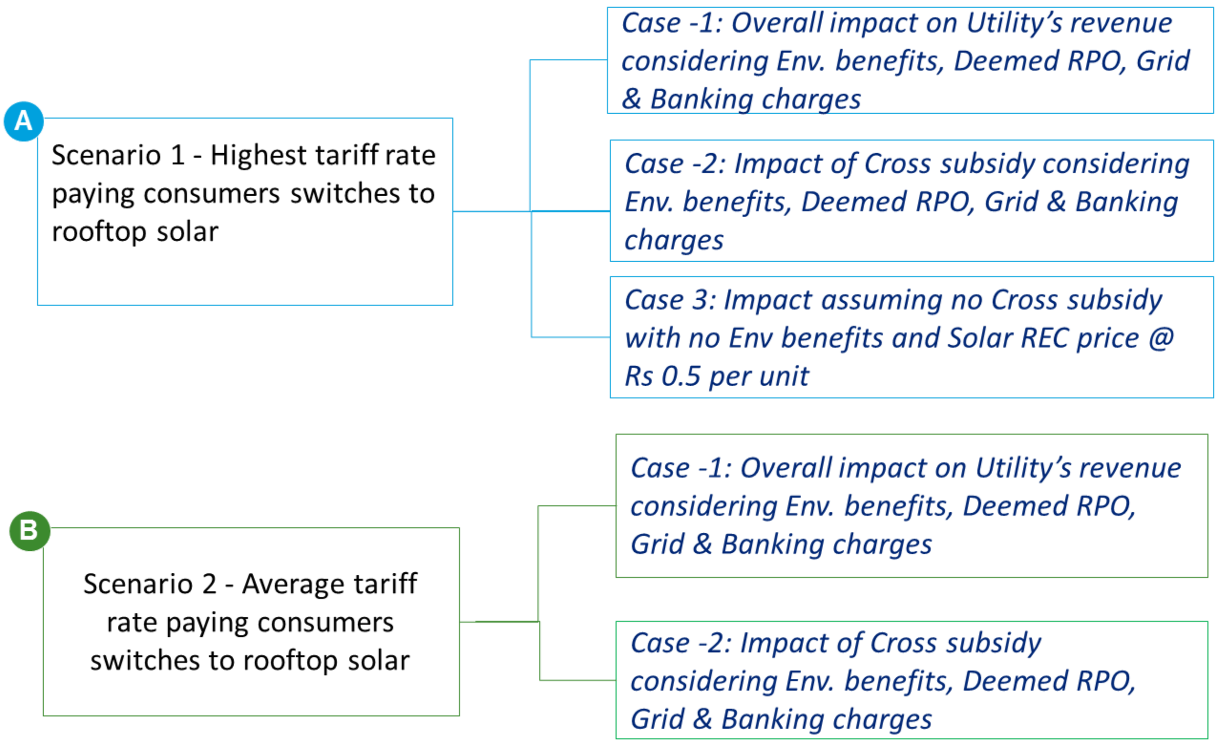
- **Environmental Benefit -** Various tangible impacts as reduction in water, land and CO_2 emission has been used in line with the prevailing prices for these savings to determine total tangible benefits on account of rooftop solar generation vis-s-vis thermal power projects.
  - Water Saved : Water saving is calculated based upon water required by thermal power plants subtracting water requirements by PV plant for module cleaning for MNRE rooftop targets FY 2022
  - CO_2 Impact assessment: CO_2 emission factor (0.82 ton CO2/MWh) assumed (Source - CEA report). CO_2 emissions reduction potential has been estimated by multiplying total annual PV generation and emission factors.
  - Avoided Land Impact assessment: Land use impact data (in acres/MW) has been collected for and thermal power plants to calculate effective land savings (in acres) by installing rooftop PV plant. Land coverage factor of 5 acre per MW for ground mounted PV and 1.42 acre/MW for thermal power plant has been assumed.

4.1.1 Cases & Scenarios

The case details indicative analysis to understand the impact on utilities as well as benefits from rooftop solar in case utilities achieve the rooftop solar capacity targets proposed by MNRE for different states for FY 2022.

The utilities wise targets are mapped based on the projected energy requirement of the respective utility in year FY 2022. To analyze the impact on Utility, different cases and scenarios have been developed, which are shown in the figure

Figure 20: Cases and Scenarios



C. Scenerio-1: Highest tariff Paying Consumers Switch to Rooftop Solar

The Scenario 1 considers that rooftop solar power will replace the consumer consumption mapped at highest tariff slab in a particular consumer category. The analysis below covers three cases under Scenario 1.

- **Case-1: Impact of solar Rooftop on Utility Revenue**

Case 1: This assumes the highest tariff paying consumer's switch to rooftop solar. The impact on utility is in terms of : revenue loss, loss in fixed charges (assuming 10% of the solar capacity will result in sanctioned load reduction), loss in banking charges (assuming 30% of energy generated from rooftop solar is banked and do not pay 2% banking charge @ APPC price). The benefits for utility is Deemed RPO (@ Solar REC price of INR 3.5/kWh), environmental benefit and savings in T&D losses.

Proliferation of Solar Rooftops will have both positive and negative impact on the Utilities' revenue, this case explains the impact of solar rooftops on utility revenue for FY 2022 assuming that the capacity addition in rooftop segment will be as per MNRE's target. With increase in the retail tariff, higher number of consumers will shift to rooftop, this will result in the reduction of sales volume and hence reduction in utility revenue. As the rooftop capacity is expected to increase with time in view of increase in retail tariff and falling cost of rooftop system, the loss of revenue is expected to increase with time. However, Rooftop capacity will also have positive impact on utility revenue due to deemed RPO benefit, environmental benefit, saving in infrastructure and reduction of technical losses etc., which will also increase with increase in rooftop capacity.

As per the analysis the overall impact under this case for utilities will be negative. Revenue loss to selected utilities due to solar rooftops will be in the range Rs. 7.3/kWh to 1.2/kWh depending upon the retail supply tariff and energy requirement to be met through solar rooftops.

The overall impact (Rs/kWh) of rooftop on utility revenue in FY 2022 is shown in the following graph. The graph also depicts the impact of rooftop on various factors of utility revenue:

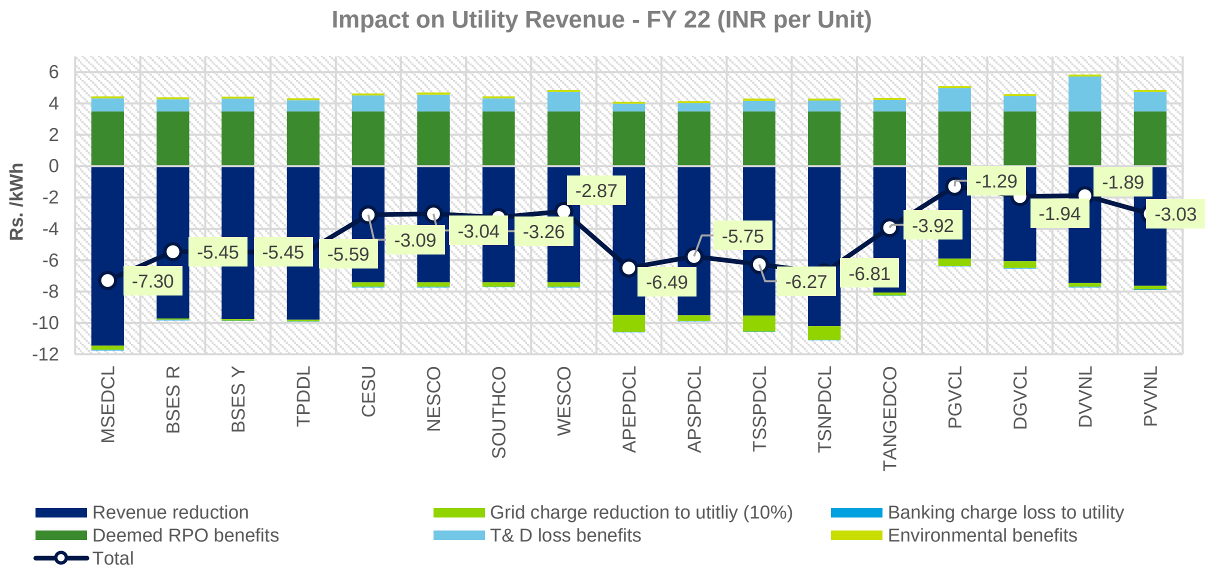


Figure 21: Impact on Utility Revenue due to Solar Rooftops

Utilities with low energy charge have lower negative impact. Utilities having high T&D losses will gain from rooftop solar

- **Case-2: Impact of solar rooftop on Cross Subsidy**

Case 2: This Case assumes that the highest tariff paying consumer's will switch to rooftop solar. The impact on utility is in terms of : cross subsidy loss, loss in fixed charges (assuming 10% of the solar capacity will result in sanctioned load reduction), loss in banking charges (assuming 30% of energy generated from rooftop solar is banked and do not pay 2% banking charge @ APPC price). The benefits for utility is environmental benefits, Deemed RPO (@ Solar REC price of INR 3.5/kWh) and savings in T&D losses.

This case explains the impact of solar rooftops on utilities from the perspective that the loss utility is linked with loss of cross subsidy (and not complete energy charge). With increase in the affordability of solar rooftop system and rising retail tariff, utility consumers are expected to go for solar rooftop. As the high tariff paying consumers will start shifting to solar rooftop, the utility sales will start falling. This will also impact the collection of cross-subsidy, which utility was collecting from consumer.

In addition to this utility will also lose revenue through exemption in banking charges for solar rooftops and reduction in demand charges. However it will also earn though deemed RPO benefit and reduction in technical losses.

In this case, the overall impact on the revenue is positive. The impact of all the parameters including the cross subsidy for utilities for FY 2022 is shown in the following graph. As per the analysis, except MSEDCL, all utilities other are having positive impact of solar rooftop.

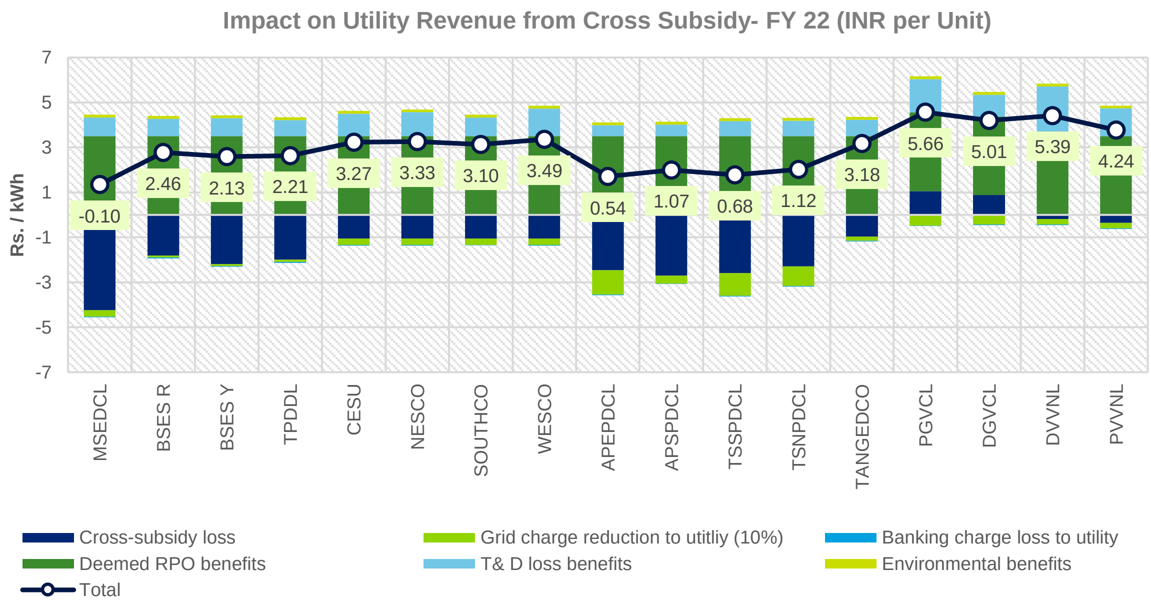


Figure 22: Impact of Solar Rooftops on Cross Subsidy

Utilities with low cross subsidy levels will have lower impact. Consumer categories having energy charge lower than COS & adopting rooftop solar will benefit utilities.

- **Impact of Solar Rooftop in progressive scenario**

Case 3: This assumes the highest tariff paying consumer's switch to rooftop solar. It is assumed that the Cross subsidy will become zero in FY 2022 and no environmental benefits is considered to analyze the impact. The impact on utility is in terms of: loss in fixed charges (assuming 10% of the solar capacity will result in sanctioned load reduction), loss in banking charges (assuming 30% of energy generated from rooftop solar is banked and do not pay 2% banking charge @ APPC price). The benefits for utility is only Deemed RPO (@ Solar REC price of INR 0.5/kWh) and savings in T&D losses.

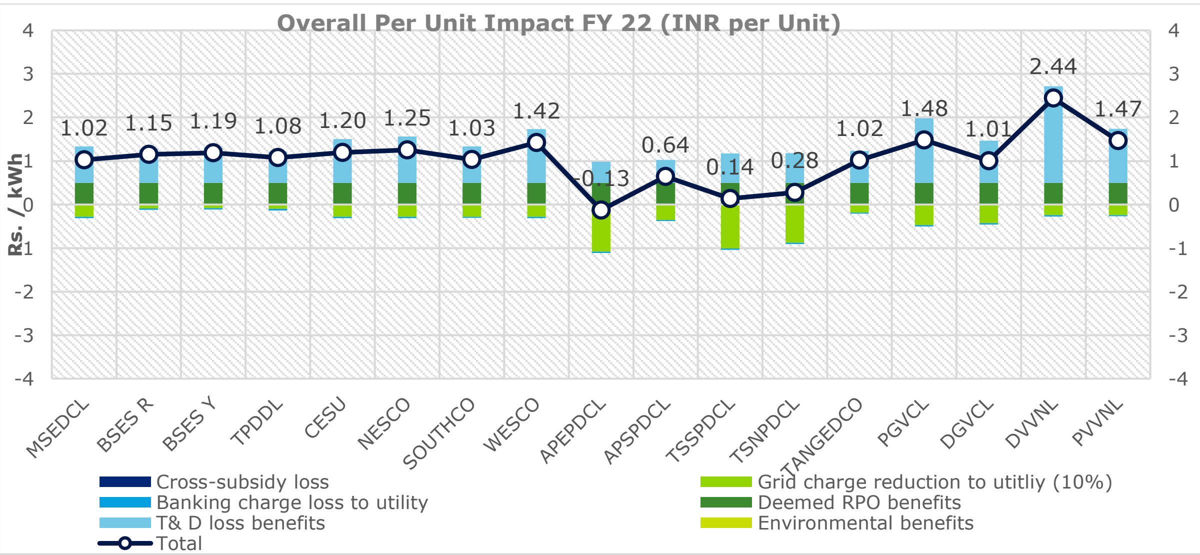


Figure 23: Impact on utility revenue in Progressive scenario

This is assumed to be a progressive case where it is assumed that the cross subsidy component from retail tariff will become zero and utility consumers will charge consumers as per the cost of supplying to that particular consumer. Recognizing the falling cost trend, it is also assumed that the floor price of solar REC will drop down to Rs. 0.50/kWh from Rs. 3.50/kWh in 2022.

In this case the impact on utility due to solar rooftop will be on the revenue loss from fixed charges, banking charges, and benefits from deemed RPO & reduction in technical losses.

As per the analysis, the overall impact of solar rooftop on utilities will be positive in this case.

As the reduction in power purchase cost on account of reduction in technical losses will have dominating impact on the utility revenue as compared to revenue loss on account of reduction in demand and waiver of banking charges. The graph above is depicting the impact of solar rooftop on utility revenue in progressive scenario.

D. Scenerio-2: Average tariff Paying Consumers Switch to Rooftop Solar

The Scenario 2 considers that rooftop solar power will replace the consumer consumption mapped at average tariff slab in a particular consumer category. The analysis below covers two cases under Scenario 2.

Case 1: This assumes the Average tariff paying consumer's switch to rooftop solar. The impact on utility is in terms of : revenue loss, loss in fixed charges (assuming 10% of the solar capacity will result in sanctioned load reduction), loss in banking charges (assuming 30% of energy generated from rooftop solar is banked and do not pay 2% banking charge @ APPC price). The benefits for utility is Deemed RPO (@ Solar REC price of INR 3.5/kWh) and savings in T&D losses. The following graph is showing the result of the analyses for FY 2022 for selected utilities

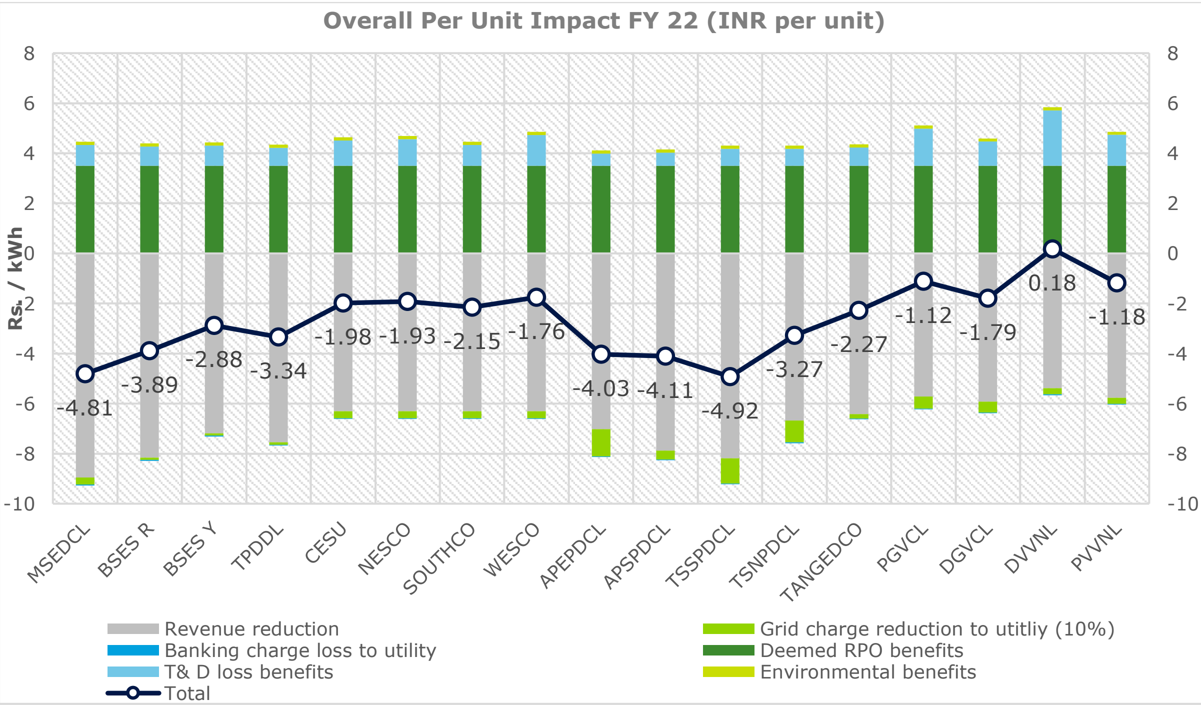


Figure 24: Impact on Utility Revenue due to solar rooftop

The result of the analysis is shown with the help of above graph, which represents the behaviors of various parameters of utility revenue to be impacted due to installed solar rooftop capacity for year FY 2022. The analysis shows that utilities will have negative impact on revenue due to solar rooftop as due to solar rooftop, utility sales volume will decrease and so as its revenue. However, Utility will also have saving in expenses due to deemed RPO benefit and reduction of technical losses but the impact of sales on revenue will be much higher than the benefits accrued from solar rooftops.

Case 2: This Case assumes that the average tariff paying consumer's will switch to rooftop solar. The impact on utility is in terms of : cross subsidy loss, loss in fixed charges (assuming 10% of the solar capacity will result in sanctioned load reduction), loss in banking charges (assuming 30% of energy generated from rooftop solar is banked and do not pay 2% banking charge @ APPC price). The benefits for utility is environmental benefits, Deemed RPO (@ Solar REC price of INR 3.5/kWh) and savings in T&D losses.

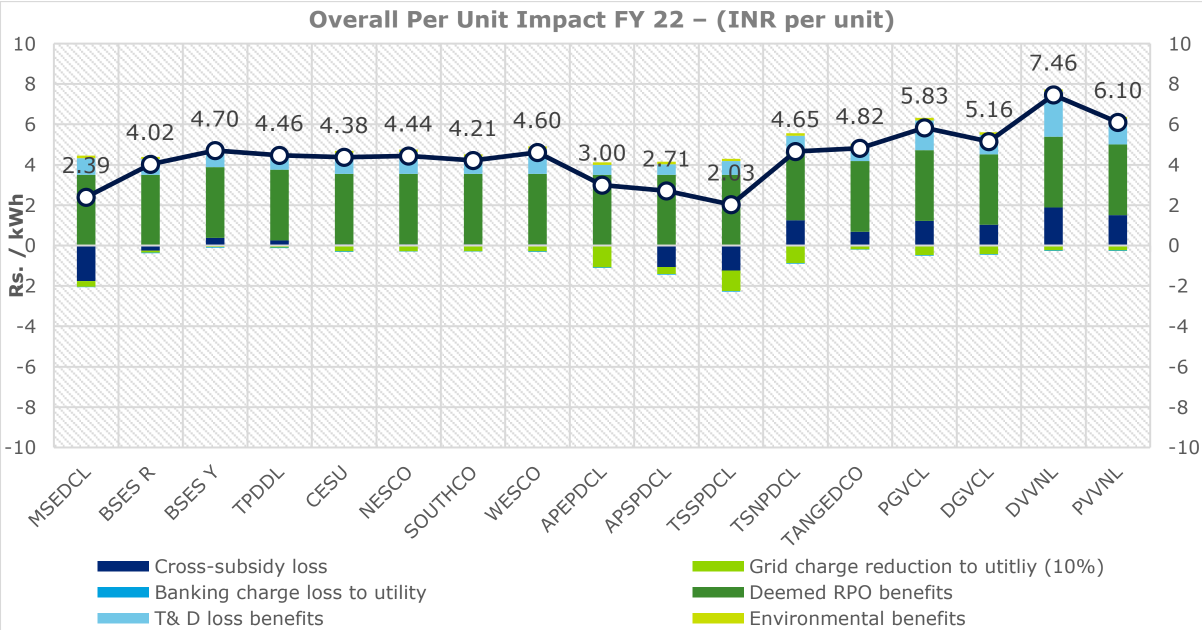


Figure 25: Impact on Cross Subsidy due to Solar Rooftop

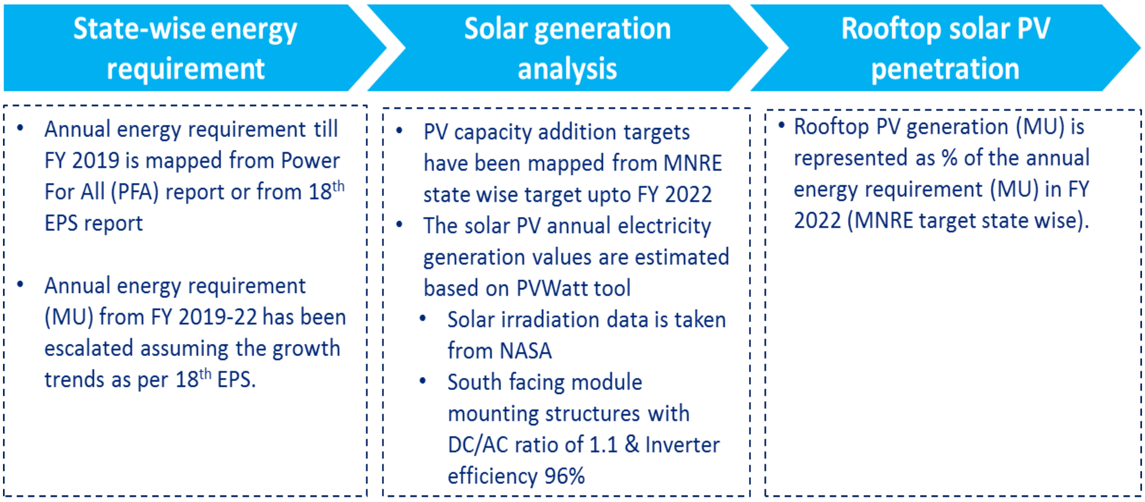
This case explains the impact of solar rooftops on utilities from the perspective that the loss utility is linked with loss of cross subsidy (and not complete energy charge).With increase in the capacity of solar rooftops utility sales will decrease and with decrease in the sales utility cross subsidy collections will be impacted. However, at the same time utility will also save revenue from other benefits such as deemed RPO and reduction in technical losses, thus the overall impact on cross subsidy will be positive in this case.

4.1.2 Impact on Operational Parameters

Proliferation of solar rooftop will also impact the operational parameters of utilities such as variation in demand, variability in generation, voltage and frequency, active or reactive power etc. this section focuses on analyzing these operational parameters & its impact on utilities. The parameters analyzed and the outcome of the analysis is as follows

i) Rooftop Solar energy penetration scenario by FY 2022

This case is analyze to assess the state wise contribution of rooftop solar in the overall energy portfolio (assuming MNRE targets are achieved). Key objective of energy penetration analysis is to understand the energy penetration on account of MNRE rooftop capacity as well as overall solar targets (MW) in FY2022. The approach to estimate the energy penetration scenario for FY 2022 is as follows



Solar energy penetration is defined as the value of the solar generated electricity (MU) as a percentage of total electricity requirement utility. Energy penetration value less than 4% is generally referred as low penetration systems, while 4-10% penetration is referred as medium and a value greater than 10% is referred as high penetration level. Based on the analysis of different States of India, the rooftop solar energy penetration scenario for FY 2022 is shown below in the following table :

Table 7: Rooftop Solar energy penetration scenario for FY 2022

State	Rooftop PV target FY2022 (MW)	Annual Energy Requirement, 2022 (MU)	Solar PLF (%)	Solar Generation, MU	Energy Penetration,%
Maharashtra	4,700	2,20,917	16.0%	6,588	**2.98**
Gujarat	3,200	1,40,767	16.0%	4,485	**3.19**
Delhi	1,100	52,930	16.0%	1,542	**2.91**
Orissa	1,000	36,961	16.0%	1,402	**3.79**
Telangana & AP	4,000	2,05,833	16.0%	5,606	**2.72**
Uttar Pradesh	4,300	2,09,046	16.0%	6,027	**2.88**
Tamil Nadu	3,500	1,71,718	16.0%	4,906	**2.86**

As per the analysis, the penetration level in all the selected States is below 4% i.e. Low penetration. Out of the eight State's only Orissa and Gujarat have penetration level above 3%, rest all have penetration below 3% only.

ii) Rooftop PV capacity (MW) penetration scenario for FY 2022

This analysis will map State wise monthly and hourly rooftop PV generation and peak demand. Key objective of this analysis is to estimate the instantaneous PV penetration based on MW penetration across different hours of the day and during different months. The approach for estimation of Rooftop Capacity (MW) penetration for FY 2022 is shown below

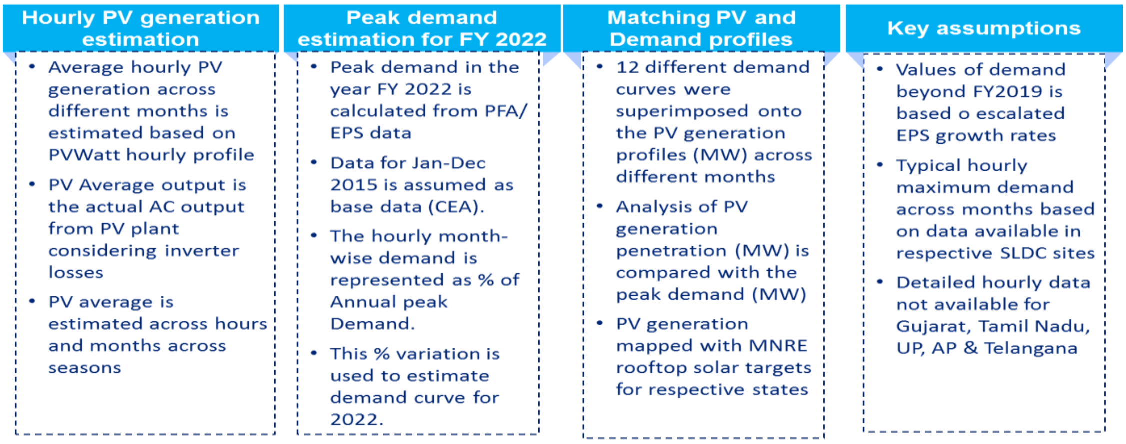


Figure 26: Approach for estimation of hourly generation of solar rooftop in FY 2022

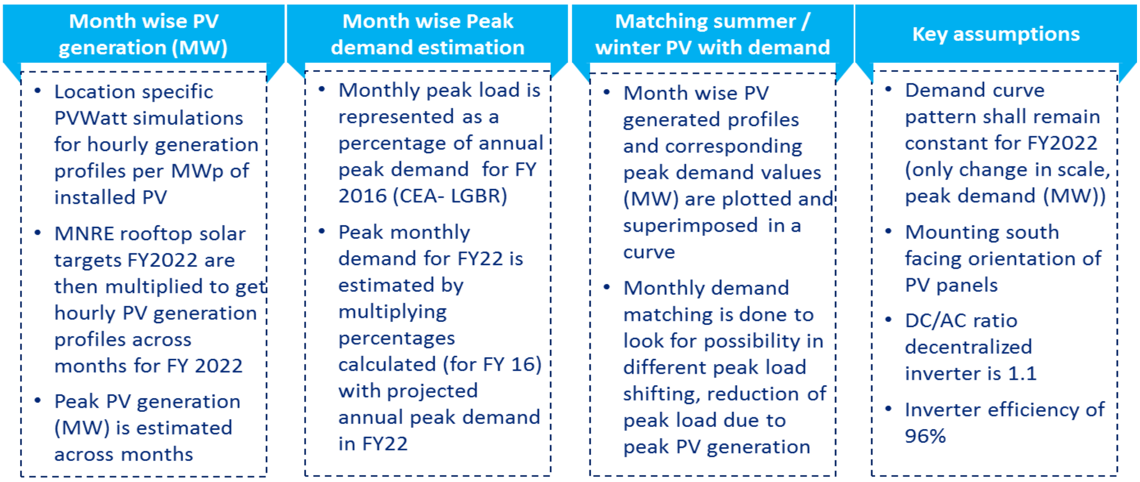


Figure 27 Approach for estimation of Monthly Rooftop PV penetration for FY 2022

The analysis is carried out for eight States, the result of Delhi is described in this section, and Analysis of other States are covered in Annexure 4. Results are explained with of graphs plotted on Hourly and Monthly PV penetration vis-a-vis overall demand of the state.

- **Delhi –** The analysis of Delhi shows that it has peak demand during the day time, especially during the month of Jan, Feb, March where the demand rise rapidly during early morning period and maintains during the day. The peak demand is high during the summer months and falls during the winter months The TOD structure also defines peak period during the day and evening time. High energy charges, along with TOD charges, make rooftop solar a viable option in Delhi. The PV Generation and Month wise peak rooftop demand for FY 2022 of Delhi is shown below

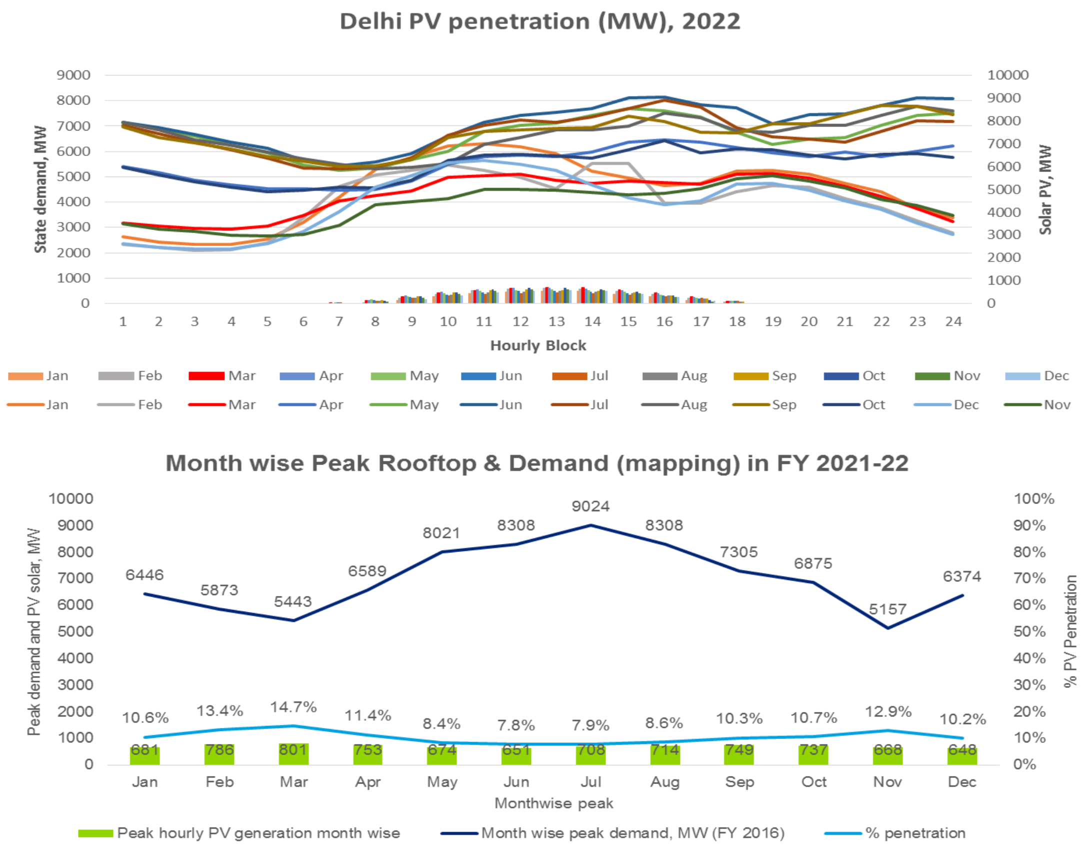


Figure 28 : Delhi - Solar rooftop & demand mapping

iii) Time of day (TOD) Analysis across selected state utilities

The objective of mapping time of day tariff structure is to map the peak hour / off peak hour time blocks matching with that of PV generation hours across different hours and months in a year. This will assist in developing a case for various options for re-structuring/defining TOD slots across consumer categories from the perspective of supporting rooftop solar proliferation.

Mapping of the TOD tariff of different States provides that most Time of day tariffs (TOD) are applicable for Industrial and Commercial segment and generally at higher voltage levels HT (except Maharashtra). There is a strong superimpositions of time of day tariff (TOD) with peak solar generation hours for Delhi, Orissa and Tamil Nadu. TOD superimposition makes these states ideally suited for incentive mechanism / tariff deign mechanism for rooftop solar proliferation. Mapping of TOD tariffs of different States is covered in Annexure 4: Impact on Operational Parameters.

Surplus electricity production during peak sunny hours matching with states having TOD during peak solar generation can incentivize solar surplus generation dispatch and hence presents case to review banking limit designs, self-consumption and load behaviors, and selection of consumer categories.

States observing evening peak i.e. Maharashtra, Gujarat, AP, UP and Tamil Nadu have possibilities for off peak storage (Normal TOD or off peak TOD time storage) and peak dispatch through electrical batteries. Storage solutions and incentive mechanism for such scenario may provide peak demand offset by a certain percentage depending upon the peak demand offset capacity battery dispatch limitations of the local grid.

iv) Avoided Capacity and Energy benefit due to Solar Rooftop

In addition to the benefits like deemed RPO, reduction in technical losses, solar rooftops are also beneficial for utilities in terms of avoiding additional capacity required to meet the growing energy demand. The objective of this analysis is to compute the capacity credit (%) for FY 2022. As per NREL Capacity credit is the actual fraction of decentralized PV installed capacity that could reliably be used to offset conventional peaking capacity. Capacity credit is typically measured as a percentage of name plate (STC) capacity rating of Solar PV. The capacity credit range of different utilities in USA and Germany is shown below in the Table

Table 8: Capacity Credit Limit in US and Germany

Country / Subcategory	Technology	LSEs (Load Serving Entity)	Capacity credit range, %
USA, Excluding Pacific Northwest	Solar	APS, CA IOU, Duke Energy, NV Energy, PNM, TEP	27% to 77%
Pacific Northwest	Solar	PGE, Idaho Power	5% to 36%
Germany	Wind	Country wide, no utility assigned	5% to 40%

Computation of capacity credit necessary to estimate the avoided energy from solar rooftop to displace energy that Utility generally required to procure from other sources. Avoided energy is generally measured in terms of cost of avoided energy. For computation of capacity credit, approach as per NREL is considered, which is explained in the following figure :

Inputs	Activities	Tools & Methods used
▪ Hourly demand data across months (MW) for FY2022 ▪ Solar PV generation profiles (hourly MW profiles) for FY2022 ▪ Peak Time of day duration mapping from state latest tariff orders FY2015-16	Following steps have been followed to calculate capacity credit: • Preparation of hourly demand values and PV generation output across months • Peak demand is mapped from Time of Day (TOD) tariff peak hours. • Average of PV output is calculated for the same TOD peak hours. • Capacity credit refers to the average PV capacity estimated in the same TOD peak hours. This average solar PV capacity is represented as a percentage of installed PV capacity.	• Excel tool is used for modeling capacity credit calculation • Capacity credit is measured as a percent of total installed PV capacity (%)
Outputs	• State wise capacity credit values in percentage (%) and in absolute term avoided capacity (MW)	

Figure 29: Approach for Computation of Energy Credit

Higher capacity credits implies higher solar generation during peak hours, which means higher avoided capacity and the cost of avoided energy would also be high. The result of the analysis is shown in the table.

Table 9: Avoided capacity for FY 2022 due to rooftop solar

State	TOD Peak hours*	Peak hours considered for capacity credit	Capacity credit, FY2022 (%)	Avoided capacity, MW	Target Rooftop capacity, MWp	Avoided energy FY2022, MU
Gujarat	7 AM – 11 AM	8 AM – 11 AM	37.39%	1197	3200	490
Delhi	1 PM – 5 PM	1 PM – 5 PM	36.96%	407	1100	219
Odisha	10 AM – 6 PM	10 AM – 5 PM	45.89%	459	1000	461
Tamil Nadu	6 AM – 9 AM	7 AM – 9 AM	17.62%	617	3500	79

The analysis shows that capacity credit has much higher relevance than avoided capacity as the avoided capacity of Gujarat is highest with 1197 MW but due to capacity credit of 37.39% its avoided energy is 490 MUs only, while the avoided capacity of Orissa is 459 MW but due to higher capacity credit its avoided energy is 461 MUs. This indicates suitability of Orissa is higher for solar rooftops.

v) Active and Reactive Power Support

Solar rooftop systems can support utilities in controlling active and relative power with the help of advance inverters. In order to adopt active and reactive power control there is a need to develop voltage and frequency regulations in India.

As a part of this study, International frequency regulation practices covering countries like USA and Germany having high penetration of rooftop solar have been analyzed. In addition various secondary published research which includes Federal Electricity regulatory commission (FERC), California Utility Public Commission (CPUC) orders, NERC, Germany Utility references, and other publically available reports for mapping international rooftop penetration so as to understand how these countries have adopted regulations, technical standards that facilitated in proliferation for large scale deployment of rooftop PV systems have also been reviewed which can be replicated in Indian context to support utilities in managing the operations of solar rooftops

Germany in order to manage the high capacity of solar rooftop, in 2011 introduced a new grid code (VDE directive) to strengthen LV grid from smart inverter functionalities and introduced following provisions

1. Active power control (back down) for PV inverters in case grid demands for it with compensation. Existing systems with larger than 30 kW capacity taken into service on or after 2009 must be retrofitted with such provision to reduce active power feeding within two years
2. Active power control by Inverter (typically in four steps 100%, 60%, 30% and 0%) with the help of a GSM based Remote control systems
3. Reactive power support mechanism to provide power factor of range 0.9 leading to 0.9 lagging > 13.8 kVA, 0.95 lagging to 0.95 leading 3.68 kVA to 13.8 kVA and no requirements below < 3.68 kVA inverters
4. Introduction of Hardship clause (section 15): If the feed-in of electricity generated from renewable sources is reduced due to a grid system bottleneck , grid system operator must compensate the operator for on account of lost electricity due to limiting active power of the inverter
5. Retrofitting existing system for frequency response, Risk of complete black out upon automatic shutdown of PV systems and network frequency rises above 50.2 Hz so as to make a provision that PV inverters remain connected with the grid at preset conditions for recovering from such situations
6. On Load tap changer for MV / LV transformer, applying same can reduce cost of distribution expansion by 60%

Similarly USA allowed reactive power injection/consumption from solar rooftop. PG&E electric utility of USA surpassed the operational challenges by mandating use of automated inverters having added functionality of grid automation in support of voltage regulation. Currently, PG&E utility has voltage regulation for decentralized PV inverters as an added functionality which support the grid in case of grid demands for it by way of regulating the reactive power (either absorb or back feed). Further, different voltage zones have been defined in conformance to IEEE 1547a (modified Rule 21) which recommends (DER) distributed energy resource to remain connected with the distribution grid with clearly defined different zones voltages (must disconnect and connection zones).

Following table illustrated the provisions for connection or disconnection of DER in different voltage zones

Table 10 : Connection/disconnection limits

Connection Limitation	Voltage level multiplier	Stay connected until	Disconnection Limitation	Voltage level multiplier	Disconnection time
Above			Above	>1.2	<0.16 sec
Above	1.09-1.17	12 sec	Above	1.1 -1.2	13 sec
	0.92-1.09	Indefinite		0.88-1.1	Do not disconnect
Below	0.7-0.92	20 sec	Below	0.6-0.88	21 sec
Below	0.5-0.7	10 sec	Below	0.45-0.6	11 sec
Below	0-0.5	1.0 sec (range between 0.16 to 2 sec)	Below	0-0.45	2.5 sec

Source: California Public utility Commission, Smart Inverter Working Group publications

PG&E has mandated that solar rooftop inverters based generating facilities need to provide reactive power (VAr) to control voltage. It shall be measured at facility side which is generally the low voltage side of the step up transformer that connects to PG&E at point of interconnection. In addition, Reactive power capability for interconnecting PV generation shall be limiting from 31% to 43% of the facility watt rating into the system.

However in Indian context there are gaps in terms of managing the reactive and active power, as per the current mandate of grid code, distributed energy resource shall cease to energize the circuit to which it is connected in case of any fault in the system voltage and frequency going beyond the specified limits. IEGC provides the following guidelines for operating range of frequency and voltage in Indian electricity grid.

Voltage Band	Frequency	Anti-Islanding
V > 110% or < 80% (<2s)	[49.5 – 50.2 Hz]	UL 1741/ IEEE1547 <2s

The gaps in the existing regulatory framework are as follows

- Large integration of distributed energy sources such as rooftop solar requires that these settings for voltage and frequency linking is restructured to accommodate higher variable renewable penetration using advanced inverter functionality and these alterations can prove to be helpful for safe/reliable operation of the grid.
- Unavailability of communication interface between DER (distributed energy resource) and utility.
- Unavailability of H/LVRT functionality for capability of DER against temporary fault ride through events
- Unavailability of a nationwide certification framework (0-10kW, 10 kW-100 KW & >100 kW systems)

To plug these gaps and makes the operations of lager capacity of solar rooftop healthy for our grid, the study suggests following recommendation

- **Regulatory intervention -** Regulation facilitating advance inverter functionalities such as reactive power feed-in for voltage support, active power control features.
- **Communication with utility -** Utility communication interface for advance control features for decentralized rooftop Inverters, Compensation in case of any back-down of active power
- **Formation of a working group -** Formation of a working group with clear timelines and implementation schedule. Various stakeholders involved such as regulators, utility, generators, private IPPs, load dispatch centers etc. should be the part of the working group. Working group should focus on voltage support (dynamic VAR) for improvement of tail end voltage profile, control active feed in current by the inverter by way of a communication from the utility.

5 Stakeholder Consultations

Solar Rooftop segment is increasingly becoming popular with steep fall in the price of key solar power components, increase in retail tariff, increasing concerns over climate etc. Further, it provides benefits for utility in terms of reducing technical loses, managing day time peak demand, meeting growing energy demand etc. However growing capacity of solar rooftops can also create concerns for utilities as seen globally in terms of reduction in revenue, increase in administration cost, affecting operational parameters etc.

For a study that is complex in nature and is to be formulated for large consumer base, Stakeholder consultation becomes very critical. Stakeholder consultation is important to understand the future scenario of solar rooftop segment and its impact from utilities prospective. Further, it also helps in validating the analysis and recommendations derived on the basis of the outcomes of the analysis. Thus as a part of this exercise our team met with several state agencies/utilities from Rajasthan, Karnataka, Tamil Nadu, Delhi, Odisha etc. to discuss our analysis and to know their view points on final recommendations.

As the penetration of solar rooftop is quite low in India, almost all the stakeholders interviewed during the process specified solar rooftops as one of their focus area. Majority of the utilities expressed their interest in development of solar rooftops in their jurisdiction despite of the fact that it can hurt their main business i.e. supplying power to consumers. Moreover stakeholders supported the argument by saying that solar rooftop helps utilities to meet their day time peak demand thus reduced the power purchase cost during peak time. Stakeholders also accepted that de-centralized generation by means of solar rooftop is a much better way to tackle the increase energy demand in comparison to MW scale utility projects as it requires huge infrastructure, land, O&M Cost etc. Some stakeholders also stated that solar rooftop is going to become the mainstream power in coming future and utilities role may only restrict to management of the distribution grid.

Some stakeholders which already have high penetration of solar rooftop, accepted the commercial and operational challenges of it and supported the recommendations of imposing additional charge in the form of "grid tied" charge on rooftop consumers to recover the cost of providing backup power.

They also supported the TOD metering for solar rooftop consumers but only in commercial and industrial category as the cost of TOD meters are too high. Some stakeholders also supported the analysis of reduction in revenue from cross subsidy and said increasing fixed charge or by rationalizing tariff slabs will overcome this issue. Some stakeholders were of the view that segregating export and import tariff under net metering shall be adopted to avoid utilities loss of cross subsidy.

Majority of the stakeholders favored the recommendation of adopting utility driven models as it is easy to implement and monitor for utilities moreover it reduced the administration burden of utilities to deal with number of rooftop consumers. stakeholders also accepted that utility driven model is a better approach for accelerating the growth of solar rooftop on Indian market as it reduces the capital risks for end consumers.

6 Recommendations

Deployment of customer-sited photovoltaics (rooftop solar PV) in countries like United States has expanded rapidly in recent years, driven in part by public policies premised on a range of societal benefits that PV may provide. With the success of these efforts, heated debates have surfaced in a number of countries about the impacts of customer-sited PV on utility shareholders and ratepayers, and such debates will likely become only more pronounced and widespread as solar costs continue to decline and deployment accelerates.

Utility executives are often concerned about revenue erosion and reduced shareholder returns when customers with net-metered PV are able to avoid charges for fixed infrastructure costs, as well as potential cost-shifting between solar and non-solar customers. At the same time, net metering is viewed as essential by customers with solar PV to protect their investments, by the solar industry to grow their businesses, and by states and environmental advocates to achieve climate or other environmental policy goals.

Rooftop solar development in India is currently at the initial phases of development. However, with GOI targeting 40 GW of rooftop solar capacity addition and with expected increase in rooftop solar penetration levels, it can be expected to face issues from distribution utilities in India.

Distribution utilities have an important role to play in promotion of rooftop solar projects, especially keeping in mind the distributed nature of these projects and the framework of net metering. Financial health of distribution utilities in India has persistently been an area of concern- partly attributed to high levels of Aggregate Technical and Commercial (AT&C) losses as well as inability of power tariffs to recover the cost of supply. However given the impact of rooftop solar proliferation on utility business, it is important to analyze the growth of solar rooftop vis-a-vis its impact on utility business.

Thus, based on the analysis of various state utilities, their energy requirement, financial health, technical and operation issues, potential for solar rooftop etc. some recommendations have been suggested to support the development of solar rooftop and create a win-win situation for both consumer and distribution utilities. Table below is summarizing the recommendations of the study, analysis of the same is covered under annexure 5.

6.1 Regulatory

Sr. No	Suggested Initiative	Description
1.	**Rationalization of Consumption Slab**	• Most Indian states have high number of consumption slabs (even up-to 5) for a consumer category. This may impact revenue realization for utilities due to net metered solar consumption. • <u>Slab rationalization should be adopted by SERCs to protect utility interest (Short term initiative)</u>
2.	**TOD framework on net-metered consumers**	• Consumers not covered under TOD have the benefit of utilizing off-peak injected power during peak power. With increased rooftop solar capacity addition in future, this may pose operational/commercial challenge to utilities. • <u>Rooftop solar net metered consumers can be mandated to come under TOD framework (long term initiative)</u>

3.	**Allow surplus solar power injection during peak time**	• Solar power generation peaks during the peak time of day tariff (TOD) defined in states like Delhi, Orissa, and Tamil Nadu etc. • Allow surplus power injection during peak time for an accounting year by a net metered consumer. Limits for surplus power injection can defined by SERCs (Short term initiative)
4.	**Promote peak-time solar injection through attractive tariffs/ incentives**	• Injection of power during peak time to assist utility operation • Provide higher level of tariff/incentive for power injection by rooftop solar projects during the peak demand period • Providing higher level of tariff/incentive will also encourage rooftop solar based storage options (Short term initiative). • States such as Maharashtra, Gujarat, TL&AP, and Uttar Pradesh, Tamil Nadu etc. having peak evening demand can benefit from this.
5.	**De-Coupling of Import and Export tariff under Net Metering**	• Net Metering is coupling of export and import tariff, due to this utility may get impacted due to losses in terms of cross subsidy, recovery in fixed charge etc. • Net metering compensates the consumer for solar power at the utility tariff. In certain cases, the Utility tariff may be very high than the LCOE of solar rooftop power thereby providing very high returns to consumers. • As utility is providing grid infrastructure to rooftop solar projects, to protect interest of Utility, segregation of the import and export tariffs for net-metered rooftop solar consumers can be considered. • Import tariff will be energy charge and export tariff can be capped at Solar rooftop FIT, linked as % of energy charge indicated by SERC (Long term initiative)

6.2 Operational

Sr. No	Suggested Initiative	Description

1.	**Active power control on rooftop solar systems**	• Large scale rooftop proliferation create the need for higher utility visibility on rooftop solar generation pattern & control of the same
		
		• International Experience: Advance Inverters having active power curtailment options are being used to control the excess power in the grid (frequency regulation).
		
		  • During high frequency events in the grid on account of mismatched demand / supply, PV advance inverters can be utilized to curtail a certain portion of active power to maintain grid stability.
		
		  • Retrofit regulation mandates that all new inverters and existing inverters shall be equipped with smart inverter functionality by which it enables inverter to curtail down its output base upon a signal command from the utility(Germany)
		
		• <u>Regulations for enabling active power function of advance inverter</u>
		
		• <u>Utility command regulatory framework for control & Instrumentation functions to enable advance inverter regulations in Indian context need to be prepared and framed.</u>
		
		• <u>Compensation mechanism for loss on account of active power curtailment (Long term Initiative)</u>

2.	**Reactive tariff & standards**	• Advance Inverters can be used to provide voltage regulation for improvement of tail end voltage profiles. • Germany and PG&E Rule 21, USA have specific requirements for installing advance inverters for reactive power support functionality. • Advance inverter functions allow for more elaborate monitoring and communication of the grid status. Ability to receive operation instructions from utility and capability to change operational parameter (reactive power) help in maintaining grid stability, support power quality. • Areas with relatively low solar irradiance are ideally suited for reactive power compensation since most of the time inverters will be operating at lower capacity than the rated. • Oversized PV inverters to meet the reactive power as required is another proposed option

		• Regulations for enabling reactive power function of advance inverter • Incentive/tariff mechanism and level of incentives for adopting advance inverter functionality (Short term Initiative)

6.3 Commercial

Sr. No	Suggested Initiative	Description
1.	**Explore utility driven rooftop solar models**	• Utilities need to play an active role in rooftop solar capacity addition and promote utility owned/driven models. • Consumer should get additional incentive to participate in utility driven models. MNRE can provide incentive to utilities to encourage such models.

6.4 Implementation

Sr. No	Suggested Initiative	Description
1.	**Dedicated rooftop aggregation program**	• Apart of initiatives at Discom level, achieving large capacity addition will require dedicated program from MNRE for aggregation of rooftops. The objective of this shall be to assist Discoms in meeting their rooftop solar targets. • MNRE/SECI with the assistance of SNAs undertake dedicated rooftop solar aggregation program ▪ Initiate consumer registration for the program ▪ MNRE to provide subsidy to participating consumers to encourage participation ▪ Standard documents (Contract, leasing agreement) to be in place for consumers participating in the program – this will reduce the risk of RESCOs ▪ MNRE/SNA shall facilitate bid process for aggregated capacity with assistance from Utility o This will assist RESCOs in getting higher capacity & minimize efforts in aggregation o Consumer will get benefit from competitive bidding & scale o Provisions for robust O&M and performance in RESCO selection to benefit consumer

2.	**Support to Discoms to facilitate implementation of rooftop solar**	• Given the low level of rooftop solar capacity, it is important to improve the capacity of utilities, MNRE can provide support to utilities : ▪ Developing web-portal for online processing of application ▪ Setting up consumer helpline center; Consumer grievance cell ▪ Procurement & installation of net meters ▪ Organizing consumer awareness; ▪ Training for utility – energy accounting & billing software, business models & net metering ▪ Upgradation of distribution transformers (DT) to accommodate higher solar penetration; ▪ Training to ensure quality installation and O&M ▪ Online consumer feedback/rating for RTPV installers
3.	**Incentive scheme for distribution utilities**	• Given the nascent phase of rooftop solar development in India, it is important to have a clearly defined incentive framework to encourage distribution utilities to support rooftop solar implementation. The MNRE can devise a **dedicated scheme for incentivizing distribution utilities**. • Under this framework, all the distribution utilities shall be eligible for incentive based on the rooftop solar capacity added in their jurisdictions. The incentive can be a fixed value of INR/MW of the rooftop solar capacity added. • **Performance linked incentives**, based on ▪ Meeting rooftop solar targets on yearly basis ▪ Number of consumers connected under net metering arrangement ▪ Avg. time taken for processing the net metering consumer connection application ▪ Initiate regulatory reforms for rooftop solar capacity addition

7 Annexure

Annexure 1: Scope of Work

In countries where distributed energy installations are rising, the utilities have been opposing this transformation. Their concerns stem from potential implications of such systems on their finances and operations. Direct financial impact have been stated to include pay-outs for surplus power fed to the grid and cost of maintaining and balancing the grid. The latter also poses operational challenges. At the same time, there are core systemic and legacy issues such as tariff design structures which do not reflect true costs and thus adversely impact the distributed clean energy sector.

A counter-argument could be the value that any distributed system could offer in times of peak load, if planned properly and market / regulatory signals are clear.

India has an ambitious target to deploy 40 GW of grid-connected rooftop PV systems by 2022. However, unless the concerns of distribution utilities are addressed, a situation similar to Tamil Nadu's wind sector, where utility is opposing any additional wind installations, can hit the solar rooftop sector as well. These debates have been rising even in other countries. For example, the United Kingdom, which to a great extent inspired the injection of free-market principles into electric power systems, is generally not encourage net metering.

Thus, it is necessary to analyze the actual local and aggregate impacts of rooftop systems on utilities considering actual demand and supply profiles of the distribution areas, and tariff and cost structures. To analyze the actual impact on solar rooftop on utility business, this study is conducted. The terms of reference for the study are as follows

1. Review international literature to:
   i) Identify pros and cons of rooftop deployment models in US, UK, and Germany, from a system-wide perspective – Gross-metering, net-metering, self-consumption, any other
   ii) Using case studies / real examples, determine direct and indirect financial as well as operational impacts of such models on the utilities
   iii) Study alternatives that have been adopted to ensure support from utilities

2. Select a sample of Indian distribution utilities to:
   i) Analyse their actual demand and supply profiles, and cost and tariff structures
   ii) Estimate the value of rooftop generation and net impact on utility revenues and operations, if any
3. Propose mechanisms including, but not limited to, tariff design, storage solutions (peaking power support) etc. that would ensure utility support to rooftop PV
4. Propose changes to the existing models to balance the interests of utilities, regulators, prosumers and consumers
5. Propose regulatory provisions necessary to implement the proposed models/ alternatives
6. Consult stakeholders at appropriate stages to test the applicability of the suggested solutions

Annexure 2: Key Assumptions for analysis for evaluating impact on utilities

S No	Parameter	Data Source/ Approach
1	Energy requirement	• Upto 2016: Respective tariff orders and or PFA. • 2017 – 2019: PFA report/EPS • 2020 – 2022: Growth rate provided in 18th EPS report has been applied on 2019 data
2	Peak Demand	• Past data based on the PFA report and Tariff orders • Projections based on using the projected energy requirement for the utility and state specific load factor as provided in the PFA or 18th EPS report
3	Energy Consumption	• Upto 2016: Energy consumption (sale) mapped using tariff orders of respective utilities • 2017-19: PFA report for the state or energy requirement reduced by T&D losses to arrive at the energy consumption • 2020-2022: Energy requirement reduced by T&D losses to arrive at the energy consumption values till 2022. For states where PFA not published, 2017 onwards values till 2022.
4	Tariff rates	• Both fixed and energy charges were mapped for 3 categories (residential, commercial and industrial) for HT and LT level in each of the categories with sub-categories as per adopted framework by the utility • For future, these rates forecast are based on cross subsidy levels & growth in average billing rates.
5	Average cost of supply	• Value for average cost of supply was taken from tariff order. For few years if the values were not available then the same has been taken from PFC report • Future values were forecasted using historical trends as reference & appropriate assumptions.
6	Average billing rate	• Average billing rate was taken from the tariff order for various categories and forecasted using historical trends as well as maintaining the cross subsidy levels.
7	Cross subsidy	• Cross subsidy was calculated using the category wise differential between average billing rate and average cost of supply • Cross subsidy levels for different categories in year FY 2016 (based on Tariff Order/PFA) are considered as reference. Cross subsidy levels are assumed to be constant for future years.
8	T&D losses	• Distribution and intra-state transmission losses were used for the utilities from the tariff orders. Fur future years, it is assumed that the values as per PFA/Tariff orders for FY 16/FY19 will remain same till FY 2022.
9	Categories considered	• Residential, Commercial, Industrial categories were taken for the analysis. Rest of the categories were not used for the reason that these categories will be front runner in adoption of rooftop solar.
10	Category-wise allocation of energy consumption	• For calculating energy consumption values during 2017-22 for residential, commercial and industrial categories; total energy consumption is divided in the ratio of energy consumption across categories as present in year 2016.

Annexure 3: Approach for analysis

S No	Parameter	Approach
1	Revenue loss to utility	Revenue loss to utility has been calculated on the assumption that all solar MUs would be replacing the energy sold by utility to customers in the 2 cases as described below. • **Case- 1:** If the rooftop solar replaces the energy MUs consumed by the existing customers and that customer falls in the highest energy slab tariff paying category. This is most likely scenario because the customers paying the highest tariff in a category will be biggest beneficiary of solar adoption by saving the differential. • **Case-2:** If the rooftop solar replaces the energy MUs consumed by the existing customers and that customer falls in the average tariff paying category.
2	Cross subsidy loss/Benefit to utility	• The utility will lose the cross-subsidy from the customers who were paying more than the average cost of supply if they chose to switch to solar. This parameters is also calculated in both the potential cases as discussed in impact on revenue. The impact would be worst for utility in Case-1. On the other hand, if currently subsidized customers move to solar then utility will benefit. But this is a low probability event. • The Impact is calculated as difference b/w avg. CoS and Energy Charge/Avg. Energy Charge considered and depending on quantum of energy replaced.
3	Loss of Grid Charges	• Utilities may lose the Grid charge (fix charge) collected from the customers in the case the customers will reduce their contracted demand. The chances of this happening is there only with the customers who have demand curve coinciding with solar generation. Else consumer will be dependent on the grid for non-solar hour demand thus cannot reduce their contracted demand. • Grid charges loss to utility is calculated assuming loss in contract demand by 10%.
4	Deemed RPO benefits to utility	• If the customers who adopt solar are non-obligated entity then the utility can retain the RPO benefits accrued. This will help minimizing the cost for utility as in absence of this arrangement they would have to pay higher price for meeting RPO obligation set forth by regulation. • The impact is assumed considering Solar REC price as alternative option for meeting Solar RPO compliance
5	Loss of Banking Charges	• Banking charges are not applicable on rooftop solar projects in general. This can be considered as a loss to utility. • Loss for utility is calculated assuming 30% of energy generated from rooftop solar is banked and do not pay 2% banking charge (assumed in-kind i.e. MU). Price for calculating the impact has been taken as APPC price.
6	Environmental benefit	• Various tangible impacts as reduction in water, land and CO_2 emission has been used in line with the prevailing prices for these savings to determine total tangible benefits on account of rooftop solar generation vis-s-vis thermal power projects. • MNRE rooftop PV cumulative targets for FY2022 have been considered for estimating environmental benefit. Key environmental benefit parameters of water, CO2 and land

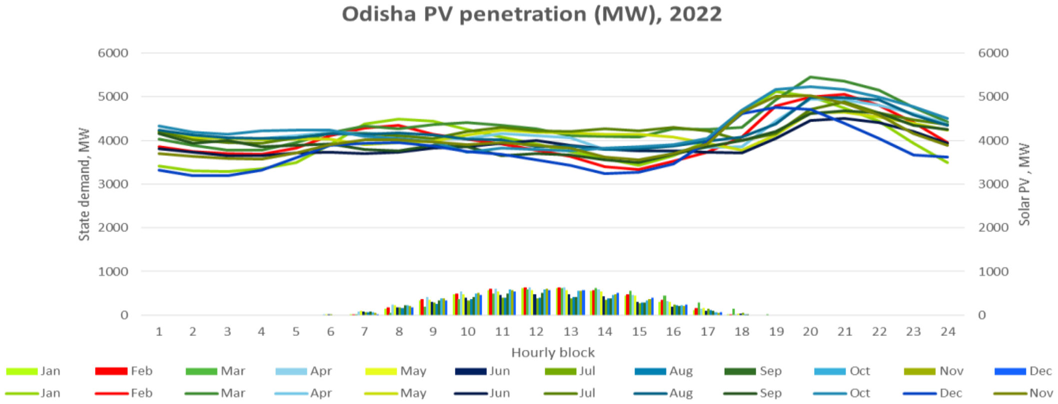
S No	Parameter	Approach

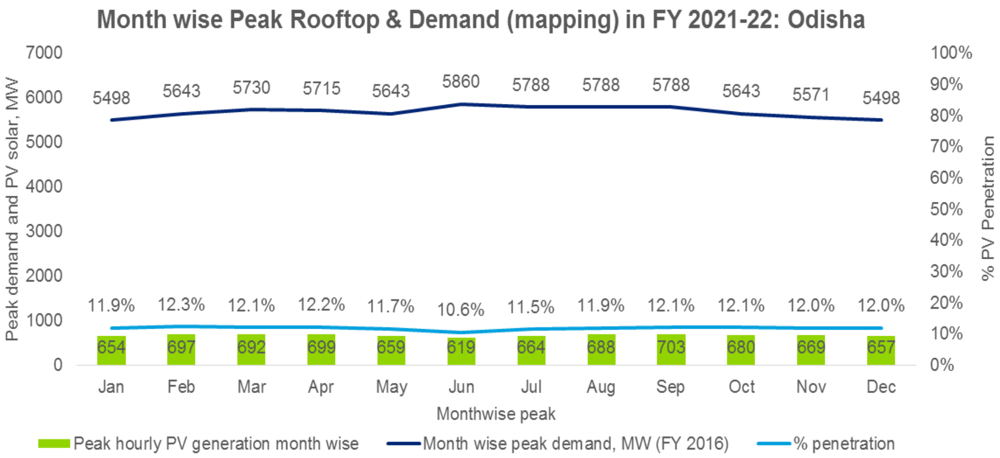
		displacement has been considered for evaluating environmental benefits.
		
		• Water Saved: Water saving in million litre is calculated based upon water required by thermal power plants subtracting water requirements by PV plant for module cleaning for MNRE rooftop targets FY 2022.
		    • Water savings in million litre of water has been estimated based upon multiplying water requirements in litre / sq m with sq m /kWp output for a crystalline module.
		    • Water required for cleaning PV module assumed as 247 cu m per MW per year
		    • Water requirements for thermal power plant is taken as 0.55 cu m/ h/ MW (dry cooling system - CEA)
		
		• CO_2 Impact assessment: CO_2 emission factor (0.82 ton CO_2/MWh) assumed (Source - CEA report). CO_2 emissions reduction potential has been estimated by multiplying total annual PV generation and emission factors for MNRE FY 2022 targets.
		
		• Avoided Land Impact assessment: Land use impact data (in acres/MW) has been collected for and thermal power plants to calculate effective land savings (in acres) by installing rooftop PV plant. Rationale for the calculation is that rooftop PV plants do not use any land for installation and fully utilizes rooftop space. Suitable factors in ratio of CUF have been considered to account for replacement.

Annexure 4: Impact on Operational Parameters

This case analyses the indicative impact of solar rooftop on operational parameters of utility by estimating the penetration of solar rooftop vis-à-vis the monthly demand of a particular State. The result of the analysis for different States is shown below

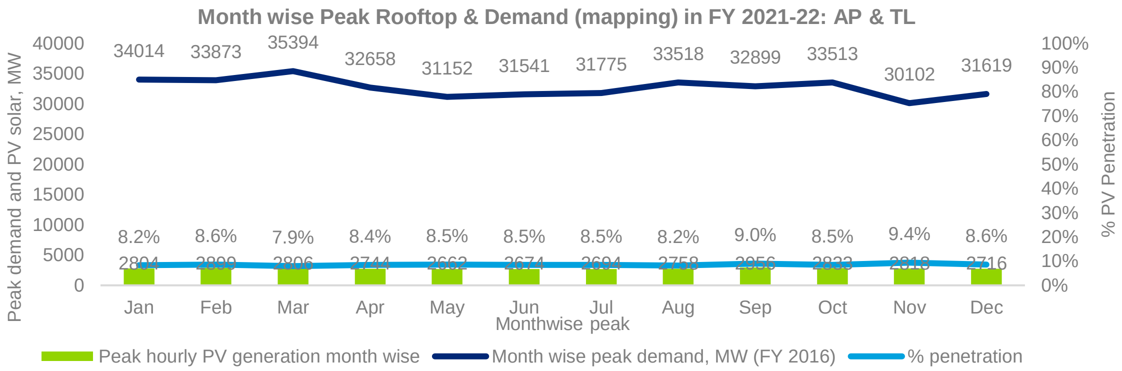
1. **Odisha** – As per the analysis, the state of Odisha does not have very high variation in demand across different months in the year. Also, the hourly review indicates that the peak occurs during the evening time only, when solar generation is not available. For the targeted rooftop solar capacity, the state can have very high instantaneous rooftop solar penetration of 17.27% during 12th hour block (February). In view of the TOD tariff defined in the state in general are lower in the state in comparison to other states. Hence, may not offer viable option for storage based rooftop solar.





The above analysis implies that, the solar rooftop capacity shall be well below the expected demand of different States in FY 2022. Moreover the generation from solar rooftop will support utilities in managing the demand time peak demand and the States. The States, wherein the peak demand is coming during evening hours presents a strong case for promoting storage based rooftop system to manage the demand and generation from solar rooftop systems.

2. **Andhra Pradesh and Telangana** – The analysis shows that the state witnesses high demand during the months of Feb, March, Sept. and Oct. These months corresponds to high solar power generation also. Hence, solar rooftop will definitely support the peak demand requirement. Both the states combined are expected to have very high growth in future energy requirement as per PFA plan, Hence, proper generation planning can ensure better integration of rooftop solar power.



The TOD structure of the States defines peak period during evening time. The tariff structure provides for high tariff applicability for higher consumption slabs across categories, including residential. Hence, rooftop solar may become viable for select consumer category/consumption slabs.

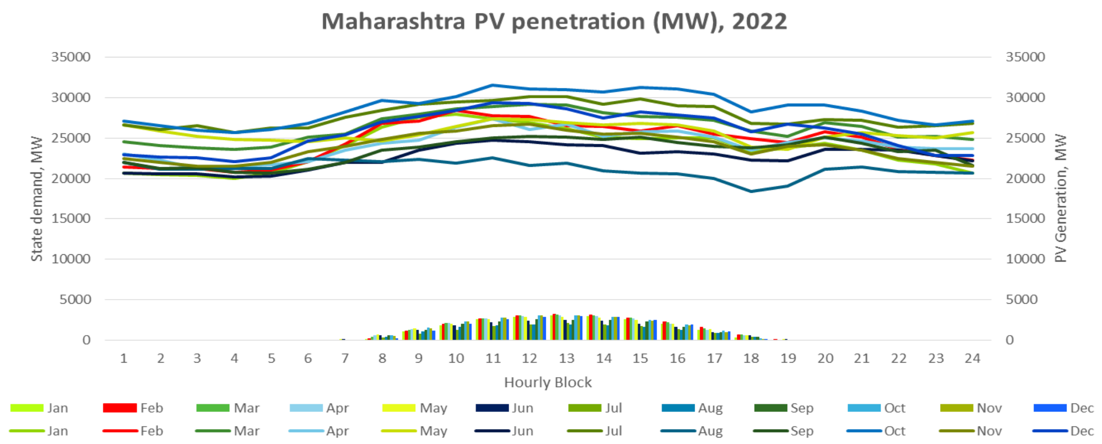
Table 11: TOD tariff of Andhra Pradesh

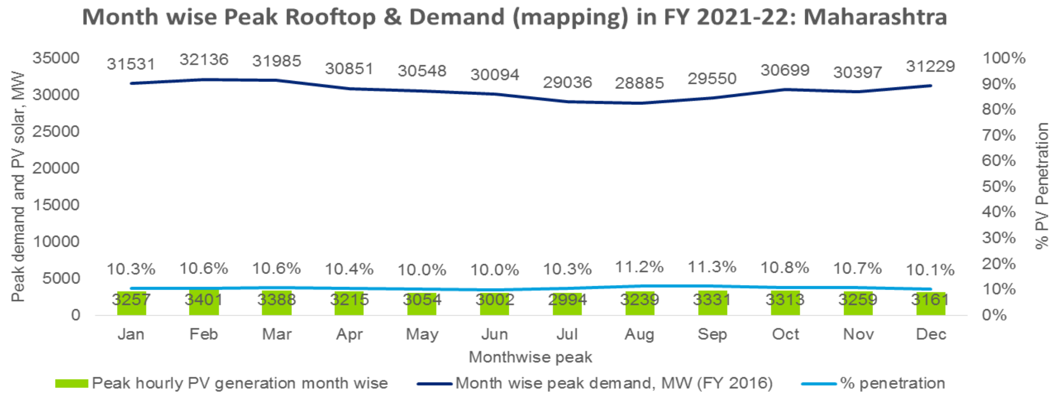
<table>
<tr><th>State</th><th>Andhra Pradesh</th><th>EC</th><th colspan="24">Time of day</th></tr>
<tr><td>Sr. No.</td><td>Applicable Category</td><td></td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td></tr>
<tr><td>1</td><td>HT -1 A, Category, General</td><td>6.69</td><td colspan="18">6.69</td><td colspan="4">7.74</td><td colspan="2">6.69</td></tr>
</table>

Table 12: TOD tariff of Telangana

<table>
<tr><th>State</th><th>Telangana</th><th>EC</th><th colspan="24">Time of day</th></tr>
<tr><td>Sr. No.</td><td>Applicable Category</td><td></td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td></tr>
<tr><td>1</td><td>HT II - Others</td><td>6.77</td><td colspan="18">6.77</td><td colspan="4">7.77</td><td colspan="2">6.77</td></tr>
<tr><td>2</td><td>HT III - Airports, Bus Stations, and Railway Stations</td><td>6.47</td><td colspan="18">6.47</td><td colspan="4">7.47</td><td colspan="2">6.47</td></tr>
</table>

3. **Maharashtra -** The Analysis of Maharashtra shows that Maharashtra has a peak demand during the day time (apart from evening time) and is in line with the peak solar power generation. Thus, solar power generation can contribute during the peak demand period. It is assumed that the utilities will encourage solar power to meet their solar RPO compliance. Further, Solar power can also support consumers during evening peak time by using storage solutions, As the TOD tariff of Maharashtra during evening for some consumer categories goes above Rs. 14 /kWh, which can be avoided using storage based solar power systems by the consumers.





4. **Tamil Nadu** – The analysis shows that the state is expected to have high demand levels & has the potential to absorb high rooftop solar potential in absolute terms. The rooftop solar penetration (in MW) is expected to be below 11% of the peak demand for the month across all the months. The peak period is during early morning time or late evening time. Only during 7 am – 9am is the period where rooftop solar will contribute towards the peak period defined under current TOD structure (for select months). Solar generation will be negligible during the evening time peak period as per TOD structure.

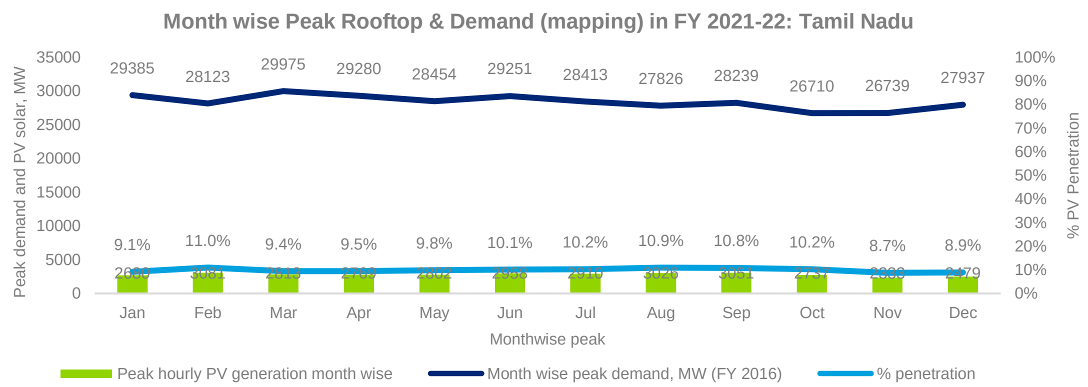
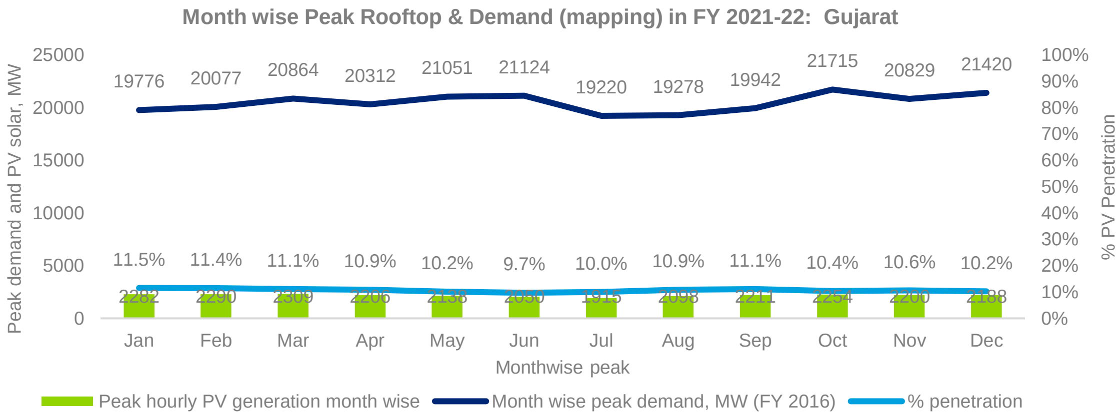


Table 13: TOD tariff of Tamil Nadu

State	Tamil Nadu	EC	Time of day																							
Sr. No.	Applicable Category		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	HT Consumers - 1A	6.35	6.03					6.35	7.62			6.35									7.62			###	6.03	

5. **Gujarat** – The State of Gujarat has high demand during the month of March which also corresponds with the high solar generation month. The energy charges applicable on consumer categories (in general) is low in the state in comparison to other states. Hence, rooftop solar may not be a viable option for select categories currently



The TOD structure also defines peak during the morning time 7 am to 11 am, which is also a time of solar power generation. This definitely will support viability of rooftop solar due to TOD.

Table 14: TOD tariff of Gujarat

State	Gujarat	EC	Time of day																							
Sr. No.	Applicable Category		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	HTP 1, HT Consumers	4.52	4.52							5.17				4.52							5.17				4.52	
2	HTP 3, HT Consumers	6.60	6.60							7.25				6.60							7.25				6.60	

6. **Uttar Pradesh** - The state witnesses' very high variations in demand across months, hence provides a case for evaluating incentive for feeding surplus power generation during these months. The peak period as per the TOD structure is during the evening time, when the solar generation is negligible. The state in general provides for high energy charges for select consumption slabs, making rooftop solar viable.

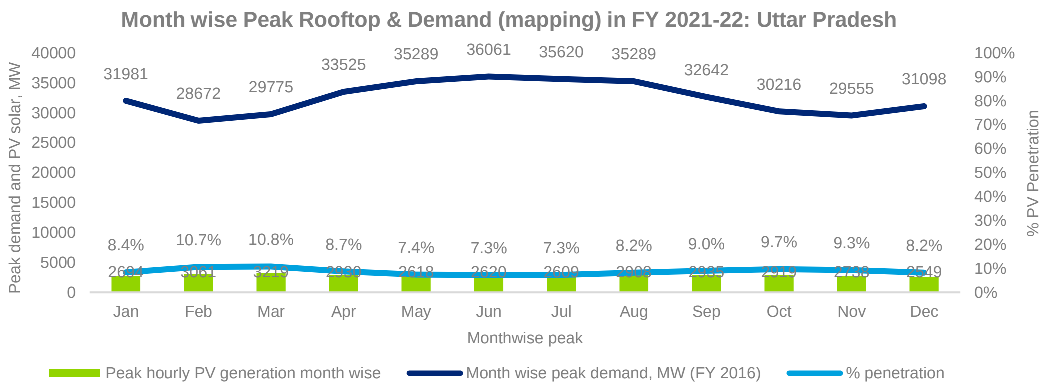


Table 15: TOD tariff of Uttar Pradesh

<table>
<tr><th>State</th><th>Uttar Pradesh</th><th>EC</th><th colspan="24">Time of day</th></tr>
<tr><td>Sr. No.</td><td>Applicable Category</td><td></td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td></tr>
<tr><td>1</td><td>LMV-6 (Small and medium power)</td><td>6.85</td><td colspan="6">6.34</td><td colspan="11">6.85</td><td colspan="5">7.88</td><td colspan="2">6.34</td></tr>
<tr><td>2</td><td>Optional, LT TOD</td><td>6.85</td><td colspan="6">5.82</td><td colspan="11">6.85</td><td colspan="5">7.88</td><td colspan="2">5.82</td></tr>
<tr><td>3</td><td>HT-2 (Large and heavy power) consumer categories</td><td>6.85</td><td colspan="6">6.34</td><td colspan="11">6.85</td><td colspan="5">7.88</td><td colspan="2">6.34</td></tr>
</table>

Annexure 5: Recommendation Analysis

Solar rooftop has several benefits for utilities however it also has some un-intended consequences which is causing concerns for utilities. Globally utilities are proposing additional charges on solar rooftop consumers as growing rooftop solar capacity is hurting their business. As India is also envisaging a big solar rooftop program of 40 GW capacity, it is expected that Indian utilities may also face similar consequences.

On the basis of through analysis of Indian energy sector, growing rooftop capacity and learning from international experience, this study proposes some recommendations, which can help Indian utilities to support development of solar rooftop while also saving their interest. This annexure details supporting analysis for the recommendations provided in the report.

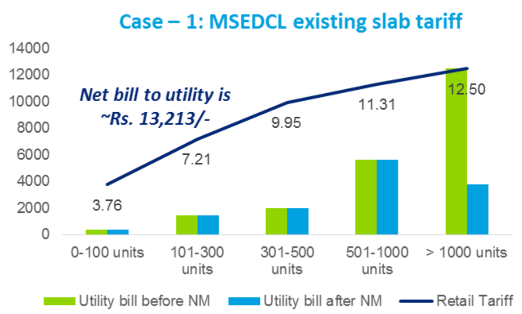
1. Reduction of Consumer Tariff Slab

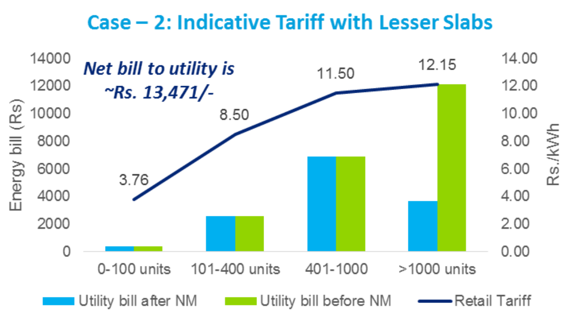
Solar rooftops under net metering framework allows consumers to meet their captive energy requirements and at the same time provides backup supply though grid when solar energy is not available. This helps consumer to reduce their utility bill by meeting the base demand through rooftop and using utility grid to meet their peak demand.

By doing this, consumers falling in higher tariff slabs before installing rooftop system can move to lower tariff slabs and thus impacting utility revenue. To elaborate this case further, case of MSEDCL, Maharashtra has been considered. For domestic consumer, MSEDCL has five tariff slabs. For a domestic consumer having monthly energy requirement of 2000 units, its energy bill can come out as Rs. 21,963/- before installing the rooftop system.

Once the consumer installs rooftop system under Net Metering arrangement, its energy requirement from the grid will reduce. Assuming it is procuring 700 units from rooftop and 1300 units from grid its energy will reduce to Rs. 13,213/- under five tariff slabs. However, if the number of slabs are reduced, the utility revenues can be increased to certain extent.

The following graph is representing an indicative impact of reduction in tariff slabs on utility energy bill.





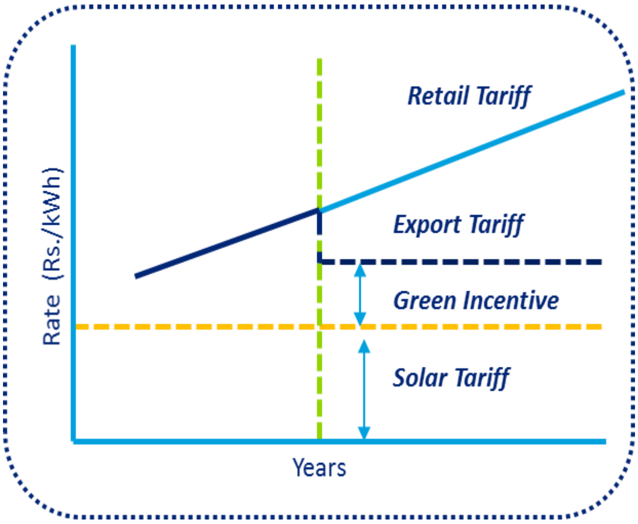
The analysis shows that the weighted average of grid tariff is improving with reduction in number of slabs while the weighted average of solar tariff is reducing, thus utility revenue will increase with reduction in tariff slabs.

Reduction of consumer tariff slabs, could help utilities in improving the average tariff to be charged from the net Metered consumers

2. Decoupling of Import and Export tariff under Net Metering

The net metering mechanism couples Import and Export tariff, due to this utility may suffer losses in terms of cross subsidy, reduction in sales volume, reduction in demand etc.

Figure 30: De-coupling of Import and Export tariff



In order to create sustainable market for Net Metering in long run, there can be a possible modification in existing net metering framework.

A simple approach could be to segregate import and export tariff as explained in the figure.

De-coupling should be done above a specified level of rate, i.e. export tariff shall be applicable if the energy charge applicable is above the export tariff

- the rate can be linked as % of energy charge indicated by SERC
- solar FIT plus incentive
- Solar FIT

As long as the retail tariff is above export tariff fixed by SERCs, consumers will go for net metering. However, it is important to maintain balance between the interests of utility as well as solar consumers.

De-coupling of Export and Import tariff for Net Metering based solar rooftops to safeguard utilities interest in long run.

3. Imposing Additional Charge on Net Metering Consumers

In Indian electricity market, retail electricity tariff relies heavily on volumetric sales to recover a part of utility fixed cost. However with increase in the capacity of net Metering based rooftop systems utility sales volume will drop and utilities may not be able to recover the share of fixed cost which is a part of retail tariff, under the current framework.

The table below is showing the share of Power purchase cost and other costs for Tamil Nadu and its revenue realization though energy charge, demand charge and other charges

Tamil Nadu			
Approved ARR (2013-14)		Actual Revenue Recovery	
PPC	79.1%	**Energy Charges**	89.91%
Others	20.9%	**Demand**	7.46%
		Others	3%

As of now utilities have only a handful of net-metered customers, so they have not yet felt the need to consider alternative rate designs. However, with increase in penetration & reduced revenue, there can be huge demand from utilities to impose additional charges on Net Metered Consumers as experienced globally. However there are some key issues in increasing the fixed charges

1. Voltage wise asset mapping not undertaken by utilities – important for rationalizing fixed charges across consumer categories
2. Certain states do not have fixed charge for select category consumers. Concept of Minimum Monthly Charge is adopted by select states

3. Select States have fixed changes on per connection basis for residential category consumers (not per kW basis)

Globally utility have proposed to increase the fixed charges on the consumer bill so as to safeguard against the revenue drop on account on net metering.

To recover the utility fixed cost from Net Metering consumers, there is a need to impose Grid tied charge or increase fixed charges on Net metered consumer

4. Applicability of TOD framework on Rooftop Consumer

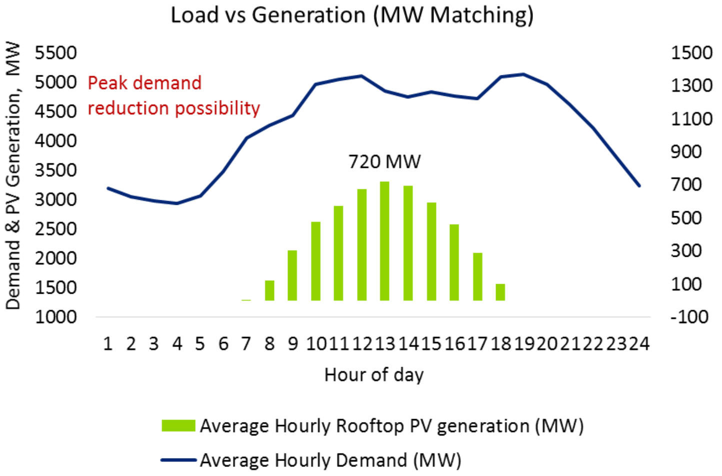
In India, Generally time of Day tariff is applicable only on consumers connected at higher voltage levels. While the rooftop consumers typically are not covered under the TOD framework have the benefit of utilizing off-peak injected power during peak time. This can impact utilities operationally as well as commercially and may become an issue with large scale proliferation of rooftop solar capacity, at later stages.

The possible solution to this issues could be mandating TOD for rooftop consumers so that energy injected during off-peak can only be adjusted against energy consumed at off-peak or Utilities need to provide banked power to consumers during peak power – may be at high cost of purchase at retail tariff pegged with normal rates.

5. Allowing surplus power from rooftop projects during peak time

Some State in India have peak during day time and solar rooftop also generate power during day time. In States like Delhi, Orissa and Tamil Nadu, Solar rooftop generation peaks during the peak time of day tariff (TOD) defined in the states. Thus solar rooftop generation is in line with the demand curve and supporting utilities in meeting the demand during peak time.

Hence in such States, Net-metered rooftop solar systems should be encourages to inject surplus power during peak time by providing an additional incentive/tariff to them. To illustrate this, case of Delhi is explained with the help of following graph (different scale used in graph)



Analysis on typical hourly demand for Delhi state shows maximum rooftop penetration in the peak sunny hour which exactly matches with the peak demand of the utility. Hence, corresponding rooftop capacity addition have possibility for demand reduction of utility during peak hours or providing surplus power.

Analysis is based on the hourly values for the month of March where MW penetration of PV is highest

Analysis shows that peak generation from solar rooftop is in line with the day time peak demand of the State. Thus, State where solar generation follows the demand curve should incentives rooftop consumers to inject during peak demand so as to avoid costlier power purchase by utilities from short term market to meet the peak demand. Table below is showing the provision of surplus injection and incentive for excess generation from solar rooftop for selected States.

Table 16: Provision of Surplus Injection and Incentive for solar rooftop

Sr. No.	State	Capacity cap on rooftop	Surplus allowed (Yes/No)	Separate incentive for peak injection	Incentive for net exported energy at end of each Financial year
1	Maharashtra	Sanctioned load, ±5% variation	Yes	No	DISCOM to purchase net exported energy at APPC
2	Delhi	Sanctioned load	Yes	Yes, not quantified	DISCOM to purchase net exported energy at APPC (provision for incentive is mentioned for consumers injecting solar power during peak demand of utility)
3	Odisha	Sanctioned load	No	No	Net energy credit maximum limit upto 90%, no financial incentive
4	Andhra Pradesh	Applicable for 3 ϕ connection	Yes	No	No financial incentive (free)
5	Uttar Pradesh	Sanctioned load	Yes	No	Net energy credit @ 0.5 Rs/kWh
6	Tamil Nadu	Sanctioned load	No	No	Net energy credit maximum limit upto 90%, no financial incentive

The table shows that States like Odisha and Tamil Nadu which have peak demand, during day time, have not allowed surplus injection and also have limitations on the upper cap of capacity / energy injection up to a certain limit.

The state of Delhi unlike others have differentiated incentive provision for excess generation between peaks / off peak solar injection. State of Delhi have mentioned a clause on the incentive for the rooftop consumer but not clearly quantified the same. Even States incentivizing net energy credit, are not provide attractive tariffs to rooftop customers. Some states have the provision of buying energy credit remained un-utilized at the end of financial year at APPC while in some states, energy credit remained un-utilized at the end of the year will be consider free. Thus discouraging consumers to generate excess energy.

Solar rooftop under Net metering arrangement should be encouraged by attractive incentive or tariff to inject surplus power during peak time to support utilities in meeting peak load.

6. Encourage storage solutions through attractive tariff

States having evening peak can also encourage surplus generation by providing attractive tariff during peak time. This can be done with the help of storage based rooftop systems. Consumers will opt for storage based systems if they will get attractive tariff for injection during peak time.

States such as Maharashtra, Gujarat, TL&AP, and Uttar Pradesh, Tamil Nadu have peak evening demand and Solar with battery storage could be a potential solution to bring down the peak evening demand of these utility states. Vehicle batteries after a certain period of charging- discharging cycles, become inefficient for vehicular application, while same can be used for power applications (grid power balancing).

The possible options for providing incentive could be as shown in the following figure.

Figure 31: Incentives Options for encouraging injections during peak time

1 Compensation linked with Rooftop Solar Feed in Tariff	• The rationale behind incentive linkage to FiT is as FiT is directly linked with cost of power generation from renewable sources and is in a decreasing trend
2 Incentive linked with marginal cost of power procurement	• States where solar injection is facilitating in reducing the peak demand of utility, incentive could be linked with top 5-10% of the marginal cost of power procurement. • Linking incentive with cost of short term power procurement by utilities
3 Incentive linked to retail tariff applicable in the same consumer category	• Incentive options under retail tariff is to link incentive with the energy charge that consumer pays for the electricity quantum (kWh) consumed.
4 Value of Solar rooftop	• Provide additional incentive over base rate (say APPC) linked with the net value of rooftop solar power to utility accounting the saving on account of T&D loss, avoided energy saving, avoided capacity savings, Transmission and distribution capacity savings (Reduced peak loading on the T&D system, postponing the need for capital investments) and environmental benefits.

7. Utilities role in controlling Active Power

Large scale rooftop proliferation create the need for higher utility visibility on rooftop solar generation pattern & control of the same. Currently it is not an issue because the capacity of solar rooftop is very low in the country but soon it may become an issue due to large scale replication. Due to this, utilities can face various issues such as

1. Voltage imbalance issue due to lack of visibility and control on distributed solar generation
2. Operational challenges in distribution grid management and control in balancing the supply and demand with such large scale rooftop feeding into distribution grid
3. Utilities have limited visibility at LT levels

In order to tackle these issues, Utility control is desirable in following identified areas.

- **Curtailment** – Active power curtailment requirements for advance inverters if grid demands
- **Communication interface** - Control and communication protocol by which Utility could manage the large scale rooftop proliferation in most optimum scenarios.
- **System Retrofits –** Retrofit requirements in current inverter technologies.
- **Accurate RE forecasting** – Ramp up requirements under variable solar generation and ways to handle the intermittent nature of solar generation.

For this, utilities will have to adopt advanced inverter, which will facilitate utility in controlling active power. In order to adopt advance inverter, the study proposed following recommendations.

Sr. No	Recommendation	Responsible Agency
1	Regulatory recommendations: a) Regulations for enabling active power function of advance inverter • H /L FRT function enabling framework and regulation	CERC / SERCs

	b) Utility command regulatory framework for control & Instrumentation functions to enable advance inverter regulations in Indian context need to be prepared and framed. c) Compensation mechanism for loss on account of active power curtailment	
2	Grid connectivity standard a) Implement Active power control support (Frequency regulation) b) Model regulation for enabling framework for active power controls	CEA/ FOR

8. Reactive Power - Determination of tariff and changes in standards

Adoption of smart inverters can provide reactive power support to utilities. Advance Inverters can be used to provide voltage regulation for improvement of tail end voltage profiles. Germany and PG&E Rule 21, USA have specific requirements for installing advance inverters for reactive power support functionality. Advance inverter functions allow for more elaborate monitoring and communication of the grid status. The ability to receive operation instructions from utility and capability to change operational parameter (reactive power) help in maintaining grid stability, support power quality. In order to adopt advanced inverters, following aspects needs to be considered

- Determination of compensation structure and level of compensation to generators for grid services provided
- System disconnect and operation standards, changes and requirements of grid connect standards (IEEE 1547)
- Communication protocols and requirements for availability of grid services by inverter based systems

Globally regulatory considerations include compensation on account of making these reactive power services available and estimated based upon the payment for reactive power generated. Areas with relatively low solar irradiance are ideally suited for reactive power compensation since most of the time inverters will be operating at lower capacity than the rated. Oversized PV inverters can also be used to meet the reactive power but it will cost higher due to the oversize designs.

For reactive power control following recommendations are proposed

Sr. No.	Recommendation	Responsible Agency
1	a) Regulations for enabling reactive power function of advance inverter b) Utility command regulatory framework for control & Instrumentation functions to enable advance inverter regulations in Indian context need to be prepared and framed. c) H / L VRT function enabling framework and regulation	CERC / SERCs
2	Grid connectivity standard – changes in the existing grid standard so as to take advantages of advance inverter functionality – Reactive power support (voltage regulation)	CEA

3	Incentive mechanism and level of incentives for adopting advance inverter functionality. Incentives could be derived from cost associated with maintaining voltage profiles across voltage levels (LT/HT)	CERC/SERC
4	Model Regulation need to be framed for Reactive Power Compensation	FOR

9. Encourage utility Driven Solar Rooftop Models.

Net Metering framework help market to grow itself, but it also has some limitations like coupling of import and export tariff, higher profitability for Consumers with high retail tariff, reduction of utility revenue etc.

While determining the retail supply tariff, SERCs generally set supply tariff higher than the ACOS of utility to recover other costs linked with supplying consumers such as cross subsidy, infrastructure cost, fixed charges etc. However with net metering system in place, utility loses sales and thus revenue. In order to safeguard utilities interest, utilities would intend to increase the retail tariff, which will encourage more consumers to shift to Net Metering and hence higher loss in revenue.

Thus, there is a need to encourage business models which are driven by utilities rather than customer driven. The benefits and implementation framework of utility driven model is illustrated in the figure below

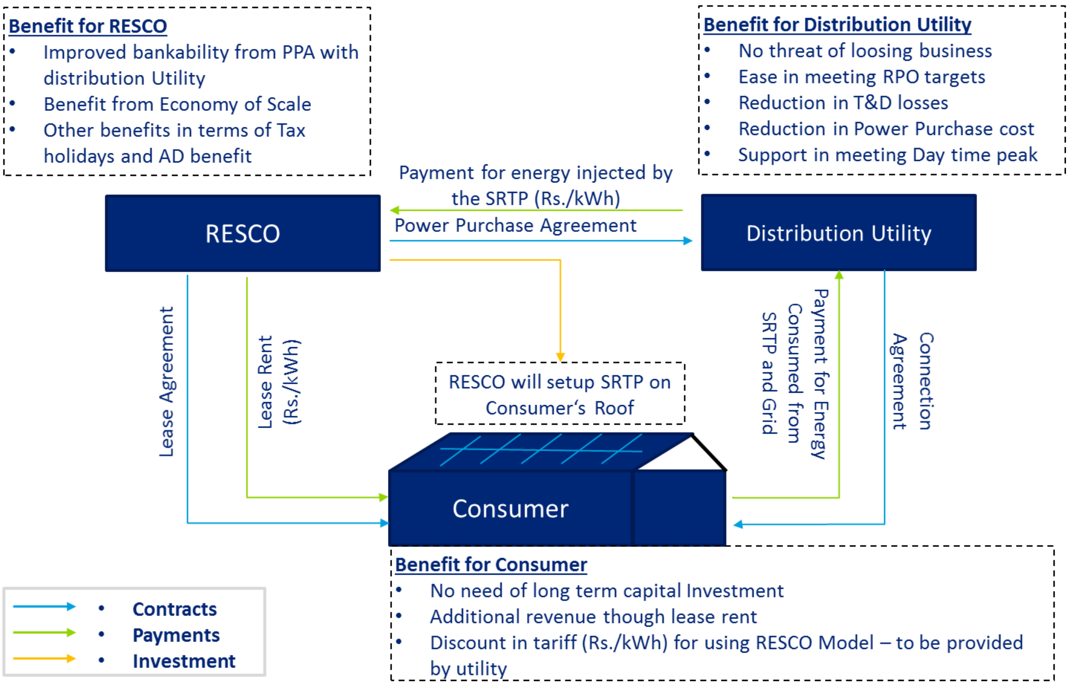


Figure 32: Utility driven Rooftop Model

Under utility driven model, RESCO will setup the rooftop system on consumer's roof but it has power purchase agreement with utility instead of consumer. Utility buys all the power generated from the rooftop system (which gets passed through in ARR). Consumer pays to utility based on its consumption from the grid and rooftop. In order to encourage consumers to take part in this scheme Utility offers discount on retail tariff.

In this arrangement, consumer gets the benefit of discounted tariff and lease rent from the RESCO, while RESCO gets assured payment though PPA with the utility. While utilities have the benefit in terms of RPO, reduction in T&D loss etc. Moreover this arrangement does not impacts utility sales as consumer are still buying from utility, thus there is no loss of revenue for utility.

To illustrate the benefit of utility driven model, two cases have been developed

- Case-1: Consumer Owned Net Metering
- Case-2: RESCO Owned Net Metering (Utility driven Model)

The comparison of both the cases is show below

Case – 1: Consumer Owned Net Metering

Assumption	
Monthly Requirement	1500 kWh
Rooftop Capacity	10 kW
Consumption – Rooftop Solar	1200 kWh
Net Consumption from Grid	300 kWh

Case – 2: RESCO Owned Net Metering (Utility Driven)

Assumption	
Monthly Requirement	1500 kWh
Rooftop Capacity	10 kW
Energy from Rooftop	1200 kWh
Energy from Grid	300 kWh
Utility may offer discount on retail tariff for solar consumed	0- 20% on retail tariff

Tariff for Domestic Category		Case-1		Case-2					
Energy Charge	Unit	Tariff	Energy Bill	Tariff (-0%)	Energy Bill	Tariff (-10%)	Energy Bill	Tariff (-20%)	Energy Bill
0-100 units	Rs./ kWh	3.76	376	3.76	376	3.76	376	3.76	376
101-300 units	Rs./ kWh	7.21	1442	7.21	1442	7.21	1442	7.21	1442
301-500 units	Rs./ kWh	9.95	-	9.95	1990	8.955	1791	7.96	1592
501-1000 units	Rs./ kWh	11.31	-	11.31	5655	10.179	5089.5	9.05	4524
> 1000 units	Rs./ kWh	12.5	-	12.5	6250	11.25	5625	10	5000
Utility Energy Charge		**Rs. 1,818/-**		**Rs. 15,713/-**		Rs. 14,323.5		Rs. 12,934	

The analysis shows that in case-1 (Consumer driven Net Metering) the energy bill of consumers for monthly requirement of 1500 units is Rs. 1818/- as it is meeting its majority of the requirement though its own solar rooftop system. While in Case-2 (Utility Driven Net Metering) the energy bill is in the range of Rs. 12,000/- to Rs. 15,000, as in this case consumer is buying total energy from the utility (either from the grid or from solar rooftop).

10. Encouraging dedicated rooftop aggregation program

Dedicated solar rooftop aggregated programs should be adopted to encourage utilities to support implementation of solar rooftop program. The benefit of these programs is that it allows utilities to implement rooftop programs and at the same time it also safeguard them against the danger or losing business as in the case of traditional consumer owned net metering arrangement. The proposed implementation model for rooftop aggregation program is shown in the following figure

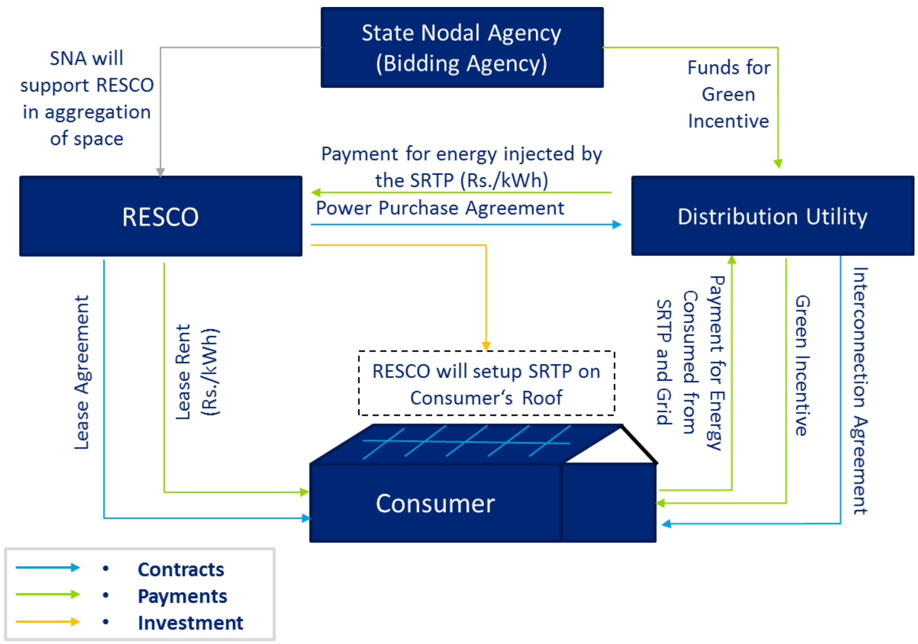


Figure 33: Implementation Model for Aggregated solar rooftop Program

The Roles and responsibilities of different parties under this model is given below

Key Stakeholders	Roles and Responsibilities
1 MNRE or State Nodal Agency	• MNRE/SNA shall aggregate Roof Space • MNRE/SNA shall facilitate bid process for aggregated capacity • MNRE/SNA shall provide funds to State discoms for disbursement of Incentive • Prepare model leasing agreement
2 Distribution Utility	• State discoms shall sign PPA with RESCO on price discovered through bidding process • State Discoms shall support consumers for Installation of Rooftop Projects through designing efficient Interconnection process • State discoms shall disburse incentive (Rs/kWh) to consumers for using solar power based on generation from solar rooftops • State Discoms shall sign Interconnection agreement with consumers and will ensure grid stability and quality
3 RESCO	• RESCO shall sign lease agreement with roof owner and will provide lease incentive • RESCO shall sign PPA with discoms at price discovered through bidding process • RESCO shall sign O&M Contract with consumer and ensure smooth operations
4 Consumer	• Consumer shall lease its roof space and provide access to RESCO • It will sign Lease agreement with RESCO and Interconnection agreement with discom to become eligible for any incentive

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Deloitte.

About the study

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About Shakti Sustainable Energy Foundation

Shakti Sustainable Energy Foundation works to strengthen the energy security of the country by aiding the design and implementation of policies that encourage energy efficiency, renewable energy and sustainable transport solutions, with an emphasis on sub sectors with the most energy saving potential. Working together with policy makers, civil society, academia, industry and other partners, we take concerted action to help chart out a sustainable energy future for India (www.shaktifoundation.in).

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