Distribution Utilities Forum

SOLAR ROOFTOP: PERSPECTIVE OF DISCOMS

A study to highlight the current development of 'Solar Rooftop Programme' in India and viewpoints of Discoms on technical, financial, operational, administrative & regulatory aspects

Rashi Singh | Rishabh Sethi | Robin Mazumdar

SHAKTI SUSTAINABLE ENERGY FOUNDATION

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Creating Innovative Solutions for a Sustainable Future

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Tel.: 24682100, 41504900
Fax: 24682144, 24682145
India +91 • Delhi (0) 11
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Message

AJAY MATHUR

Director General, TERI

In its commitment to install 175 GW renewable energy, India had set a target of setting up an installed capacity of 40 GW to be met through rooftop solar PV systems. The rate of deployment of solar rooftop calls for a closer look at ways and means to achieve the target of 40 GW installed capacity by 2022 in the first instance and make concerted efforts to exploit the potential so as to address energy security, environment and climate change concerns. The slow growth of the sector can be attributed to various reasons; Discoms' passive role in the entire implementation process for solar rooftop could be one.

In the second meeting of the Distribution Utilities Forum (DUF), an initiative launched by The Energy & Resources Institute (TERI) and Shakti Sustainable Energy Foundation (SSEF), it was discussed that the issues faced by Discoms in implementing Rooftop Solar Systems and measures that are required to be taken are to be addressed from a Discom's perspective. A discussion paper on the theme was prepared by TERI based on literature review and consultations with Discoms officials. TERI presented its findings from the study in the Forum meeting held on 22 February 2019. The participating Discoms shared their challenges and best practices in implementing the Solar rooftop.

This analysis and experience has been captured in this report, which provides an update understanding of best practices and of ways and means to address the challenges faced by Discoms.

Dr. Ajay Mathur

Message

KRISHAN DHAWAN

CEO, Shakti Sustainable Energy Foundation

As you are aware, Shakti Sustainable Energy Foundation and The Energy and Resources Institute launched the Distribution Utilities Forum came together last year to provide Indian power distribution companies with an independent platform where they can meet with their peers and share perspectives on the issues and challenges that confront the sector and discuss potential solutions to these problems.

Last year we held two meetings and released a report titled, Rural Electrification: Impact on Distribution Companies. The third one, held on February 22, 2019, focussed on the issues faced by Discoms in implementing Rooftop Solar Systems and what measures need to be taken to make this a win-win for all stakeholders - Discoms, customers, large and small, to reach the government's goal of 40GW by 2022. Discoms suggested multiple changes in their operational environment including regulatory changes and changing over to a Discom-centric business model to make Rooftop Solar an attractive proposition for them.

This report flows out of our initial findings combined with the discussions at the Forum meeting.

I trust you will find the report of interest.

Krishan Dhawan

Foreword from Chairman

GIREESH B PRADHAN

Honorary Chairman, DUF

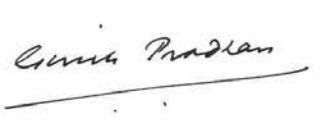
At the tail end of retail supply, Discoms are crucial to not only delivering last mile connectivity to the end-consumer but also in meeting the Government's Renewable Energy commitments.

Though we have made significant progress on utility-scale solar projects, achieving 40 GW of solar rooftop capacity seems to have become a challenge for most Discoms, especially for state-owned Discoms. It was with this in view that Distribution Utilities Forum took up the subject for discussion at its 3rd meeting in February this year.

I am happy to note that meeting witnessed robust discussions with Discoms airing their operational constraints in implementing rooftop solar systems and coming forward with suggestions that can improve their operational capacity and contribute to higher off take of energy from renewable sources.

Discussions at the meeting along with responses from preliminary surveys with Discoms on the subject have been captured in this report.

I trust that you will find the report interesting reading.



Gireesh B Pradhan

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LIST OF *ABBREVIATIONS*

AC	Alternating Current
APDCL	Assam Power Distribution Company Limited
ARR	Aggregate Revenue Requirement
AT&C	Aggregate Transmission and Commercial
BESCOM	Bangalore Electricity Supply Company Limited
BRPL	BSES Rajdhani Power Limited
BYPL	BSES Yamuna Power Limited
CAPEX	Capital Expenditure
CEA	Central Electricity Authority
CED	Chandigarh Electricity Department
CEEW	Council of Energy, Environment and Water
CERC	Central Electricity Regulatory Commission
CESC	Calcutta Electric Supply Corporation Limited
CFA	Central Finance Assistance
CREST	Chandigarh Renewal Energy and Science & Technology Promotion Society
c-Si	Crystalline Silicon
CUF	Capacity Utilization Factor
DC	Direct Current
DER	Distributed Energy Resource
DERC	Delhi Electricity Regulatory Commission
DGVCL	Dakshin Gujarat Vij Company Limited
Discom	Distribution Company
DSM	Deviation Settlement Mechanism
DT	Distribution Transformer
DUF	Distribution Utilities Forum
EPC	Engineering Procurement and Construction
FiT	Feed-in Tariff
GCRTS	Grid Connected Rooftop Solar
GEDA	Gujarat Energy Development Agency
GoI	Government of India
GW	Gigawatt
GWp	Gigawatt Peak
INR	Indian Rupee
IREDA	Indian Renewable Energy Development Agency
ISGS	Inter-State Generating Station
JNNSM	Jawaharlal Nehru National Solar Mission
kW	Kilowatt

LIST OF *ABBREVIATIONS*

kWh	Kilowatt Hour
kWp	Kilowatt Peak
LV	Low Voltage
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MPMKVVCL	Madhya Pradesh Madhya Kshetra Vidyut Vitaran Company Limited
MPUVNL	Madhya Pradesh Urja Vikas Nigam Limited
MW	Megawatt
MWp	Megawatt Peak
NAPCC	National Action Plan on Climate Change
NCEF	National Clean Energy Fund
NISE	National Institute of Solar Energy
NSM	National Solar Mission
OPEX	Operational Expenditure
PPAs	Power Purchase Agreements
PV	Photovoltaics
PVVNL	Pashchimanchal Vidyut Vitran Nigam Limited
R&D	Research and Development
RE	Renewable Energy
REC	Renewable Energy Certificate
RESCO	Renewable Energy Service Company
RPO	Renewable Purchase Obligation
SCADA	Supervisory Control and Data Acquisition
SECI	Solar Energy Corporation of India
SERCs	State Electricity Regulatory Commissions
SLDCs	State Load Dispatch Centres
SMC	Surat Municipal Corporation
SNAs	State Nodal Agencies
T&D	Transmission and Distribution
TERI	The Energy and Resources Institute
ToD	Time-of-Day
TPDDL	Tata Power Delhi Distribution Limited
VAR	Volt Ampere Reactive
WBSEDCL	West Bengal State Electricity Distribution Company Limited

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We thank Shakti Sustainable Energy Foundation (SSEF) for supporting this initiative, and **Mr. Vivek Sen**, Programme Manager (Power)**, Ms. Gayatri Ramanathan**, Programme Manager (Projects), **Ms. Disha Agarwal**, Programme Officer (Renewable Energy), and **Ms. Vrinda Sarda**, Senior Program Associate for their inputs during the course of this research.

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ABOUT THE AUTHORS

This report has been authored by **Ms. Rashi Singh**, Research Associate, Electricity and Fuels Division, TERI, **Mr. Rishabh Sethi**, Consultant, Electricity and Fuels Division, TERI and **Mr. Robin Mazumdar**, Consultant, Electricity and Fuels Division, TERI.

EXECUTIVE **SUMMARY**

"Solar will come and it can't be stopped"

Government of India has set an ambitious target of 175 GW of installed capacity of renewable energy (RE) by 2022, including 100 GW of grid-connected solar power, comprising 60 GW utility-scale solar, and 40 GW solar rooftop. Though India has made significant progress in implementation of utility-scale solar projects, achieving 40 GW of solar rooftop installations is still a substantial challenge. As on December 2018, installed capacity of solar rooftop systems was approximately 3.85 GW[1].

Distribution Companies (Discoms), being at the tail end of electricity supply chain, constitute a crucial link with the consumers and can, therefore, help accelerate the growth of solar rooftop sector. On behalf of the Distribution Utilities Forum (DUF), DUF Secretariat interacted with 10 representative Discoms across all grid regions of India to understand the challenges and opportunities associated with integration of solar rooftop into their systems. The study also reviews the literature (of last 2-3 years) available on this sector in the country and examines current policies and regulations notified by the central and state governments meant to drive the growth of the sector in the country.

During the course of our discussions, it was observed that Discoms perceived that solar rooftop could be a profitable business proposition if they can take an anchor role in its implementation. However, to accelerate the growth of the sector, certain challenges are required to be addressed through regulatory interventions and customized business models. Consultations with the Discoms under this study brought out their views towards solar rooftop presenting different aspects of opportunities, challenges, and apprehensions.

- As far as the **technical** aspects are concerned, Discoms perceive challenges in integration of increasing penetration of solar rooftop, which are presently not apparent on account of injection of solar rooftop in the grid being quite nominal. Need for storage of excess energy generation for use in accordance with the system demand, importance of anti-islanding feature, and determination of appropriate PV hosting capacity in their distribution network & accessibility to the solar inverters as and when required. Other issues underlined by the Discoms that may arise with increasing solar rooftop capacity in the grid are mainly related to the quality of power injected into the grid, especially the harmonics effects due to power electronic devices used in solar PV system. Discoms suggested need for power flow simulation studies to understand the technical impacts of increased penetration of solar rooftop on the distribution network, and corresponding mitigation measures.
- Most of the Discoms expressed revenue impact due to solar rooftop as a major concern as they still have to pay the fixed charges under PPAs with generating stations, contend with reduced energy sales and an increased burden of cross subsidy. It was also discussed that despite the challenges on the **financial** aspects of the Discoms, solar rooftop could also provide an opportunity for them to optimize their scheduling of power procurement, reduce their power purchase cost, and defer their network augmentation expenditure. In order to avail the benefits of solar rooftop, the Discoms suggested need for new and innovative business models (which could be utility-driven) addressing their concerns so as to provide required impetus for implementation of solar rooftop systems.

"Agricultural consumers must be solarized!"

[1] India Solar Compass Q4 2018, Bridge to India

In this respect, some Discoms expressed that gross-metering with a moderate feed-in-tariff is a better arrangement over net-metering for a well-developed solar rooftop market, as the net-metering arrangement have greater financial implications on the Discoms. One of the solutions suggested at the DUF meeting was a regulatory arrangement where both the models co-exist, allowing the Discom to choose the appropriate model for each customer category.

- With regard to the **operational** aspects, Discoms mentioned that metering and billing & energy accounting as the main hurdle while implementing solar rooftop within their license area. This was mainly due to lack of skilled manpower and lack of generation data through real-time monitoring & forecasting of solar rooftop generation. These operational challenges faced due to solar rooftop as discussed by the Discoms have an impact on their operational expenditure as well. Apart from the challenges brought out, the opportunities that solar rooftop brings on the operational front were also discussed, especially in terms of reduction of T&D loss, help in meeting their RPO obligations, and improving the life of the assets utilized due to reduction of net-load in their network. On the **administrative** part of it, Discoms expressed lack of consumer awareness as one of the biggest hurdles. As the consumers are not aware of (a) benefits of solar rooftop, (b) procedure and guidelines for putting up solar rooftop systems, and (c) quality standards, giving a thrust to these systems is a huge challenge. Lack of co-ordination among different implementing agencies is another challenge in implementation of the programme. Discoms strongly emphasised the need for operational and administrative challenges being looked into by the respective state government and other concerned agencies, and come up with utility specific operational strategies.
- **Policy and regulations** for implementation of solar rooftop projects have been notified in almost all the states. However, Discoms were of the view that they are consumer-oriented and do not take into consideration the losses and challenges faced by them. They felt the need for amending these policies and regulations to make them balanced from the perspective of consumers as well as Discoms. According to them, mandating Discoms as one of the key implementing agencies for solar rooftop duly taking care of their operational and administrative costs & revenue loss on account of introduction of solar rooftop would go a long way in giving requisite thrust to the solar rooftop programme.

"Installing solar rooftop system is fine, but monitoring is essential!"

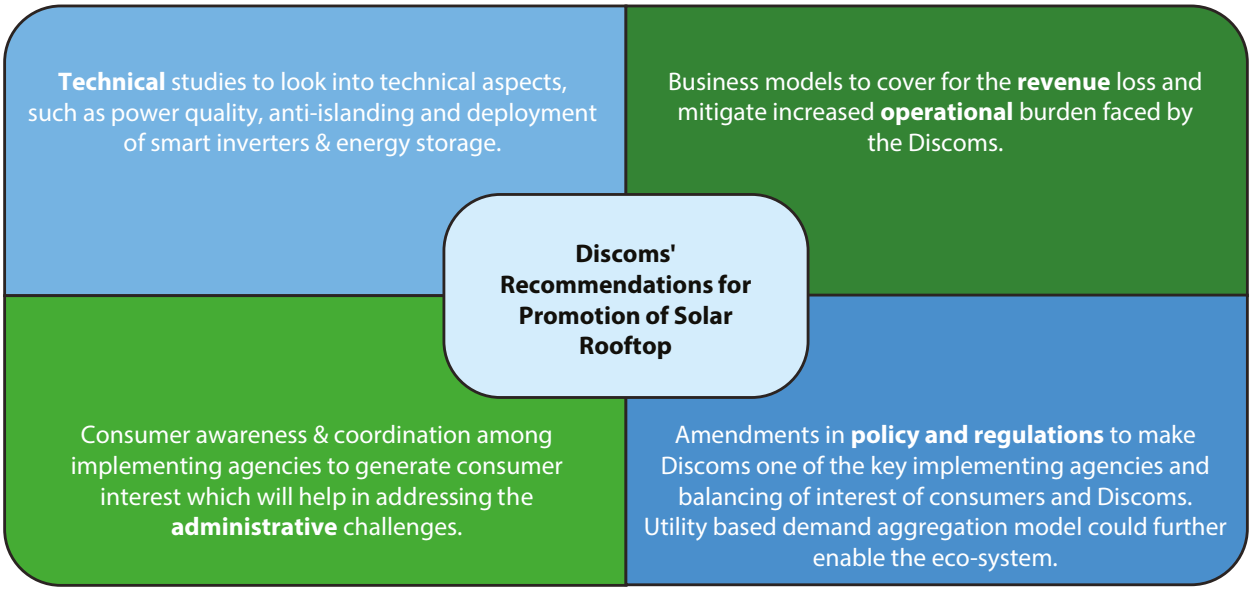

Figure 1: Discoms' Recommendations

INTRODUCTION

Overview of Solar Rooftop Sector in India

India lies in the high solar insolation region, endowed with significant solar energy potential. The total solar power potential in the country, as estimated by National Institute of Solar Energy (NISE), is approximately 749 GW[2] including solar rooftop. TERI has estimated that the realistic market potential for solar rooftop PV in urban settlements is about 124 GWp [1]. Central and the state governments have from time to time announced various policies for development of solar rooftop in the country. Under National Action Plan on Climate Change (NAPCC), the Government of India (GoI) had approved the Jawaharlal Nehru National Solar Mission (JNNSM) in January 2010, which paved way for the growth of solar capacity in the country. A target of 175 GW of installed capacity of renewable energy sources by 2022 was set including 100 GW of grid-connected solar power, comprising 60 GW utility-scale solar and 40 GW solar rooftop.

The institutional arrangement for implementation of the programme is clearly specified, both at the central as well as state level. At the central level, Ministry of New and Renewable Energy (MNRE) and Ministry of Power (MoP) of Government of India act as its nodal ministries. Solar Energy Corporation of India (SECI) has been constituted to act as the implementing agency for solar policy initiatives and plays a vital role in bridging the supply-demand gap in the market through diverse facilitation and support services. National Institute of Solar Energy (NISE), an autonomous institution of MNRE, was set up as a national R&D institution in the field of solar energy. Indian Renewable Energy Development Agency (IREDA) under the administrative control of MNRE, financially supports implementation of various policy initiatives by providing term loans for renewable energy projects. Central Electricity Authority (CEA) and Central Electricity Regulatory Commission (CERC) are key organizations that advice the government on technical and regulatory matters. At the state level, a similar institutional structure is present, with respective state energy/power departments as the nodal departments for the state governments. Various state energy development agencies are present to facilitate the implementation of policy initiatives at the state-level. The state electricity regulatory commissions (SERCs) act as the regulatory body at the state-level and look into the policy and regulatory matters respectively at the state level.

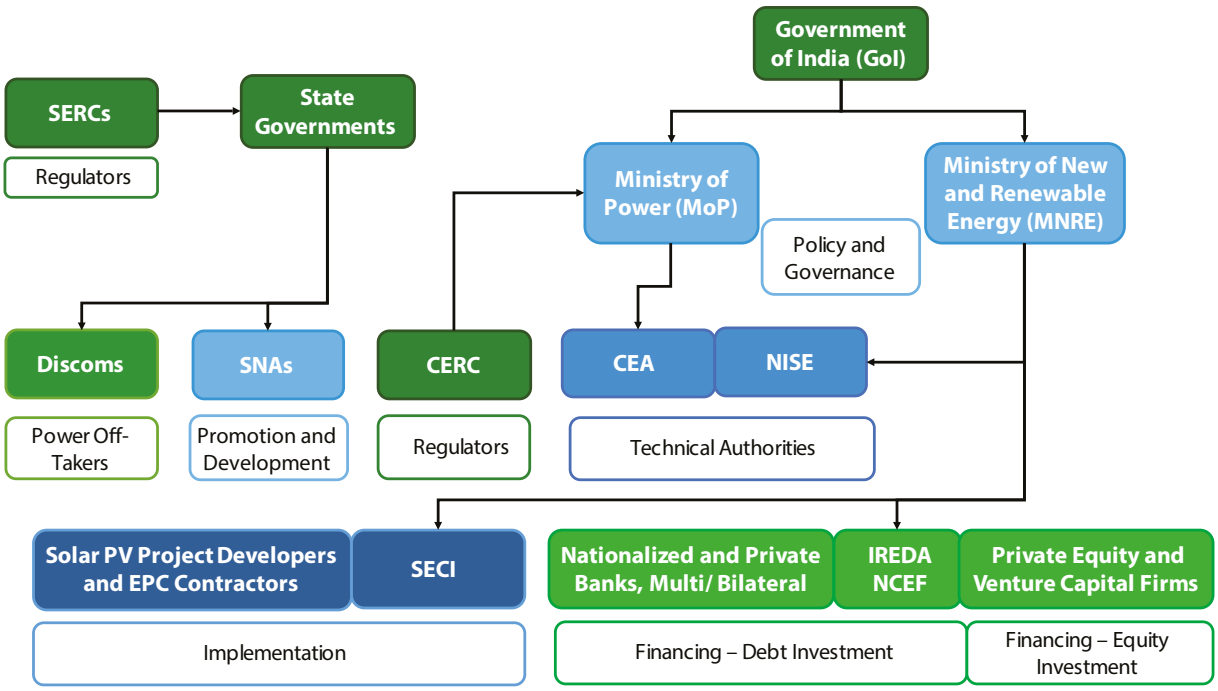

Figure 2: Institutional Arrangement for the Solar Rooftop Sector in India [2]

[2] https://mnre.gov.in/file-manager/UserFiles/Statewise-Solar-Potential-NISE.pdf

For the promotion of solar rooftop under the JNNSM, Off-Grid and Decentralized Solar Application Scheme was launched in the mission's 1st Phase during the 11th Plan Period. This phase of the scheme was focused on promotion of applications of solar energy to meet/ supplement power, heating and cooling requirements[3]. Under the 2nd phase of the scheme during the 12th Plan Period, the Grid Connected Rooftop and Small Solar Power Plants Programme[4] was launched for the promotion of grid-connected solar rooftop, under the National Solar Mission (NSM).

Government of India approved Phase-II of Grid Connected Rooftop Solar Programme on 19th February, 2019, inter-alia revising distribution of the Central Finance Assistance (CFA). CFA can only be availed by the residential sector consumers (40% CFA for systems under 3 kW and 20% CFA for systems between 3 kW and 10 kW[5]) for setting up 4000 MW of grid connected solar rooftop projects[6] from the allocated budget of INR 6,600 crore. Details of the programme are mentioned in Annexure 1.

Despite considerable decline in the cost of solar rooftop installations, cost discovered through auctions and the advantages which these systems provide, the deployment rate would need to be accelerated to realize the national target of 40 GW by 2022 as only around 3.85 GW has been installed as of December, 2018.

This study aims to present the key challenges and opportunities that the Discoms perceive in regard to implementation of the solar rooftop within their license area. It also aims to present practices in solar rooftop sector followed by certain Discoms, which could also be adopted by various other Discoms.

Objectives of the Study

With the above backdrop, and based on the discussions held at the second meeting of the Distribution Utilities Forum (DUF) on 31st October 2018, this study aims to:

- Review of literature on solar rooftop with regard to the technical, financial, operational & administrative, and regulatory aspects of solar rooftop.
- Present an overview of Discoms' perspective in regard to the aforementioned aspects of solar rooftop implementation.
- Highlight key implementation and post implementation challenges identified by Discoms while executing solar rooftop programme.
- Present some of the leading operational and institutional best practices that have enabled specific Discoms to achieve better progress in implementation of solar rooftop in their license area.

Approach and Methodology

The approach adopted to achieve the objectives of this study included a combination of literature review and consultations with Discom officials. A total of 10 Discoms (Annexure 2) in the seven states – Delhi, Madhya Pradesh, Gujarat, West Bengal, Assam, Karnataka and Uttar Pradesh – were selected for consultation. The selection was done with a view to include Discoms from states which have larger potential for solar rooftop, different consumer mix and ownership structure of utility- public or private.

The project team met a cross-section of mid-to-senior level Discom officials which included MDs, Directors, Chief Engineers, General Managers and Superintending Engineers – in-charge of commercial, technical, revenue and project (solar rooftop, new technologies) implementation functions. Face-to-face and telephonic-group and individual meetings/ discussions/ interactions were held with 30 Discom officials in January 2019. The duration of interviews ranged from 40 minutes to 2 hours. The list of questions forming the basis of discussions is provided at Annexure 3.

[3] https://mnre.gov.in/sites/default/files/schemes/aa-jnnsm-2012-13.pdf
[4] https://mnre.gov.in/file-manager/UserFiles/Scheme-Grid-Connected-Rooftop-&-small-solar-power-plants.pdf
[5] http://pib.nic.in/PressReleaseIframePage.aspx?PRID=1565282
[6] https://mnre.gov.in/sites/default/files/uploads/newadministrativeapproval.pdf

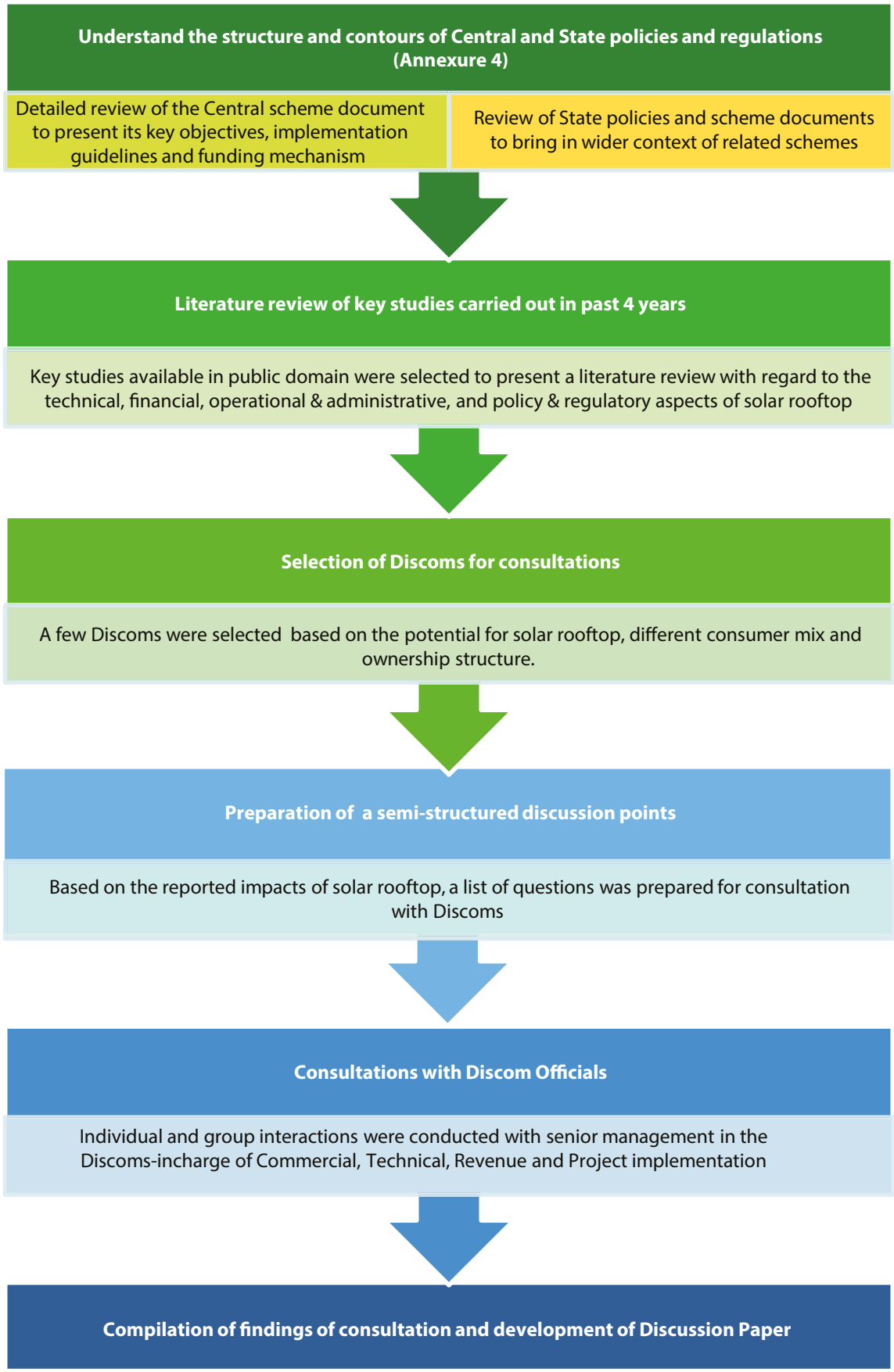

Figure 3: Approach and Methodology adopted for the study

FINDINGS OF STUDY

Financial and Operational Aspects

Over the years, the initial cost of solar PV has reduced, but owing to the small size of the projects, upfront cost of installing solar rooftop systems continues to be high for majority of consumers. Although the economies of scale will bring down the costs of setting up of systems eventually, there is a need to attract financial investments to reach the target of 40 GW by 2022 [3].

One of the main hindrances in the growth of this sector that comes out from various studies is that Discoms are hesitant to promote solar rooftop in their license area as they perceive it as a **threat to their revenue** [1]. They anticipate substantive revenue loss from decreased energy 'sales' and the amount payable by them for any excess energy generated and injected into the grid. Though a few Discoms see solar rooftop as a profitable business case as it can help in meeting the demand locally, reduce transmission and distribution (T&D) losses and manage day time peaks. This can lead to optimized scheduling of power procurement from power stations or power exchange and thereby reduce their power purchase cost.

Apart from the direct impact on the energy sales, the Discoms underlined other financial repercussions of implementing solar rooftop. Despite reduction in power procurement, the Discoms will still have to **pay the fixed-charges to the generators**, as the contracted power cannot be surrendered under their long term Power Purchase Agreements (PPAs). Discoms also mentioned that the state generating companies are not in a favour of reducing the power procured by the Discoms from them. Discoms, therefore, find solar rooftop implementation leading to unwanted revenue loss for them, especially with net-metered prosumers in their service-area.

Some Discoms perceive solar rooftop as an opportunity. Being an obligated entity, Discoms are required to meet their Renewable Power Obligation (RPO) targets or have to purchase Renewable Energy Certificates (RECs) to avoid the penalty for failing to meet their RPO target. While a few Discoms reported that, due to the declining solar tariff, it is cheaper to buy solar power from ground-mounted solar plants; some expressed that solar rooftop can help in **meeting their RPO targets** thereby **reducing their purchase of RECs**.

Regarding financial investments in the network infrastructure, solar rooftop systems, according to most Discoms, present significant challenges and few opportunities. In terms of challenges, Discoms are faced with an increased **burden of additional infrastructure** in order to integrate the growing number of rooftop systems into their grid especially if their existing distribution infrastructure is not in good condition. Only a few Discoms see an opportunity in terms of reduction in operational burden due to load reduction on the network, which in turn improves the life of the assets/ equipment utilized and helps in **deferring capital expenditure on network augmentation**.

Some studies have highlighted the impact of solar rooftop on the utility in terms of **cross-subsidy** collected from its consumers [4], [5]. Most of the Discoms shared that since it is the high revenue consumers, with generally larger rooftop space, install solar rooftop systems, the quantum of energy charges realized reduces, while the low-paying consumers, with smaller/ no roof-space will continue to depend on Discoms for power supply. Thus, there is an **increased burden of cross-subsidy** on 'non-solar' consumers, more so on the low-paying ones. Certain Discoms had shown interest in solar rooftop as a tool to **address the challenge of increased cross-subsidy burden**, if their low-paying consumers (which are mostly residential/ rural) could be mobilized to implement solar rooftop at their premises.

With proliferation of solar rooftop, various studies have anticipated that the utilities may face some operational challenges while integrating these solar rooftop systems into their grid [4], [5]. The operational challenges may vary from demand balancing and variability of power generation to daily operational burden, such as application processing, inspection and connectivity, **metering and billing**. Owing to their small & distributed nature, generation forecasting for these systems is not carried out and utilities may find it difficult to do **real-time monitoring** of these distributed energy resources (DERs) [6]. Discoms put forth **metering and billing** of power and **energy accounting** as their main operational challenge. A **shortage of skilled and trained staff and lack of data on the generation** of solar rooftop systems makes it difficult for the Discoms to handle the billing for solar rooftop system for the prosumers (especially,

in the case of net-metering connection arrangement) and undertake real-time monitoring and forecasting of generation for such systems and, thus, affect their power scheduling.

Another major challenge faced by utilities is that the residential 'prosumers' with solar rooftop systems are not covered under '**Time-of-Day' (ToD) framework**, which is highlighted in the literature as well [4]. Certain Discoms expressed that this issue has an impact on both, financial and operational aspects as these 'prosumers' can use their excess solar generation exported to the grid during off-peak hours to settle energy imported from the grid during peak time. In the process, the utility grid is treated as a back-up power source by these 'prosumers'.

As discussed in the literature and emphasized by the Discoms during the interactions, there is a need to amend and formulate policies and regulations to be more Discom-oriented by taking into consideration the operational and financial burden/ challenges faced by them while implementing solar rooftop. The literature discusses the revenue loss for the utility in terms of energy sales along with the operational challenges, but it does not quantify the impact of solar rooftop on the finances of a utility. Amendments to the present policy and regulations were underlined by the utilities to address their financial burden arising on account of cross-subsidy, power procurement locked in long term PPAs and operational challenges in regard to metering and billing, energy accounting and also on account of skilled human resource. Incentives could be given to help Discoms recover financial loss which they would have to incur with the implementation of solar rooftop. Discoms also opined that at present, the incentives provided to them under recent Cabinet-approved Phase-II of Grid Connected Rooftop Solar (GCRTS) Programme, though encouraging, may not be sufficient to recover their financial loss. However, as per Discoms, more clarity is required on the programme, in order to know more about these incentives, which is awaited as of now.

The issue of revenue loss of the utilities due to solar rooftop can be addressed by exploring the 3rd generation of business model (Annexure 5), i.e., the **Utility-Based Business Model** [7]. In this model, the utilities are actively involved in promotion and implementation of the solar rooftop systems so as to capture benefit from the solar markets [8]. Discoms expressed their opinion that the adoption of new and innovative Discom-oriented business models can help mitigate some of the financial challenges faced by them during the uptake of solar rooftop systems.

New and Innovative Utility-Based Business Models

In the year 2018, with the help of Council of Energy, Environment and Water (CEEW) and support from Shakti Sustainable Energy Foundation, BSES Yamuna Power Ltd. (BYPL) has developed three new innovative utility-based business models that can accelerate the deployment of solar rooftop systems in the residential sector [12], which are, namely:

1. *Utility-Led Community Solar Model (Suitable for consumers without roof access)*
2. *On-Bill Financing Model (Suitable for consumers without access to credit)*
3. *Solar Partners Model (Suitable for all residential consumers)*

Deploying these models, the utility plans to charge a service fee from the consumers and developers, so as to mitigate any revenue loss from the solar rooftop and thus making it a viable business case for the utility. BYPL has requested Delhi Electricity Regulatory Commission (DERC) for their approval for a pilot project on these solar rooftop business models in order check the feasibility of each model for the Discom.

Technical Aspects

As per the literature available on technical studies on integration of solar rooftop with the distribution grid, major concern of utilities/grid operators is the technical issue of grid balancing. The technical impact of solar rooftop on the distribution network is discussed under a study [9]. The study suggested that the technical impact on the distribution network expected from solar PV integration can be attributed to two characteristics associated with such generation systems - the **inherent intermittency due to resource-side variations** and the other is the **power electronics based connection interface**. Due to the diurnal variability of solar

radiation, the generation from a PV array is never constant. Hence, grid-tied PV inverters inject a variable AC output linked to variation in solar insolation. There are also instances of cloud cover that could lead to a sudden fall in generation which in turn leads to sudden stress on the distribution system.

The power electronics-based interface makes a solar PV system characteristically different in terms of the nature of generation. This is also a major reason behind a variety of technical impacts that a distribution system may experience with higher penetration of solar PV generation. The likely technical impacts of solar PV integration on a distribution feeder have been presented in the figure 4, categorizing under various heads that indicate different aspects of a distribution system that are likely to be impacted with rising solar PV penetration.

At present, the percentage share of solar rooftop in the grid being nominal, no major technical issues have come to the fore so far. However, with higher penetration of solar into the grid, Discoms anticipate **power quality issues** such as harmonic distortions, managing peak load with intermittent solar rooftop generation, improper forecasting and scheduling of generation from solar rooftop, leading to higher charges under Deviation Settlement Mechanism (DSM) Regulations. A study, based on a review of global and Indian policies and regulations, highlights the technical issues involved, for both PV systems as well as the distribution grid [9]. Apprehension of Discoms regarding the quality of power being injected into the grid has also been discussed in the study. Primary causes identified to be impacting the LV distribution grid with higher penetration of a large number of distributed solar generators were flicker, harmonics and DC injection. **Lack of reactive power** due to the static nature of these generators was also a concern flagged in the literature as well as by Discoms. Discoms stressed the need for connecting solar rooftop to the distribution system through smart inverters for VAR support and voltage-conditioning. With currently available inverters being equipped with smart technology and regulations also being in place in regard to safety while installing solar rooftop system, Discoms need not consider it to be a cause of concern.

Discoms suggested that a **proper quality check** of the components and system is required to ensure power quality and durability of the system. Although, CEA and MNRE have already specified design qualifications and quality standards for both crystalline Silicon (c-Si) and thin film modules as well as testing guidelines[8]

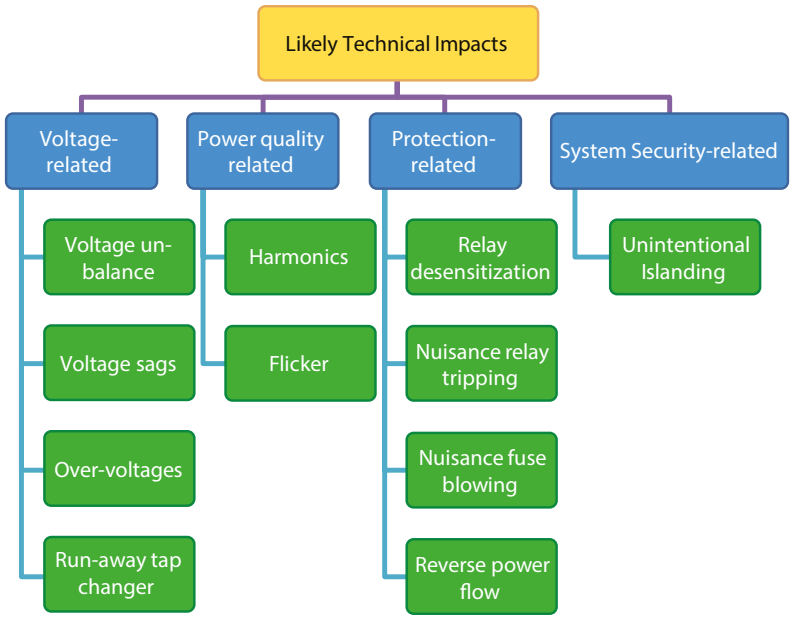

Figure 4: Impacts of solar PV integration related to different aspects or parameters relevant for a distribution system[7]

[7] https://www.blogger.com/blogger.g?rinli=1&pli=1&blogID=7874127038449813252#editor/target=post;postID=6900577849660863164;onPublishedMenu=allposts;onClosedMenu=allposts;postNum=0;src=postname
[8] https://mnre.gov.in/file-manager/UserFiles/Rooftop-Solar-PV-Quality-Standards_Revised.pdf

for PV modules and inverters, faulty systems may still affect the distribution grid. Discoms suggested that solar rooftop installations should be periodically checked to ensure that the generation injection is as per the set limits in the agreement and does not create power quality issues for the grid. Discoms were of the view that they may hire other agencies or outsource manpower for periodic check-ups of solar rooftop systems in their service areas as, they believe, thus, is very crucial for the safety of the distribution grid. However, one of the biggest challenges for carrying out regular inspections of the solar rooftop systems is that these systems being installed in consumer premises are beyond the reach of Discom's authority and getting consent of the owner of the premises is a major task for the Discoms. Hence, quality check or monitoring of these systems becomes difficult.

One of the major issues Discoms highlighted is **lack of availability of real-time generation** data from solar rooftop PV systems. Discoms opined that there is a need for forecasting of solar rooftop generation on day-ahead basis as well as centralized monitoring system for real-time report of such generation. It is important for Discoms to account for anticipated generation in the day-ahead scheduling of power and recording of solar generation would also help them in reporting RPO compliance. If these data are available with Discoms, it can also help in managing the day-time peaks observed by some utilities, thereby optimizing the costly power procured from power stations or, power exchange and thus reduce their power purchase cost. A study mentions that data acquisition from distributed solar plants is critical in planning and operation of the grid, especially in high penetration scenarios [9]. However, the high cost of such systems, like SCADA systems, is the major issue for the Discoms who are already financially strained. Currently, there is no immediate need to mandate data acquisition and monitoring systems for distributed PV systems since the penetration is low and it comes at a significant cost to the consumer or Discoms. It is further suggested by the study that the CEA may look at introducing data reporting requirements for plants above a specific capacity (say 100 kW) and this data should be accessible as part of a central database for utilities, SLDCs, etc.

Most of the Discoms were of the view that solar rooftop systems could help in the r**eduction of T&D loss**, avoid over-loading of distribution transformers (DTs) & network congestion and also help in meeting demand with higher degree of reliability as generation is at the contract demand side. However, in case of power surplus utilities, excess generation from the solar rooftop with lack of storage, there is reverse power-flow into the distribution grid. A study has quantified these benefits, presenting several benefits for distribution utilities in terms of meeting the day time peak demand, curbing technical losses, reducing power purchase cost, etc., with the support of solar rooftop [4]. However, Discom-specific studies need to be carried out to quantify these benefits and assess how solar rooftop could be a viable case for each Discom.

Discoms emphasized that **solar rooftop capacity** should not exceed contract demand and there should be a cap on the maximum-size of these systems that can be installed by each consumer category; primarily to ward off potential revenue loss due to increased injection of energy from solar rooftop systems into Discoms systems. Also, before installing solar rooftop, capacity of the distribution systems has to be checked and at times they may have to be upgraded so as to accommodate larger system sizes. Hence, capping of the solar rooftop system size is an amendment for the considerations in the regulations. Most regulations limit solar rooftop PV system sizes to be in the range of 1 kWp to 1 MWp [2]. Although, the policies and regulations encourage self-consumption of solar power at the end use, regulations limit the system size to 80–100 % of the facility connected load. Most state-regulations allow injection of solar power in the grid limited to 15–30 % of the rated capacity of distribution transformer. However, a simulation-based study shows that PV penetration levels of 75% of distribution transformer capacity and higher can be implemented without having to undertake any measures to contain voltage problems or overloading [10]. This is significantly higher than the limits usually prescribed in the regulations (15–30% or higher in few cases) in most of states today. Solar rooftop penetration level of the DT may be lower in weaker grids, or if additional free field PV power plants are connected. In addition, presently the section 4 (6) (a, b) of the CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2013 as well as section 7 (3) of the CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Amendment Regulations, 2019 mandate that the utility should undertake an inter-connection study to determine the maximum capacity of distributed generators at a particular location. Discoms were of the view that once the first check-point penetration limit of rated DT capacity suggested in the state net-metering regulations is reached, studies can be undertaken to determine maximum capacity for each DT in the Discom's license area.

Phase-balancing is also an issue associated with integration of distributed single phase grid-connected solar rooftop PV systems. Solar rooftop PV plants having capacity of 5 to 10 kWp are allowed to be connected in single phase in some states, e.g. Karnataka and

Madhya Pradesh. While, no technical difficulties have been reported so far, some Discoms perceive that with increasing penetration levels of such systems, one of the phase conductors may remain over-loaded in comparison to other ones. The reverse power flow may also occur if the net-metered systems start injecting excess power, back towards the DT. Thus, unequal phase current flowing in the system would cause more current to flow in the neutral conductor that may have implications on conductor life. Although, the issue of phase-imbalance has been duly noted in the technical studies on integration of solar rooftop with the distribution grid as well as by the CEA in their technical standards, detailed literature quantifying or highlighting the effects of this issue or any specific guidelines to prevent them is lacking [9], [10].

Anti-islanding is also a critical feature of a solar rooftop inverter. Islanding refers to the condition in which a distributed solar system disconnects in the event of a grid outage and stops supplying power. However, improper islanding can be dangerous to utility workers, who may not realize that a circuit is still powered through solar rooftop systems, when carrying out repair or maintenance. For the safety of the maintenance personnel, anti-islanding feature is a challenge for the utilities, especially in the case of solar rooftop system coupled with battery energy storage. The issue of safety of the personnel has been highlighted in a study, especially while working around the possibility of formation of an unintentional island from the operation of the distributed solar PV systems as a cause of major concern for the utilities [9].

The penetration of solar rooftop being nominal at present, the grid security is not a matter of concern for the Discoms as of now. But with more solar rooftop penetration, the grid must be ready to integrate generation from the variable renewable energy sources, with proper measures in place. Literature review suggests that with present technologies, most technical challenges in implementing solar rooftop systems can be addressed. As discussed above, there are sufficient studies suggesting that all perceived technical issues with respect to solar rooftop PV systems can be managed with appropriate smart inverters, forecasting and grid-interactive centralized data monitoring systems for solar generation. Technology development, such as smart inverters and appropriate monitoring and forecasting mechanisms, can play crucial role in mitigating technical impacts of solar rooftop on distribution network. However, there are still a few issues like harmonics, phase-balancing etc. whose impacts need to be seen as the penetration of solar rooftop increases into the grid. In this context, power system simulation-based studies to assess impact of aforementioned issues for planning and operations assume critical importance.

Administrative Aspects

With the development of the solar rooftop sector, the utilities are facing some administrative challenges while integrating solar rooftop systems into their grid. Interpretation and implementation of various provisions of policy and regulations is done by the utilities. The implementation, i.e., the administrative processes, mark the actual success of the overall solar rooftop program and thus are one of the most critical aspects of any solar rooftop program at the state or the central level. Aligning the administrative process with the regulations can ease the implementation of the said program(s) [8].

The increased administrative burden faced by the Discom is presented in various studies [4], [5]. These studies highlight the additional tasks the Discoms have to undertake, such as application processing, inspection and connectivity, metering and billing. **Lack of skilled man-power** came out to be a major concern for Discoms. Timescales of interconnections and application processing had been uncertain or prolonged due to shortage of trained and skilled manpower. Discoms, in addition to their day-to-day operations, have to take up the additional task of solar rooftop monitoring and billing and have expressed that there are not many personnel present with requisite knowledge on solar rooftop. They stressed the need for capacity building for accelerating deployment of solar rooftop.

The Discoms who consider solar rooftop as an advantageous proposition for them are working on promoting it in their license area. However, **consumer awareness** remains one of the main hindrances faced by all the Discoms while promoting solar rooftop as there is lack of information on how such systems can benefit the consumers. Different consumer awareness strategies with a targeted approach with

respect to various consumer categories, is required so as to provide information on the benefits of such systems as well as its implementation and installation process. The importance of consumer awareness has been underlined in various studies for the growth of solar rooftop sector [4], [5], [8]. Information booklets with technical as well as other necessary information regarding solar rooftop photovoltaic system installation must be available with the utilities and the developers to give appropriate recommendation to the consumers [6]. Increasing the consumer awareness can help them in making informed investment decisions for solar rooftop. To facilitate the same, credible information for the consumers is important and could be outsourced to neutral, trusted bodies that can help consumers make effective choices about systems and suppliers [5].

Addressing the challenges faced by Discoms, so as to operationalize net-metering regulations and implementation of solar rooftop project, requires substantial **coordination of several implementing agencies**, viz. Discom (for providing net-metering & approvals), Chief Electrical Inspector (for approvals), State Nodal Agency (SNA) (for release of subsidy), banks (for housing/ improvement loan), urban local body (for enforcing model building by-laws), rooftop owner (for providing access to roofs), developers/ aggregators/ EPC contractors (for project implementation & maintenance), etc. This gap has been highlighted in a few studies , which has led to inefficient service-delivery and lag in uptake of solar rooftop in the country as it creates various issues for concerned stakeholders [4], [6].

The administrative aspects discussed above, as highlighted by the Discoms and literature, need to be addressed to ensure rapid uptake and long term development of solar rooftop sector. As long as the Discoms remain strained with additional tasks of solar rooftop implementation, the uptake of solar rooftop will remain a challenge for the nation. Certain measures, such as capacity building or training programs for Discom personnel, support for implementing consumer awareness programmes on solar rooftop, etc. could be considered by the state governments to address the increased administrative burden faced by them. Such measures can help distribution utilities in giving impetus to solar rooftop systems.

Leading Consumer Awareness Programme

*The city of Surat has been listed as one of model cities under 'Development of Solar Cities' programme by MNRE and 'Smart Cities Mission' by Ministry of Housing and Urban Affairs (MoH&UA). Surat Municipal Corporation (SMC) has been pro-actively taking measures to meet the expectations of the state in regard to deployment of renewable energy sources. To kick start the solar rooftop programme, SMC launched the '**Solar Revolution**' program in 2016. It focused on creating consumer awareness using the **#SuratSolar** brand through various mediums of communication, such as website, mobile apps, pamphlets, newspapers & magazines, social media, FM radio, public hoardings, special video messages by prominent social figures as brand ambassadors. SMC also became the nodal agency for Gujarat Energy Development Agency (GEDA) for receiving the applications for installation of grid connected solar rooftop systems in Surat.*

Out of an estimated solar rooftop potential of 418 MW, estimated by TERI, Dakshin Gujarat Vij Company Limited (DGVCL) and Torrent Power Limited have achieved a total installed solar rooftop capacity of 40 MW by them and facilitation for applications and their processing, mostly from the residential sector as a result of the consumer awareness strategies were adopted. Concerted coordination between various implementation agencies such as SMC, Discoms, GEDA and other key stakeholders is one of the main reasons for the success of this programme.

Policy & Regulations

Government of India has announced a series of policy measures to promote solar energy. There are direct and indirect tax benefits, excise duty exemptions and customs duty exemptions provided to renewable energy including solar rooftop. Few notifications[9,10] by MNRE and some studies give a pretty clear overview as of how policy and regulatory interventions can help accelerate the deployment of solar rooftop [4],

[9] SRISTI Draft Concept, December 2017, https://mnre.gov.in/file-manager/UserFiles/comments-on_RTS.pdf
[10] https://solarrooftop.gov.in/notification/Notification-08112016901.pdf

[5], [11]. These studies present the key policies and regulations promoting the solar rooftop sector and their development during past few years. The studies also highlight the incentives and initiatives on the part of MNRE and states to support such development in either of the models, CAPEX or RESCO/ OPEX, under net-metering regulations; few of them being Central Finance Assistance (CFA), benefits such as accelerated depreciation, customs duty concessions, excise duty exemption, tax holiday and 'Achievement-linked Incentives' for installing solar rooftop for government institutes. MNRE have been notifying revised benchmark costs for Grid Connected Solar Rooftop Power Plants, the latest being for the Year 2018-19, so as to attract the rooftop owners to set up solar rooftop on their roof.

Policies and regulations for the promotion of solar rooftop sector are available at, both, the state as well as the central level. However, certain challenges are reported by the Discoms in this regard. Need for clarity in the policy and regulations was also flagged by few Discoms for increasing uptake of solar rooftop. Most of them were also of the view that most **government policies are more consumer-oriented** and do not

Demand Aggregation and Consumer Awareness

*With an aim to accelerate the solar rooftop implementation within the utility's licensee area, BSES Rajdhani Power Ltd. (BRPL) launched a **"Utility-Anchored Rooftop Programme"** known as **BRPL Solar City Initiative**. BRPL acts as the facilitator for aggregating demand of interested rooftop consumers and inviting bids for supply from the empanelled solar rooftop vendors. BRPL also ensures strict technical compliance and plant monitoring of all the upcoming projects. The programme also included creating consumer awareness in regard to benefits of solar energy.*

*The first phase of this programme was launched to target Group Housing Societies in Dwarka sub-city, with an aim to **Solarize Dwarka**. Under this phase, around 100 residential societies have shown interest and have signed for installing solar capacities aggregating ~6 MWp. The second phase of the programme has been launched in Shakur Basti area, with an aim to **Solarize Shakur Basti**.*

take care of impact on the Discoms. They stressed the need for amendment to the policies and regulations considering the aforementioned operational, administrative as well as financial challenges faced by the Discoms.

Apart from the aforementioned issues and challenges, the following challenges were noted during the interaction of project team with the Discoms where policy and regulatory interventions could help in overcoming the same:

i. All the Discoms expressed the pressing need to address the challenge of unavailability of **communication interface between the distributed energy resource (DER)**, i.e. solar rooftop system and the utility, alongside monitoring and data management of generation from solar rooftop systems in their license area. Amendments to regulations making monitoring and forecasting of renewable energy generation mandatory mandatory of renewable energy generation for Discoms would help them in addressing this concern and also in carrying out operations as well as in reporting RPO compliance.

ii. Some Discoms emphasized that the bulk of the benefits of solar rooftop in terms of savings are availed mostly by the upper-middle class or the higher tariff slab consumers as they have large roof space and are financially capable to install these systems. On the other hand, the lower tariff-slab consumers cannot avail the benefits of solar rooftop due to smaller roof-size and/or financial constraints. Such consumers can be targeted through **demand aggregation**, undertaken by the Discoms, so as to increase the overall project size and reduce the project cost as well as risk perceived by developers. Alongside the present metering arrangements, **new metering arrangements** such as **virtual or group net metering** also need to be looked into to promote solar rooftop for low-paying consumers, especially the rural or agriculture consumers. Hence, in-line with the Delhi Solar Policy 2016, Group Net-Metering and Virtual Net-Metering could be included in other state policies and/or net-metering regulations. Many Discoms expressed that this amendment would help in growth of solar rooftop sector for low-income segment of consumers and also help in decreasing their burden of cross subsidy. This would also attract project developers as they don't have to bear the additional cost for aggregation of demand as it is difficult to identify and persuade willing and financially capable customers on individual basis. Due to increased project size and reduced developer's risk, Discoms can help increase the bankability of these projects at large.

iii. Strength of rooftop is a very important parameter for increased reliability of solar rooftop system. Discoms suggested inclusion of '**rooftop-strength**' in building standards and also in the **checklist of documents required before installation of a solar rooftop system**.

iv. Non-availability of a nationwide **certification framework** (0-10kW, 10 kW-100 kW & >100 kW systems) as well as lack of **standardization of processes** of application, such as documents to be submitted for connection application for a solar rooftop system, quality of workmanship to be followed during the installation process were also underlined as a key challenges. While certification framework would help in building consumer confidence as well as getting best possible yield on sustained basis, standardization of processes can give a thrust to implementation of the solar rooftop programme.

v. For tariff determination, the regulations across the states have considered the Capacity Utilization Factor (CUF) as 19% for solar rooftop system across country. Some Discoms were of the view that this value is not practical in their states. For appropriate tariff determination, **region-specific values of CUF** must be considered in the state regulations.

vi. Most of the Discoms prefer **gross-metering** connection arrangement over **net-metering** connection arrangement. While net-metering is better from consumers' point of view, the same is not true for Discoms. Moreover, in most states there is no provision for gross-metering connection. Discoms expressed that for a certain category of consumers with specified systems sizes, the choice between the metering arrangements (net metring/ gross metering) could be given to the consumers; the consumer category and system size limits can be decided by the Discoms considering the impact of these systems. This flexibility in metering options can make a win-win case for both, consumers and the Discoms.

vii. Promoting **solar rooftop at rural sub stations** could enable Discoms to supply reliable electricity to agricultural consumers during day-time. Further, the Discoms would be saving on power purchase costs for meeting the demand for agriculture and can avoid the AT&C losses, which are usually high for agricultural consumers. As the burden of subsidy for supply of practically free electricity for agriculture in most states is met by cross-subsidy, this would also reduce the burden on other consumer categories.

Discoms opined that support from the Government in terms of financial incentives and clear policy can encourage Discoms to consider promoting solar rooftop in their license area. While the aforementioned suggestions for amendments in the regulatory and policy framework for solar rooftop could be considered, the State Governments may also help the Discoms in addressing the challenges in implementing solar rooftop by supporting Discoms in taking their own initiatives.

SUMMARY AND CONCLUSIONS

The discussions held at the third Distribution Utilities Forum (DUF) meeting and various interactions with key officials of the distribution utilities provided views and perception of the distribution utilities in regard to implementation of solar rooftop. While there was a general consensus in regard to quite a few issues/ challenges affecting uptake of solar rooftop; some of the issues stemmed from state-specific on-ground conditions. According to Discoms, solar rooftop can be a profitable business proposition for them if they are mandated an 'anchor' role in its implementation by the central and/ or state government along with regulatory interventions and customized business models. Key technical, financial, operational & administrative issues and challenges as well as policy & regulatory aspects identified by the Discoms, as well as their suggestions are presented hereunder:

- On the **technical** front, the issues and concerns of the Discoms arise from the fact that with increasing penetration of distributed solar PV systems, having inherent characteristics of variable and intermittent generation, in the conventional radial feeders could significantly impact the static and dynamic behaviour of the power system in terms of voltage regulation, phase imbalance, protection coordination, power quality and safety aspects. Discoms stressed upon adequacy of technical studies needed to assess the extent of these impacts - depending on the network characteristics, consumer demand pattern, level of penetration and spatial distribution of PV systems, protection settings, etc. - and how these can be mitigated. The Discoms were also of the view that it would be of interest in this context to assess the impacts of localized energy storage, presence of electric vehicles and non-linear loads such as air conditioners.
- On the **financial** front, most of the Discoms apprehended that solar rooftop can have an impact on their financial position when it is assumed that there is no increase in the demand, unchanged fixed charge liability under the PPAs with generating stations as well as increased cross subsidy burden on the consumers. Discoms also perceived opportunities that solar rooftop has to offer in terms of reduction in power procurement, deferring capital expenditure required for network augmentation. Discoms expressed need for business model(s) factoring in recovery of expenses required to be incurred by them in playing anchor role in implementation of solar rooftop. Some of the Discoms opined that gross-metering arrangement with attractive feed-in-tariff is a better proposition for a well-developed solar rooftop market. Under the net-metering arrangement, the revenue loss to the Discoms is more on the account of generation injection from such systems getting paid at the retail tariff.
- In regard to **operational and administrative** challenges in implementation of solar rooftop, Discoms stressed lack of skilled manpower and consumer awareness as the biggest challenges. Moreover, majority of the consumers are hardly aware of the benefits of solar rooftop and/ or the installation process and standards. Few other challenges underlined by Discoms relate to metering and billing, real-time monitoring & forecasting and data management of the generation from the solar rooftop systems as well as lack of coordination among various implementing agencies. It was discussed that the operational challenges faced by the Discoms could also have an impact on its finances. There are various operational opportunities that solar rooftop has to offer to the Discoms, namely reduction of T&D losses, help in meeting their RPO obligations, and improving the life of the assets in use due to reduction of loading of their network. Discoms suggested that these need to be looked into holistically by the concerned agencies/ department(s) and necessary support from them would go a long way in facilitating implementation of solar rooftop systems.
- **Policy and regulations** for implementation of solar rooftop are in place in most of the states. But Discoms perceived them to be tilted in favour of consumers, and therefore, opined balancing of the same. Requisite emphasis and clarity in the policies and regulations and standardization of bidding documents so as to mandate explicit role of Discoms in regard to uptake of solar rooftop was emphasized by them.

Apart from the overarching issues discussed above, common for most Discoms, a few issues specific to a Discom, highlighted in the discussions, are presented below:

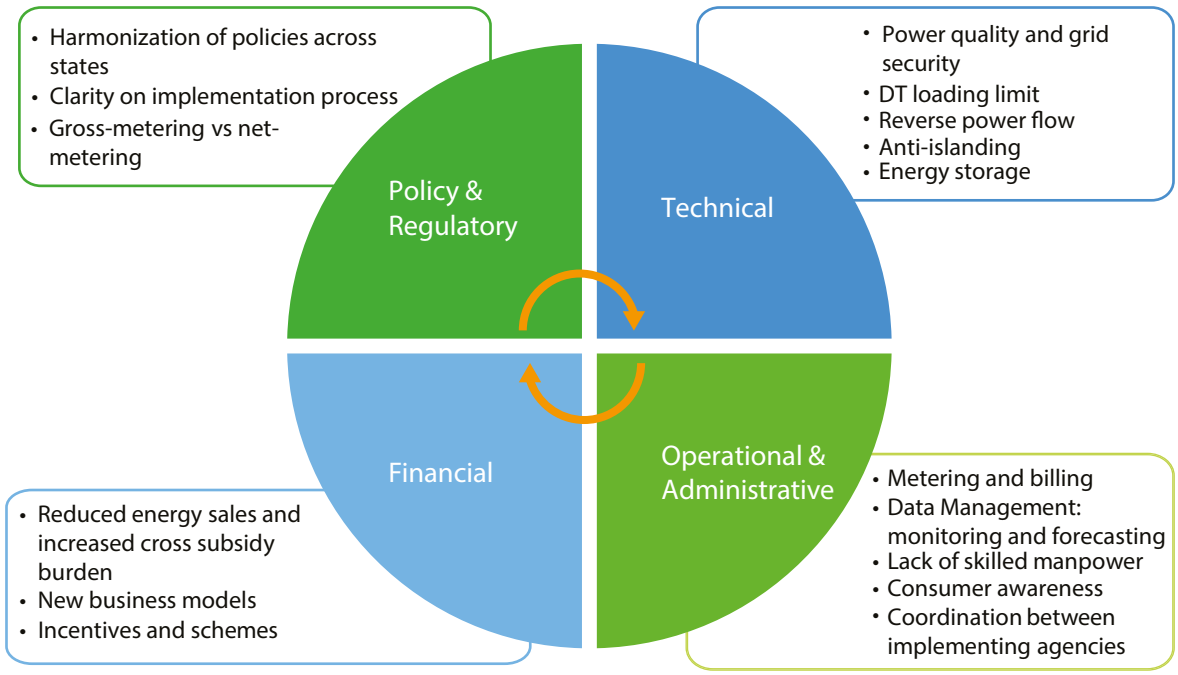

Figure 5: Overview of Findings

- Discoms which are surplus in power find difficulties in absorbing additional solar power, as this leads to backing down of conventional power plants in the state and/or reduction in schedule from Inter-State Generating Stations (ISGS) with long-term PPAs having committed fixed charge liability. In case of **CESC, Kolkata**, they are even required to shut down their own conventional power plants in order to accommodate generation from solar rooftop PV.
- In hilly areas, the households being sparsely located, metering & billing of premises with solar rooftop systems as well as revenue collection become more challenging. In **Manipur**, the Discom has provided these consumers with pre-paid meters to avoid billing and collection expenses.
- **Delhi,** being a small land-locked state with high cost of land, solar rooftop becomes a natural choice/ option for increasing generation. Further, the daily day time peak demand profile for the Discoms broadly matches the generation profile of solar system. Thus, solar rooftop helps in shaving off peak demand, and therefore, becomes an optimum solution. Further, solar rooftop helps in deferring new distribution infrastructure, which assumes added importance in congested localities in the state.

Other key points and recommendations emphasized by Discoms during the ***focused group discussions*** in context of solar rooftop implementation are given below:

i. There is a need for **redesigning retail tariffs** (minimizing cross-subsidies and making retail tariffs reflective of the true cost of supply), to provide a level-playing field to solar rooftop systems encouraging consumers to shift to solar rooftop based on financial considerations at the same time benefitting the utility as well.

ii. There is a need to relook at the **legacy contracts** with the conventional power plants. Suggestions such as seasonal PPAs were proposed in this context.

iii. **Additional cost** implications on account of implementation of solar rooftop maybe allowed to be factored in ARR.

iv. There is a need for revisiting the existing regulations in the states in order to facilitate **co-existence of net-metering and gross-metering arrangement regimes**. In the gross-metering arrangement, Feed-In Tariff (FiT) could be determined by the respective SERCs so as to make it a win-win situation for Discoms as well as consumers. Levelized tariff could help in promoting solar rooftop.

v. Implementing solar **rooftop business models on a pilot basis**, to reduce risk by aggregating low paying consumers' rooftop capacity and inviting bids on their behalf for implementation in RESCO mode and putting in place a system of recovering cost of solar power together with conventional electricity bills.

vi. Need for provision(s) to address implications of charges on Discoms under **Deviation Settlement Mechanism** (DSM) due to increased distributed renewable energy generation assumes importance on account of variable nature of such generation.

vii. **Capacity building** of Discom personnel on various aspects solar rooftop, e.g. grid management, solar technologies, and business models is vitally needed.

SUGGESTED WAY FORWARD

With an aim to look into the perspective of Discoms in regard to solar rooftop, the study has elucidated that all Discoms, by and large, face a similar set of challenges in regard to technical, financial, operational, administrative and regulatory aspects of uptake of solar rooftop as discussed in this report. Given the fact that the Discoms differ in regard to the technical potential of solar rooftop, consumer mix, and retail tariff for different categories of consumers, etc., Discoms may like to adopt different approach for promotion, facilitation and implementation of solar rooftop systems. The practices and approaches followed by a few Discoms in recent times could also help other Discoms to draw learnings while moving forward. The Distribution Utilities Forum (DUF) will continue to act as a platform for sharing of experience and best practices. At the same time, there is also a need to have a mechanism to build capabilities of Discoms which could benefit them through exchange of on-the-job best practices.

No single solution to address the issues brought out by Discoms in regard to solar rooftop can be suggested. DUF secretariat can take up specific studies of identifying key important issues of respective Discom on case-to-case basis and suggest suitable measures to the Discom for the challenges faced by them in implementing solar rooftop. However, a few suggestions that can facilitate all Discoms in uptake of solar rooftop systems are summarized below:

Technical Studies

Detailed **power system simulation studies** may be taken up by Discoms for representative urban and rural feeders on aspects of technical impacts for present level of solar penetration and increasing levels of penetration covering different scenarios of load and PV growth in coming years. The objective of these simulation studies is to come-up with recommendations in regard to various mitigation techniques. There is a need to revisit the existing protection arrangement as well as protection co-ordination. Appropriate policy and regulatory decisions could be undertaken with the objective of ensuring safe and reliable operation of distribution network. **DUF secretariat could help in developing suite of simulation studies in-consultation with interested distribution utilities**.

Consumer Awareness and Capacity Building

Some of the Discoms have already launched **consumer awareness campaign** within their license area, highlighting benefits and facilitating implementation through a 'single-window' online application. These practices can form the basis for other distribution utilities while initiating such drive.

A framework for rating of developers and empaneling them accordingly could be helpful in accelerating pace of uptake of solar rooftop systems by providing consumers a choice among reputed developers and ensure quality. It would not only help in building consumer confidence, but Discoms would also tend to have better degree of confidence in regard to quality of solar rooftop systems getting integrated with their distribution network.

There is also a need for capacity building in regard to various aspects of solar rooftop, such as implementation, monitoring, etc. **Capacity building programmes** can be organized by the Discoms, in-order to train their officials across the Discoms in

Master Plan- roadmap for solar rooftop implementation

A robust and comprehensive master plan for implementing a model solar city project in Chandigarh, called the Master Plan, was prepared by TERI and approved by MNRE in 2012. It laid out a roadmap which guided the executing agencies in effective implementation of the model. Chandigarh Renewable Energy and Science & Technology Promotion Society (CREST) have been aggressively promoting solar energy by creating awareness campaigns through e-media, newspapers, solar camps and door to door campaigning. The executing agencies have also built their capacity through interactions, seminars and visit to solar plants throughout the country. Initiatives have also been taken to promote solar energy both in public and private buildings in cities, as well as villages, with lucrative subsidies being offered to private buildings to promote solar rooftop. Under

the master plan guidelines, the project developers hold the responsibility of monitoring, reporting and verifying power generation from each installed plant either through an online or offline portal. This data is used by CREST to keep a check on the efficiency of the plant and also prepare monitoring reports. Chandigarh Electricity Department (CED) is the Discom concerned which is responsible for monitoring grid-based evacuation by consumers, i.e. injection of surplus electricity to the grid.

The Chandigarh Solar City project achieved the targeted 10% reduction of conventional energy demand in its first 5 years through various innovative measures, such as installing solar rooftop photovoltaics (PV), increasing forest cover, and awareness campaigns on the benefits of solar energy. This has started a holistic and sustainable transition of the electricity sector in the city. A website had been created by CREST for providing all the requisite clearances for installation of Solar Power Plant by any individual/ institution as part of ease of Business. This could help in meeting their target for solar rooftop, of 69 MW of installed solar capacity by 2022.

regard to various aspects of solar rooftop systems. **DUF secretariat could help in organizing and conducting such workshops and seminars, in-order to help the Discoms.**

New Business Models

To address the challenges brought out by the Discoms, business models are required to promote the uptake of the solar rooftop systems. Discoms may take an anchor role and devise utility-driven solar rooftop models suitable for various consumer categories, so that it becomes a win-win proposition for the consumers as well as utilities. Some Discoms have already initiated such business models on a pilot basis. Success of such a business model could serve as a reference model for other Discoms depending on their consumer mix.

DUF Secretariat suggests a '*utility-based*' business model' for promotion of solar rooftop systems. It could be based on demand aggregation of interested consumers and tri-partite agreements between utilities, consumers and developers to ensure payment security, giving an anchor role to the Discoms for implementation of solar rooftop systems in their license area. Similar approach has been facilitated by TERI for implementing solar rooftop through demand aggregation in Surat Smart City with Surat Municipal Corporation (SMC) in 2016 and in Solarize Dwarka initiative with BSES Rajdhani Power Limited (BRPL) in 2018. Payment of service charge to the Discoms as decided by the SERCs would help the Discoms in implementation of solar rooftop systems in their license areas (Annexure 6).

Reducing Developer's Risk

For project developers, there is additional cost for aggregation of demand as it is difficult to identify and persuade willing and financially capable customers. Madhya Pradesh Urja Vikas Nigam Limited (MPUVNL), in-order to resolve this challenge faced by the developers, looked into demand aggregation from a different approach. In their recent tender for 35 MW of grid connected solar rooftop project under the RESCO model, they identified 567 project site locations across the state. With the sites for the projects already having been identified for the developer, the risk of aggregating the demand was reduced.

Other unique ways of reducing the developer's risk adopted by MPUVNL were:

- Creating an innovative data-base of site specific information along-with the World Bank;
- Pre-cleared PPAs with the beneficiaries;
- Providing central and state subsidies together (which were as high as 48% of the CAPEX for the institutional sector);
- Compensation for pre-mature termination; and
- Reduced payment risks.

*The result of these measures was seen in the auctions with the **solar rooftop PV tariff reaching a low of INR 1.58 per kWh in 2018**, which is a significantly low tariff observed in solar rooftop PV segment in the country. With the tariff reaching this low, this approach to demand aggregation could be adopted by other utilities as well and this could contribute to higher uptake of solar rooftop.*

Support for Discoms

Under the Phase II of Grid-Connected Rooftop Solar Programme[11], focus of Government of India is an **increased active involvement of Discoms** with performance based incentives based on solar rooftop capacity achieved in a financial year.

The State Governments may also revisit their existing programmes, policies & regulations, so as to encourage the distribution utilities to take lead role in implementation of solar rooftop. The SERCs could facilitate the same by specifying the role of distribution utilities in implementation of solar rooftop systems in the respective solar rooftop regulations.

Addressing all the four aspects of solar rooftop is essential for accelerating uptake of solar rooftop by the Discoms. In view of diversity across Discoms, mainly in terms of consumer mix, solar insolation, Discoms may choose an appropriate implementation model. A review of solar rooftop policies and regulations at the state level taking note of the foregoing issues and challenges would facilitate acceleration in uptake of solar rooftop systems in a bid to achieve the target capacity set by MNRE for the year 2022.

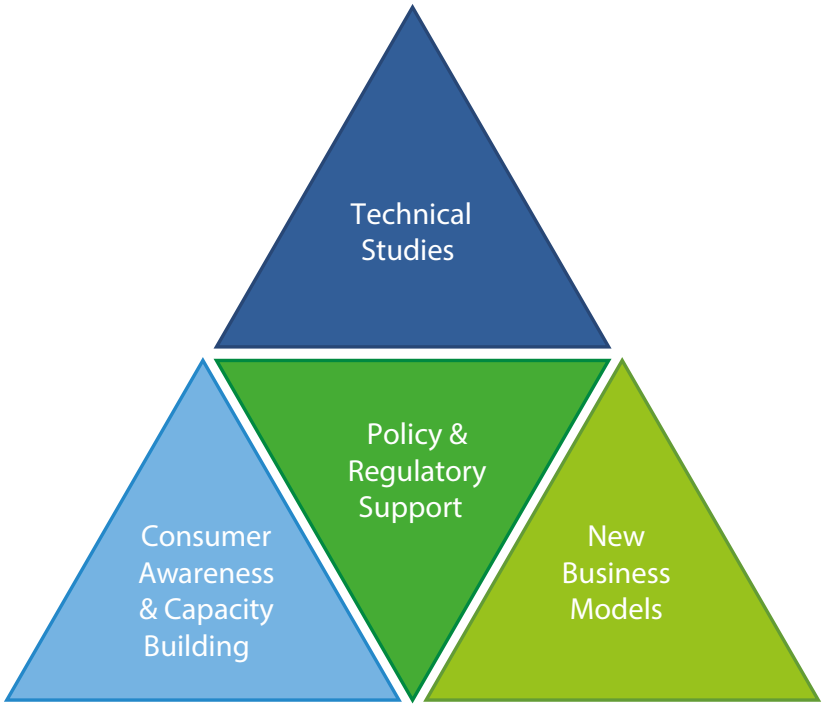

Figure 6: Suggested Way Forward for Implementation of Solar Rooftop

[11] http://pib.nic.in/PressReleaseIframePage.aspx?PRID=1565282

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[1] Ministry of New & Renewable Energy, TERI, and Shakti Sustainable Energy Foundation, "Reaching the Sun with Rooftop Solar," 2014.

[2] GIZ, TERI, and KfW, "Grid Parity of Solar PV Rooftop Systems for the Commercial and Industrial Sectors," 2016.

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[6] GIZ, "Technical evaluation of existing commercial and residential PV rooftop systems in South Delhi," 2017.

[7] USAID and Ministry of New and Renewable Energy, "Challenges for Scaling Up Solar Rooftop in the BESCOM Region," 2017.

[8] Ministry of New and Renewable Energy, USAID, and Germi, "Best Practices Guide : Implementation of State-Level Solar Rooftop Photovoltaic Programs in India," 2016.

[9] Prayas (Energy Group), "Grid Integration of in India Distributed Solar Photovoltaics (PV) in India Distributed Solar," 2014.

[10] GIZ, "Analysis of Indian Electricity Distribution Systems for the Integration of High Shares of Rooftop PV," 2017.

[11] WRI India and Shakti Sustainable Energy Foundation, "Here Comes the Sun: Residential Consumers' Experiences With Rooftop Solar Pv in Five Indian Cities," 2018.

[12] CEEW, BSES Yamuna Power Limited, and Shakti Sustainable Energy Foundation, "Scaling rooftop solar: powering India's renewable energy transition with households and DISCOMs," 2018.

ANNEXURES

Annexure 1: Central Finance Assistance (CFA) under Grid Connected Rooftop and Small Solar Power Plants Programme

MNRE, earlier, provided Central Financial Assistance (CFA) to all consumers under the residential, institutional, government and social categories for implementing solar rooftop systems at their premises, with an aim to subsidize the project cost. The CFA, at the beginning, was 15% of the benchmark cost for solar rooftop system set by the Ministry[12]. CFA allocations were later revised and MNRE had maintained CFA support only for the residential, institutional and social sector, which was 30% (or 70%, in special category of states, i.e., North Eastern States including Sikkim, Uttarakhand, Himachal Pradesh, Jammu & Kashmir and Lakshadweep, Andaman & Nicobar Islands) of the benchmark cost or the actual project cost as applicable, whichever is lower. Government Institutions were entitled to avail Achievement-link Incentives for installing solar rooftop at their premises[13].

The Government of India on 19th February, 2019 notified "Phase-II of Grid Connected Rooftop Solar Programme for achieving cumulative capacity of 40,000 MW from Rooftop Solar Projects by the year 2022", with increased involvement of Discoms[14]. As per the new notification regarding the Cabinet approval of the Phase-II of Grid Connected Rooftop Solar Programme[15], the CFA distribution has been restructured to provide financial support for setting up 4,000 MW under the residential category. It also seeks more active involvement of Discoms for the implementation of the said programme by making them the respective nodal points. More details of the new structure are awaited in the detailed scheme document.

Performance-based incentives (only for initial capacity addition of 18,000 MW) will be provided to Discoms based on solar rooftop capacity achieved in a financial year over and above the base capacity (i.e., cumulative capacity achieved at the end of previous financial year) to help Discoms create an enabling ecosystem for efficient implementation of RTS programme in their area. Applicable cost is the applicable benchmark cost of MNRE for the state/UT for mid-range solar rooftop capacity of above 10 kW and up to 100 kW or lowest of the costs discovered in the tenders for that State/UT in that year, whichever is lower. The incentive to Discoms will be as follows:

Table 1: CFA as per new notification regarding Phase-II of Grid Connected Rooftop Solar Programme

S.No.	Sub-category Under Residential Category	CFA Allowed
1.	Solar Rooftop systems up to 3 kW capacity	40% of benchmark cost or tender cost, whichever is lower.
2.	Solar Rooftop systems between 3 kW to 10 kW capacity	20% of benchmark cost or tender cost, whichever is lower.
3.	Group Housing Societies/Residential Welfare Associations (GHS/RAW) with solar rooftop plants for supply of power to common facilities (capacity of 10 kW per house and maximum total capacity of 500 kWp)	20% of benchmark cost or tender cost, whichever is lower.

[12] https://mnre.gov.in/file-manager/UserFiles/CFA-Solar-Rooftop-03082015.pdf
[13] https://mnre.gov.in/file-manager/UserFiles/gcrt-guide-080916.pdf
[14] http://pib.nic.in/PressReleaseIframePage.aspx?PRID=1565282
[15] http://pib.nic.in/PressReleaseIframePage.aspx?PRID=1565282

Table 2: Incentives for Discoms as per new notification regarding Phase-II of Grid Connected Rooftop Solar Programme

S. No.	Parameter	Incentive
1.	For installed capacity achieved up to 10% over and above of installed base capacity within a financial year.	No incentive.
2.	For installed capacity achieved above 10% over and up to 15% over and above of installed base capacity within a financial year.	5% of the applicable cost for capacity achieved above 10% of the installed base capacity.
3.	For installed capacity achieved beyond 15% over and above of installed base capacity within a financial year.	5% of the applicable cost for capacity achieved above 10% and up to 15% of the installed base capacity plus 10% of the applicable cost for capacity achieved beyond 15% of the installed base capacity.

Annexure 2: List of selected Discoms for interactions

Table 3: List of selected Discoms for interactions

S.No.	DISCOM	City/ State	Region	Interaction Date	Public/ Private
1	Tata Power Delhi Distribution Limited (TPDDL)	Delhi (North)	North	01.01.2019	Private
2	BSES Rajdhani Power Limited (BRPL)	Delhi (South and West)	North	03.01.2019	Private
3	Madhya Pradesh Madhya Kshetra Vidyut Vitaran Company Limited (MPMKVVCL)	Bhopal, Madhya Pradesh	Central	11.01.2019	Public
4	West Bengal State Electricity Distribution Company Limited (WBSEDCL)	Kolkata, West Bengal	East	14.01.2019	Public
5	Calcutta Electric Supply Corporation Limited (CESC)	Kolkata, West Bengal	East	15.01.2019	Private
6	Bangalore Electricity Supply Company Limited (BESCOM)	Bangalore, Karnataka	South	23.01.2019	Public
7	Assam Power Distribution Company Limited (APDCL)	Guwahati, Assam	North-East	24.01.2019	Public
8	Dakshin Gujarat Vij Company Limited (DGVCL)	Surat, Gujarat	West	28.01.2019	Public
9	BSES Yamuna Power Limited (BYPL)	Delhi (East)	North	31.01.2019	Private
10	Pashchimanchal Vidyut Vitran Nigam Limited (PVVNL)	Uttar Pradesh (West)	North	26.02.2019 [16]	Public

[16] Interaction happened after DUF meeting

Annexure 3: Points for discussions with Distribution Utilities with regard to solar rooftop

1. Development of solar power projects, including solar rooftop installations, in the state/city
2. Central/state government's support (technical/financial) available for grid-connected solar capacity development
3. Discoms' major role in the development of grid-connected solar PV and solar rooftop in the city/state
4. Any business/financial model followed by Discoms for solar rooftop implementation
5. Discoms' difficulty in complying with the provisions of state solar policy/solar rooftop policy and SERC Regulations – both technical/operational and commercial and legal with regard to solar rooftop installations (residential, office buildings, school buildings, commercial, and industrial)
6. Challenges faced by Discoms while implementing solar rooftop in residential, office buildings, schools, commercial, and industrial – technical and operational
7. Additional support from central/state government (technical/financial) required by Discoms for developing solar rooftop
8. Discoms' future plan for solar rooftop development in the state
9. Success story(ies) of Discoms with respect to solar rooftop installation in some key cities
10. Difficulties of Discoms with respect to solar rooftop installation in some cities with reasons
11. How /DUF can help to mitigate the issues faced by Discoms in solar rooftop installations
12. Discom nodal person(s) for information support to DUF Secretariat
13. Any other points for discussions

Annexure 4: Grid Connected Rooftop Solar and Small Power Plants Programme: Policy and Regulatory Status

Table 4: Grid Connected Rooftop Solar and Small Power Plants Programme: Policy and Regulatory Status [17]

S. No.	States/ UTs	Maximum Cap of System capacity (kWp) as a percentage of sanctioned load	Allowed Capacity		Limit on Distribution Transformer capacity	State Subsidy/ Incentives	Exemption of chief electrical inspector	Mandatory Notification
		%	Max	Min	%			
1	Andhra Pradesh	100%	1,000 kW	1 kW	60% or LT; 100% for HT*	Up to 1 kW for domestic 20% For govt. 20%	Yes up to 10 kW	No
2	Bihar	100%	1,000 kW	1 kW	15%	N/A	No	No
3	Chhattisgarh	NA	1,000 kW	50 kW	N/A	1 kWp to 50 kWp - INR 24 per watt	No	No
						50 kWp to 100 kWp - INR 15 per watt		
4	Delhi	NA	NA	1 kW	20%	GBI is given @ INR 2 per unit for residential only for three years	No	No
5	Gujarat	No limit on residential consumers For others, 50% *	1,000 kW*	1 kW*	65%*	Limited to only residential with INR 10,000 per kW and INR 20,000 for 2 kW	No	No
6	Haryana	100±5%	1,000 kW	NA	30% (LT) and 15% (HT) *	N/A	Yes	Yes
7	Himachal Pradesh	30% for single part tariff, 80% for double part tariff	1,000 kW	5 kW *	30%	N/A	No	No

[17] https://solarrooftop.gov.in/notification/Notification-09012017.pdf
* Secondary research carried out by DUF Secretariat

S. No.	States/ UTs	Maximum Cap of System capacity (kWp) as a percentage of sanctioned load	Allowed Capacity		Limit on Distribution Transformer capacity	State Subsidy/ Incentives	Exemption of chief electrical inspector	Mandatory Notification
		%	Max	Min	%			
8	Jammu & Kashmir	50%	1 000 kW	1 kW	20%	N/A	No	No
9	Jharkhand	100%	1,000 kW	1 kW	15%	20% for residential, Institutional and Social Sector 10% for commercial and industrial sector	No	No
10	Karnataka	100%	1,000 kW	1 kW	80% *	N/A	No	No
11	Kerala	N/A	1,000 kW	1 kW	80%	INR 7200 per kW limited to 100 kW	No	No
12	Madhya Pradesh	N/A	10,000 kW	112 kW *	15%		No	No
13	Maharashtra	100%	1,000 kW	NA	40%	N/A	No	No
14	Odisha	100%	1,000 kW	NA	30%	N/A	No	No
15	Punjab	80%	1,000 kW	1 kW	30%	N/A	No	No
16	Rajasthan	80%	1,000 kW	1 kW	30%	N/A	Yes	No
16	Tamil Nadu	100%	up to sanctioned load	1 kW	30%	INR 20,000 per kW for residential (limited to 1 kW)	Yes up to 10 kW	No

* Secondary research carried out by DUF Secretariat

S. No.	States/ UTs	Maximum Cap of System capacity (kWp) as a percentage of sanctioned load	Allowed Capacity		Limit on Distribution Transformer capacity	State Subsidy/ Incentives	Exemption of chief electrical inspector	Mandatory Notification
		%	Max	Min	%			
18	Telangana	100% - residential 80% - industrial, commercial and other consumers	1,000 kW	1 kW	50%	N/A	No	No
19	Uttarakhand	NA	500 kW	1 kW	NA	20% State Subsidy	No	No
20	Uttar Pradesh	100%	1,000 kW	1 kW	15% *	N/A	Yes up to 10 kW	Yes
21	West Bengal	90% of yearly consumption		5 kW		N/A	No	No
22	Arunachal Pradesh	No	1,000 kW *	1 kW *	No	N/A	No	No
23	Assam	40%	1,000 kW	1kW	NA	N/A	No	No
24	Manipur	100%	1,000 kW	1 kW	40%	N/A	No	No
25	Meghalaya	N/A	1,000 kW	1 kW	15%	N/A	No	No
26	Mizoram	100%	1,000 kW	1 kW	40%	N/A	No	No
27	Nagaland	No	1,000 kW *	1 kW	15% *	N/A	No	No
28	Sikkim		1,000 kW *	1 kW *		N/A	No	No
29	Tripura	100%	1,000 kW	NA	15%	N/A	No	No
30	Chandigarh	100%	500 kW *	1 kW	30%	N/A	No	No
31	Goa	100%	NA	1 kW	30%	N/A	No	No
32	Dadra and Nagar Haveli	100%	NA	1 kW	30%	N/A	No	No
33	Daman & Diu	100%	NA	1 kW	30%	N/A	No	No
34	Puducherry	100%	NA	1 kW	30%	N/A	No	No

* Secondary research carried out by DUF Secretariat

S. No.	States/ UTs	Maximum Cap of System capacity (kWp) as a percentage of sanctioned load	Allowed Capacity		Limit on Distribution Transformer capacity	State Subsidy/ Incentives	Exemption of chief electrical inspector	Mandatory Notification
		%	Max	Min	%			
35	Andaman & Nicobar Islands	100%	NA	1 kW	30%	N/A	No	No
36	Lakshadweep	100%	NA	1 kW	30%	N/A	No	No

* Secondary research carried out by DUF Secretariat

Annexure 5: Business Models for Solar Rooftop

Designing of appropriate business models has huge importance as it can help deployment of the solar rooftop systems as a viable business case for the stakeholders, which is one of the main drivers in its success. The ownership structures of the rooftop and the solar rooftop system are among of the most important parameters for designing a relevant revenue model for the stakeholders which forms the key to a successful model. Over generations, the business models deployed in this sector has restructured for the development of solar rooftop systems, as can be seen in the figure below.

First Generation of Business Model

Rooftop systems developed under the self-owned business model can either generate electricity for onsite consumption or for injecting into the grid. Based on the usage and connection to the grid, self-owned business model can be divided into:

1. Captive (off-grid)

Under this type of sub-model, there is no connection between the grid and the rooftop systems. It is basically utilized for self-consumption for the consumer. Under this, it helps in either replacing the more costly diesel generators or providing grid quality electricity services, wherever absent.

2. Gross Metered

The gross metered solar rooftop PV systems feed all the energy generated by them to the grid at feed-in tariff determined. It allows all consumer categories to participate in solar rooftop programme and earn a minimum rate of return on the investment.

3. Net Metered

Under the net metering arrangement, the electricity generated is firstly used for the internal consumption and any surplus or deficit is maintained by the grid. The main value proposition is the difference between the consumer tariffs and the cost of solar energy generation from solar rooftop systems.

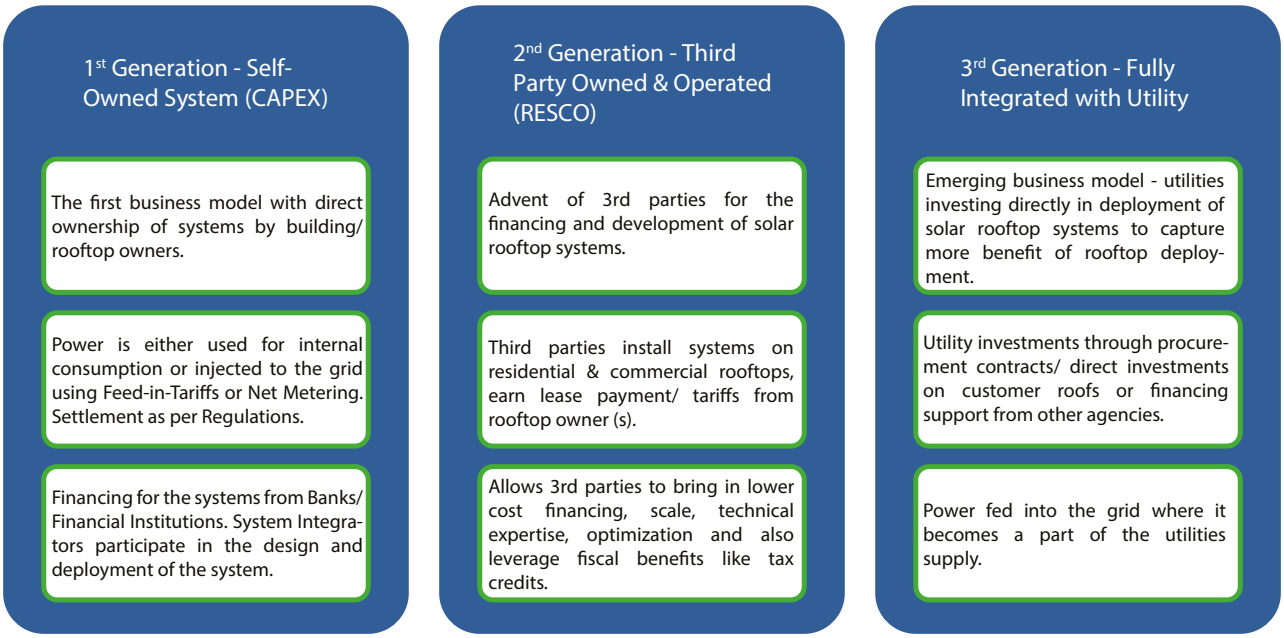

Figure 7: Business Models for Solar Rooftop [8]

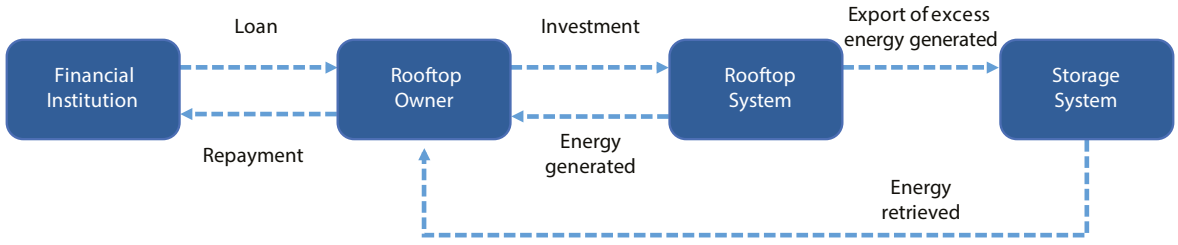

Figure 8: Self Owned Captive Solar Rooftop System (Off-Grid)

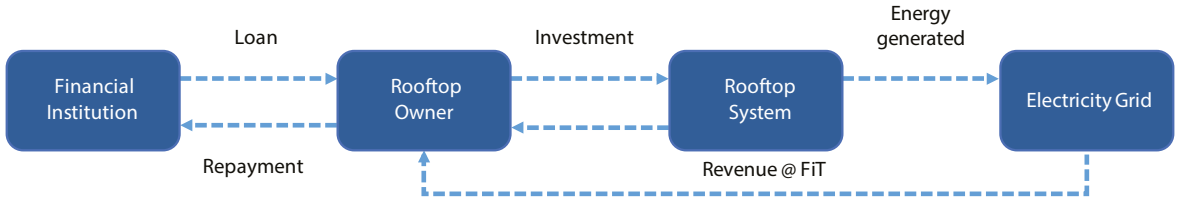

Figure 9: Self Owned Gross Metered Grid Connected Solar Rooftop System

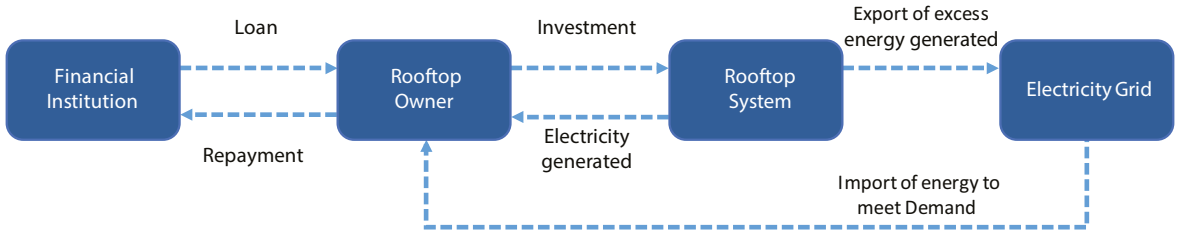

Figure 10: Self Owned Net Metered Grid Connected Solar Rooftop System

Second Generation of Business Model

The third party may rent rooftop from the rooftop owner and sell the generated power to the grid or to the rooftop owner through a PPA, or may also lease out the entire system to the rooftop owner who may utilize power from the system to replace utility-based power supply. Based on the agreement, the model can be categorized into various sub-models, namely:

1. Solar Leasing

Under this sub-model, the system is leased to a rooftop owner who makes monthly lease payments as per the agreement for the consumption of the electricity generated by the solar rooftop system. The third party investor (lessor) earns steady cash flows in the form of lease payments on a month-to-month basis. The savings from the electricity generated by the rooftop system is a source of revenue for the rooftop owner.

2. Solar PPAs

Instead of leasing, power purchase agreement can also be made between the rooftop owner and the system owner, based on the connection arrangement adopted for:

a. Gross Metered

A part of revenue generated by exporting the generated electricity from the system to the grid is shared with the rooftop owner for providing its roof on lease to the system owner. The developer generates revenue by exporting the solar energy generated from the rooftop system to the utility at a tariff as per SERC. Roof lease is a source of revenue for the rooftop owner.

b. Net Metered

The electricity generated by the system situated at the roof is used for meeting the internal consumption

for the rooftop owner. The system developer gets incentivized by the revenue generated from the payment made by the rooftop owner as per their agreement. The savings for consumer are due to avoided cost of grid power to be purchased from the utility. The sale of surplus power generated within a settlement period is a source of revenue stream for the developer.

Another sub-model which can be seen developing is combined rooftops on lease. Under this model, all the demand is aggregated and the rooftop is leased to a third party for the installation of solar rooftop PV system, which, then can be connected in either gross metering or net metering arrangement as explained above for single rooftop systems.

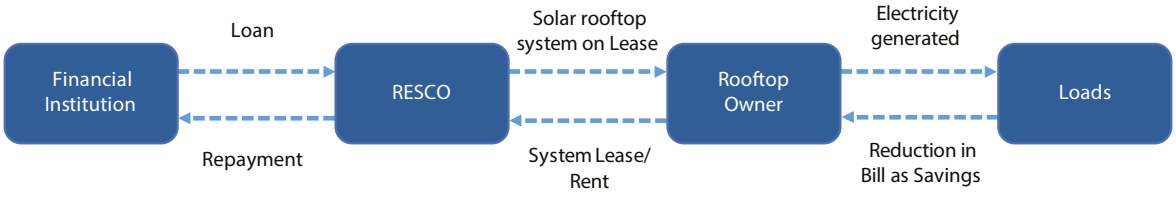

Figure 11: Third Party Owned Leased Solar Rooftop System

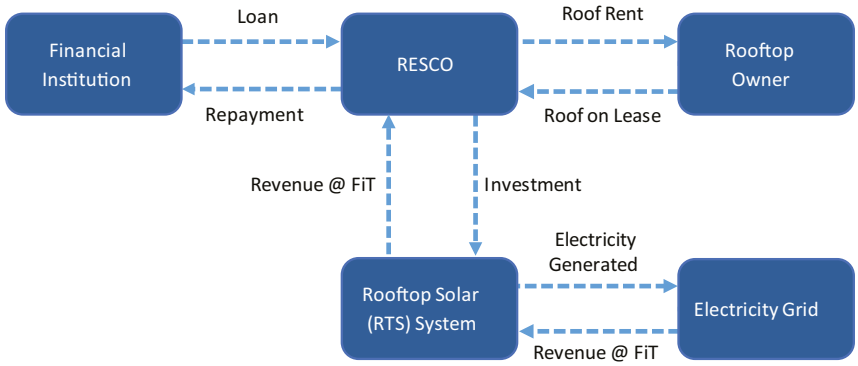

Figure 12: Third Party Owned Gross Metered Grid Connected Solar Rooftop System

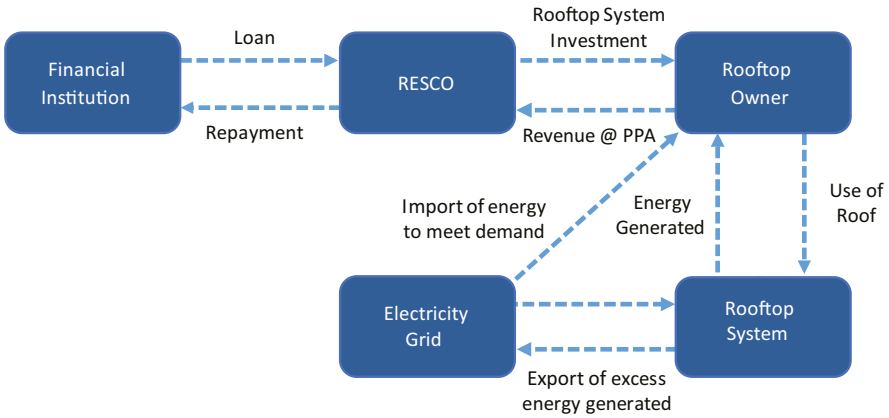

Figure 13: Third Party Owned Net Metered Grid Connected Solar Rooftop System

Third Generation of Business Model

The latest generation of business model, i.e., the Utility-Based Business Model is started to be being explored now, which can be used to addresses the issue of revenue loss of the utilities due to solar rooftop. Under this model, utilities are now actively involved in innovative solar rooftop business model in order to capture benefit from these solar markets.

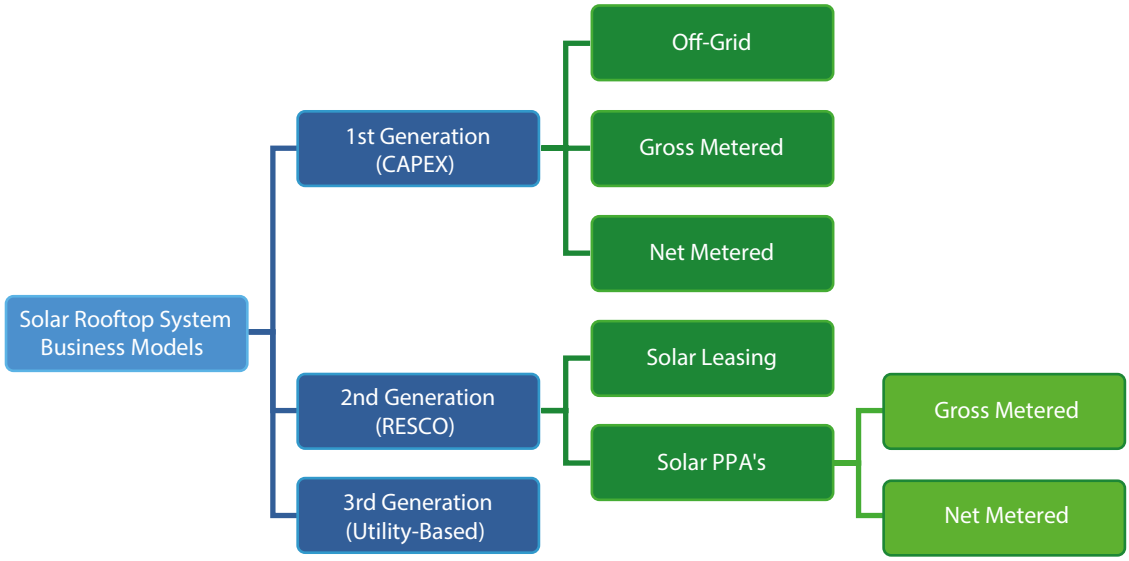

Figure 14: Classification of Business Models for Solar rooftop Based on the Usage and Connectivity

Annexure 6: Utility-Based Business Models for Solar Rooftop Proposed by DUF Secretariat

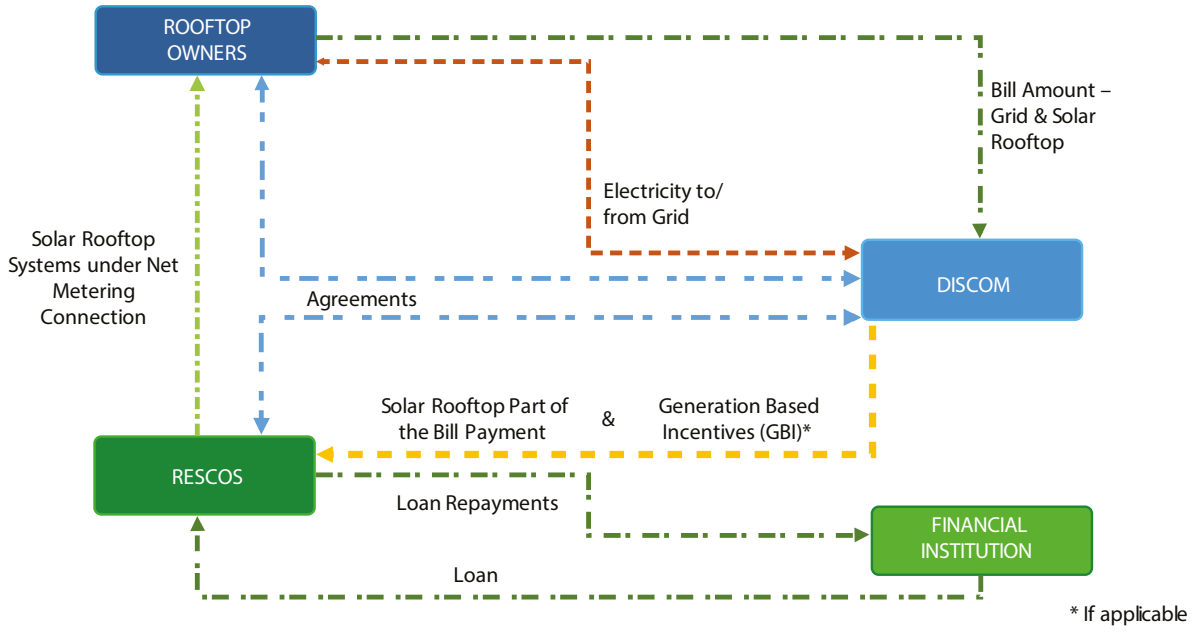

Figure 15: Proposed Utility-Based Business Model based on Net Metering Connection

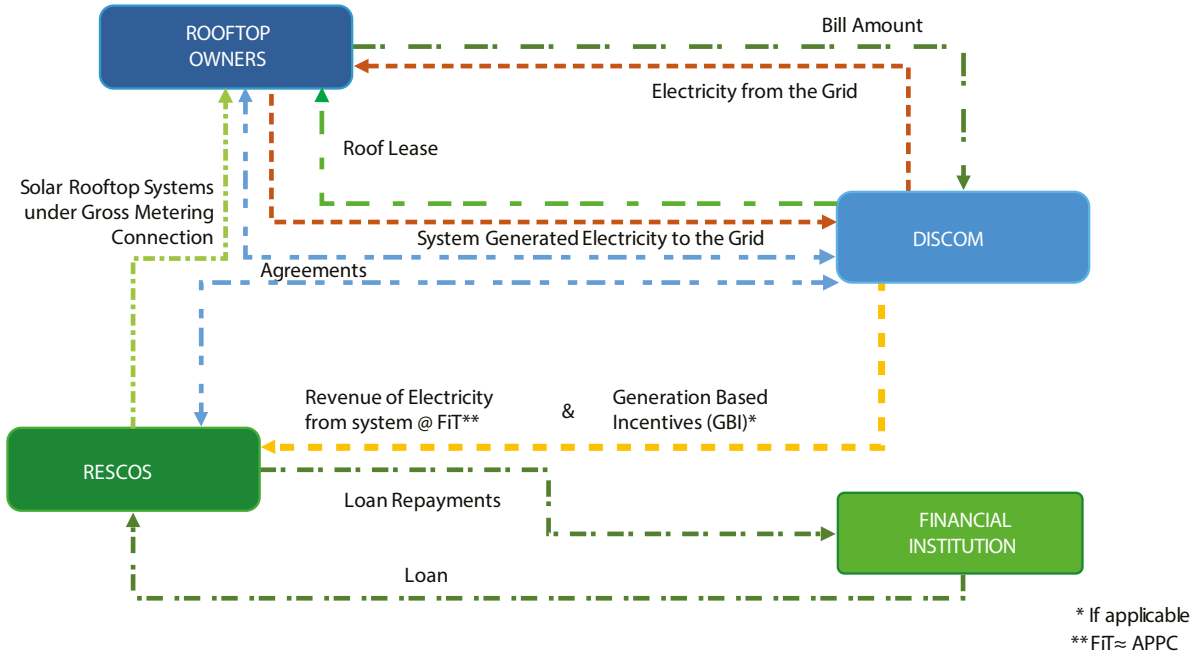

Figure 16: Proposed Utility-Based Business Model based on Gross Metering Connection and Roof-Lease Arrangement

DUF Secretariat:
The Energy and Resources Institute,
6C, Darbari Seth Block, India Habitat Center Complex,
Lodhi Road, New Delhi, Delhi 110003
Email: DUF_Secretariat@teri.res.in
Phone: 91 11 24682100 • Extn 2205

An initiative supported by:
Shakti Sustainable Energy Foundation,
4th floor, Capital Court, Munirka Phase III,
New Delhi 110067.
Phone: 91 11 474744000.
Email: powerteam@shaktifoundation.in