"DEVELOPING BUSINESS MODEL BASED ON PRODUCT SERVICE SYSTEM APPROACH FOR SUCCESSFUL IMPLEMENTATION OF ROOFTOP SOLAR PV SYSTEMS IN INDIA"

A Thesis submitted to the
UPES

For the Award of
Doctor of Philosophy
In
Management

By
VIDHI TYAGI

AUGUST 2023

SUPERVISOR (S)

Dr. Prasoom Dwivedi
Dr. Anshuman Gupta
Dr. Arun Kumar Tripathi

Department of Energy Management,
School of Business (SOB)
UPES,
Dehradun- 248007: Uttarakhand

"DEVELOPING BUSINESS MODEL BASED ON PRODUCT SERVICE SYSTEM APPROACH FOR SUCCESSFUL IMPLEMENTATION OF ROOFTOP SOLAR PV SYSTEMS IN INDIA"

A Thesis submitted to the
UPES

For the Award of
Doctor of Philosophy
In
Management

By
VIDHI TYAGI

(SAP ID 500033974)

AUGUST 2023

INTERNAL SUPERVISOR(S)

Dr. Prasoom Dwivedi
Professor
Department of Economics and International Business,
School of Business, UPES.

Dr. Anshuman Gupta
Professor
Department of Economics and International Business,
School of Business, UPES.

EXTERNAL SUPERVISOR

Dr. Arun Kumar Tripathi
Director General
National Institute of Solar Energy, MNRE, GOI

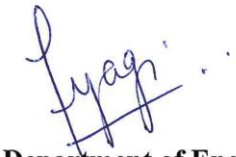
Department of Energy Management,
School of Business (SOB)
UPES.
Dehradun- 248007: Uttarakhand

JUNE, 2021

DECLARATION

I declare that the thesis entitled '**DEVELOPING BUSINESS MODEL BASED ON PRODUCT SERVICE SYSTEM APPROACH FOR SUCCESSFUL IMPLEMENTATION OF ROOFTOP SOLAR PV SYSTEMS IN INDIA'** has been prepared by me under the guidance of Dr. Prasoom Dwivedi, Professor of Economics and International Business, School of Business, University of Petroleum and Energy Studies. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

VIDHI TYAGI



Department of Energy Management,

School of Business,

University of Petroleum and Energy Studies,

Dehradun, Uttarakhand.

Date: 22/06/2021

CERTIFICATE

I certify that **VIDHI TYAGI** has prepared his thesis entitled "**DEVELOPING BUSINESS MODEL BASED ON PRODUCT SERVICE SYSTEM APPROACH FOR SUCCESSFUL IMPLEMENTATION OF ROOFTOP SOLAR PV SYSTEMS IN INDIA**", for the award of PhD degree of the University of Petroleum & Energy Studies, under my guidance. She has carried out the work at the Department of Energy Management, University of Petroleum & Energy Studies.

Internal Supervisor (s)

Dr. Prasoom Dwivedi
(supervisor)

Dr. Anshuman Gupta
(co-supervisor)

Professor
Department of Economics and International Business,
School of Business, University of Petroleum and Energy Studies,
Dehradun, Uttarakhand.
Date; 30.06.2021

राष्ट्रीय सौर ऊर्जा संस्थान
(नवीन और नवीकरणीय ऊर्जा मंत्रालय, भारत सरकार का स्वायत्त संस्थान)
National Institute of Solar Energy
(An Autonomous Institute of Ministry of New and Renewable Energy, Govt. of India)
गुरुग्राम–फरीदाबाद मार्ग, ग्वाल पहाड़ी, गुरुग्राम–122 003, हरियाणा, भारत
Gurugram-Faridabad Road, Gwal Pahari, Gurugram - 122 003, Haryana, India

CERTIFICATE

I certify that **VIDHI TYAGI** has prepared her thesis entitled **"DEVELOPING BUSINESS MODEL BASED ON PRODUCT SERVICE SYSTEM APPROACH FOR SUCCESSFUL IMPLEMENTATION OF ROOFTOP SOLAR PV SYSTEMS IN INDIA",** for the award of PhD degree of the University of Petroleum & Energy Studies, under my guidance. She has carried out the work at the Department of Energy Management, University of Petroleum & Energy Studies.

External Supervisor

22/06/2021

Dr. Arun Kumar Tripathi

Director General

Dr. Arun K. Tripathi
Director General
National Institute of Solar Energy
(An autonomous institute of ministry of New and Renewable Energy, Government of India)
Gurugram-Faridabad Road, Gwalpahari, Gurugram-122 003 (Haryana)

दूरभाष / Tel. No. : 0124-285 3060
ईमेल / Email : dgnise.mnre@gmail.com, nise.mnre@gmail.com, वेबसाइट / Website : www.nise.res.in

ABSTRACT

Renewable Energy is the key for future sustainable electricity option for developing country like India. In 2010, Jawahar Lal Nehru National Solar Mission (JNNSM) mission was launched with the objective of encouraging solar power generation and clean energy use in India. Since then, only 67 GW of solar power has been generated in the country. The capacity addition is much less than the target set for solar generation in the country. The government is making continuous effort in launching new schemes and initiative to encourage residential electricity consumers to adopt solar power for their captive load, but the outcomes are not promising.

Various challenges hinder the growth of solar PV system deployment in India. Some of the issues are grid instability, huge financing cost of solar systems, irregular policies, niche market and process of getting necessary approvals. The rooftop solar market took off for the commercial and industrial consumers, but residential consumers still rely on utility offered electricity. The current business model for rooftop solar PV generation is not giving desired results and it does not contribute to the growth of rooftop solar market specially for residential consumer segment in India. Hence it is the need of the hour to bring new improved business models for rooftop solar deployment in India. The new business model will incorporate the best practices followed globally, it shall be beneficial for all stakeholders in the long run and in turn will help to achieve the solar generation targets in the country.

The Research thesis is divided into 7 Chapters-

The first chapter, 'INTRODUCTION AND BACKGROUND' talks about the need for renewable energy generation and decreasing the dependency on fossil-based resources in India. The chapter throws light on solar energy potential in the country and highlights the recent developments. The chapter outlines the need for the research, motivation for the research study and business problems.

The second chapter 'INDIAN ROOFTOP SOLAR PV MARKET' highlights the business problem, 'Despite of several initiatives taken by central and state government, India is still unable to harness the actual/ estimated potential of grid connected rooftop solar PV specially for residential consumer segment. This in turn is affecting business growth and has adverse environmental effect'. This chapter details the policies and regulations in India for solar power generation and its impact on residential consumers.

The third chapter 'LITERATURE REVIEW' is undertaken based on three broad themes; The Role of central and state policies for business growth of grid connected rooftop solar PV systems in India, International experience of solar PV policies, and Initiatives for growth of grid connected rooftop solar PV systems deployment and understanding the impact of product service system (PSS) concept and applicability in business model innovation. This structured review of literature helps to understand the gaps and these gaps led to our research problem. The study leads to three research questions and concludes by arriving at research objectives critical for our research.

The fourth chapter ‘RESEARCH METHODOLOGY’ highlights the methodology adopted to achieve the research objectives of the study. The research design consists of the methodology adopted for each objective, the tools used and data analysis methods.

The fifth chapter ‘ANALYSIS AND FINDINGS’ provides the interpretation of data analysis and findings from the research study undertaken. The data collected and findings have been summarized for easy interpretation of the research conducted. The data is presented in the form of tables, pictures, and graphs.

The sixth chapter ‘SUGGESTIVE FRAMEWORK’ presents a framework along with structure of new business model. Pictorial representation of the new business model is presented in the chapter and the new business model is explained in detail in this chapter.

Finally, chapter seven ‘CONCLUSION’ provides a closing to the research by elaborating the contribution to literature, limitations of the research, future scope of study and final conclusions of the research undertaken.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my research guides, Prof (Dr) Prasoom Dwivedi and Prof (Dr) Anshuman Gupta for their immense support and encouragement throughout my PhD journey. They have guided me at every step of the research process. Their patience, motivation and vast pool of knowledge helped me achieve my goals. I would also like to extend my gratitude to my external guide Dr. Arun Kumar Tripathi for his encouragement and motivation for conducting my research.

I would like to dedicate this research work to my father Arun Kumar Tyagi and Mother Sadhna Tyagi who were standing pillars for me whenever I needed them. I am grateful to God for their immense love, care, and emotional support in my entire life. A very special thanks to my loving husband Nishant Tyagi and my beautiful daughter Kyra Tyagi who is always there holding my hands and providing me with positive reinforcement throughout my research journey. Finally, I am thankful to my extended family and close friends for their continuous inspiration and support.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABBRIVIATIONS

AD	Accelerated Depreciation
ADB	Asian Development Bank
CAPEX	Capital Expenditure
CFA	Central Financial Assistance
CO2	Carbon dioxide
COP21	21st Conference of the Parties
CUF	Capacity Utilization Factor
DG	Diesel Generator
DISCOM	Distribution company
FDI	Foreign Direct Investment
GHS	Group Housing Society
GOI	Government of India
GW	Gigawatt
IBM	International Business Machines Corporation
INR	Indian Rupee
ISA	International Solar Alliance
JNNSM	Jawahar Lal Nehru National Solar Mission
KMO	Kaiser-Meyer-Olkin
KUSUM	Kisan Urja Suraksha Evam Utthaan Mahabhiyan
kW	Kilowatt
LCOE	Levelized Cost of Electricity
MNRE	Ministry of New and Renewable Energy
MW	Megawatt
O&M	Operation and Maintenance
OPEX	Operational Expenditure
PPA	Power Purchase Agreement
PPP	Public Private Partnership
PSS	Product Service System
PV	Photovoltaic
RE	Renewable Energy
REC	Renewable Energy Certificate
RESCO	Renewable Energy Supply Company
RGO	Renewable Generation Obligations
RPO	Renewable Purchase Organization
RPSSGP	Rooftop PV & Small Solar Power Generation Program
RTS	Rooftop Solar Photovoltaic Systems
RWS	Residential Welfare Society
SJVN	Satluj Jal Vidyut Nigam Ltd

SNA	State Nodal Agency
SPSS	Statistical Packages for Social Sciences
SPV	Solar Photovoltaic
UDAY	Ujjwal DISCOM Assurance Yojna

CHAPTER 1

INTRODUCTION AND BACKGROUND

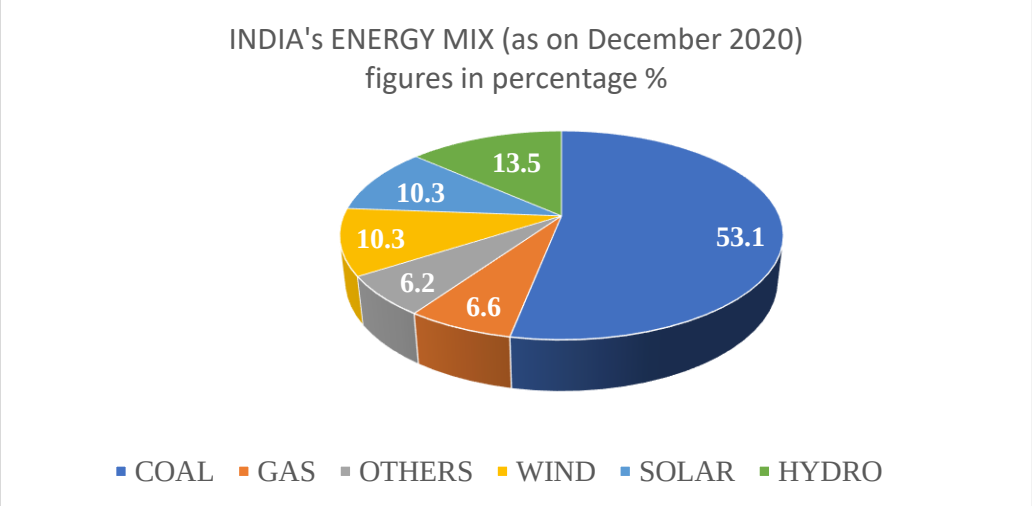
1.1 BACKGROUND

Depletion of fossil fuel and adverse impact on climate change has led countries to rethink energy generation sources. In 2015, 196 countries including India signed a treaty on climate change in Paris with the goal to limit the temperature increase to 2 degrees Celsius above the predefined levels. They pledged to come together every 5 years to access the collective progress towards the long-term goals of climate change (IEA-Pvp, 2020). Solar energy is freely available and is a zero-emission source of producing electricity. This renewable source of generation is very popular in the world. In India and other emerging nations, the cost of solar power fell to about one-third of its 2010 market price, making solar the cheapest form of renewable energy source. Solar energy generation from PV sources is performing very well in developed countries and has proved to be a mature technology of energy generation (Jacobsson, Sandén, & Bångens, 2004). Installing the Rooftop PV Systems on buildings has been successful in mitigation climate change and plays a crucial role in clean energy development in various countries. It is very well researched that PV rooftop systems can significantly reduce the GHG emissions (Monna, S. 2020). This technology offers many opportunities for mitigating the climate change issue and because the availability of solar is in abundance it is used for various other energy needs such as heating, cooking etc. (Hoggett, 2014). However, the growth of solar photovoltaic is very dynamic and it differs at country and location level.

1.2 OVERVIEW OF POWER SECTOR IN INDIA

The power sector in India is very diversified. From conventional to renewable sources, India can harness all available technology due to its favorable location and climate conditions. The generation sources which are common in India are fossil-based sources like gas and coal, while renewable energy is making steep growth in the energy mix. The demand for electricity in the country has increased rapidly due to economic growth of the country. To meet this rising demand for electricity in the country, huge capacity additions are required. Among G20 nations, India is the only country who has achieved renewable targets and made progress under Paris agreement. India made significant investments in clean energy and invested around US$ 90 and ranked 6th in the world (Jan Burck, 2020). However, India's energy mix is still dominated by conventional source of generation, which cover 79% of the energy generated (CEA, 2021). The figure below gives a snapshot of India's energy mix during FY 2020.

Figure 1 - Energy mix in India



Source – (CEA, 2021)

During December 2020, India became the third-largest producer and consumer of electricity in the world with an installed power capacity of 377.43 GW and electricity production at 1,252.61 billion units (IBEF, 2020). The power sector in India faces challenges of fuel shortage for coal based thermal plants, huge transmission, and distribution losses due, and poor financial health of its state distribution companies. The cost of importing coal has significantly impacted the generation and the power distribution companies has to rely on the expensive imported coal which leads to high tariffs. Due to high coal import cost the generation of electricity becomes expensive thus leading to blackouts, high fixed costs, local shortages. Extensive load-shedding and unstable electricity supply have led to short term solutions of using diesel gensets which are costly and not environment friendly sources of electricity generation. These power generation problems in India are hampering the growth of the sector.

The power generation in India was primarily focused on thermal or gas-based generation sources since the renewable sources of power generation were expensive for mass generation. However, over the years renewable generation sources became viable in comparison to thermal based generation. Hence, additional choices of power sources were available to policy makers to evaluate technical, economic, and environmental characteristics of a future power sector which can keep pace with the economic growth of the country. The target for 2022 is 227 GW generation of renewable energy in the country. This is to be sourced from solar, wind and other clean energy sources (MNRE, 2020a). The increase in targets for renewable energy generation attracted many financial investors to invest in clean power generation.

Investments in India Power Sector- Since year 2000, The government of India attracted Foreign Direct Investment (FDI) of around 15 billion to ramp up the power generating capacity in India. The investment is made mainly in the renewable

energy sector. The government signed agreements with international banks to modernize and improve the grid network in India. The loan is signed for more than 100 million dollars (ADB, 2021). Many private and public companies announced investments in renewable energy sector in India. By 2022, INR 500 crores of equity infusion is made by Sembcorp Industries mainly to enhance the renewable capacity in India. The largest power generating PSU in India plans to add 10GW of solar projects by 2022. Few other private power generating companies partnered to invest INR 750 crores in solar capacity additions in the state of Uttar Pradesh. Other initiatives by government of India include ramping up of renewable targets focusing on solar capacity addition to 114 GW by 2022.

Structure of Indian Power Sector- The Indian power sector is governed and dominated by government regulations and policies. The Central and State government issues regulatory guidelines and floats various policies and initiatives to enhance capacity additions in the country. Electricity Act 2003, laid down various competitive measures and introduced second generation reforms in Indian Power Sector (Sundaray, Mann, Bhattacharjee, Garud, & Tripathi, 2014a). This led to the establishment of wholesale electricity markets, competitive bidding, electricity trading and the introduction of Renewable Purchase Obligation (RPO). The other central government-owned companies involved in the generation of electricity are; National Thermal Power Corporation (NTPC), the Satluj Jal Vidyut Nigam (SJVN), the Damodar Valley Corporation (DVC), the National Hydroelectric Power Corporation (NHPC) and the Nuclear Power Corporation of India (Central Electricity Authority, 2019). The Indian power transmission network is developed and maintained by the Power Grid Corporation of India. The power ministry is responsible for policy related matters for governing power sector in India. The renewable energy sector in India is governed and regulated by MNRE. This Ministry of New and Renewable Energy is responsible for renewable portfolio, new initiatives, and policy advocacy for new renewable projects.

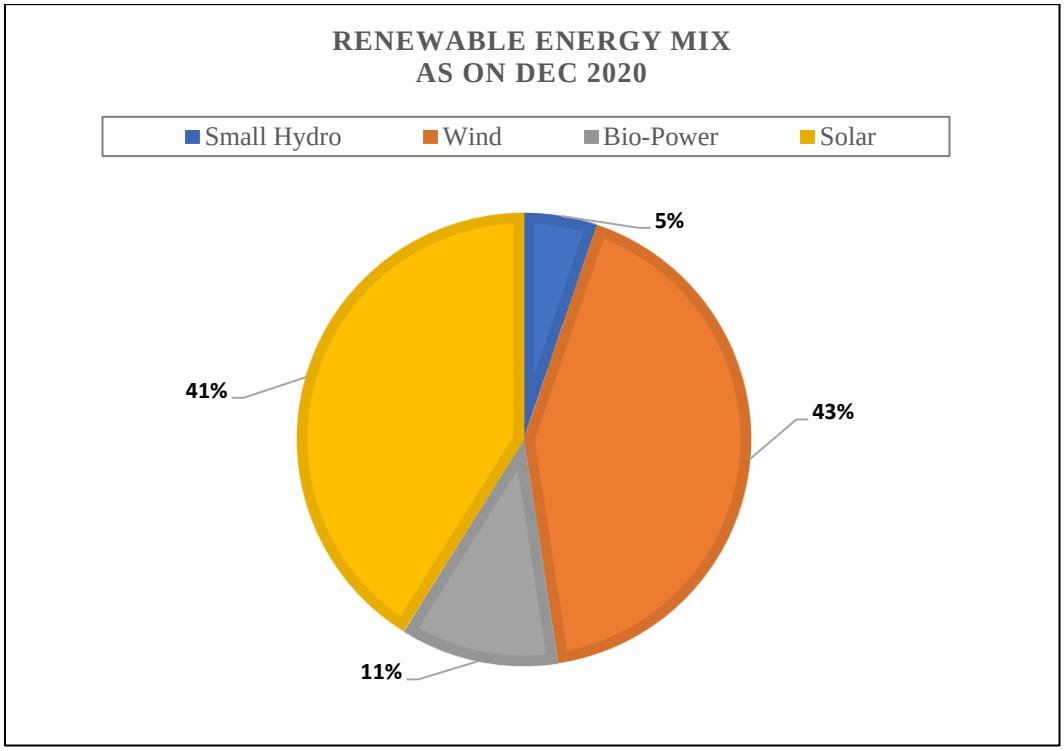
1.3 SOLAR POTENTIAL IN INDIA

The potential for solar generation in India is very attractive. The National Institute of Solar Energy (NISE) has assessed that India has a potential to add 748 GW of solar power in the country. This is assuming that 3% of the waste land area is to be covered by Solar PV modules (NISE, 2013). According to the IEA report of 2011, India receives 5,000 trillion kWh of insolation yearly and is one of the nations with ample amount of sunshine (Behuria, 2020a), this is much higher than the annual consumption and a daily global radiation in the world. Huge solar energy targets are set in India's National Action Plan on Climate Change with National Solar Mission as one of the key missions. There has been a visible impact of solar capacity additions in the Indian energy scenario during the last few years. Solar based applications both distributed as well as decentralized have made huge impact on lives of people in villages either by meeting their lighting, cooking, heating and other energy requirements. The solar energy use benefitted the women who were engaged in collection of fuel for their daily cooking and heating requirements.

Grid connected solar PV sector has evolved as a major technology which utilizes sun to generate power over the years. It supports the agenda of Indian government of sustainable growth, while, emerging as an integral part of the solution to meet the nation’s energy needs. As per National Institute of Solar Energy, States like Jammu and Kashmir, Rajasthan, Madhya Pradesh, and Maharashtra have solar potential of above 50 GW. There is a huge requirement to make solar power as dominant source of energy generation in the country. Since 2010, the government of India is working on target setting for capacity additions by various means and by establishing various schemes at state level.

In the below figure solar and wind share is more in the renewable mix in the country. Solar based generation is slowly becoming a dominant source of renewable energy mix. The current renewable energy mix in India is given in the figure below.

Figure 2 - Renewable Energy Mix in India

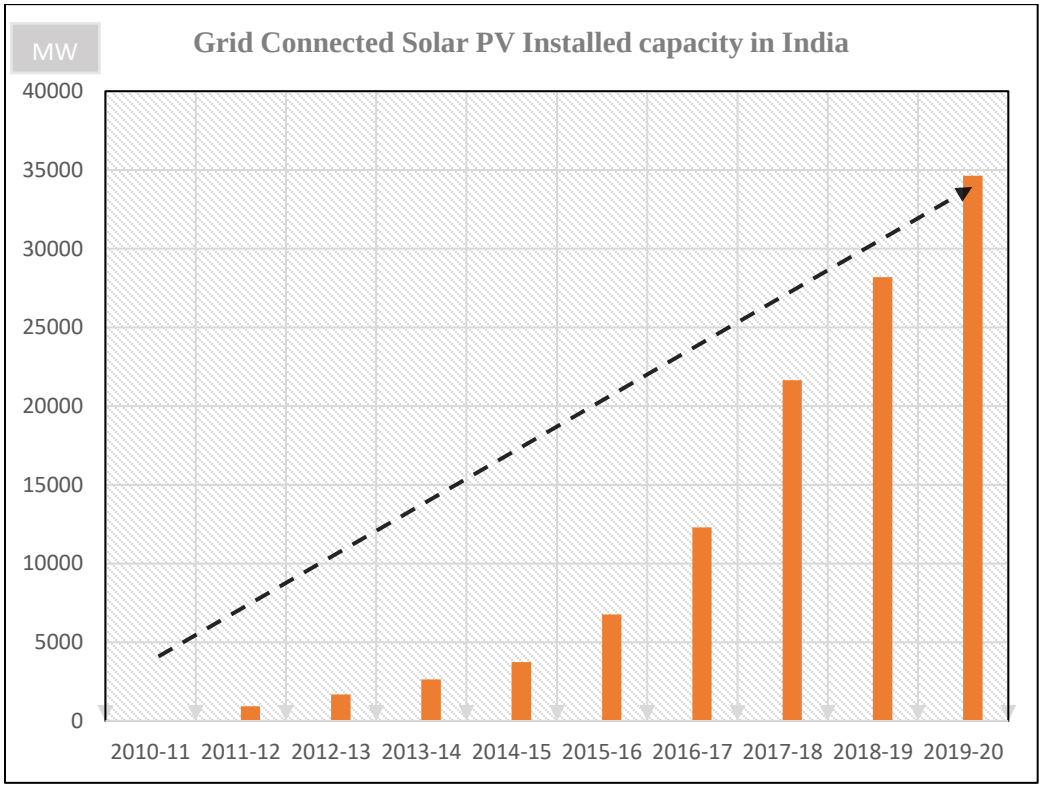


Source – CEA, 2020 (Government of India,Central Eectricity Authority, 2020)

Solar Power has increased multiple folds since 2010. India has been exploring solar power generation sources for many years and with onset of Jawahar Lal Nehru National Solar Mission (JNNSM) in 2010, it provided the platform for multiple stakeholders to invest in the solar technology (Dey, 2013). However, the initial push for solar generation was focused on utility scale projects which brought huge capacity additions to the country. Since the per-capita land availability in India is very low, utility scale solar power plants are not enough to meet the solar generation targets. During 2010 the solar grid capacity in India was 161 MW and it increased to 3.4 GW in 2020. The rapid increase in the capacity addition is due

to progressive policies and fall in solar photovoltaic module price. Many ground-mounted Solar PV plants are installed in India which helped to increase the solar share in renewable energy mix. The below figure gives details on grid connected solar PV generation since 2010 in India.

Figure 3 - Grid Connected solar PV generation.



Source -MNRE, 2020

While the Grid connected Solar systems mounted on the ground were successfully implemented in India, the off grid connected solar systems were not very successful.

The below table reflects the capacity additions from grid connected rooftop solar system (RTS) and Off grid RTS systems in India.

Table 1 - Solar PV capacity additions in India

Sector	Capacity Additions (MW) as on Feb 2020	Cumulative Capacity Addition (MW) as on Feb 2020
Grid-Connected		
Solar – Ground Mounted	2646.64	34759.13
Solar- Rooftop Systems	1809.28	4324.58
Off- Grid Connected		
Solar PV Systems	145.13	1123.15

Source – MNRE, 2020 (https://mnre.gov.in/solar/current-status/)

To set up a 20 MW solar power plant around 7.9 acres per MW of total land is required. (Margolis & Zuboy, 2006). Due to scarcity of land area the architecture best suited to India for solar capacity increment is rooftop solar systems connected via a local grid. The rooftop solar systems connected to the grid is a promising technology in India since these systems can be installed with ease and with flexibility and on vacant rooftops. Rooftop solar systems help save cost of buying land and provide huge savings in electricity bill. The data by Ministry of New and Renewable Energy (MNRE) predicts that an annual savings of INR 830 crore can be achieved by about 50 buildings if they install these systems on their rooftops. Several government institutions/ buildings in India are rapidly switching over to solar (partly) and are reaping benefits by saving huge costs.

India is a frontrunner in terms of solar deployment targets and to achieve them timely, there has been lots of hurdles on the way such as low level of investments, delayed projects, and lack of expertise among the leading players. With all the

policies laid down by the government, the slow deployment of solar in the country is a concern.

The industrial and commercial consumers have shown keen interest in installing rooftop solar systems, while the residential sector lacks trust in these systems. The residential consumers are dependent on huge government subsidies and grants for purchasing these systems. However, countries like China, Spain, USA, Germany have made huge progress in deploying residential rooftop solar systems in very less time, India is still working on best rooftop solar deployment business model in its states. The researchers have studied that installing solar systems on residential rooftop buildings will make household communities self-sufficient in electricity use (Sovacool, 2010). There is an evidence that if huge investments are done on installing rooftop solar systems on residential premises it would led to positive action on climate change mitigation (Bazán, Rieradevall, Gabarrell, & Vázquez-Rowe, 2018).

The countries who have developed solar capacities are shifting towards large scale utility projects whereas in developing countries, the market growth is seen by encouraging more rooftop solar growth. Developing countries are taking benchmark examples from international rooftop solar business models and funding options to augment and step up the adoption of rooftop solar PV systems. However, these models vary based on the policies, schemes and government initiatives of each country. In India, the solar growth rate might sound very impressive, but the fact is that solar is yet to achieve its full potential.

The below table highlights the solar potential versus the actual solar generation in various states in India.

Table 2- Solar Potential vis-à-vis Actual solar installed capacity

States	Solar Potential (MW)	Ground Mounted (MW)	Rooftop Solar (MW)
Andhra Pradesh	38440	3858.24	138.26
Gujarat	35770	3125.17	943.13
Himachal Pradesh	33840	24.00	18.73
Jammu and Kashmir	111050	8.49	12.24
Madhya Pradesh	61660	2386.31	76.91
Maharashtra	64320	1642.24	647.73
Orrisa	25780	383.56	18.16
Rajasthan	142310	5053.58	419.00
Telangana	20410	3784.27	152.09
Uttar Pradesh	22830	1410.25	257.25
Karnataka	24700	7346.85	255.10
Tamil Nadu	17670	4090.15	313.33

Source -(CEA, 2021)

The Government of India has worked to tap the solar potential with the help of policies focused on ground mounted solar plants with large capacities as well as rooftop solar systems. It is observed from the data and from the reports that the government has been quite successful in adding ground mounted installation but the full growth of RTS in India is yet to be experienced. The Grid Connected Rooftop Solar PV technology is promising for a country like India where the per capita land availability is very low. This solar technology will help to mitigate issues of carbon emissions and reduce dependency on use of fossil-fuel based technology for electricity generation in the country. However, for India to achieve

the national target of 40GW of RTS system, there is a need to increase the solar capacity to 32fold. Only five states account for 54% installation, Maharashtra and Tamil Nadu being on top (Ram, Abhishek Pratap, Anand Prabhu Pathanjali, & Abhishek Pratap, 2013). The statistics reflect that there is a very slow growth of rooftop solar market in India. From the total installed rooftop solar capacity of 2.5 GW (until June 2020), Commercial and Industrial (C&I) consumers account for 70-80% of the entire rooftop solar installations. Globally, the residential segment leads in capacity addition for RTS system installations (India, 2019). New attractive initiatives and policies by government at state and central level in India has helped in capacity additions for states like Tamil Nadu, Karnataka, Gujarat, and Rajasthan. Many other states and Union Territories (UTs) have net metering regulations in place but issues with grid restrictions persist.

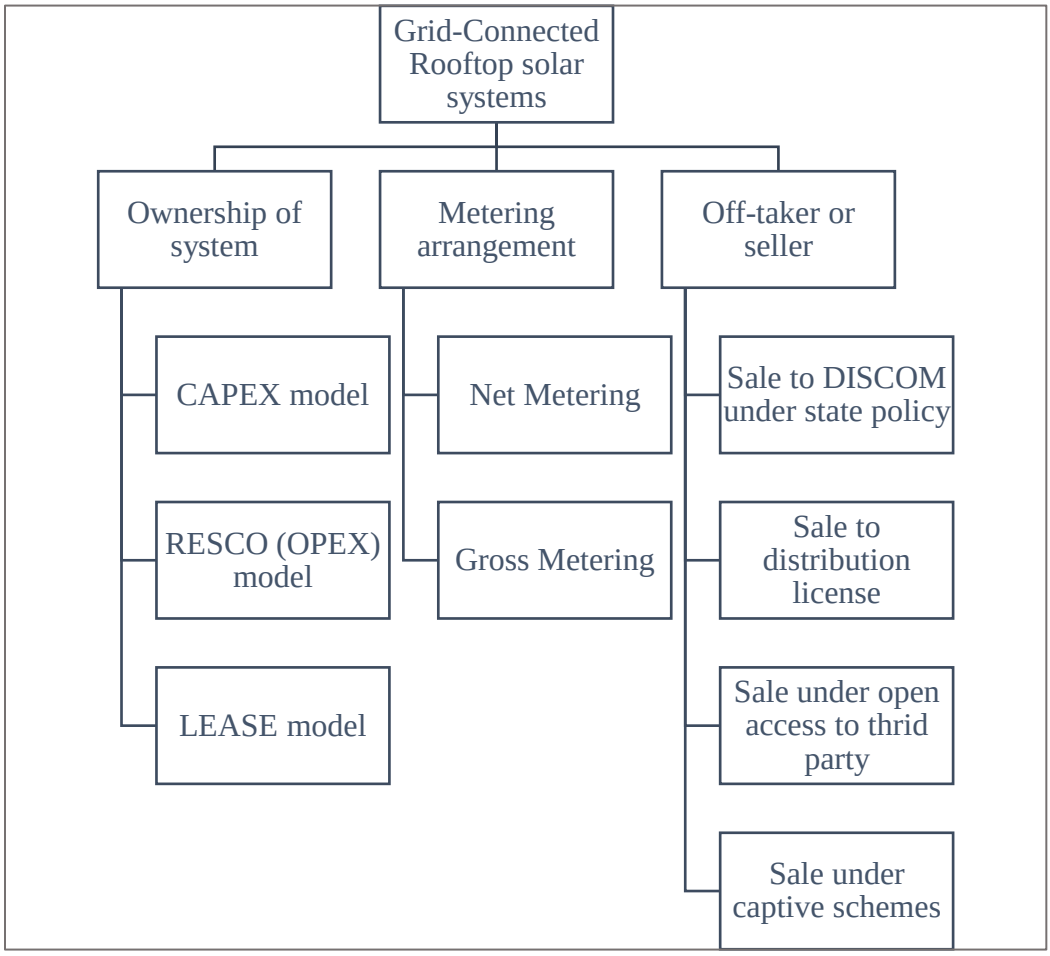
1.4 MOTIVATION FOR THE RESEARCH

For many years in India, the development of solar power is funded by the central government. The capacity addition of these solar projects remains limited because of the lack of regulatory policies to promote renewable projects. However, after the decline in price of solar modules, retail electricity tariffs became at par with solar tariffs. Many private players entered the renewable market with attractive deals and rather than depending on government grants and subsidies the private players started to focus on developing the solar market.

To enhance the capacity of rooftop solar it is important that the role of stakeholders in the implementation process be clear and simple. From the planning to implementation and maintenance stage, each stakeholder has a major role to make any business model a success. Each stakeholder, such as consumers, policy makers, regulators, state nodal agencies, financial investors, suppliers of system and off-takers of power such as distribution companies contribute to success of deployment

of rooftop solar systems. The undeveloped grid network and technical limitations of grid connectivity are some of the biggest challenges for rooftop installations under net metering arrangements in India. Broadly there are two types of business models existing in the market - customer owned (or self-owned business model) and third party owned business model. The below figure gives snapshot of the prevailing business model structure.

Figure 4 - Snapshot of the prevailing business model structure in India



Source – MNRE (Sundaray et al., 2014a)

In a self-owned system, the owner of the rooftop operates and maintains the solar system and the generated energy is first consumed by the owner and excess if any is fed into the grid under metering arrangements or a combination of both. The net

metering arrangement is popular in India as many states have enacted net metering policies and have initiated many schemes under this metering agreement.

In a third party owned system, the rooftop owner does not own the solar system and they are either leased from the developer or from another company. The power generated is sold to consumers or both as the case maybe. This model has restrictions for end consumers as they do not have benefits of tax credit and capital subsidy. In the third-party business model, the lease can be an operating or financial lease. Finally at the end of the term of the lease, the system is completely transferred to the consumer as per the agreement. The business model for rooftop solar revolves around the two main variables - system ownership and revenue structure. The financing plays an important role in business models for solar rooftops given that the consumers might opt for self-financing or third-party financing for their system. Besides the owner of the system or the seller of power generated, there are other stakeholders who are involved in various support services such as consultancy, support services, regulatory advice, and incentives disbursements.

The solar business models have evolved over many years with changes in ownership of systems and government schemes. In countries like Germany and Japan, ownership model became popular where the ownership of the system remains with the consumer, this was accepted mostly by residential and was very successful in scaling up their solar rooftop targets. Now the third party or project developer are also capturing the solar market by clubbing many small-scale solar projects and investing in them. Under this model the consumer can avoid the burden of high upfront capital cost, and still benefit from the rooftop solar system by procuring the power generated and by leasing the rooftop space. These two models have been implemented and followed by developed countries with high rate of rooftop solar installations. There is a strong case that solar rooftop market going down 10-20 years will look very favorable for residential consumers in India. The RTS will become an important component of power generation source over the

years. Solar rooftop PV will be very competitive once a large segment of residential consumers starts considering the benefit of solar photovoltaic as clean energy source. In the coming years, once the residential consumers accept the technology and its benefits, they will not wait for utilities tariff to be at par with solar generation installations. There are other attributes which are considered for adoption of PV generated power such as reduction in carbon footprints, no fuel cost, increased flexibility, and use of vacant rooftops. To help achieve the true value of RTS technology, new business models will be required for market penetration. Hence, the need of the hour is to have a very efficient and robust business model for rooftop solar installations in the country for residential consumers. To enable an environment of sustainable rooftop solar system solution to residential consumers, we must explore broad customized solutions to the consumers which would not only just sell the product but will add value to it. For creating such customizable solutions for residential electricity consumers in India, we will explore Product Service System (PSS) approach which will help provide solutions by integrating the need of all the stakeholders. Through PSS approach, all the support systems such as resources, technology, policies, and people would help in delivering the integrated solutions of products and services.

1.5 BUSINESS PROBLEM

In India, renewable energy generation sources have been encouraged traditionally through various financial incentive determined by the Electricity Regulators. In 2010, Jawahar Lal Nehru National Solar Mission (JNNSM) was introduced for boosting solar energy generation with an objective to make India self-sustainable in solar energy. Since the introduction of JNNSM about 35 GW of Solar Power capacity has been added in the country and only 5.9 GW is from Rooftop Solar Systems, of which 70% is from Industrial and Commercial consumers.

Despite of several initiatives taken by central and state government, India still is unable to harness the actual/ estimated potential of grid connected rooftop solar PV specially for residential consumer segment. This in turn is affecting business growth and has adverse environmental effects.

1.6 STRUCTURE OF THE THESIS

The present thesis is organized into seven chapters for the purpose of presentation. The first chapter, 'Introduction and Background' constitutes the structure of power sector in India, solar energy scope and its challenges, the chapter concludes with business problem and its scope. Chapter two 'Indian Rooftop Solar PV Market' presents the market evolution of RTS systems. The chapter highlights the business model adopted in India for RTS deployment. Chapter three 'Literature Review' provides a structured review of the literature and summarizes the research gaps, research problems, research questions and research objectives. Chapter four 'Research Methodology' describes detailed research design and methodology to achieve results from the research objectives. Chapter five' Analysis and Findings furnishes the analysis and findings of the research conducted. This chapter provides a detailed report of findings from data analyzed which helps us to prepare our framework of business model. Chapter Six 'Suggestive Framework' explores the framework of the new business model. This chapter captures the elements of the new business model and gives pictorial description of proposed new business model. Finally, chapter seven 'Conclusion' includes detailed conclusion with limitation of the study and scope of future research.

CHAPTER 2

INDIAN ROOFTOP SOLAR PV MARKET

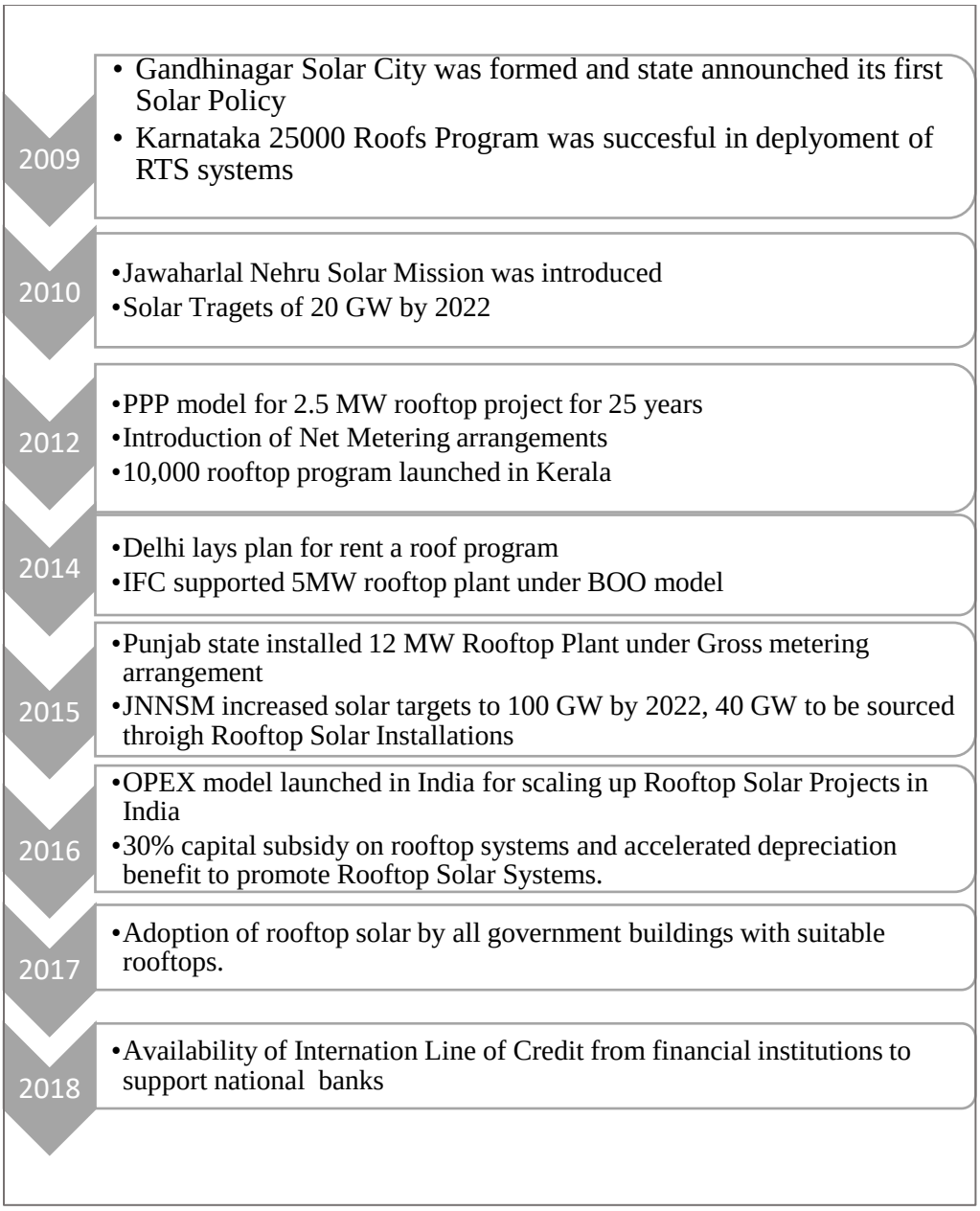
The previous chapter discusses the background of Indian power sector, potential of solar energy in India and benefits of solar generation. Currently, the Indian power sector is dominated by fossil-fuel based generation, with 50% share of coal and gas-based generation in the energy mix. This section of the thesis will cover insights into rooftop solar technology in context of Indian market. The grid connected rooftop solar PV systems have been growing market share since the announcement of JNNSM mission, but the growth is very slow. The present chapter discusses the market evolution of rooftop solar systems in India, challenges faced by rooftop solar market and existing operating business models for grid connected solar rooftop systems in India.

2.1 MARKET EVOLUTION OF ROOFTOP SOLAR PV SYSTEMS

There is a dramatic evolution of rooftop solar technology, with increasing efficiencies and lower costs/watt. The new initiatives are evolving in the markets that offer many benefits to end consumer of electricity. No doubt the benefits are huge. The trend of adoption of rooftop technology is positive, however, despite many enablers of grid parity and new initiatives the actual installation capacity is only 1.1 GW as of December 2020 for residential consumer category in India (BTI, 2020). Clearly, the achievement of solar targets truly depends on the acceptance of new technologies. If the national goal of 40 GW of rooftop solar, as per the National Solar Mission, is to be realized, it is important to understand the triggers of purchase intent of the rooftop solar systems by Indian residential households.

To understand the market, we study the challenges and issues relevant in the market and also gain deeper understanding on existing business models prevalent for rooftop solar PV systems in India. The rooftop revolution began in early 2009 in India with central and state governments working together towards the goal of providing solar based electricity to every household. The market evolution of rooftop solar systems in India is illustrated in the figure below.

Figure 5 - Market Evolution of Rooftop Solar Systems in India



Source- (MNRE, 2018)

2.2 CHALLENGES IN ROOFTOP SOLAR SECTOR

India is progressing towards renewable energy generation as solar energy is becoming viable in the country. The solar energy developers are focusing on developing big solar power projects to meet the current energy needs. The transition of power sector in India from fuel-based generation to clean energy generation depends on various factors such as location, economic conditions, social and institutional requirements. Huge government grants and financial support is provided to encourage use of renewable energy technologies in India. However, this sector is still lagging. There are several barriers prevailing in the rooftop solar market which are discussed in detail to understand the deep impact of these issues on market growth of RTS systems in India.

- **Stakeholders' Challenge:** There are four stakeholders involved in solar market growth; utilities/ policy makers, service providers, financial institutions, and electricity end consumers. The utilities which provide grid electricity to consumers face the challenge of loss of revenue from high paying consumers shifting to rooftop solar (Robin Burgess). They face shortages of skilled staff and lack of incentives to promote rooftop solar systems in India. The other barrier faced by utility companies is overloading of transmission capacity. The service providers face challenges such as; financial arrangements, faulty payments, fragmented distribution of installations, rooftop ownership issues, regulatory approval delays and creditworthiness of consumers (Kollins, Speer, & Cory, 2010).

- **Market Development Challenge:** Achieving mass attraction brings the major challenge for market developers since the size of each rooftop installation is significantly small. Each solar system implementation goes through the various stages of planning including contract formation, financial planning, regulatory clearances, and technical feasibility. These solar contracts are non-standard, and it requires right fit for consumers. Hence these are time consuming processes and

seen as resource intensive technology by many developers. Rooftop solar presents challenge in terms of credit risk of the consumers. since these contracts are long term. Besides this the contract laws in India are not the strongest. In India, RTS technology is becoming favorable for most consumers but still it is required to come to a point where it achieves a product status. For residential market, solar plant connected to the grid is considered as a huge investment which comes with long payback period and lacks trust in the market. The lock in of 25-years life of system is also a factor which hinder higher penetration. Another barrier is the supply gap by the major developer of solar systems who target consumers which have high credibility leaving out a large proportion of consumers.

- **Policy formulations Challenge:** The regulatory framework in India is unstable, and the absence of technical regulations for small scale solar systems acts as important barrier to deployment of net metering regulations. The arrangement of net metering regulations conflicts with technical guidelines for Electricity Act 2003. Important parameters such as grid synchronization, islanding and protection should be made mandatory in the regulations.

- **Infrastructure Challenge:** The major infrastructure challenge in Indian context is grid synchronizations. There are various reasons for this challenge such as variations in voltage and frequency, unavailability of reliable equipment like invertors and lack of grid synchronization equipment. Another barrier is availability of grid network across India, right now the country is still finding ways to provide electricity access to all. Presently the focus of the development of rooftop solar system in India is on institutional buildings such as government offices, schools and colleges, hospitals and other big buildings having more connected load. The urban population live in settlements which are either temporary or informal. The average income of consumers is lower than the average of pollution in these places. The residential buildings in urban India are multiplexes and housing communities. The RTS systems are less attractive in such settlements, because of complexities of

regulatory burden, low interest in small scale technology adoption, financial burden on housing communities and lack of interest in investment in renewable energy.

2.3 FINANCING ARRANGEMENTS

Capital cost structure for residential and commercial consumers is different due to differences in the size of the system they are able to install on rooftops. However, the bulk system purchase cost advantages can be seen for residential premises in some cases. The self-owned systems have high upfront cost, maintenance cost and in some case replacement cost attached to it, while the commercial/ industrial or third party adopts project finance based structures for accounting such as depreciation, interest on loan, interest on working capital and return on equity (Sundaray et al., 2014a).

Recognizing the tremendous financing needs, the governments of India and U.K. launched India's National Investment and Infrastructure Fund (NIIF) which will provide $341 million to a green fund focused on India. Along with this, China's Golden Concord Group and Japan's SoftBank are also planning a solar venture in India. The $930 million project involves the production and sale of solar ingots, silicon wafers, batteries, and components and will have a capacity of 4 GW (Sharma, 2011a). This project more than doubles India's current annual solar-cell manufacturing capacity of 3 GW and aligns with Prime Minister Modi's "Make in India" program (Behuria, 2020a). These much-needed investments work toward ensuring that India is on track to meet its Paris Agreement goals and promotes energy access for all.

Ministry of New and Renewable Energy (MNRE) and Government of India (GOI) gives 40% Central Financial Assistance (CFA) (MNRE, 2020a) for installation of SPV system on rooftop premises and State Nodal Agencies (SNA) can now

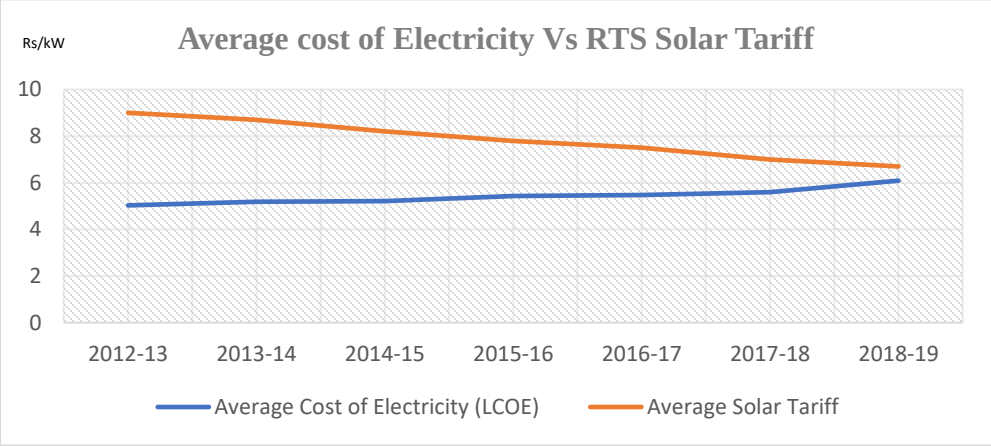
independently approve and implement projects up to 50kW (Narula & Sudhakara Reddy, 2015).

- ✓ For residential consumers the banks have introduced home improvement loans up to 10 lakhs under priority sector lending (MNRE, 2018).
- ✓ For industrial or commercial installations, there is a 10-year tax holiday, about 40% Accelerated Depreciation (AD), Custom Duty concessions and Excise Duty exemptions. Also, loans are available for up to INR 15 Crore for renewable energy projects under priority sector lending.(MNRE, 2015).

Most households in India live in owned houses in both rural and urban areas. The three main things which govern the requirement and financial feasibility for any residential consumer category are - LCOE (levelized cost of electricity) from the grid, cost of rooftop solar system connected to the grid and finally the capital cost requirement.

I. **Levelized cost of electricity in residential households in India-** Average electricity tariffs for different states along with rooftop solar generation. cost.

Figure 6 - Average cost of electricity versus Solar tariff in India



Source- ("Smart City; Mission Statement & Guidelines," 2015)

II. Rooftop solar system cost (Rs. Per kW)

Most residential households will procure a system with capacity of 1-5kW.

Table 3 - Cost structure of grid connected RTS system in India.

Grid-Connected Rooftop Solar System Size (kW)	Approximate System Cost (Rs.) per kW (Inclusive of taxes, freight, etc.)
1-3	60000-78000
3-5	64000-68000
5-10	59000-640000
10-30	51000-59000
30-50	49000-51000
50-100	44000-49000
100-1000	41000-43000

*System cost calculated as per SPIN software and applying subsidies available as on 31st October 2018

** SPIN is an online application (web portal) of the Ministry of New and Renewable Energy (MNRE) for managing the grid-connected rooftop solar photovoltaic installation database under the Grid Connected Rooftop Solar and Small Power Plant Program. The portal is developed and maintained by National Informatics Centre (NIC) and can be accessed at https://solarrooftop.gov.in/.

III. Capital cost requirements.

Capital investment needs for 40GW of rooftop solar in India by 2022

Table 4 - Capital investment requirement for 40 GW capacity addition

Sector wise- Capital Investment	Rs. in crores
Government and Residential Sectors	43,870
Commercial and Industrial Sector	163,308
Total Cost in INR	207,165

*MNRE estimates 2017, *INR 65= 1 USD

Source - (Kar, Sharma, & Roy, 2016)

2.4 TYPES OF BUSINESS MODELS FOR ROOTOP SOLAR PV SYSTEMS IN INDIA UNDER NET METERING ARRANGEMENT

Two types of business models exist in India.

- Self-owned business model
- Third party owned business model.

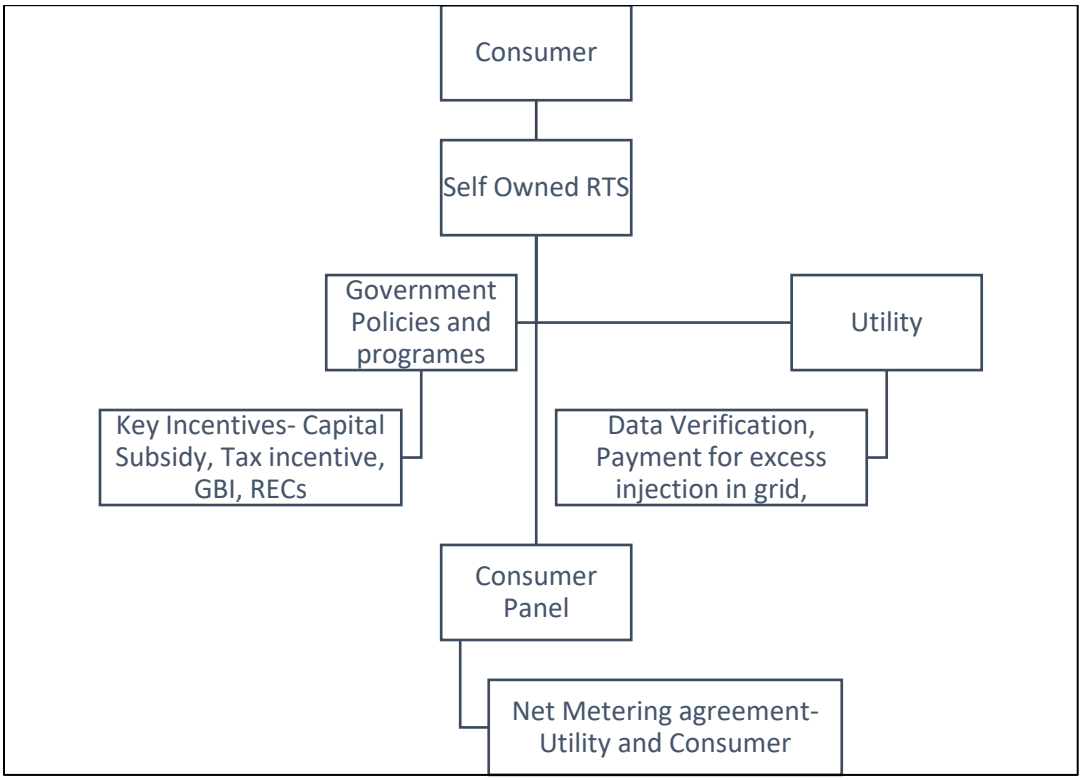
Both these models are relevant in the Indian context and are discussed in the section below:

I. Net Metering based Self-owned business model for RTS.

In the self-owned business model of RTS system, the end consumer installs the system on its premises and owns the system. The energy generated from the self-owned system is first utilized by the consumer and or supplied to the grid under net metering regulations as the case maybe. In the self-owned business model, the consumer initially uses the electricity for captive purpose and feds the excess to the grid through a bi-directional net meter installed at their premises, The excess units fed into the grid is credited to the consumers electricity bill either monthly or annually.

The pictorial description of a self-owned net metering model is given below. The consumer can either install the RTS system under any government scheme and avail subsidy or can use self-financing and get net metering benefits.

Figure 7 - Self owned net-metering model



Source - (Hairat & Ghosh, 2017a)

The attractive scenario of declining solar component costs and increasing retail tariffs across most consumer categories in India has led to net metered projects being financially viable. The consumers who can afford the cost of solar system and have suitable rooftops are opting for this model to benefit from green energy consumption and savings in electricity bills. In the self-owned model, the risk of payments, loans, subsidy disbursements and rebate from government is under the consumers portfolio.

II. Third party owned rooftop PV net metering model.

In this type of business model, the solar developer leases out the RTS systems to interested consumers who have suitable roof tops to install the system. The consumers select the developer/installer and give the contract to install the system. The developer or installer offers various services such as commissioning of the system technical feasibility, leasing terms, and maintaining the system over the period. They maintain the general technical standards and get the approvals in place for the commissioning of the system. The energy generated from the third party owned RTS system is utilized by consumer and the excess generation is fed into the grid under net metering arrangement.

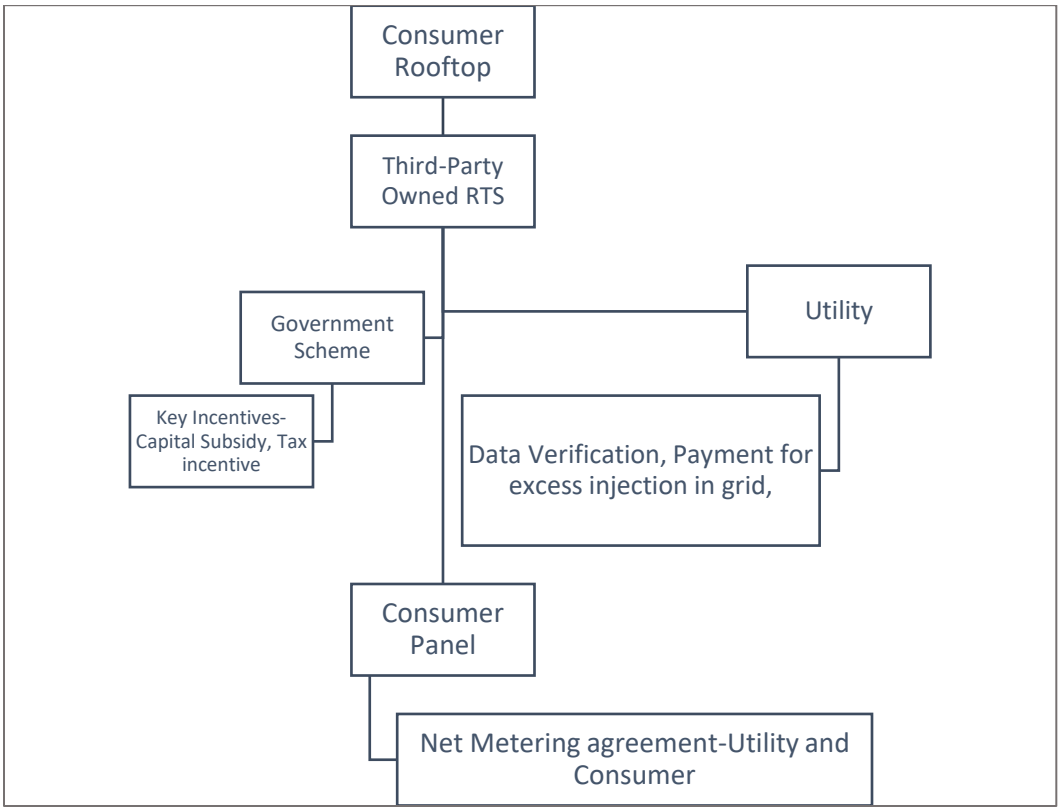
Benefits of third-party model to consumers are:

- The upfront cost responsibility is eliminated.
- Net-metering allows the consumer to save money by injecting the excess generation into the grid.
- The lease agreement for a long term helps the consumers in sharing the regulatory burden by arranging for approvals, feasibility, and other technical requirements to install a system.

Benefits of third-party model to developers are:

- Revenue is generated because of lease rental from the consumer under PPA contract.
- The developer claims the Accelerated depreciation on the capital cost of the system and enjoys the tax benefits related to installation of RTS systems on rooftops.

Figure 8 - Third party owned net metering model



Source - (Hairat & Ghosh, 2017a)

The business model for rooftop solar systems in India involve roles of many stakeholders. The utility company provides grid electricity to end consumers, the product suppliers who are also the developers of the solar system, the state nodal agencies which promotes the schemes, and the state regulatory board who is the regulatory body. These stakeholders come together to work for the success of each business model. There is a role for each stakeholder in the business model structure. The next part of the chapter will elaborate on the role of stakeholders for better understanding on their responsibilities.

2.5 KEY ROLES OF STAKEHOLDERS IN ROOFTOP SOLAR PV MARKET DEVELOPMENT

Stakeholders	Key responsibilities
State's Energy (Power) Department	• State rooftop solar PV policy rollout • They advertise the schemes launched through online portals and print media. • The scheme is floated, and feedback is evaluated from project developers, suppliers and interested consumers. • The state energy department set up a monitoring cell for monitoring the progress of schemes and initiatives and addressing the concerns of the policy implications.
DISCOMs (Distribution Company)	• Implementation of the regulations and the policy provisions • Role is limited to PV systems interconnected to the grid. • Empowering the committees and delegating the power • Budget approval and integration of existing bill processes and introducing monthly/annual billing mechanism. • Empanelment and procurement of information on new schemes or policies are made public.
State Nodal Agencies (SNAs)	• Technical capacities, load sanctions for RTS systems

	• Managing the channels for promoting RTS installation program through funds and subsidies • Processes are well integrated with the state utilities processes,
Consumer (end-users)	• Key financers in the rooftop PV system or can have financial assistance. • Evaluates the risk associated with and the payback time of a rooftop PV system. • Completes applications for getting RTS system installed including financing such as availing loans, application to DISCOM, applying for grants and interaction with supplier for commissioning and operation. • Maintain the system and adhere to other technical compliances
System Provider	• Construct, design and procure materials for RTS system commissioning. • Incorporating best practices and complies with all statutory and technical guidelines. • Install system while making sure of safety and maximize energy. • Working on system cost as per consumers requirement while not compromising on the quality

2.6 DISCUSSIONS ON INDIAN SOLAR ROOFTOP PV MARKET

- The solar PV business model end consumers need low-cost financing, hassle free approvals and an efficient supply chain. The business models revolve around the role of utility companies and their active involvement in all the management of the solar power plant setup. It is noted that once RTS systems reach a scale, the market penetration of these systems will increase which will then translate into significant value.

- The RTS systems development has potentially greater benefit than just power generation. The business model development for solar PV in India will not be driven by the potential for grid services but also these systems will be installed to provide the benefit to the nation's energy infrastructure, as these systems in aggregate could offset significant investment requirements in new generation, transmission, and distribution capacity.

- The present transmission and distribution network planning and operation practices in India do not take into account the potential value from solar PV generation. These functions are largely separate within distribution companies which hampers inclusion of solar generation and other distributed resources in system planning.

- Installing RTS systems has environmental benefits known to the world. In many scenarios the benefits such as reduced transmission and distribution losses have been observed. DISCOMs and utilities are eligible for RPO benefits for the solar power consumed under net-metering framework. This would help the financial & operational capabilities of Indian utilities, there is a huge need to support them with necessary manpower and funds for developing this market.

CHAPTER 3

LITERATURE REVIEW

The previous chapter helps us to understand the Indian rooftop solar PV market in detail and examines the evolution of market, its challenges, and issues. The previous chapter also explains the existing business model structure of RTS in India. There is a requirement to dig deep into the literature to understand and review the rooftop solar market globally. This chapter presents a detailed and structured review of literature based on the themes identified from the previous chapter. The first part of the chapter gives justification of identified themes which is followed by detailed theme wise discussion on reviewed studies. The second part of the chapter explains the consolidation process of research gaps. The consolidated research gap is critically analyzed to reach research problems and research questions. The structured approach is used to arrive at the research objectives based on our literature review and gaps derived from them.

3.1 INTRODUCTION

Literature review searches and evaluates the available literature around the specified subject of research (Swanson & Smalheiser, 1997). Literature review surveys the scholarly articles, books and any other published information in the chosen area of study (Webster & Watson, 2002). The review provides the summary of existing literature by synthesizing the information (Galvan & Galvan, 2017). Thus, the researcher also reviewed the literature on all the identified themes and underpinning theory. The researcher will identify research gaps based on the discussion of reviewed literature.

3.2 JUSTIFICATION OF LITERATURE REVIEW THEMES

The literature review is planned under three broad themes. The role of central and state government policies for business growth of grid connected rooftop solar PV systems in India is reviewed and studied in theme one. This is further divided into three sub-themes for better understanding of the government intervention and regulatory aspect of rooftop solar systems in India. The sub-themes help us to understand the role of central and state government initiatives in India for ramping up rooftop solar systems connected to the grid. This theme also establishes the understanding of the rooftop solar business models connected to the grid. These models have been reviewed in detail in the study.

The second theme of our literature review is comprehensive study and analysis of global rooftop solar PV markets. The analysis is done to understand the rooftop solar systems in developed and developing countries. This theme is further divided in two sub-themes, the first one helps us to understand the policies and initiatives taken to reform the rooftop solar market and second one analyzes the business models adopted for the growth of rooftop solar markets for residential consumers.

The third theme of literature review is understanding the impact of Product Service System (PSS) concept and applicability in business model innovation. The PSS approach is reviewed in detail by studying the advantages and applicability of the concept. This theme establishes the understanding of the concept and approach of PSS. Further, the literature review concludes by examining the various case studies where PSS approach has been applied to business model for better understanding of application and results.

3.3 THEME WISE REVIEW OF LITERATURE

3.3.1 The central and state government policies and initiatives-

The policies and initiatives are studied to understand the stakeholders' role, regulatory structures, subsidy grants, renewable targets and schemes for residential consumers floated by government to support the rooftop solar system installations.

Central government initiatives: The Ministry of New and Renewable Energy (MNRE) announced various programs and schemes to encourage deployment of solar rooftop capacity in India. Under National Solar Mission, Grid Connected Rooftop and Small Solar Power Plants Program provided subsidy at 30% on the benchmark cost of the solar system for general category states and subsidy at 70% on benchmark cost of solar system for special category states in India. These benefits were provided for installation across the residential, institutional, and social sectors. Moreover, for RTS installations on government buildings, incentives of up to 25% of the benchmark cost in general category states and up to 60% of the benchmark cost for special category states were provided (MNRE).

Under JNNSM the objective is to establish India as a global leader in solar energy. Under the mission guidelines (Ministry of New and Renewable Energy; USAID; GERMI, 2016), the Indian government mandated the use of domestic manufactured cells and modules for RTS systems. The modules and cell account for 60% of total solar rooftop system costs (Hairat & Ghosh, 2017a). The target was later revised from 20 GW to 100 GW by 2022 (Dey, 2013). Out of the 100 GW target, 60 GW was to be achieved from large/medium scale solar project and 40 GW through small scale RTS installations (Hairat & Ghosh, 2017b).

During 2012, the government rolled out scheme along with IREDA (Indian Renewable Energy Development Authority) called Rooftop PV and Small Solar Power Generation (RPSSGP). The objective of the initiative is to encourage small scale grid connected solar PV plants (ground mounted and rooftop) (Tyagi, Dwivedi, & Gupta, n.d.). Under this program no subsidy grant was made available for RTS capacity addition in the commercial and industrial sectors, but subsidy and incentives were made available for projects from government, residential/ social and institutional sectors. The result of JNNSM and RTS schemes were well noticed in urban sector but the rural agricultural sector was also in need of power at subsidized rates (Sahu, 2016).

Ujjwal DISCOM Assurance Yojana (UDAY) was started in 2015 by the government of India to overcome the burden of distribution companies in India (Central Electricity Authority, 2019). The objective of the reform was to improve operational challenges, renewable development, generation cost reduction and efficient use of available resources. Later in the year 2016, International Solar Alliance (ISA) was formed in order to encourage solar generation and solar product manufacturing for countries lying between the Tropic of Cancer, northern most latitude with overhead sun, and Tropic of Capricorn, southern most latitude with overhead sun. ISA planned to invest 1000 billion dollars for development of solar energy and its availability at affordable cost (Parekh & Modi, 2008).

The Ministry of New and Renewable Energy (MNRE) released Rs.1577.99 crore as Central Financial Assistance (CFA) to state nodal agencies for deployment of rooftop solar projects (MNRE, 2018).Around Rs.400 crore of financial assistance has been provided by central government for the initiative called SRISTI (Sustainable Rooftop Implementation for Solar Transfiguration of India). The scheme was launched to provide CFA (Central Financial Assistance) for installation of RTS systems in residential sector. However the subsidy support from

government was limited up to 5 kW capacity of system (Ministry of New and Renewable Energy, 2017). For the phase two, the funding for grid-connected rooftop solar scheme to speed up the installation was given at USD 1.7 million, which is aimed at improving the proliferation of rooftop solar in India.

During 2019, PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan) Scheme was launched to encourages the use of solar energy on barren land in remote rural areas of India. This scheme laid grounds for the installation of grid-connected solar power plants of up to 2 MW each in areas for farmers' use (NISE, 2013). Government incentivizes farmers to run solar farm water pumps and use barren land for generating power for extra income of up to Rs 60,000 per acre every year and by selling the surplus electricity to state DISCOMs they can earn extra source of income. The government will provide 60% subsidy, which will be borne by central and state governments, while 30% will be provided through bank loans.

An achievement linked incentive scheme was launched by the MNRE in May 2016, which promises an incentive to state/ UT ministries for achieving their targets. All major government-controlled sectors such as railways, airports, hospitals, educational institutions, government buildings of center/ state/ PSUs are being encouraged to install rooftop solar. In addition, the government is promoting solar rooftops in many cities by encouraging residential households to adopt the technology by providing them with financial support such as subsidies. The Ministry of Urban Development of India is coordinating with other ministries to avail solar rooftop benefits in smart city project of government. Financial incentives are being provided for development of RTS systems on government buildings. To develop RTS systems, the platform for digital forms and applications are being launched along with empanelment of channel partners and training of Suryamitras (Khanna, Magal, Karandikar, & Awalikar, n.d.). The Indian government increased the budget to 8 folds, from INR 600 crores, for grid-connected solar rooftop and

small solar power plants program during 12th FYP. The government plans to mobilize investment of more than USD 1000 billion by 2030 for the deployment of solar technology at low cost for various sectors (Jan Burck, 2020).

Mandatory Policy Implementations – The states of Uttar Pradesh, Maharashtra, Delhi, Rajasthan, Haryana, and Andhra Pradesh have achieved grid parity in residential sector since the cost of solar generation is affordable. Many other states have notified regulatory policies for encouraging net metering in RTS deployment. In some states, the cost of electricity (LCOE) of rooftop solar is lower than the utilities tariff making it affordable for residential consumers to adopt the technology (Agarwal, Mani, Jain, & Ganesan, 2020). In a few years the gap in tariffs from utility power supply and solar power will decrease leading to solar power supply to be more competitive than conventional power supply. In initiative to promote RTS deployment, the government of Haryana has mandated installation of RTS in all institutional and government buildings having a connected load of 30 kW and for all industrial and commercial establishments having a connected load of 50 kW. In the capital state of the country, the metering policies are favorable, and the combination of effective regulations and subsidies has helped deployment of solar technology in fast and efficient ways. In the state of Maharashtra the RTS deployment has taken off by installation of the biggest solar power plant; The Sakri Solar Plant with a capacity of 125 MW (Srivastava & Srivastava, 2013). In the capital city of Maharashtra, various housing societies and communities have RTS system installed which helps to save on the energy bills (Manju & Sagar, 2017a).

Subsidy as incentives – The government of India through MNRE is providing 30% capital subsidy on benchmark cost to states which lie under general categories and 70% capital subsidy on benchmark cost for special category states such as Northeaster states, J&K and Uttarakhand (MNRE, 2020b). 100% subsidy is offered by municipal corporations in Maharashtra for construction of new buildings, offices and colonies which opt for RTS installations for their connected load. For

government buildings and PSUs about 100% and 15% subsidy respectively is being granted to set up RTS on buildings in various locations of the state. The government of Chhattisgarh state approved Solar Policy in the state during 2017. The policy facilitated 10kW grid connected RTS plant and 15% capital subsidy would be provided for institutional and residential sectors for using domestic manufactured solar panels for installing RTS.

Net Metering Incentives - The electricity generated from RTS can be used for self-consumption under the net metering arrangement. The net metering arrangement allows for a two-way flow of electricity. The consumer consumes the power generated from solar system and is billed only for the extra units by the utility company (Gajjar, Raizada, Kumar, Abraham, & Ghosh, 2019). The electricity generated from solar PV rooftop can be fed into the grid at regulated tariff as per states guidelines. The consumer has the option of solar power consumption or export to the utility under this arrangement.

State Government Policies and regulations: Rooftop solar as a source of electricity is fast catching up on the conventional sources in many states, since the LCOE for solar generated power is at par with utility provided electricity for residential consumers. In states like Uttar Pradesh, Maharashtra, and Rajasthan the LCOE and solar tariff are achieving parity (Trivedi, Ray, & Vulturius, 2018). 30 states in India have considered Net Metering regulations as favorable for deployment of RTS systems, however the subsidy grants can be different in each state. Some of the states allow maximum of 1 MW capacity addition while some states limit the capacity below 1MW. The table below gives details on state wise and year-wise actual targets set by each state-

Table 5 - State-wise rooftop solar annual addition targets (MW)

STATE/YEAR	2017	2018	2019	2020	2021	2022
Uttar Pradesh	510	538	650	752	860	970
Telangana	240	250	300	350	400	450
Tamil Nadu	420	438	524	613	700	790
Delhi	132	138	165	190	220	250
Gujarat	385	400	480	560	640	720
Odisha	120	125	150	175	200	225
Andhra Pradesh	240	250	300	350	400	450
Maharashtra	565	588	704	823	940	1060

*Actual figures as per (MNRE, 2018)

The state targets mentioned in table 5 for solar additions reflect that future growth of Solar PV and to achieve these huge targets the state government offer various incentives and introduces policies to attract the consumers. The solar policies in states of Tamil Nadu, Rajasthan and Haryana offers exemption from banking and wheeling charges along with cross subsidy charges for commercial and residential solar sector. In the state of Haryana, the RTS systems can be installed without requiring permission from authorities and in Tamil Nadu the rooftop solar system cannot be more than 90% of the electricity consumption at the end of the settlement period for residential and industrial sector. The state wise rooftop solar policies in India have been tabulated to understand the different regulations within the states (Appendix E).

Accelerated Depreciation (AD) allows for solar energy producers to claim 40% of the costs in the first year itself (*MNRE*, 2020a). Many states have rolled out subsidy grants for installing rooftop solar systems in the state. States like Karnataka, Andhra Pradesh, Telangana, Maharashtra, Madhya Pradesh, and Chandigarh have issued subsidies of 30% on the cost of solar systems over and above the MNRE subsidy.

The state government is also providing loans up to 10 lakhs for individuals under private sector lending (SNAs, 2010).

Capital and Operational business model for RTS in India: Rooftop solar systems are classified based on the ownership of the solar systems, arrangement of off-taker and metering arrangement in India. The most common business model for rooftop solar installations in India is the CAPEX (capital expenditure) model. Under this model, the consumer owns and installs the rooftop solar system and power generated from the system is used for self-consumption. The customer can self-finance or can take a loan to fund the system and have an option to avail capital subsidy if applicable. The CAPEX model (Vimpari & Junnila, 2019) is simple and the system owner takes the risk associated with the project. This model is famous in India and about 90% of rooftop solar installations falls under this arrangement. The CAPEX model enables risk free returns and quick payback, low payment risks and clear individual ownership of the system installed (Amala Devi, 2018). The challenges are however arranging upfront cost of system, high rate of interest and delays in subsidy disbursement (if applicable).

Under the OPEX (Operational expenditure) or the third-party model, a third-party or a RESCO (Renewable Energy Service Company) (Trivedi, Ray, Vulturius, et al., 2018) invests in the RTS system and sells the power generated to the rooftop owner at a rate which is lower than the electricity rates of utility (grid tariff). However, RESCO sells the power at a rate where they make profits. This model eliminates the risk of upfront cost of the system as RESCO invests in the system and owner of RTS pays for the system over the years. The 'third party' which is the company that enters in the arrangement between the system owner and DISCOM as the third party under a power purchase agreement (PPA) usually for 25 years. This model is not very popular in India, and it accounts for only 10% of projects installed. The benefit of OPEX model is that all the feasibility risk is covered by the third party.

There are two metering options available worldwide for grid connected rooftop solar systems; gross metering and net metering arrangement (Narula & Sudhakara Reddy, 2015). Under gross metering, import and export of power generated is measured separately and under net metering the consumers consume the generated electricity first and feed extra if available in the grid. Under the gross metering, the utility providing electricity to consumer charges for solar energy units generated and number of units consumed separately. This is imposed by having dual energy meters. In this type of arrangement, the power generated is exported to the grid and the end consumer does not get any incentive to increase self-consumption. The Power Purchase Agreement (PPA) is signed between the owner and the utility where the utility agrees to pay the owner either Feed-in-Tarff or tariff as fixed by the electricity regulatory commission of each state. The rooftop systems can be either installed by the owner or third party.

On the other hand, the net metering arrangement can be either self-owned model or third party owned model. The electricity generated from the system is consumed by the owner of the rooftop at a mutually agreed tariff between the third party and owner (GIZ, 2016). In case of excess power generation, the extra units are fed into the grid and the same can is adjusted in the monthly electricity bill of the consumer or the utility can provide banking facility for a particular time as defined in the state regulations.

Two case scenarios can be built up, one where the system is generating excess units which are exported to the grid and another where the system is generating less units than the owner's consumption. In case of excess generation, the owner is paid for units exported to the grid and if less units are generated from the system, then the owner must pay the differential of excess energy consumed as per the tariff in that region. In the self-owned model under net metering arrangement, the owner of the rooftop system injects own equity and arranges for the loan from the bank. Hence, the owner evaluates the risk, returns and payback period from the installed system

while replacing a certain part of power from the grid. The off-taker arrangements vary from state to state in India.

The off-taker agreement is between the owner of the system and the utility of the state. The power generated can be sold under conditions such as sale to utility company, sale under government schemes, sale to distribution companies for meeting Renewable Purchase Obligations (RPO), sale under open access category to third party, sale through group captive under open access regime and finally sale under Renewable Energy Mechanism.

The rooftop solar projects can either fall under central or state policies depending on the area selected. At present, the most common off-take arrangement for residential consumers in India is sale of power generated to the utility company.

The **summary** of the discussions on role of central and state government policies and initiatives is reviewed as follows-

1. The government of India at both central and state level have made many attempts to promote RTS technology in India by floating new regulations and policies. However, many challenges exist in the processes and deployment of large-scale solar systems.

2. From the above analysis it was noted that there are challenges in the grid integration and capacity allocation in many states. It is important to define technical standards for smooth and efficient installation of the systems. The government policies for rooftop solar are not consistent and to ensure quality installations the guidelines need to be clear.

3. Financing companies do not find the RTS as an asset and due to small size, they are not attractive proposition for banks and major financial institutions. The national banks are comfortable to provide loans for large scale projects and make process cumbersome for small project loans.

The above review of literature highlights the following research gaps:

1. The literature lacks understanding of regulations for implementation of rooftop solar projects on residential consumer premises in India.
2. Lack of clarity on role of utilities in encouraging residential consumers to opt rooftop solar systems on vacant roofs.
3. No literature is available on comprehensive state wise plan and procedure for rolling out rooftop solar plant implementation for residential consumers in India.

3.3.2 Understanding the International Scenario of Rooftop Solar PV in developed countries.

The second theme of Literature review is studied to understand the international scenario and global business models in developed countries which helped in growth of rooftop solar are studied in detail.

INTERNATIONAL EXPERIENCE ON ROOFTOP SOLAR PV ADOPTION BY RESIDENTIAL CONSUMERS

Global Policies and Initiatives: The top 10 countries (including Japan, Australia, Vietnam, Spain, Germany, US, Ukraine and China) contributes 72% capacity addition in solar PV technology (IEA-Pvp, 2020). Between 2010 and 2016, the global PV system cost (including BOS and hardware cost) dropped by 65% and the Levelized Cost of Electricity (LCOE) also dropped for utility scale solar PV projects by around 67%. The residential solar PV systems gained popularity during 2004, when Germany introduced 'Feed-in-Tariff' regulations for solar generation and made huge capacity addition. Japan along with Germany installed 1GW of Solar PV capacity in 2004. For a very long time, the European countries and Japan dominated the Solar PV market and as a result the cost of solar started to decline because of improvement in technology and economies of scale.

In Thailand, about 99% of solar PV installations are done by utility company. Around 0.003% solar capacity is built in residential sector. High upfront cost, lack of investors and unclear regulations are few of the challenges causing the delay of implementation of RTS in Thailand (Chaianong & Pharino, 2015). Under the

present FIT arrangement and various policies for deployment of grid-connected residential rooftop solar systems in Thailand is considered very unfavorable. The major reason being the lack of financial aid which is causing slow growth of residential-scale rooftop solar projects in Thailand (Tantisattayakul & Kanchanapiya, 2017).

Netherland's growth in Solar PV capacity addition is attributed to low cost of PV modules and high electricity prices which made the solar installations very attractive in the country. However, from the literature review it was implied that the main reason for development of Solar PV sector was introduction of new business model. The business model is financially supported by government agencies and provides benefits in the form of tax deductions after investments. The net metering arrangement in particular is attracting residential consumers since they get rewarded for generating solar power and with every increase in the generation per kilowatt, the RTS becomes even more attractive (Huijben & Verbong, 2013).

China has the highest concentration of solar PV installations in the world. But only 27% of its total solar PV installations are on residential consumer buildings as there are lots of issues in policies from government. The main reasons for the slow implementation on residential buildings in China are - financing, technical and policy issues, awareness barriers, problems with roof resources and unclear property rights (Gao & Rai, n.d.).

The regulatory framework in Germany has been able to increase the
renewable energy consumption from 6% in 2000 to 15% in 2015. This also led to significant reduction in CO2 emissions by 57 million tons as of 2007 (Büsgen & Dürrschmidt, 2009). The solar deployment in Germany impacted the job market very positively, 280000 jobs in renewable energy sector were created and this was mainly driven by the Renewable Energy Act, 2008 (Fritsche et al., 2009). Small scale solar PV installations (10KW or less) contributed around 14% of the capacity

installed in Germany and these usually fall in the residential consumer category. Europe made significant solar PV capacity addition by 2018, with 80 GW installed and the market was segregated into residential, commercial, and industrial installations. However, the commercial rooftop solar PV still has the highest installation capacity in the region.

Spain is the second most popular country after Germany to have renewable technology's law in place. During 2008, Spain had an installed solar PV capacity of 3.4 MW. The incentives for small scale solar PV systems were established at € 0.34 /kWh as compared to € 0.32 /kWh for large scale solar development (García-Alvarez & Mariz-Pérez, 2012). The increase in renewable technologies acceptance during 2005-2008 led to a huge increase in GDP of the country. It was noted that CO2 emissions were reduced by 23.6 million tons over the period of 2005-2010. Also, 62% of direct jobs were created in renewable energy market with jobs in technology, fabrications, installations and innovative profiles (APPA, 2012).

Japanese government supported residential solar PV systems by attracting consumers through various subsidies (national and local) such as FITs and tax incentives. Since 1994, the country has had a well-established national subsidy program, however, there was a delay in the subsidy (buy-back) program for rooftop solar systems between 2006-2008. In 2008, the government of Japan restarted the program with change in metering arrangement to FIT after which the Solar PV was priced at $0.44 /kWh for 10 years. The rooftop solar capacity addition spiked from 2.6 GW in 2009 to 38.7 GW in 2016 (Kobashi & Yarime, 2019)

Australia already started with favorable financial incentives which attracted residential household to deploy green energy technologies including rooftop solar systems. However, shift from subsidies-based mechanism to market-based mechanism has made the changes in solar technology adoption in the country (Meiklejohn, Bekessy, & Moloney, 2018). Australia is one of the countries with

highest rate of rooftop solar adoption in the world, with 20% of its households already have installed rooftop solar. The most influencing factors for solar adoption in residential households is education about solar benefits, environment effects and renewable energy policies. Also, factors such as high electricity prices, decreasing cost of solar storage influenced the solar adoption rate in the country (Zander, Simpson, Mathew, Nepal, & Garnett, 2019).

In 2014, the U.S. residential solar market picked up pace when residential solar PV price started to decline making solar systems economical. The average price of solar came down to $3.48 per watt and it represented absolute decline across all market segments. According to the report by green tech media, soft costs like customer acquisition, labor, and permits make up 60 percent of system prices, and there is ample opportunity for improvement which will continue to lower system costs. California became the most prominent state to have the highest penetration of residential solar and cities like San Diego and San Francisco had the highest percentage of residents that installed rooftop solar PV. Third party solar models and solar lease models were responsible for 70% of the residential solar installations in the states of California, Colorado, and Arizona. Attractive financial structures such as federal incentives including accelerated depreciation, investment tax credits and production tax credits helped in getting investors to invest in third party model in the US (Lopez, Roberts, Heimiller, Blair, & Porro, 2012).

Different Business Models for deployment of Rooftop Solar PV Systems globally are discussed in detail in the table below.

Table 6 - Description of Residential Rooftop Solar Business Models in 5 countries - USA, Spain, Germany, Japan, and Australia

Rooftop Solar Business Models	**Detailed description of models**	**Countries**
Self-owned business models	In the self-owned business model, owners of single-family households prefer to self-finance the RTS systems. The main purpose of RTS for them is self-consumption despite relatively low self-consumption rates. This self-owned business model allows FITs and Net Metering arrangement as per the regulations of the country.	USA, Spain, India
Multi-Family residential building	Multi-family residential building projects are governed by Power Purchase Agreement (PPA) and cooperative business models using all kinds of financing. The community or neighbor solar business model is promising in such scenarios.	Spain, Japan
End user owner-residential retrofit	The owner of the residential rooftop pays for the RTS system. They either use full equity or avail loan. Loan is usually given for 10-20 years which helps to reduce burden on the consumers. In some countries, the distribution companies work to create financing options. However, the	USA, Germany, Australia

	government subsidy or federal tax incentives are majorly dependent on location and time.	
End user owner-residential new construction	The owner of the RTS system is the buyer of new premises. The RTS system is considered an additional asset and adds to the cost of the house, especially when incentives and environmental sentiment are strong. In few cases the RTS comes as a standard feature along with new listings, giving the homebuyer no choice in the decision. Home sellers use smart building PV products which help to improve aesthetics. Interconnection with utility grid, net metering (available in most markets). The sellers are building RTS into every new home, so that it becomes a standard part of the home. The homeowner generally rolls the PV system into the mortgage. State rebates and federal tax incentives are paid to homeowners.	Germany, USA, Australia
Third party ownership-commercial retrofit	The third-party model is attractive to consumers who are interested in electricity savings, hedge against future electricity rate escalation and recognition for green energy consumption. Clear financial systems have been created, like third-party ownership with purchase power agreements; these generally have 10-25year	India, Australia

	terms. This helps the consumer from having to fund capital (debt or equity) and transfers most risk to the third party.	
Third party Owner- Grid sited	To fulfill obligations of renewable energy consumption, the utility companies opt for these models. However, this model exists for compliance purposes. These are generally larger systems with more than 1 MW. There is a long term PPA agreement between developer/ third party and utility. This model is presently only famous in United states.	USA

Source - (Vimpari & Junnila, 2019);(Palm, 2017);(Alhaj, 2017);(Fina, Fleischhacker, Auer, & Lettner, 2018);(Ramalho[1], Câmara, Pereira, Pereira Da Silva, & Dantas, n.d.);(García-Alvarez & Mariz-Pérez, 2012);(Geddes, Schmidt, & Steffen, 2018);(Goel, 2016);(Chunhachoti-Ananta, Tongsopit, & Sugiyama, 2017; Hahn & Fellow, 2014; James, Feldman, & Margolis DOE -Solar Program Washington, 2013; Kobashi & Yarime, 2019; Noguchi, 2005; Rai & Zarnikau, n.d.);(García-Alvarez & Mariz-Pérez, 2012; Quirós, Pozo, & Ceballos, 2018; Sáez & Requena, 2007);(Jha & Leslie, 2020; Langham, 2013; Li & Liu, 2017; Meiklejohn et al., 2018; Tanesab, Parlevliet, Whale, & Urmee, 2018; Tayal & Rauland, 2017);(Bazán et al., 2018, 2018; Bianchi, Evans, Revetria, & Tonelli, n.d.; Buesing & Yang, 2013; Fina et al., 2018; Ginsberg, 2018; Manju & Sagar, 2017b; Ministry of New and Renewable Energy; USAID; GERMI, 2016; Noguchi, 2005; Thompson1, Ny1, Lindahl1, Broman1, & Severinsson2, n.d.; USAID, 2016; Yong, 2014). **The details are mentioned in Annexure D*

The learnings from the international experience helped identify several initiatives that support the long-term development of RTS in India. They provide a sustainable scenario for both consumers and policy makers. Various journals and reports were studied in detail to understand the business models and parameters which lead to success of rooftop solar PV systems in India.

The **summary** of the above analysis of global rooftop solar PV technology review is as follows -

1. Top countries to add rooftop solar capacity in residential consumer category are USA, Germany, Italy, China, Australia, Spain, Korea, Ukraine, and India. These countries contribute to 72% of the installations of the world in Solar PV (Global PV Market 2019).

2. Countries like China, Italy and Saudi Arabia geared up with large capacity additions in residential consumer sector but due to various policy changes they had an adverse effect on the sector. Few challenges faced were unstable rooftop solar policies, financial barriers, issues with roof resources, changes in FIT policies, funding gap from subsidies and non-existing business models for residential consumers.

3. In most of the cases discussed above, the demand for RTS projects in residential consumer category is significantly lower without subsidies and incentives. Historically, there is some market push initiated by the government programs that provide solar high visibility.

4. Renewable technologies deployment requires high upfront cost that must be financed to kick start the project (Steffen, 2020). In developing countries like India, the cost of capital is usually around 50% of the LCOE for solar PV (Schmidt, 2014).

5. Many authors suggested that the developing countries need to consider renewable energy cost of capital for cost-effective deployment strategies and also address finance costs in the future policies (Geddes et al., 2018).

The above literature theme review highlights the following research gaps:

1. Literature lacks understanding of developed countries implementation strategy for small scale rooftop solar projects connected to the grid.

2. No clarity is given in the research articles on which financing mechanism works best for residential households willing to adopt this technology.

3. The literature lacks clarity on savings on electricity bills and grid load after implementation of rooftop solar plants by residential consumers.

3.3.3 Product Service System Approach and its applications

The third theme of literature review helps to understand the concept and approach of Product Service System (PSS). The PSS approach has been applied in various business models across many fields including renewables.

PRODUCT SERVICE SYSTEM CONCEPT: In recent research Product Service System (PSS) has been promoted as a way of providing sustainable solutions by utilizing the resources in an efficient way. Many authors over the years have developed the theory of PSS and its approach. While few believe that it is an integrated set of products and services capable of delivering solutions to consumers' needs, but others are of a viewpoint that it is an instrument which helps to bring sustainability and environment friendly solutions to the consumers. Under the PSS model, the products and services are designed to satisfy consumers' needs. The model is also designed to be competitive and is more environmentally friendly than the traditional business models. The PSS models target the systems and structures within the communities like recycling, waste plant management, reuse. The new products and services should be developed considering these sustainable options (Maleki, Belkadi, & Bernard, 2018).

The PSS model has an huge impact on environment since it helps to minimize both consumption and production (Hamwi & Lizarralde, 2017). Few authors discuss that Product-Service System is an innovation strategy (Marques, Cunha, Valente, & Leitão, 2013) that leads business not only to design and sell physical products, but to sell a system of products and services which are jointly capable of fulfilling specific client demands (Tan, Mcaloone, & Gall, n.d.). The main idea behind the Product Service System approach is to provide the customer with solutions and meeting their requirements based on combination of products and services (Lipiak, Kulesza, & Salwin, 2019). Also, the solutions provided would have positive impact

on resource utilization, thus will have positive impact on sustainability. Sustainable With the help of PSS mechanism, sustainable designs are created to overcome environmental burden and resource use, this includes the development of product as part of sustainable whole system, that provide a service or function to meet essential needs (Pirayesh et al., n.d.). Many researchers discuss innovation in product service and provide that standard PSS models identify three motivations for developing and enhancing the offering such as cost, quality and variety (Utterback & Abernathy, 1975). The literature review finds that the PSS can be equally important for all the functions of business model (Pereira, 2013). The Product Service System (PSS) business model is an attractive solution for reducing the cost burden and by allowing the consumer to benefit from RTS without the actual need to purchase them (Tukker, 2004). The PSS approach results in combination of innovative business model and leading to more sustainable model for satisfying consumers need. This approach overtakes the traditional business model where the focus was only selling of products.

In practice there are three types of PSS - Product Oriented, User Oriented and Result Oriented. The table below provides a description of applicability of all three types of PSS.

Table 7 - Types of Product Service System approaches used in Business Models

Types of PSS	**Description**	**Implementation Ease**
Product Oriented	Feature's sale of products with additional services. The ownership rights are with the consumers.	Easier to implement, however the environment benefits are achieved incrementally

Use Oriented	The consumer uses the product for a limited amount of time and the ownership remains with the service provider.	High usage of product along with greater environment benefit
Result Oriented	Features the sale of service or capability instead of actual sale of product. The products here are mostly tangible and the ownership rights stay with service provider.	Risk lies with the service provider and the consumer may not have control over the product.

Source - (Pergande et al., 2012); (Tukker, 2004)

ADVANTAGE OF PRODUCT SERVICE SYSTEM: Companies are progressing from just selling a product to selling services too. The shift in more consumer-friendly options will make new ways for client management and interaction. (Pirayesh et al., n.d.). The company who delivers to its consumers under PSS model provides its consumers with customized solutions to their problems, it helps to deliver a satisfactory product along with simple materials to have a sustainable solution. The product-service system represents a competitive opportunity for many companies since they look for altering their products by reducing consumption and by providing the benefit of services along with products. The main advantages of the PSS approach to customers in business model context; It suggests that PSS offers more customized products without compromising the quality (Thompson1 et al., n.d.). It allows combination of products and services along with new functions which caters to customers need and benefits by responsibly monitoring and completing the work transferred to the manufacturer.

Companies may choose PSS model as strategic innovations to separate the resource consumption from its traditional way of profit and standard of living improvements. This would help in finding new profit centers and to compete and generate value while decreasing resource consumption (Wasserbaur, 2018). In other words, PSS is a win-win solution: providing value for the producers/ providers, the users, and the environment. Finally, PSS create a new business model and shows how combining products and services in a combination can meet specific needs of the consumers (Lipiak et al., 2019). The distribution renewable energy sources can contribute to economic development of the country simply by creating employment opportunities, by bringing technology innovations and developing new revenue sources for local investors in the market (Emili, Ceschin, & Harrison, 2016).

There have been various cases where the concept of Product Service System has been applied in renewable energy context. One of the examples is seen in Sunlabob, Laos. Sunlabob gives services related to energy through a renting model. Under this model the Sunlabob leases energy using products along with charging station for a village community. Then the village community rents the products for the individual households. The village committee formed takes charge of setting prices, collecting rents, and performing basic maintenance. The company Sunlabob is the owner of the services they maintain and are responsible for training. Consumers rent the recharged lantern by giving a small fee and the lantern in turn provide light for up to15 hours. While the committee pays monthly fees to lease the charging station (Emili et al., 2016).

Another example of similar service system approach can be seen in sales of individual energy systems with additional services by Grameen sale to in Bangladesh for rural communities. Because of the high capital costs of systems, their model proposes an extension of the well-known micro-credit approach developed by NGOs as the Grameen Bank and BRAC (Biswas, Bryce, &

Diesendorf, 2001). In Peru, Practical Action Co. offers training and consultancy services for community owned and managed isolated mini grids. There are several companies in South America which offers mini kits as additional service accessories to attract residential consumers to buy the products. (Emili et al., 2016).

The **summary** of the above analysis of PSS is as follows--

1. Product Service System is a concept where all the needs of the stakeholder are integrated to fulfil the need of the consumer by providing a customized solution for their problems.

2. While designing the product through PSS approach, it is important to consider all the operation related constraints at a very early stage so that the issues are highlighted before the product is delivered to the consumers. To facilitate the customization process, it is important to use a solution ready, mixed and matched product service arrangement to reach the desired goals.

3. All three types of PSS models provide solutions which satisfy the need of the consumers by combining products and services which are systemized to deliver the desired utility or function. However, the results orientated PSS model is more sophisticated and represents the most popular interpretation of the features of a PSS (Salwin, Kraslawski, & Lipiak, 2020).

The above literature theme review on Product Service Systems, highlighted the following research gaps:

1. Literature lacks clarity on PSS approach for renewable energy-based business models
2. While PSS approach is successful in overcoming the high-cost barriers in various business ventures, no studies have been done to reflect the impact of PSS approach for residential rooftop in India.
3. Several studies have been done for PSS approach and its benefits in business models but there is lack of guidelines for companies to assist them in implementation of business models using PSS approach.

3.4 CONSOLIDATION OF RESEARCH GAPS

From our study, three literature themes were identified and reviewed. After in-depth review of each theme, the following research gaps were identified.

Research Gap identified from Part 1: The role of central and state government policies for business growth of grid connected rooftop solar PV systems in India,

1. The literature lacks understanding of regulations for implementation of rooftop solar projects on residential consumer premises in India.

2. Lack of clarity of role of utilities in encouraging residential consumers to opt for solar rooftop plants.

3. No literature is available on comprehensive state wise plan and procedure for rolling out rooftop solar plant implementation for residential consumers in India.

Research Gaps identified from Part 2: Comprehensive study and analysis of global rooftop solar PV markets,

1. Literature lacks understanding of developed countries implementation strategy for small scale rooftop solar projects connected to the grid.

2. No clarity is provided in the research articles on which financing mechanism works best for residential households willing to adopt this technology.

3. The literature lacks clarity on savings on electricity bills and grid load after implementation of rooftop solar plants by residential consumers.

Research Gaps identified from Part 3: Understanding the impact of Product Service System (PSS) concept and applicability in business model innovation,

1. Literature lacks clarity on PSS approach for renewable energy-based business models

2. While PSS approach is successful in overcoming the high-cost barriers in various business ventures, no studies have been done to reflect the impact of PSS approach for residential rooftop in India.

3. Several studies have been done for PSS approach and its benefits in business models but there is lack of guidelines for companies to assist them in implementation of business models using PSS approach.

The research gaps were further refined for better understanding and considering literature review three research gaps were identified which led to our research problem.

Research Gap 1 - Factors responsible for slow deployment of grid connected rooftop solar PV systems in residential consumer segment in India.

Research Gap 2 - Literature lacks the learning experiences from successful countries in the grid connected rooftop solar PV systems for residential consumer segment.

Research Gap 3 - Product Service System (PSS) approach lacks its applicability in business model innovation for grid connected rooftop solar PV systems for residential consumer segments.

3.5 RESEARCH PROBLEM

The literature survey has clearly indicated that there are various business models that exists for the promotion of RTS system in India. In Indian context, the RTS business model lacks the service components while the RTS business models outside India have used service component as different perspectives such as consume as per pay model or leasing to third party and community use models (Tukker, 2004).

Therefore, literature has clearly explained that service component is an integral part of a business model for successful implementation of RTS, but literature lacks this understanding in Indian context. Thus, Product Service System (PSS) Approach of

Business Model which suggests an excellent mix of product along with services for a successful business model for a company, but PSS approach does not provide insights for the critical factors for successful solar RTS implementation in India.

Identify critical factors for successful implementation of RTS systems in India to leverage vacant and available roofs in the country and to develop a proposed business model.

3.6 RESEARCH QUESTIONS

Research questions give clarity to the study, its helps to guide in all stages of research by regulating the methodology, reporting, analysis, and inquiry. In light of the above discussions the following research questions are identified:

1. What are the factors critical for growth of grid connected RTS systems in India?

2. What are the strengths and weakness of existing business models for implementation of grid connected RTS systems in India and how do they compare with global business models? and,

3. What business model can facilitate the stakeholders to harness the solar potential and ensuring the business growth?

3.7 RESEARCH OBJECTIVE

The research objectives aim to provide the research study a purpose. Research objectives are required to transform the aim of the research into operational statements (Abdulai & Owusu-Ansah, 2014). This helps in specificity and unambiguity of the study. The objectives help in understanding the relevance of the study while making the research easy to understand. Research objectives of this study are as follows:

Objective 1 - To identify factors which are critical for growth of grid connected RTS systems on residential consumer premises.

Objective 2 - To benchmark grid connected rooftop solar PV business models in India with business models in five countries: USA, Japan, Australia, Germany, and Spain

Objective 3 - To develop a new business model for residential consumers in India based on Product Service System Approach by identifying critical factors from Objective 1 and 2.

3.8 THEORETICAL PREMISE

Services play a larger role than production in the market which makes the technology provider a service provider. This leads to the services offered along with technology.

3.9 THEORETICAL UNDERPINNING

Theory of Business Model Innovation- Business model innovation is seen as a potential mechanism which helps to bring sustainability into new business (Schmidt-Costa, Uriona-Maldonado, & Possamai, 2019). However, there is a lack of clarity in the use of the terms 'business model innovation' and 'sustainable business models' (SBMs) (Osterwalder, Pigneur, & Tucci, 2005). Over the years, many researchers have explored the 'business model innovations' in detail but there is no consensus on the classification of the concept of sustainability (Spieth, Schneckenberg, & Ricart, 2014), which results in significantly slows progress in the field of innovation in business model (Zott, Amit, & Massa, 2011).

The new innovative business model must attract new consumers into the market and encourage existing consumers to buy more. Capturing the mass market requires that the business model innovation is much more than the discovery of a new strategy. It is also important that the existing products and services are redefined and not just discover new products, they simply redefine what an existing service is and how it is useful to the end consumer. Researchers suggested that the business model is more than just making a profit by selling products and services. He debates that every business model has a value proposition which is constantly changing and it provides competitive edge to the companies selling products and services (Hosenuzzaman et al., 2015). Servitisation is referred to the manufacturers' capability to provide customer-specific, industry-specific or product–service

specific solutions (Hosenuzzaman et al., 2015) through close product manufacturer-client relationships (Howard, Tim, & Palie, 2013).

The innovations in service by companies opens up dialogue with consumers by engaging them and creating channels to boost value-in-use contexts (Bustinza, Gomes, Vendrell-Herrero, & Baines, 2019). The companies' are driven by consumers demand and they are not only selling products but also focusing on selling services, reducing competition and decreasing profit margins (Rogelio & Robert, 2003).

In the previous studies, researchers have studied various aspects of Product and Service integration, servitisation, including PSS approaches to business models and service-dominant logic (Barquet, de Oliveira, Amigo, Cunha, & Rozenfeld, 2013). The study undertaken addresses the business model development based on service component, and system concentrating on deployment of not only the product but also services. The Product-Service System concept is a promising business model solution which is strategically capable of helping achieve the growth required to move to a more sustainable society by deploying rooftop solar systems on consumers' premises.

CHAPTER 4

RESEARCH METHODOLOGY

The literature review done in the previous chapter helped to understand the scope and significance of rooftop solar PV market in India, global solar market and Product Service System (PSS) approach and its applicability in business models. The literature review study helped to identify the research gaps which were further consolidated into three major research gaps for our study. Based on research gaps, the research problem, research questions and research objectives were formulated. The research problem presents a value question, the research question helps to give focus to the study while research objective fulfills the purpose of the study (Isaac & Michael, 1995). The present chapter elaborates the research design and methods. The right choice of a suitable research methodology is a crucial decision to perform effective research which focuses on linking research methods to research objectives (Yannis & Nikolaos, 2018).

4.1 INTRODUCTION

Research methodology is largely exploratory and descriptive type, it follows analysis using appropriate statistical tools. The proposed research work has used benchmarking and questionnaire as survey tool for qualitative research. Qualitative research embraces research methodologies that deal with phenomena by analyzing behaviors, experiences and relations without the use of statistics and mathematics and the processing of numerical data (Harrison, Birks, Franklin, & Mills, 2017). Open ended questions helped to get data from experts in the field while closed ended questions were used to gather numeric data for quantitative research.

4.2 METHODOLOGY FOR OBJECTIVE 1 - To identify factors which are critical for growth of grid connected RTS systems on residential consumer premises, primary data was collected from analysis of central and state government policy. The variables were identified, and a questionnaire survey was conducted. The methodology for carrying out questionnaire survey is given in detail below:

Methodology - To accomplish the first objective, a survey was carried out using a questionnaire tool. The following steps were undertaken to conduct questionnaire survey:

A. **Reliability -** The reliability of the questionnaire has been verified using **Cronbach's Alpha Test**. Initially a pilot study was carried out and the responses received from the pilot study with a sample of 25 respondents were recorded. These respondents were experts from renewable energy generating companies, local distribution utilities/ DISCOMs, state regulators, and other government officials involved in renewable energy generation portfolios.

B. **Variable identification -** The following variables were identified through primary and secondary source of information for designing the questionnaire:

Table 8 - Variable identified from primary and secondary source-

Parameters	**Variables**	**Source**
Policy Framework	Robustness of metering regulations	(Tarai & Kale, 2018); (GIZ, 2016); (Narula & Sudhakara Reddy,

		2015); (USAID, 2016)
	Effectiveness of policy implementation	(Rohankar, Jain, Nangia, & Dwivedi, 2016); (Matisoff & Johnson, 2017)
	Incentive disbursement	(Goel, 2016);(Sharma, 2011b)
Effectiveness of Policy support	Local grid availability and sanctioned load	(Dondariya et al., 2018); (Kappagantu, Daniel, & Venkatesh, 2015)
	Billing mechanism by utilities and DISCOMs	(Amala Devi, 2018); (Al-Saqlawi, Madani, & Dowell, 2017)
	Ease of application process for availing benefits of RTS systems and subsidies	(Sahoo, 2016);(MNRE, 2019)
Financing Mechanism	High upfront rooftop system cost	(Overholm, 2015);(Goldman, Mckenna, & Murphy,

		2005);(Kar et al., 2016)
	Ease of secured loans from banks and financial investors	(Steffen, 2020);(Philip, 2014)
	Government subsidies and grants as per MNRE orders	(Behuria, 2020a);(Narula & Sudhakara Reddy, 2015)
Consumer Experience	Consumer's awareness of the technology	(Bairiganjan et al., n.d.); (Venkateswaran, Solanki, Werner, & Yadama, 2018)
	Trust in market players such as suppliers of system	(Manju & Sagar, 2017a);(Motocorp & Energies, 2014)
	Interactive consumer interface	(*Rooftop Solar-Garnering Support from Distribution Utilities*, 2016);(Narula & Sudhakara Reddy, 2015)
Business Enabler	Post installation maintenance and services	(Bairiganjan et al., n.d.); (Sundaray, Mann,

		Bhattacharjee, Garud, & Tripathi, 2014b)
	Skilled manpower	(Manju & Sagar, 2017b); (Singla, 2018); (MNRE, 2015)
	Reliable and trustworthy service providers	(Energy Sector Management Assistance Program, 2010); (Horváth & Szabó, 2018)

Factors like net metering regulations and its compliance, transmission infrastructure and need for addressing issues concerned with development of RTS were also included.

C. **Designing Questionnaire -** Designing a questionnaire is an important part of the research tool. It is an efficient way to collect data (Kazi & Khalid, 2012). The questionnaire was designed based on **the Likert Scale**. The Likert scale-based questionnaire is a set of questions provided for a situation under study. The participating members are asked to show their level of agreement (from strongly disagree to strongly agree) on a metric scale (Joshi, Kale, Chandel, & Pal, 2015).

Questionnaire was designed on 5-point Likert scale and response range was as follows:

A. Strongly Disagree

B. Disagree

C. Can't say

D. Agree

E. Strongly Agree

D. **Sampling Plan & Sample Size -** Method of **simplified sampling** has been used for collecting the primary data. Formula for sample size determination has been adapted from: Sample size of the strata = size of entire sample / population size * layer size (Andale, 2013).

Table 9 - Overall Sample size

Sources	Population Size*	Responses received	% Sample size
Consumers**	1100	102	48
Energy Consultants	400	40	19
Service Providers	300	30	14
Utilities+ State Nodal Agencies+ Policy Makers	375	38	10

Though the questionnaires were sent to 620 respondents, responses from 210 persons (filled questionnaires) were received.

*Population size considered as per data available till 2016 and,

**The consumer selection is based on five parameters: Consumers who have installed 4KW and above Grid connected RTS systems by 2016 and have completed one annual billing cycle, Consumers who have paid at least 10% for procuring the system.

E. **Statistical tool -** In order to identify the major factors affecting the growth in implementation of the rooftop solar PV system, **Factor Analysis** (Yong, 2014) was carried out.

   The data was further analyzed using the IBM SPSS statistical software (version 25). SPSS (Statistical Package for Social Science) software is a statistical tool which is easy-to-handle and widely used in academia, however, it is facing increasingly tough competition from more comprehensive and freer open-source software (Frey, 2017).

   The broad purpose of factor analysis is to examine data so that relationships and patterns can be easily interpreted and summarized. The variables are regrouped into a limited set of clusters based on shared variance. Hence, it helps to isolate constructs and concepts (Yong, 2014). Factor analysis is applied with a notion that the variables will be reduced to fewer latent variables that can be measured and observed easily. These reduced variable share a common variance and are unobservable, which is known as reducing dimensionality (Frederking, 2016). These unobservable factors are not directly measured but are essentially hypothetical constructs that are used to represent variables (Cattell, 1973). The data needs to be reduced to a manageable level to achieve the second objective of identifying critical factors. The best way for this data reduction was through factor analysis.

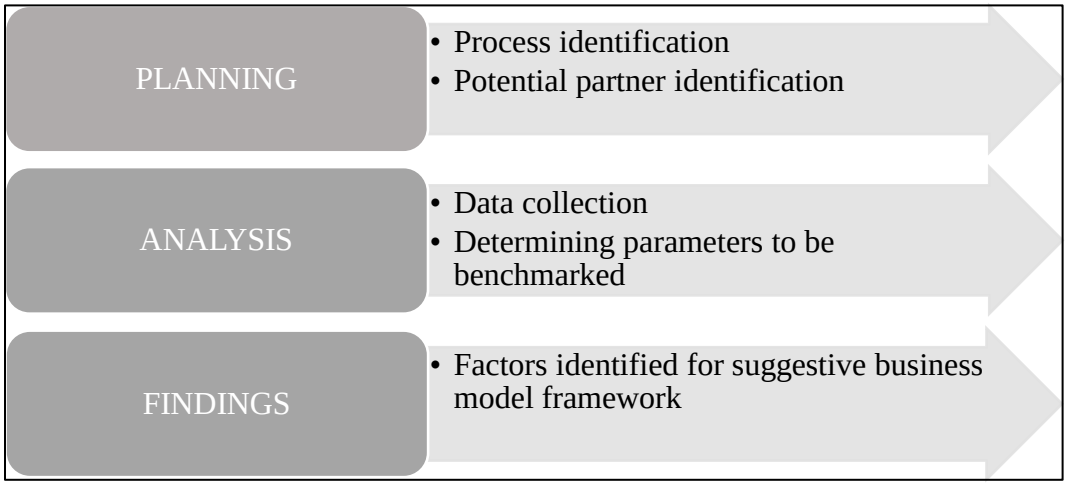
4.3 METHODOLOGY FOR OBJECTIVE 2 - To benchmark grid connected rooftop solar business models in India with business models in five countries; USA, Japan, Australia, Germany and Spain, **External Benchmarking** of business models for rooftop solar systems for residential consumers in five countries was carried out.

External benchmarking is an analysis of how your business compares to others in your industry, to gain a clearer idea of where you fall short (if anywhere) and what you can do better. External benchmarking is the process of finding best practices and high performances which are measurable with the goals of company. It involves identifying, understanding, and adapting outstanding practices from organizations anywhere in the world to help an organization improve its performance.

External benchmarking focuses on activities, functions, or operations to achieve continuous improvement. It involves studying the process followed by companies or simply comparing their products with best in the market. Benchmarking is emerging as leading edge tool for obtaining the important information required for continuous improvement and gain competitive advantage (Elmuti & Kathawala, n.d.).

Methodology - In line with **Robert Camp benchmarking process (1989),** external benchmarking has been carried out to benchmark international rooftop solar PV business models with prevailing Indian rooftop solar PV models. According to Camp "Benchmarking is the search for the best industry practices which leads to exceptional performance through implementation of these best practices" (Camp, 1989). The step-by-step benchmarking process is explained below:

Figure 9 - Steps in External Benchmarking process as adapted from (Anand & Kodali, 2008) -



A. Planning

- STEP 1- *Process Identification* - In line with benchmarking process (Camp. R.C, 1989), external benchmarking has been carried out to Identify best practices business models applicable in five countries and comparing them with existing business models for grid connected rooftop solar systems in India.

- STEP 2 - *Potential Partner Identification* - Potential partners were identified based on MNRE report (Sundaray et al., 2014a) and data for developed countries with highest rooftop solar PV penetration in residential consumer segment were selected for benchmarking. The five countries selected for the benchmarking study were: **USA, Japan, Australia, Germany, and Spain**

B. Analysis

- STEP 1 - *Data Collection* - Secondary information related to international experience was collected from journals in the field of management, energy, renewable energy, and business. The keywords searched in various

abstracts and titles were combination of business model, management models, renewable energy, rooftop solar PV systems, grid connected, photovoltaics, solar, self-owned and third party, residential rooftop. Citations were examined, to broaden the existing base and get a wider overview.

- STEP 2 - *Determining Parameters* - Best practices were analyzed based on the following parameters: techno-commercial, financial, quality and standardization, customer interface, value proposition, policies, and regulations.

- STEP 3 - *Determination of critical gaps* - Data has been represented through tabulated chart to examine the gaps in Indian rooftop solar PV business model.

C. Findings

The critical factors identified from the benchmarking analysis is considered to develop a suggestive business model framework for grid connected rooftop solar PV system for residential consumer segment in India.

4.4 METHODOLOGY FOR OBJECTIVE 3 - To achieve the third objective, to develop a new business model for residential consumers in India based on product service system approach by identifying critical factors from Objective 1 and 2, analysis has been carried out based on:

- Results derived from Objective1 and Objective2
- **Expert Opinion Survey** based on **Delphi Technique** has been conducted.

The Delphi survey technique is a method of collecting the opinion of various sector experts (also called panelists) and it provides an opportunity for these experts to communicate their opinions and knowledge anonymously about the research topic. In this technique they get the opportunity to see how their opinion aligns with other experts, and they also get an opportunity to change their opinion after reviewing the collective findings of the group's ideas. Researchers like Dalkey and Helmer suggested that expert opinion surveys can gather "the most reliable consensus of opinion of a group of experts". Essential components of the Delphi technique include the communication process, a group of experts, and critical feedback (Dalkey & Helmer, 1963).

Methodology - Delphi Technique (Yousuf, 2007) was carried out in five steps to identify expert opinion on results from Objective 1 and 2. The following steps are involved in expert opinion survey using Delphi method:

Step 1 - Identification of experts
Step 2 - Determining the willingness of the individuals to serve on the panel
Step 3 - Compiling questionnaire based on requirement of the study
Step 4 - Sending the questionnaire to the experts for their comments.
Step 5 - Compiling data received from the survey and resending the data for further discussions and interviews.

Step 6 - Final compilation of critical factors based on discussions with panel members.

The Expert Opinion survey was conducted using the following research design:

A. **Tools Used -** Open ended questionnaires were designed based on the identified gaps and opinion survey was carried out. The questions in this segment of the expert opinion survey were different in format from the questionnaire designed earlier for eliciting views of stakeholders. A total of 10 questions were sent to the expert panelist.

B. **Sources of Data -** Leading experts from various agencies such as central and state government agencies, state nodal agencies, DISCOM/ utilities, service providers, end consumers and energy consultants were interviewed, and their responses were recorded. The panelist selected have no history of adequate communication and they represent diverse backgrounds with experience and expertise in the field of rooftop solar PV systems in India.

C. **Analysis of Results -** From the first set of answers received, the critical factors are identified. The critical factors identified are gathered and filtered using web-based survey software to compile results based on relevant content. These results are later sent back to each member of the panel for their further comments. The panel members were then asked to study the data and evaluate their views based on other panelist's view.

D. **Findings -** In the final step, interviews were conducted with each expert in the panel to discuss their responses and interpretation of factors identified. This is the final step in the survey response. Finally, the experts are asked to review their response based on discussions and surveys.

4.5 SUMMARY OF RESEARCH METHODOLOGY

The summary of the Research Methodology is as follows:

1. The first objective of finding critical factors affecting the growth of rooftop solar PV system markets in India is planned to be achieved using questionnaire tool. The factors derived from the questionnaire survey were further sorted using **Factor Analysis**. This helped us to generate refined critical factors which are critical for growth of rooftop solar PV systems in India.

2. To achieve the second objective, benchmarking of the best practices business models for rooftop solar PV systems of India with five countries was carried out using **External Benchmarking** tool. The process of external benchmarking was adopted from Robert camp (1989). The benchmarking of various successful business models in five developed countries with that of India led to other set of factors critical for success of business models in India.

3. To achieve the third objective of our study, we have used **Delphi Technique** to gain expert opinion on factors identified from objective 1 and 2. The expert opinion survey is used to arrive at the final factors critical to development of new business model framework for successful implementation of rooftop solar PV systems in India.

CHAPTER 5

ANALYSIS AND FINDINGS

The previous chapter discusses the research design and methodology undertaken to arrive at the analysis and results for the framework for development of new business model for rooftop solar PV systems for residential consumers in India. The data analysis chapter helps to break down various discussions into meaningful results to gain better understanding. According to researchers like LeCompte and Schensul, the data analysis method is useful in reducing data to a story and interpreting it to derive insights (Margaret Diane LeCompte & Schensul, 1999).

5.1 INTRODUCTION

The following study analyses the data based on questionnaire survey, external benchmarking, and expert opinion survey to arrive at factors which are critical in developing new business model based on Product Service System (PSS) approach. The entire analysis is divided into three parts which help us answer the research objectives. This would further lead to our suggestive framework for the development of a new business model. The table below gives snapshot of how the data analysis has been undertaken:

Table 10 - Snapshot of data analysis and findings

S. No.	Objectives	Data Analysis	Findings
1.	To find critical factors affecting the growth of RTS in India for residential consumers	Analysis based on questionnaire survey	Results from questionnaire survey undertaken for understanding on stakeholders' views on RTS market
			Factor analysis using SPSS tool to reduce the data collected from questionnaire and to gain more understanding on important factors critical for growth of RTS market.
2.	Benchmarking the existing business model for RTS in India with five countries; Japan, Australia, USA, Spain, and Germany	Analysis based on benchmarking study of rooftop solar business models with five countries: Japan, Australia, USA, Spain, and Germany	External benchmarking tool to study the rooftop solar business models in five countries and compared it with Indian rooftop solar model to gain deeper understanding on best business models for residential consumers and its benefits in long term.
3.	Finding critical factors for development of new business model based on PSS approach	Analysis of expert opinion survey	Delphi technique used to find expert opinion on the factors derived from factor analysis and benchmarking of rooftop solar business models.

5.2 ANALYSIS BASED ON QUESTIONNAIRE SURVEY

To identify the factors affecting growth of rooftop solar PV systems in India, questionnaire based on Likert scale (as discussed in previous chapter) was constructed based on parameters identified from literature review. The questionnaire design can be found in *Appendix A.* The results from the survey have been analyzed in detail using factor analysis based on SPSS software.

STEP 1 - VALIDITY

Face Validity and Construct Validity approaches have been used to establish validity of factors. Under these approaches, various factors were identified first based on literature survey. The factors so identified were used to design a questionnaire. A small sample of 25 people were chosen to start with to understand whether the factors derived from the literature survey are valid. Therefore, validity of the factors was ascertained from secondary as well as primary data.

STEP 2 - RELIABILITY

The reliability of the scale was checked before starting the analysis, the reliability was checked using Cronbach's Alpha (Statistical Tool). Validity refers to measurement what it purports to measure. Individual questions are not analyzed. Total score of respondents is added and then interpreted. Neutrals disappear.

A value greater than 0.7 is highly reliable. The results achieved by this statistical test are portrayed below:

Table 11 - Reliability Statistics

Cronbach's Alpha	N of Items
0.757	15

The scale is highly reliable as Cronbach's Alpha value is above 0.7. As the scale was accepted, factor analysis was used to reduce the data by grouping the similar parameters (variables) to a few manageable factors.

STEP 3 - ADEQUACY

The Kaiser-Meyer-Olkin (KMO) statistic was used to evaluate whether the sample size used for study was adequate to ensure the precision of factor analysis. Kaiser-Meyer-Olkin (KMO) Index is based on the idea of partial correlation. The correlation between two variables can be influenced by others because variables are correlated. Hence, partial correlation is used to measure the relation between two variables by removing the effect of the remaining variables. The KMO test measures sampling adequacy for each variable in the model. The lower the proportion, the more suited your data is to factor analysis. KMO generates values between 0 and 1. A rule of thumb for interpreting the statistic:

- Adequate sample-KMO values between 0.8 and 1
- Not Adequate Sample- KMO values less than 0.6.

The results achieved by this statistical test are portrayed below:

Table 12 - KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.619
Bartlett's Test of Sphericity	Approx. Chi-Square	740.350
	Df	105
	Sig.	.000

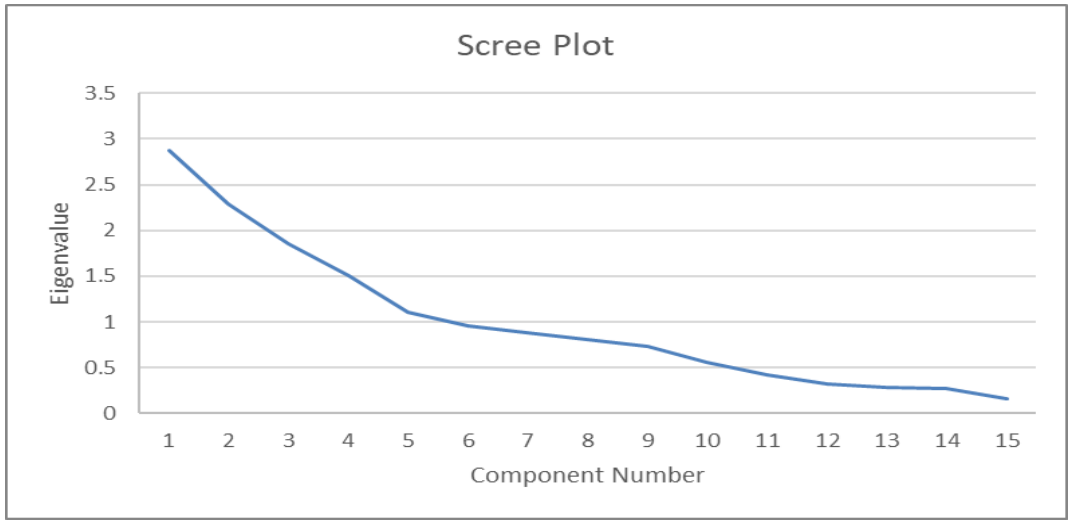
The value of KMO statistic is greater than 0.6. As such, the sample size is adequate, and the aptness of factor analysis is ensured.

STEP 4 - SCREE PLOT AND COMPONENT ANALYSIS

According to (Yong, 2014), theoretically, factor analysis is based on the 'common factor model'. This model suggests that observed measures are affected by underlying common and unique factors, and the correlation patterns need to be determined. Principal Components Analysis (PCA) is a technique in which the data reduction happens and the issues of whether it is truly a factor analysis technique has been raised. The Principal Component Analysis method was used to analyze these 15 parameters/ variables.

Under PCA, Eigen Value Method and Scree Plot Method were used to determine and justify the factors. A scree plot is used to determine the number of factors to retain within the principal components. The scree plot will display the eigenvalues in a downward curve, ordering the eigenvalues from largest to smallest. Using Principal Component Analysis, three factors were determined whose cumulative percentage of variances is explained by 67.30%. Figure 10 below portrays the Scree plot which was drawn.

Figure 10 - Scree Plot to determine factors.



After determining the three factors, the factor matrix was prepared which loaded 15 variables on the factors. Thereafter factor rotation matrix was prepared by rotating the factors using Varimax procedure, which is an orthogonal method of factor rotation. Varimax is a recommended rotation technique to use when you start exploring the dataset. Oblique rotation is selected if there is pre-existing evidence that the factors are correlated.

After the Varimax procedure, we calculated the Cronbach Alpha for each factor. It helps to measure internal consistency and shows how closely related the set of questions are. Cronbach's Alpha of each of 3 factors was calculated to establish the internal consistency and it was found to be 0.757, 0.720 and 0.813 respectively for the studied factors and is found to be consistent.

By the application of factor analysis, 15 identified variables were reduced to 3 major factors which act as the critical factors affecting rooftop solar PV framework in India.

STEP 5 - CRONBACH'S ALPHA FOR EACH FACTOR-

The significant factor loadings of each identified variable, the total variance explained for each factor and the Cronbach's Alpha for each factor is shown below:

Table 13 - Cronbach's Alpha for each factor

Financial assistance and Incentives (0.757)	F4	0.726	New and innovative financial schemes by government helps in bringing large number of consumers to install rooftop solar PV systems

	F5	0.793	Home improvement loans should be provided for consumers interested in installing rooftop solar PV systems
	F6	0.455	Tax incentives, rebates and subsidy should be provided as way of encouragement to residential consumers
	F7	0.811	Pre-approved financing mechanism should be in place for consumers interested in installation of rooftop solar systems
Policy and Regulatory (0.720)	F11	0.733	Consumers having more roof space should lease their roofs for installations of rooftop solar systems to earn extra income by way of selling power through net metering
	F12	0.747	Consumers with vacant roofs and large connected loads should opt for installing rooftop solar systems to reduce their electricity charges.
	F3	0.816	DISCOMs plays a key role in overall activities associated with rooftop solar PV systems installations and processes
	F1	0.665	Net Metering and Gross Metering regulations should be clearly notified by government of India.

	F2	0.672	Consumers with load more than 5KW and above with rooftop space should be made mandate to connect to the rooftop solar PV system.
	F9	0.407	Online application systems should be provided to consumers for smooth application process.
Marketing and Technical Support (0.813)	F10	0.904	Empaneled and registered service providers will help consumers with their experience in rooftop solar PV systems.
	F14	0.803	Manpower and financial support should be given to utilities for them to encourage their customers to opt for rooftop solar PV systems.
	F8	0.922	Solar advertisements and awareness campaigns are required for consumers' trust and knowhow in rooftop solar PV systems
	F15	0.57	Availability of skilled manpower is required for better sales and service networking

DISCUSSIONS ON FACTORS DERIVED FROM FACTOR ANALYSIS

FACTOR 1 - FINANCING ASSISTANCE AND INCENTIVES: The variables which have been loaded in factor 1 showcase need for financial support in the market for development of grid connected rooftop solar PV systems on residential consumer premises in India. The existing framework lacks a financing mechanism to invest in the system and cover the upfront cost. Provision of low interest rate loans from national banks should be made available for residential consumers willing to install the system on their suitable roofs. The lack of trust in the market and credibility of consumers to repay loans leads to issues for banks such as long period of investment lock in. Also included in factor 1 are the variables highlighting the need for addressing the incentives like rebates, tax credits, subsidies, and other benefits in terms of monetary support. The financing instruments like mezzanine and partial risk guarantees are being widely used in India but have less attractiveness in the rooftop solar sector at present. Exploring these financial arrangements by the government and providing financial support is required for robust development of the market. Hence factor 1 has been termed Financial Assistance and Incentive.

FACTOR 2 - POLICY AND REGULATIONS: Policy and Regulations factor relates to policy consistency issues as the variables loaded in this factor showcase the variables that concern the effectiveness of policy framework for growth of grid connected rooftop solar PV market. Variables like absence of clear metering regulations, ambiguity in the role of utilities, lack of skilled personnel and manpower, lack of grid regulations have been discussed in factor 2. The robust policy support is important for success of various schemes and initiatives taken for deployment of grid connected rooftop solar PV systems in India by central and state governments. The regulatory bodies including State Nodal Agencies and utilities play a key role in formulation of policies; they float state level schemes and

disburse subsidy to the consumers, they provide data on load sanctions and metering regulations, their role is crucial for deployment of small-scale systems as they are the point of contact for residential consumers. Hence, the factor is termed as Policy and Regulations.

FACTOR 3 - MARKETING AND TECHNICAL SUPPORT: Marketing and technical support variables have been loaded in factor 3. This variable includes all the elements required for market trust and growth. Since grid connected solar market is still at nascent stage in India, marketing and technical support is of prime importance. Marketing techniques such as solar campaigns, solar advisements in newspapers and media, online portals for applications processes and sales and service centers across the country are popular for capturing new markets. There is a need for independent, reliable sources of information that consumers can trust and refer as database. To enable market mode, development of solar shops, care centers and technical support solar shops are important.

5.3 ANALYSIS BASED ON BENCHMARKING OF ROOFTOP SOLAR BUSINESS MODELS

External benchmarking of Indian rooftop solar business model with business models of five countries; USA, Japan, Australia, Germany, and Spain were conducted. The analysis from benchmarking of the model is based on the following parameters and the same has been tabulated in detail (*Appendix D):*

- Techno commercial,
- Financing,
- Policies and Regulations,
- Quality and standardization,
- Value proposition and
- Customer interface

The analysis from benchmarking of the rooftop solar business models of five countries with India provided with lots of inputs which are critical for growth of residential rooftop market in India. The table below highlights the important factors which were investigated and analyzed for our study:

Table 14 - Comparison of Support Initiatives for Rooftop Solar Systems in Five countries (A; Available, NA; Not Available)

Support Schemes	***India***	***USA***	***Japan***	***Australia***	***Germany***	***Spain***
RTS specific green power schemes	NA	A	A	A	A	NA
Tax Incentives	A	A	A	A	A	A
Tax benefits for green power consumption	A	A	A	A	A	A

Direct Capital grants/ subsidy	A	A	NA	NA	NA	NA
Net Metering requirements	A	A	A	A	A	A
Renewable Portfolio Standards (RPS)	A	A	A	NA	NA	NA
Green energy funding	NA	A	A	NA	A	A

- ✓ Direct capital subsidy to eliminate the risk of upfront solar cost issue is an important factor for market growth. Many developed countries with RTS capacity have this support from federal and state government.

- ✓ Net metering requirements are available in all the countries compared above, this allows the residential consumer to consume solar generated electricity initially at the premises and sell the excess to the grid using bi-directional meter.

- ✓ Under the Renewable Portfolio Standards (RPS), the local utilities are mandated to source a portion of their electricity from renewable sources. This encourages the utilities to advocate for renewable consumption to their consumers.

- ✓ Tax benefits and credits are required for encouraging residential consumers to save taxes while consuming green energy from deploying rooftop solar on vacant rooftop, saving in tax for consuming green and zero emission.

- ✓ Rooftop solar specific schemes are popular in India for agricultural consumers, commercial settlements, and industrial consumers. The residential consumer sector needs more schemes especially in rural areas where the dependency is huge for utility supplied power, in countries like Germany and Spain, the

specific schemes like Feed in Tariff, generate and consume led to huge growth in capacity addition of RTS systems on residential households.

Rooftop solar PV business models across five countries have been analyzed based on - Value Proposition, Customer Segment, Customer Relationships, Channels, Revenue Streams, Key Partners, Key Activities and Key Resources.

Table 15 - Business Model Comparison based on selected parameters.

Parameters	**Self-Owned Business Model**	**Third-Party Owned Business Model**	**Community-Owned business Model**
Value Proposition	▪ Products and services offered by developer companies: pre-fixed, complex, and customized packages. ▪ Installations offered by companies but in the case of some countries even self-installations option is available.	▪ Consumers use clean energy without paying the high upfront costs. ▪ No risk of the long pay-back period ▪ End-consumer receive clean energy supply at competitive price.	▪ Consumers use clean energy without installing the system. ▪ The end electricity consumers receive credit on their energy bills. ▪ Eliminates the risk of system cost burden for consumers because of group purchasing.

	▪ Consumers who generate their own electricity on rooftops are also the producers and become "prosumers." ▪ By opting for Feed in Tariff arrangement consumers can benefit from investment decisions ▪ The Feed in tariff arrangement provide return of investment (ROI) which is more competitive than other investments. ▪ Residential consumers benefit from tax credits and get	▪ Avoidance of unpredictable utility's tariff rates ▪ The operations and maintenance is the responsibility of the third party ▪ Maintenance packages and performance guarantees also reduced risks for the customer	▪ Long term attractive savings with low risk ▪ Ease of sale of consumer property without risk of discarding the system. ▪ Contributes to environmental commitment to avail clean power options

	initial financial support.		
Customer Segment	▪ Consumers with a feasible rooftop and money to invest in clean technologies. ▪ An up to 10 kW system can be installed on residential buildings. The households are motivated to adopt the technology due to reasons such as environmental benefits and independence from grid electricity supply. ▪ The single-family household who are influenced by environmentally	▪ The consumers who want to have energy bill savings and green energy use but cannot pay upfront cost of the system. ▪ Younger generation, with less capital also sometimes unqualified who want renewable benefits. ▪ Farmers, public organizations, and companies	Consumers who are both renters, have commercial properties, non-profit organization and religious buildings. ▪ Other consumers part of institutions such as municipal corporations and colleges

	friendly lifestyles and engineers committed to new technologies. ▪ The small-scale farmers are another type of consumers under this model.		
Customer Relationship	▪ Seller companies use personal channels to interact with customers. ▪ Site feasibility is checked by creating sales memos for consumers and a representative is sent to premises for accessing the site and suggesting system.	▪ PPA and contract are for long term and hence the relationship is long lasting with consumers. ▪ Social meet up of selling agents, local company exhibition and use of online forum to contact interested consumers.	▪ Consumers and system providers get into long term contacts. ▪ Solar exhibitions, events in local communities and online channels lead to relationship building

Channels	• Solar Walks, Solar City's Ambassador program ▪ Word-of-mouth communication is considered to have a high impact on consumers, specially in close community towns. ▪ The use of PV magazines to post advertisements and the use of websites for existing consumers reviews.	▪ Sales representatives from suppliers' company ▪ The third-party representatives attend conferences and energy events to engage with interested consumers and network building. ▪ Advertisement both on paper and online are common tools	▪ RTS developer arranges meetings, conferences, educational programs, and community events. ▪ The website of the company is used to share knowledge of consumers and investors. ▪ The supplier companies' representative is the major foundation for channeling and providing success.
Revenue Streams	▪ Revenues come from PV system installation.	▪ Revenue is derived from PPA or solar lease solutions.	• Sale of solar bonds contribute

	▪ Complementary services such as spare parts availability, free assessments ▪ Energy consultancy and knowledge of the products and services along with added solutions customized as per need. ▪ Solar panels are sold without any additional services to end consumers	▪ Leasing of system and consumers does not pay for energy consumed. ▪ Grants and subsidies from the government, state and federal incentives, and incentives offered by municipalities and local utilities.	to the revenue in this arrangement
Key Partners	▪ Suppliers and manufacturers of solar products. ▪ Technical support firms having marketing and	▪ Banks and other large corporations ▪ Energy consultants, law firm, insurers, installers, and	▪ Utility's local consumers ▪ Distribution companies: The energy generated is synchronized with distribution

	project-specific knowledge. ▪ Distribution utilities provide approvals and regulatory support. They have a determined role.	maintenance companies are other partners in such model	companies for billing of power consumed and power sold.
Key Activities	▪ Turn-key product solutions. ▪ Sale of RTS system component or after-sales services such as maintenance and repairs ▪ Financial advice and support for taxation, incentive system ▪ Services such as insurance on	▪ Lease and PPA provision ▪ Arranging the finances by pooling small RTS systems into a fund and selling it to investors interested. ▪ Management of funds and other financial support from the service firm to manage these processes	▪ Buying or leasing solar panels ▪ Databank of consumers, data reporting and regulatory compliance ▪ Responsibility of Operational and maintenance is on service provider

	systems, legal security etc ▪ Attractive and new marketing activities to increase the company's reputation and strengthen customer relationships.	▪ All in one service providers offer services such as maintenance and system performance monitoring. ▪ Marketing activities includes media interaction and other complementary services or channels.	
Key Resources	▪ Skilled technicians, Knowledge pool, personally know how channel partners and indispensable sales representatives.	▪ Strong existing customer base ▪ Software supporting sales and marketing activities, project management and monitoring activities.	▪ The Existing consumers base is essential key resource. ▪ Excellent infrastructure, including IT software solutions to monitor energy

	▪ Market insights of customers and local distribution network ▪ Marketing and social activities have a strong influence on consumer interest.	▪ Skilled employees with appropriate financial and technological expertise	generated in real-time and manage contracts. ▪ Sales representatives are indispensable element of the workforce, who contribute to network building and management of complexity

The findings from external benchmarking of business models are as follows:

1. In the USA, most households adopted solar due to ease of leasing. Third party leasing model was successful in market maturity since the consumers could invert the financial barriers due to elimination of debt or make upfront cost for buying a solar system. In USA, the supplier of the system usually obtains the upfront capital cost through various channels such as vertical integration with the local manufacturers of the systems, low-cost bank financing for clients and low-cost logistics for the system to be procured on time. The system integrator is the one who own the system and installs it. The customer receives a guaranteed supply of zero emission solar power which also serves as a hedge against ever increasing utility prices of electricity.

2. Germany has largest consumption of solar power for many years, the business models support system leasing models, strong grid connection separate lines for solar power. The interest rates for bank loans are attractive, for example 15 years bank loan at 2.8% interest rates. The small-scale solar rooftop program encouraged residential consumers to adopt solar systems which had attractive returns. Apart from the attractive returns of the system cost, the residential consumer market was relying on domestic manufactured solar panels which were offered at concessional rates to households opting to install systems on vacant roofs.

3. The rooftop solar system components are manufactured locally in Japan and most modules are assembled domestically in the country. It can be seen from the analysis that while third party lease business model was successful for growth of residential solar market in USA, the case was different in Japan. The third-party model is uncommon in Japan's residential solar market however, PPA are more common. The 10 Year

Japanese government bonds acted as the best investment for RTS systems for residential consumers as 0.7% interest rate was very attractive. In Japan, residential rooftop market has been supported by several government initiatives, including national and local subsidies, feed-in tariff, and tax incentives. The national subsidy program since 1994 and a feed-in tariff program since 2012 and additional local incentives such as municipal subsidies helped the growth of market at initial stage.

4. The markets in Australia and Spain attracted residential consumers by using a combination of schemes and initiatives. These initiatives were successful in deployment of RTS systems by providing extra benefits such as government subsidies, tax incentives, zero interest finances, ease of third-party leasing and attractive feed in tariff programs. Overall, the ease of procuring the systems with less hurdles and elimination of regulatory barrier led to large deployment of RTS in residential consumer category.

5.4 ANALYSIS BASED ON EXPERT OPINION SURVEY

Based on literature survey, factor analysis and external benchmarking of Indian rooftop solar PV business models with five countries, factors were identified, and questionnaire was constructed. Ten 'open ended' questions were designed (*Appendix B*) based on inputs derived from data analysis done above. The questions in this segment of expert opinion survey analysis were different in format from the questionnaire designed (based on Likert scale) earlier for eliciting views of stakeholders in general.

The leading experts from both central and state government, Ministry of New and Renewable Energy (MNRE), State Nodal Agencies (SNA), state distribution companies (DISCOMs), major service providers (*Appendix C*) for rooftop solutions in the market and industry experts were interviewed and their responses were recorded. The expert opinion survey was conducted using Delphi technique and step by step process was followed in order to arrive at final factors critical for growth of RTS market in India. The expert opinion survey method provides validity and reliability of the research conducted.

The structure of the expert opinion survey was as follows; in round one, questions were asked using a questionnaire through google forms and all the experts were asked to provide their views.

Category I - Financing the RTS systems: The following questions in the survey were asked initially in round one for understanding on financial arrangements and future requirement in the business model,

Q2 - Pre-defined financial assistance to be made available for consumers showing interest in RTS systems.

Q5 - To make the RTS scheme attractive and have mass acceptance, the government should provide rebates and tax incentives.

Q8 - Reduction in the billing cycle for the adjustment of import/ export of energy into the grid

Q10 - Subsidy/ Rebates disbursement procedures should be simple, and time bound.

DISCUSSIONS - The expert panel agreed that residential consumers in India are reluctant to invest in the rooftop solar technology due to high upfront cost. For an average household, there has been no urgency to adopt solar in India, as utility tariff is not very high that it cannot be afforded. The panelist agreed that for the market to mature, government subsidies and grants are a requirement for the residential consumer category. Financial instruments should be introduced in various ways such as crowdfunding, bonds, loans, and home improvement loans. The experts debated that the bureaucratic procedures for disbursement of subsidies takes a lot of time in India, which is hindering the process of financial aid for buying solar systems. The utilities are responsible for paying the consumers for extra energy generated at a fixed cost (as per agreement), however, there is a huge delay in the same since the utilities are facing a financial crunch. The billing issues are not resolved easily, making the whole process of procuring the systems and availing its benefits a cumbersome task.

In the second round, interviews were conducted, and the expert panel members provided with their views on financing of RTS systems in India. The residential consumers in India do not wish to take loans with high interest rates. At present the interest rates on the bank loans are very high. These consumers do not get attracted to financial arrangements which require them to take loans with high interest rates. The same applies to the banks.

The RTS technology is still at nascent stage in India and trusting the suppliers is still an issue. The discussions lead to conclusion that for the RTS market to mature in residential consumer category, the banks should provide home improvement loans and government should tie up with financial agencies before rolling out schemes in the market. In new multi-residential properties, the consumers should prepay the cost of RTS systems which should be made part of the property value. The tax incentives for consuming green energy are missing in India. The government should provide tax rebated and tax incentives for consumers who avail benefits of green energy consumption.

Category 2 - Policy and Regulations: The following questions in the survey were asked initially in round one for understanding the policy and regulatory framework of Indian rooftop solar market and future requirements of policy advocacy in the new business model,

Q3 - Availability of trained/ expert staff from SNA/ DISCOMs side should be approachable to make residential consumers understand the scheme/ policies and going forward procedure.

Q6 - The empaneled suppliers and vendors list to be made available to consumers to choose their supplier.

Q9 - Impose of Renewable Generation Obligation (RGO) on multi story housing complexes and residences having more than 10 kW of connected load.

DISCUSSIONS - The expert panel members provided their initial inputs on questionnaire survey in the first round. The members agree that there is disparity in policies and regulations pertaining to rooftop solar PV market in India. The utility companies are bearing the load and are unable to promote RTS in a structured manner. The members agreed that there is shortage of skilled manpower and training is required at local utility levels for large-scale deployment of RTS systems. The utilities are facing manpower and financial crunch and these lead to delays and cumbersome process.

The panelists agree that there should be a firm policy on residential rooftop market which would also benefit end consumers and system suppliers by building trust in the market. Continuous changes in regulations and schemes lead to confusion in the market and hence slow growth. The mandates of RTS system deployment on new and renewed premises was debated, some agreed that these cannot be made mandatory while some experts believe if the RGOs are mandated it would also help in RTS growth and benefits of the solar power can be reaped by many households.

In the second round of discussions, interviews were conducted to discuss the views of expert panelists. The regulatory and policy matter is a prime concern for RTS market development. The policies are different for different states in India. Depending on location, terrain, radiation and population, the policies differ. For the market to capture requirements of the residential consumers to avail benefits of rooftop solar systems, the procedure for procuring the system should be simple and easy.

The experts highlight the entire stage of filing the application under a scheme to avail the subsidy should be very systematic. The residential consumers do not wish

to be involved in processes which takes a lot of time and efforts. The option to choose the suppliers should be open in the market. The regulation calls for empaneled suppliers who are chosen based on bidding process by SNAs. These suppliers are local in the market and the residential consumers should have the option to choose these suppliers for their products. The utility companies should have dedicated manpower for handling RTS related issues and procedures.

Category 3 - Marketing and Technical support: The questions in the survey were asked initially in round one for understanding on marketing tactics and technical support for Indian rooftop solar market and future requirements of services in the new business model,

Q1- Right advertisement and campaign approach is required to reach residential audience and make them aware of RTS policies and schemes.

Q4 - Online application portal for smooth application filing procedure to be made available for consumers to access.

Q7 - Presence of retail sale and service network which is accessible to the consumers of RTS systems.

DISCUSSIONS - The panelist provided their initial response on questionnaire and later the interviews were conducted to gain deeper understanding on marketing and technical support network for developing new business model framework. The experts debate that the market for residential rooftop solar system is yet to take off. The growth is tremendous in the commercial and industrial consumer category, but residential consumers are not finding the RTS options very attractive.

The experts believe that with the right campaign and with good advertisement on benefits of RTS systems on vacant rooftops would encourage consumers to come forward and explore options of RTS deployment. However, they believe, just advertisement is not the key to attracting consumers. There are several other factors which need to be considered as well. The factors which are critical for market development are smooth processes and defined structure of procuring the system as per customers' requirements, ease of getting clearances and approvals is equally important.

The experts agreed that there are no sales network present in India which is accessible to consumers. The consumers rely on information provided by utility companies or details under government schemes. At present the benefits of green power consumption, low dependency on utility power and payback period benefits are not known to the end consumers. The experts make a firm point on retail and sales network requirement for growth of rooftop solar market development.

The findings from the expert opinions survey are as follows:

A. Stakeholders opined that the growth of rooftop solar market strongly depends on clear policies and regulations without ambiguity. The policy should be consistent, and the framework should be clearly defined.

B. The critical factors affecting the growth of Rooftop Solar market in India are absence of financial schemes. If the business model needs to sustain in the market, financial enablers should be readily available to give loans and provide mechanism for upfront cost of systems.

C. Mixed opinions were received regarding involvement of DISCOMs in the entire rooftop solar PV system process. Some experts think that the DISCOMs should have minimal role in the entire system installation and new entity should be present side by side with DISCOMs, thereby reducing their manpower load. The new entity should be solely responsible for grid connected rooftop solar PV system processes.

D. According to some stakeholders, reasons for DISCOMs not encouraging rooftop solar could be due to extra efforts in providing new connections, no incentives for installations and the poor financial status of these entities.

E. Regarding the application process and making it online, the experts opined that this should be made mandate by each State Nodal Agency (SNA) to have a one-point portal with information for new consumers opting for rooftop systems and availability of data on empaneled channel service providers which are experienced and trustworthy and selected through fair tender processes.

F. Experts suggested to take important steps to make consumers aware of rooftop solar PV system benefits and how these systems would address the issues of high electricity bills, best use of available rooftop spaces (also vacant roofs) and along with this should advertise the environment benefits of these systems.

G. There was a strong feeling about the need for advertisement in newspapers regarding new policies and schemes by state government and solar walks and campaigns should be conducted to capture the mass consumers and develop their interest in rooftop solar PV systems.

H. The specific challenge faced by government agencies to address subsidy disbursement also had a mixed response from experts. They agree that the process of subsidy grants should be simple, and time bound.

I. According to expert's opinion, changes required in the existing rooftop solar PV framework to achieve its objectives are:

- Stable and consistent policies and regulations for residential rooftop solar policies
- Clarity on role of stakeholders with time bound activities
- Pre-approved financial loans, financial schemes, and mechanism
- Consumer awareness on benefits of rooftop solar systems when installed at vacant rooftops and the benefits in the long term
- Availability of experienced and trustworthy service providers in the market
- Online one-point portal for consumers information and queries.

CHAPTER 6

SUGGESTIVE FRAMEWORK

Detailed analysis of the primary and secondary data revealed the critical factors affecting the growth of rooftop solar PV systems in India. The data analysis which was done in three parts in previous chapter; questionnaire survey, benchmarking of rooftop solar models and expert opinion survey provided the study with important and critical insights which are required for developing new business model (as discussed in previous chapter). The suggestive framework would reflect upon - components of new business model, structure of business model based on expert opinion survey, structure of business model based on Product Service System approach, Finally the proposed business model is explained along with pictorial representation.

6.1 DISCUSSION ON NEW BUSINESS MODEL FRAMEWORK

To understand the requirement of the market and the consumers' need, the new business model framework is discussed in detail:

1. **Value Proposition -** Currently, the EPC contractors or the supplier firms offer pre-fixed, complex packages that contain specified components such as inverters, PV panels, cables that are usually fixed and cannot be modified by consumers. The installation is provided by the supplier company to the customer or there is an option of self-installation by the consumer. The consumer has an option of signing a PPA agreement for the long term and can benefit from Feed-in-Tariff (FIT) and thus have a level of return of investment that is competitive with other investment opportunities. In the

OPEX model, the consumer can avail the benefit of green power consumption without paying the upfront cost. Also, the consumer who installs RTS system realizes savings in energy bill.

Based on the factor analysis and expert opinion conducted, the major value proposition to residential consumer is savings in electricity bill and option of exporting excess electricity back to the grid at a fixed rate. However, the requirement of customized solution for each consumer as per roof availability and structure is the key for customer base. The customized system package and ease of finance availability would bring customer trust.

2. **Customer Interface -** In India the RTS system can be installed on commercial, industrial, institutional, and residential buildings based on available and suitable vacant roof tops. The consumers can avail subsidy benefit from state government if applicable depending on state's policies and regulations. The supplier firms engage with consumers when they plan to install the systems and the utility company approves the capacity in case the consumer is applying system under the policy. Currently the consumer gets information on new and existing policy through newspaper advertisements or utility websites. The other channels in India are word of mouth, subsidized power schemes in rural regions and local paper pamphlets.

   Based on the factor analysis and expert opinion survey, there is a strong requirement of understanding of system operation and advertisement in various portals such as newspaper, television media and a single point contact for consumers for all queries, approvals, processes who can be contacted as per requirement. Customer relationships play a crucial role in building trust and long-term relationships. Empaneled service providers bring trust in consumers and will act as main point of contact for all

consumer issues. Skilled technical staff at utilities ease the process and smoothen the customer interaction process.

3. **Infrastructure -** The key partners involved in RTS installations in India are utility companies, component and system suppliers and banks who provide loans to the consumer. These partners usually support firms with technical, financial, marketing and project specific knowledge. Consumers who opt for installation of RTS under state policies, contact utilities for pre-feasibility and connected load and others who install system voluntarily are in direct contact with supplier firms. The suppliers are empaneled under state government and their system costs are usually regulated. The key activities involved are application process, feasibility studies, site analysis, net metering, and grid connectivity.

   The utilities provide net meters and consumers apply for subsidy if applicable. Technical know-how, skilled and expert staff, close knowledge of consumers and local markets are indispensable resources for smooth installation of RTS systems.

   Based on factor analysis and expert opinion, technical knowledge by utility and service provider; expert and skilled staff; turnkey solutions; after care services; suppliers with technical, marketing and project related knowledge; and banks and investors willing to provide loans; are key partners required for successful RTS installation process. The requirement of the residential consumer market is suppliers who provide full services such as customized packages, arrange for the permits/ approvals, install the system, and monitor its performance and mainly carry out maintenance and services as per requirement.

4. **Revenue -** The major source of revenue comes from installation of the RTS system and little from the after-care maintenance service agreement. The utilities fulfill their RPO (Renewable Purchase Obligations) and provide net meters to the consumers which adds to their revenue component if consumers opt for RTS installation. The savings in energy bill of electricity consumers installing RTS systems also contribute to their revenue stream. PPA agreement of utility company with consumers for long period such as 25 years for fixed tariff also adds to the revenue in the business model. Other cost structures include bank loans, government rebates/ subsidy, system component cost, spare part cost, inventory holding and warehousing cost.

   Based on factor analysis and expert opinion, innovative financial schemes, and tax rebates for installing RTS systems should be provided to consumers. Nationalized banks providing home improvement loans to consumers and rebates/ subsidies from government for residential consumers will provide market trust. The utilities or suppliers providing pre financing for RTS installation will provide added revenue benefit to the consumers.

Ensconced on this understanding a suggestive framework of business model in India is being laid out. The below figures (figure 11 and figure 12) highlight the elements of the business model from our analysis done in chapter five.

Figure 11 - Business Model structure based on expert opinion survey.

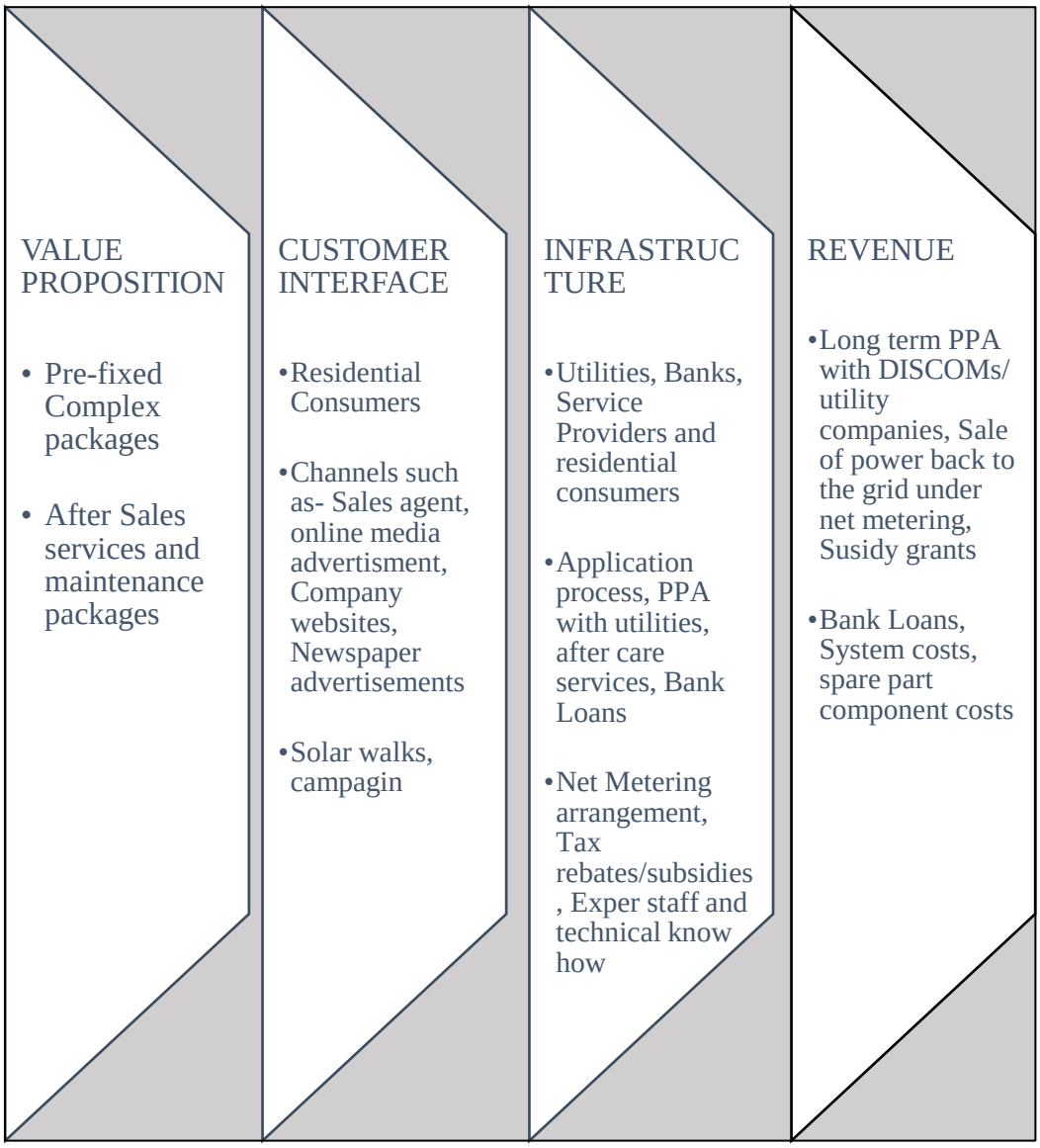
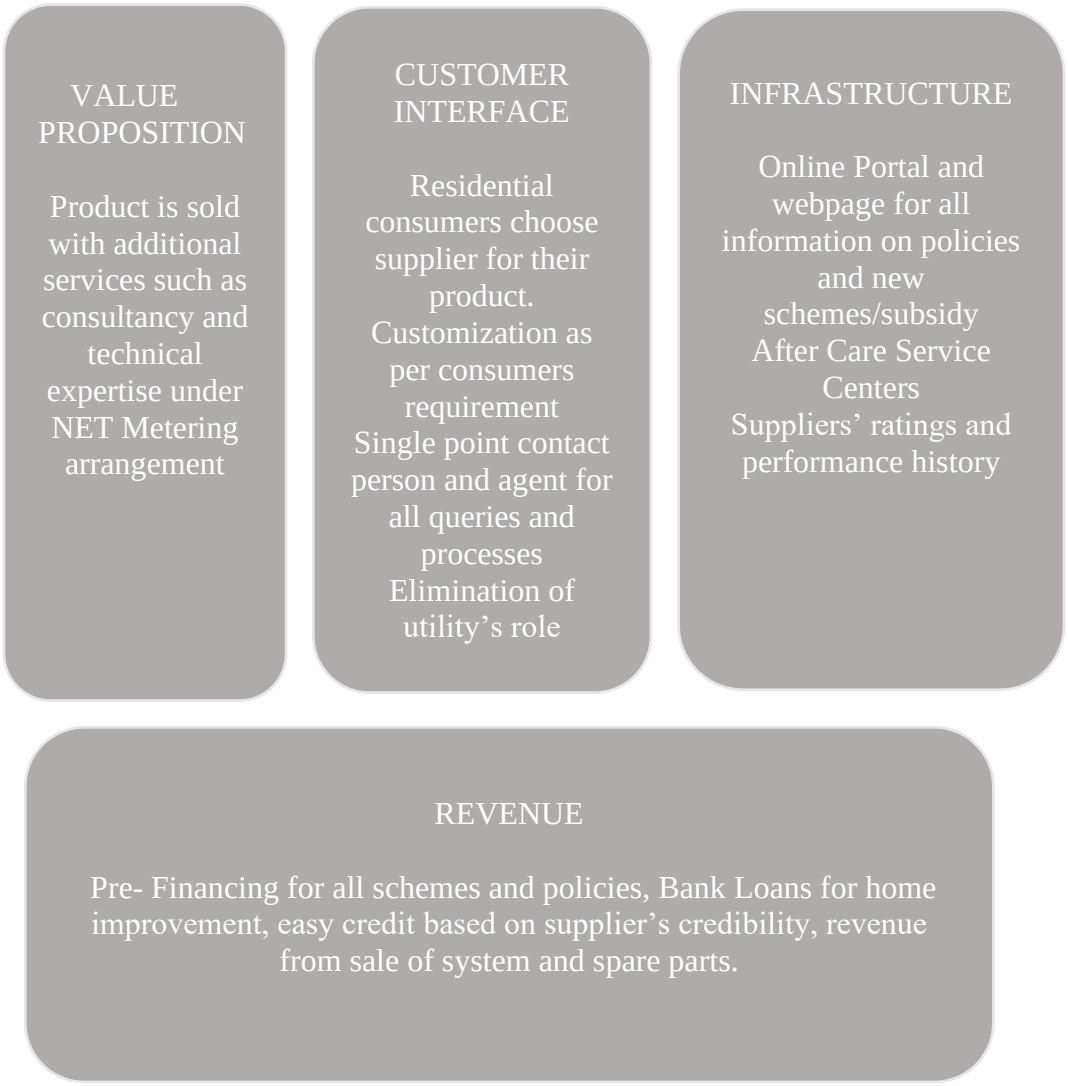


Figure 12 - Business Model structure based on Product Service System Approach



6.2 PROPOSED BUSINESS MODEL

The present study focuses on residential consumers and their requirements to install rooftop solar PV system connected to the grid on their available and vacant roof tops. The consumers are electricity end consumers who are currently connected to the grid but consuming utility's electricity supply. These consumers have the option to switch to net metering as per their state's regulations and standards. In the current market scenario, recommendations have been made to incorporate four steps for desirable business model -

Step 1 - Formulation of separate policies for Grid-Connected Rooftop Solar PV Systems

The purpose of policy is to make the intention/ plan of the government known to the public and to lay a framework of guiding rules for any given economic activity. The policy framework will serve two purposes: firstly, it provides clarity to government departments on the plan of action and direction of the government, and secondly, it also provides clarity to the public, investors, developer, and other stakeholders on the intention of the government in policy governance. Framing a good policy for residential consumers is essential since they depend on subsidies and grants for economic viability. The role of regulations is mainly to –

1. Determine benchmark tariff for rooftop solar grid-connected systems.
2. Specify the grid code, ensure standards and other technical parameters that ensure smooth functioning of the grid.
3. Ensures proper interpretation of the regulations and resolve any disputes between power producers, DISCOMs and Consumers
4. To inform the stakeholders about new incentives available by central and state government.

5. Framing a new rooftop solar policy for residential consumers would encourage investors to invest in this technology and thus penetrate in market.

Step 2 - Role of Regulators, Local Utility Companies and State Nodal Agencies

DISCOMs/ Utilities have important role in application process and implementation of rooftop solar systems in all the states in India. However, currently they are facing challenges to operationalize metering regulations and have other concerns such as reduced electricity sale, revenue erosion from paying customers and other operational challenges with regards to load distribution, grid availability and skilled manpower. To overcome these issues, the new business model framework suggests that the role of utilities needs to be minimized up to a point where they are just providing data for consumers connected load, feasibility analysis of consumer premises and they provide the access to the grid network for connecting their rooftop systems. Once the data of consumers is shared with the service providers, utilities' tasks are reduced until final approvals are provided for billing of net metering electricity.

The other agency involved is State Nodal Agencies (SNAs). The SNAs are present in each state and regulate renewable power generation. In the present business model framework, the SNAs would facilitate in providing an online portal for application process, and the consumers who intend to participate would apply on the same. Apart from this the SNAs will float tenders to invite service providers based on certain eligibility criterion and their empanelment would be based on competitive bidding route. The SNAs would further be involved only at the time of disbursement of subsidies/ incentives if applicable at that time. This would help the market to evolve with less intervention by government agencies.

Step 3 - Marketing Campaigns

Making the consumers aware of solar technology and its benefits is the upmost requirement in India. Advertisements in newspapers, media involvement through advertisement in television are required for attracting mass consumers. The main benefit of consumer awareness is their willingness to show interest in the rooftop solar systems installations once they have trust in market players (service providers). Awareness campaigns such as solar shops, solar attractive media advertisements can be assisted by government as well as private market players because this in turn will benefit all the stakeholders involved.

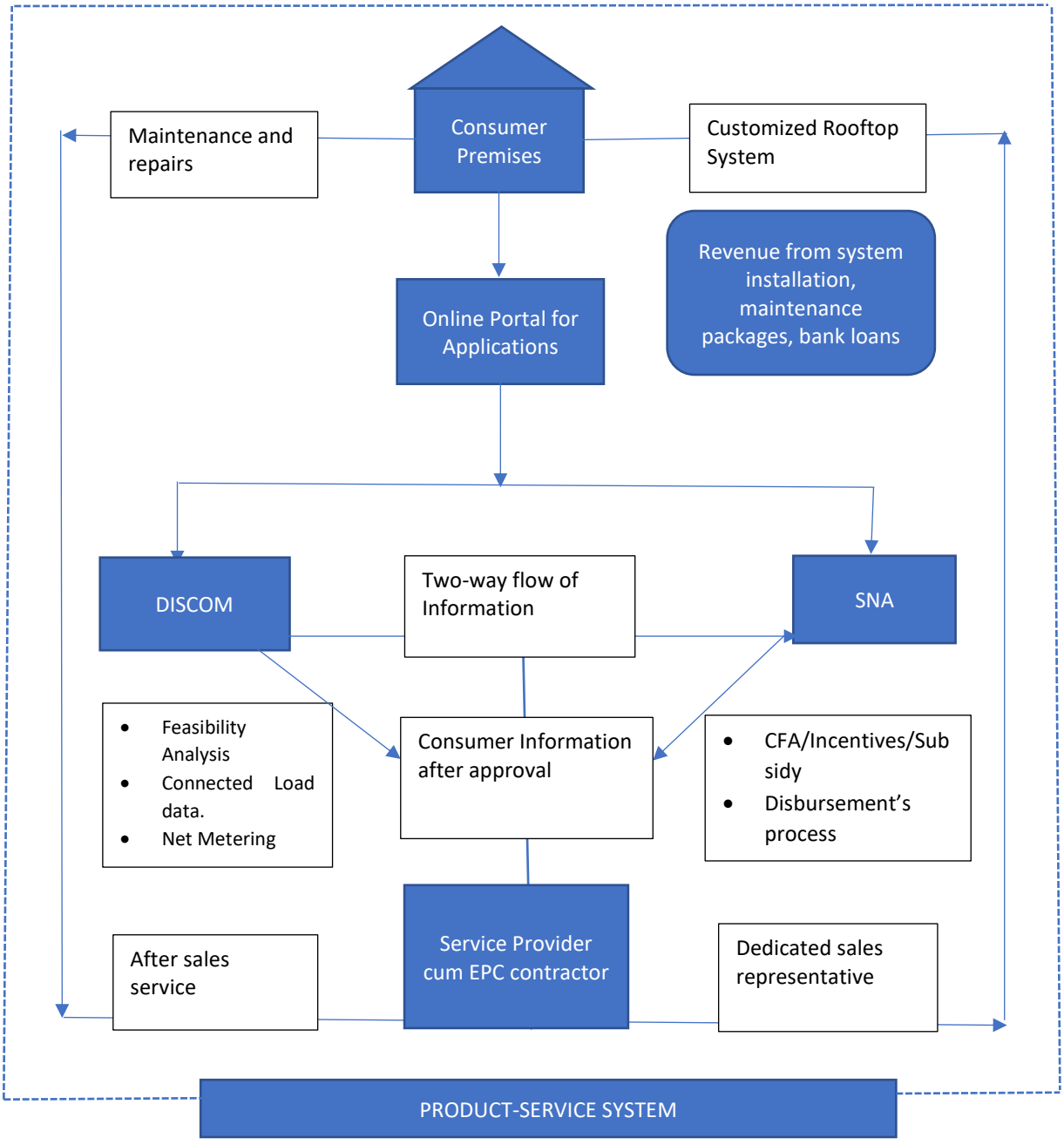
Step 4 - Post Installation Service Providers and Care Centers

Service providers have a very dominant role in our proposed business model, as the model is based on the PSS approach. The rooftop solar systems are sold as products as per the requirements of customers and hence the role of service providers is prime. Their selection is a paramount step in the entire framework. The selection will be done on competitive bidding by SNAs and service providers who are willing to provide upfront financing/ Equated Monthly Installments (EMI) schemes would be given preferences. The minimal requirement of these service providers would be their manpower, expertise, quality products, after sales services as well as market penetration. The service providers cum EPC contractors will act as single point contact for consumers who opted for installing rooftop solar PV systems on their rooftops. The contractors will help the consumers in various processes involved from selecting the system as per requirements (customization), EMI financing, warranty and guarantee, regular maintenance, and after-sales services. While the consumers would get one-point contact for all their issues and concerns. The service provider will get the benefit of customer base, market penetration, experience and the number of investors will grow over time.

Proposed Model based on Product Service System Approach

Once the major issues and barriers in adoption of Rooftop Solar PV technology are addressed, the residential market in India will evolve from nascent stage to developed stage. Based on the above framework, a pictorial presentation of Market mode business model has been proposed which incorporates the Product Service System approach.

Proposed Business Model Pictorial Representation



PROPOSED MODEL DESCRIPTION

The theoretical representation of the business model given above shows a rooftop solar system installed on residential consumer premises under the state net metering scheme. The business model encompasses the 'Product Service System'. This model is an outcome of empirical research conducted in a scientific manner. This is an outcome of interaction and survey with policy makers, consumers, suppliers, and technical staff of discom and state nodal agency.

The following are the important verticals in the proposed model. A brief description is given below:

Residential Consumer

The research focus is consumer premises because these premises have different economic dynamics in comparison to industry consumer. These premises are large in numbers but small in terms of their demand, their scatter is very large. Therefore, consumer premise in the proposed business model means that a residential consumer who owns or rents a house which is connected to the grid. The proposed business model is established around residential consumers willing to install rooftop solar system connected to the grid.

The thesis reviews business model structure which is a result of the findings from factor analysis and expert opinion review. Based on the factor analysis and expert opinion conducted, the major value proposition to residential consumer is savings in electricity bill and option of exporting excess electricity back to the grid at a fixed rate. However, the requirement of customized solution for each consumer as per roof availability and structure is the key for customer base. Under the proposed business model, we delineate the new process of applying for the RTS system and propose changes to the existing application process. In the new proposed business

model, the residential consumer applies for RTS system on State Utility Portal. A dedicated online web portal is available for all new applications filled by residential consumers. The online web portal for application submission is created and managed by local state DISCOM. The application process is governed by state regulations. In the proposed business model, we are leveraging on the fact that the first important part of improving efficiency is by bringing changes to the current system and processes. In the proposed business model, the online web portal is maintained by an Information technology (IT) expert team which is part of local DISCOM. The business model helps generate employment and training among the existing staff.

In the next steps of the application process- The technical team monitors application and provides the necessary information of current applicant who is a residential consumer to both the technical departments in DISCOM and SNA. Since the proposed business model anchors a two-way flow of information between two state government agencies which receives the consumers information at the same time This leads to efficiency in process while saving time and resources. The DISCOM and SNA work together to analyze the consumers' information such as system size, available roof space, sanctioned load, local grid availability, payment terms. The application process is smooth and decisions from technical teams are available in one place, which is helpful in saving resources and time.

Role of DISCOM and SNA

The state utility companies in India are facing challenges in terms of revenue erosion from paying customers and other operational challenges with regards to load distribution, grid availability and skilled manpower. To overcome these issues, the new business model framework suggests that the role of utilities needs to be minimized up to a point where they are just providing data for consumers connected load, feasibility analysis of consumer premises and they provide the access to the

grid network for connecting their rooftop systems. Once the data of consumers is shared with the service providers, utilities' tasks are reduced until final approvals are provided for billing of net metering electricity. In the proposed business model, the DISCOM and SNA agencies work together by sharing resources and help to generate employment. The faster decision favors the consumers by reducing the installation time of RTS system. The DISCOM company performs feasibility study of the premises where consumer decided to install the system, it studies the connected load of the premise and check on the net metering conditions. While the State Nodal Agency provides details of subsidy grants which the consumer can avail based on state current policies.

In the research conducted to arrive at the structure of business model framework, the key focus is to create an ecosystem which enables all stakeholders to work cohesively in a sustainable environment. The environment is dynamic since policies, regulations, and system integration changes over time; hence the business model incorporates these elements to sustain.

Service cum EPC provider selection

In the current OPEX model, the consumer can avail the benefit of green power consumption without paying the upfront cost. Also, the consumer who installs RTS system realizes savings in energy bill. The requirement of the residential consumer market in today's time is engaging with system suppliers who shall provide full services such as customized packages, arrange for the permits/ approvals, install the system, and monitor its performance and mainly carry out maintenance and services as per requirement. Based on factor analysis and expert opinion, technical knowledge by utility and service provider; expert and skilled staff; turnkey solutions; after care services; suppliers with technical, marketing and project related knowledge; and banks and investors willing to provide loans; are key partners required for successful RTS installation process.

The role of DISCOM and SNA is established based on expert opinion which helps eliminate the long process of application and improves efficiency. The prime focus of proposed business model is creating environment for Product Service System Approach in the installation process of RTS system. The business model construct is based on the idea of selling services along with the product. Hence the role of service cum EPC provider is key to the model success. In India, The Service cum EPC provider under state government regulations for installing RTS system is selected through process of government led empanelment program which is led by the Nodal Agencies of each state. The process of selection of companies depends on regulations existing during the time of empanelment. The list of service providers cum EPC contractors are extensive.

There is no change suggested in the proposed business model except for the consumer gets the list of all service cum EPC providers in their areas from state nodal agency. The consumer decides on their system integrator based on comparison on key elements such as system price offered, service package which includes maintenance, inventory stock, and ratings. The system providers are rated based on their services as pre and post installers by existing consumers, which becomes part of their portfolio. The consumers' decision of choosing the provider is smooth since they have all information required to select its system contractor through state agencies This structure of business model enables a competitive environment for system integrators and pricing mechanism is eliminates the risk of price monotony.

Dedicated Sales Agent

Based on the business model research advancements, the sustainability of any business model depends on growth of the business pertaining to it. Currently, the residential consumers market in India is growing at very slow pace. While there is tremendous potential in the market, the slow growth is a concern. The role of business model innovation is to capture the value and access the risks. The consumer is a stakeholder whose decision to install RTS system impacts the other stakeholders of the business model. The customer needs and satisfaction guarantee the sale of product, but the question arises about sustainability of the model.

The Product Service System approach incorporated in the proposed business model brings more value to the product than just its selling. It is required to work to capture the mass and not just few customers. In the proposed business model, the service provider's role has been very detailed and prime. The service providers' company which is selected by the consumer as system integrator, allocates a dedicated sales representative who is a single point contact for all consumers' needs. The sales representative enables an ecosystem which enables flow of information between all stakeholders involved the model DISCOM, SNA, consumer, supplier, and external agency such as bank. The agent is a salesperson whose services are dedicated to streamlining the installation process. The dedicated sales representative is a trained technician who works with consumer to design a customize RTS system, contacts DISCOM for necessary approvals, provides information to State Nodal Agencies and coordinates with all other stakeholder for efficient installation process. Once the system is installed and connected to the grid, the consumer signs a service contract with EPC provider. The business model helps create value by providing skilled staff, trained technicians, value added to the product sold and capturing the customized need of the consumer. It brings added elements of services along with sale of product. Capturing the mass market requires that the business model innovation is much more than the discovery of a new strategy. It is also important

that the existing products and services are redefined and not just discover new products, they simply redefine what an existing service is and how it is useful to the end consumer. In the proposed business model, the residential consumer purchases products along with services. The Product service system approach focuses on building sustainable business models which provide more than just product but also long-term sustainability. The consumers' installs a product (RTS) because of its benefits such as producing renewable energy, utilizing vacant roof space, and savings in electricity cost through net metering, while also getting services are part of the package to make the business model more attractive and sustainable. In the current business model, the generation of revenue is at each step. The revenue generation is through installation of rooftop solar system, signing contracts for maintenance packages, subsidy schemes by government and loans for system provided by banks.

The researchers have also approached to the solar industry and shared the proposed business model and its recommendations with the companies working for grid connected solar system in India. In this regard the researchers approached S&S Energy Systems who operate as Grid connected rooftop solar system installers and consultants for end to end conventional and non-conventional energy services. S&S Energy Systems connects with their customers by providing them with customized solutions to their home needs. They incorporate sustainable models by creating value for full solutions for their customers.

The company's senior strategy team leaders agreed to incorporate the proposed model to improve upon the issues which the company was facing for residential rooftop solar solutions business. They tested and implemented the proposed business model on a sample basis and found positive outcomes in their strategy. This helped them mitigate challenges while keeping their customers happy and increased demand from customers. The company has issued a letter to validate the proposed business model (Annexure F).

CHAPTER 7

CONCLUSION

The suggestive framework chapter six discussed above recommends the new business model for successful deployment of RTS in India. In the present chapter, the conclusion of the research study is presented in detail. Concluding the study helps us to summarize the main area of research, suggestions for improvement in the present study and speculation of future scope of work for other researchers.

The chapter conclusion is divided into four parts; part one highlights the contribution to literature, part two investigates the limitation of the research study, part three evaluates the future scope of work and finally part four concludes the present research study by giving the final comments.

7.1 CONTRIBIUTION TO LITERATURE

The present research contributes by way of recommending new business model using Product Service System (PSS) approach for addressing the challenges faced by stakeholders in deployment of grid connected rooftop solar system market for residential consumers in India. At present, the existing business model for RTS in India does not provide insights on product service system approach of business model designing. The approach of Product-Service System is a promising business strategy, which can achieve sustainability goal, which is the first step for Indian government through deployment of solar systems. International experience indicates that regulatory and administrative challenges need to be addressed to

allow each involved stakeholder to participate in the market transition from nascent to mature stage. The above study addresses business model development in service context, focusing mainly on selling products along with services to the consumer. Rooftop solar systems connected to the grid from service perspective has not been studied in Indian context. The existing business model lacks the service component which is required for market evolution and for consumers to have trust in the market. In the context of present research on RTS business models, various literature studies highlighted the issues in policy formulations and regulatory challenges.

From the literature it was found out that there are various factors which are affecting the growth of residential sector and some of the factors have been studied in isolation. For instance, the pre-dominant view emerging from the literature survey is that lack of upfront finances from installing rooftop solar systems on consumers premises is hindering the growth in deployment of such systems. Again, there is literature that present data and statistics to establish that the consumers are not showing keen interest and the adoption is low in areas where utility tariff is lower than solar tariff. However, most of these research and suggestions stand alone and do not necessarily examine the factors in totality. This study has brought out comprehensive research on all possible factors responsible for the present state of rooftop solar PV market in India for residential consumers.

The research started with understanding of factors based on literature and went on to validate them by engaging with stakeholders through questionnaire. The study then analyzed the behavior of important stakeholders like consumers, service providers, utilities, state nodal agencies and investors to reinforce the understanding of the factors. This brought a 360-degree view of the problem at hand. Subsequently, comparison of business models with international experience with focus on five countries - USA, Japan, Australia, Spain, and Germany was done to

identify the gaps in the Indian rooftop solar business models. The gaps so identified were further validated through survey of opinion of experts in the field. Based on such a detailed process of identification of factors and analysis, the study has proposed a business model which provides a robust platform for all major stakeholders. The recommendations define the steps required to be undertaken for growth of rooftop solar PV market in India.

The way forward suggested in the present research would be a real aid to policy making on formulations of future business models on solar energy deployment. This research would provide a theoretical construct of how effectiveness of alternative available generation solutions should be explored and understood before policy decision. The research also at the same time seeks to contribute to management practices by involving Product Service System approach to the business model and it is expected to enhance knowledge in emerging field of sustainable development.

7.2 LIMITATIONS OF THE STUDY

In the following research study, the findings are limited to the various factors affecting the market growth of rooftop solar in India. Based on benchmarking of the rooftop business model with international experiences from countries like USA, Spain, Japan, Australia and Germany, the researcher has suggested new business model as a way forward for residential consumers in India. The suggested business model is based on Product Service System (PSS) approach, since the concept of PSS approach is new, data availability for solar business models based on PSS concept was a constraint. The PSS approach is successful in many industrial and manufacturing products, especially for sustainability, but rooftop solar business model is yet to be studied in detailed.

The rooftop solar market is still at growing stage and hence the data on sustainability of RTS systems was unavailable. As such, details in terms of financial arrangements, utility involvement, implementation challenges are also limited in number. Equally challenging was lack of awareness amongst residential consumers about new policies and new market-based instrument for promotion of grid connected rooftop solar plants floated by the central and state government agencies in India. This posed a challenge to the process of collection of responses from stakeholders on the questionnaire framed for seeking opinion. Since the system installations were done very recently, the full impact of solar generation could not be assessed and hence the answers from survey were debatable. Another limitation was in terms of influence of external factors on the policy framework for residential rooftop solar market in India.

7.3 FUTURE SCOPE OF WORK

As has been highlighted in the Theoretical Contribution, the degree and extent of inter-relationship among factors responsible for present situation of rooftop solar systems on residential buildings in India has not been covered due to limitations of scope of the present study. It would be an interesting future scope of research. In course of the research, the researcher realized that the external factors, especially those relating to implementation of systems and grid performance, unless addressed adequately can pose a challenge to the efforts on promoting renewable technology in India. However, this was beyond the scope of the present proposition of the research.

The research reveals that that business model innovation for installing rooftop systems on residential buildings and its impact on grid could make a good case for

future research. In the present study, the Product Service System approach has been recommended as one of the desirable business model components. However, the detail analysis of the impact of Product Service System approach on business models is a topic fit for separate research. Several issues need to be examined and evaluated before this can be implemented such as availability of government subsidies; grants and up till what levels; residential, commercial, and industrial, local DISCOMS/ utility's performance (financial and operational) after systems is installed; local grid availability to sustain RTS loads; wear and tear of the local grids; availability of manufactured solar products in India; the logistics and special permits requirements. The study of residential rooftop consumers post installation of RTS on vacant rooftop is also required to be undertaken in detail to understand the long-term benefits of solar generation and savings thereafter. In the course of the research, discussions on future possible business models and its sustainability were discussed and studied. The renewable energy deployment helps in reducing carbon footprints which is a broader area of research. This aspect has not been studied in the present study.

7.4 CONCLUSION

The main purpose of adopting renewable energy technology in India is due to urgent requirement of bringing the carbon emissions to very low levels, and this is one of the many efforts the country must make. Reducing dependency on fossil-based technology and transitioning into zero emission technology is the new norm. The positive take is that in country like India, there is an immense scope for growth in solar market due to various reasons as discussed in the study.

The idea of sustainability has attracted all the stakeholders and has brought the focus on technologies which are easily available in the country, and rooftop solar systems fit best into the infrastructure of the country. However, there is a need to

relook into the business models created by companies, investors and policy makers which will help in the growth of eco-friendly and zero emission technology to evolve in the country. With this objective in mind, rooftop solar systems are promising solutions for technology shift in the process of electricity generation.

Because of the decrease in price of solar panels over the years, RTS technology has attracted mass attention and has created opportunities for all stakeholders. With breakthrough government support and focus on new policies and schemes, the RTS market has witnessed a significant transformation. Progress has reached a stage where many states in the country have taken quick steps to encourage solar generation in many forms. The net/ gross metering regulations, advertising of solar policy, online process to ease out approvals has been streamlined to achieved set renewable targets. The better utilization of roof spaces and interest from consumers to produce green energy on their vacant roofs has helped in increase demand of RTS systems in India.

Overall, it can be concluded that various initiatives from central and state schemes have been successful in bringing positive change in deployment of solar technology, however small RTS segment for residential consumers has yet to take off in the country.

BIBLIOGRAPHY

Abdulai, R. T., & Owusu-Ansah, A. (2014). Essential ingredients of a good research proposal for undergraduate and postgraduate students in the social sciences. *SAGE Open, 4(3),* 1–15. https://doi.org/10.1177/2158244014548178

Andale, G. (2012). Hypothesis Testing, other Distributions Sample Size. Retrieved, April 14th, 2017, from http://www.statisticshow to.com

Agarwal, S., Mani, S., Jain, A., & Ganesan, K. (2020). State of Electricity Access in India. *Council on Energy, Environment and Water,* (October).

Al-Saqlawi, J., Madani, K., & Dowell, N. Mac. (2017). Residential Roof-Top Solar PV Systems: Techno-Economic Feasibility and Enviro-Economic Impacts.

Alhaj, M. (2017). Implementation of Rooftop Solar PV in Qatar through the Roof Rental Business Model. *Modern Environmental Science and Engineering, 3(02),* 115–122. https://doi.org/10.15341/mese(2333-2581)/02.03.2017/006

Amala Devi, U. N. & T. M. (2018). Here Comes the Sun: Residential Consumers' Experiences With Rooftop Solar Pv in Five Indian Cities. Retrieved from https://shaktifoundation.in/wp-content/uploads/2018/11/Here-Comes-the-Sun.pdf

Anand, G., & Kodali, R. (2008). Benchmarking the benchmarking models. *Benchmarking, 15(3),* 257–291. https://doi.org/10.1108/14635770810876593

APPA. (2012). Estudio del Impacto Macroeconómico de las Energías Renovables en España. Appa, 144. Retrieved from http://www.appa.es/descargas/Informe_2012_Web.pdf

Bairiganjan, S., Cheung, R., Delio, E. A., Fuente, D., Lall, S., & Singh, S. (n.d.). POWER TO THE PEOPLE Investing in Clean Energy for the Base of the Pyramid in India.

Barquet, A. P. B., de Oliveira, M. G., Amigo, C. R., Cunha, V. P., & Rozenfeld, H. (2013). Employing the business model concept to support the adoption of product–service systems (PSS). *Industrial Marketing Management, 42(5),* 693–704. https://doi.org/https://doi.org/10.1016/j.indmarman.2013.05.003

Bazán, J., Rieradevall, J., Gabarrell, X., & Vázquez-Rowe, I. (2018). Low-carbon electricity production through the implementation of photovoltaic panels in rooftops in urban environments: A case study for three cities in Peru. *Science of TheTotalEnvironment*,622–623,1448–1462. https://doi.org/10.1016/J.SCITOTENV.2017.12.003

Behuria, P. (2020a). The politics of late late development in renewable energy sectors: Dependency and contradictory tensions in India's National Solar Mission. *WorldDevelopment,126,* 104726. https://doi.org/10.1016/j.worlddev.2019.104726

Bianchi, N. P., Evans, S., Revetria, R., & Tonelli, F. (n.d.). Influencing Factors of Successful Transitions towards Product-Service Systems: a Simulation Approach.

Biswas, W. K., Bryce, P., & Diesendorf, M. (2001). Model for empowering rural poor through renewable energy technologies in Bangladesh. *Environmental Science & Policy, 4(6),* 333–344. https://doi.org/https://doi.org/10.1016/S1462-9011(01)00031-4

BTI. (2020). Bridge to India. Indian Rooftop Solar Map 2020, *Bridge to India Report.* https://bridgetoindia.com/report/india-solar-rooftop-map-june-2020/

Buesing, B., & Yang, M. (2013). Business Model for Local Distribution Companies to Promote Renewable Energy. *Low Carbon Economy, 04(04)*, 41–54. https://doi.org/10.4236/lce.2013.44a005

Büsgen, U., & Dürrschmidt, W. (2009). The expansion of electricity generation from renewable energies in Germany: A review based on the Renewable Energy Sources Act Progress Report 2007 and the new German feed-in legislation. *Energy Policy*,37(7),2536–2545, https://doi.org/https://doi.org/10.1016/j.enpol.2008.10.048

Bustinza, O. F., Gomes, E., Vendrell-Herrero, F., & Baines, T. (2019). Product–service innovation and performance: the role of collaborative partnerships and R&D intensity. R and D Management (Vol. 49). *Blackwell Publishing Ltd.* https://doi.org/10.1111/radm.12269

Camp, R. C. (1989). Benchmarking: the search for industry best practices that lead to superior performance. Asq Press.

Cattell, R. B. (1973). Personality and mood by questionnaire. Personality and mood by questionnaire. Oxford, England: Jossey-Bass.

CCPI. (2020). Climate Change Performance Index Results 2020. *Germanwatch, New Climate Institute & Climate Action Network.* www.germanwatch.org/de/17281

Central Electricity Authority. (2019). *CEA Annual Report 2018-19.* Annual Report. Retrieved from www.cea.nic.in

Chaianong, A., & Pharino, C. (2015). Outlook and challenges for promoting solar

photovoltaic rooftops in Thailand. R*enewable and Sustainable Energy Reviews*, 48, 356–372. https://doi.org/10.1016/J.RSER.2015.04.042

Chunhachoti-Ananta, S., Tongsopit, S., & Sugiyama, N. (2017). A Review of Business Models for Distributed Solar Power Deployment in the U.S. and Japan: *Lessons and Prospects for Thailand.* https://doi.org/10.13140/RG.2.2.26120.83202

Dalkey, N., & Helmer, O. (1963). An Experimental Application of the DELPHI Method to the Use of Experts. *Management Science, 9(3)*, 458–467. https://doi.org/10.1287/mnsc.9.3.458
Delhi, N. E. W. (2021). ADB, pp. 2020–2021.

Dey, D. (2013). India's Solar Energy Mission - Major Challenges. *SSRN*. https://doi.org/10.2139/ssrn.2363939

Dondariya, C., Porwal, D., Awasthi, A., Shukla, A. K., Sudhakar, K., S.R., M. M., & Bhimte, A. (2018). Performance simulation of grid-connected rooftop solar PV system for small households: A case study of Ujjain, India. *Energy Reports, 4*, 546–553. https://doi.org/10.1016/J.EGYR.2018.08.002

Elmuti, D., & Kathawala, Y. (n.d.). An overview of benchmarking process: a tool for continuous improvement and competitive advantage. Retrieved from http://www.utsi.com/wbp/reengineering/

Emili, S., Ceschin, F., & Harrison, D. (2016). Product-Service System applied to Distributed Renewable Energy: A classification system, 15 archetypal models and a strategic design tool. *Energy for Sustainable Development*, 32, 71–98. https://doi.org/10.1016/j.esd.2016.03.004

Energy Sector Management Assistance Program. (2010). Report on Barriers For

Solar Power Development in India, 8–23. Retrieved from http://www.esmap.org/sites/esmap.org/files/*The World Bank_Barriers for Solar Power Development in India Report_FINAL.pdf*

Fina, B., Fleischhacker, A., Auer, H., & Lettner, G. (2018). Economic Assessment and Business Models of Rooftop Photovoltaic Systems in Multiapartment Buildings: Case Studies for Austria and Germany. *Journal of Renewable Energy*, 2018, 1–16. https://doi.org/10.1155/2018/9759680

Frederking, T. H. K. (2016). Peak heat flux and temperature difference. Nrel, (January), 82. https://doi.org/https://www.nrel.gov/docs/fy16osti/65298.pdf

Frey, F. (2017, November 7). SPSS (Software). *The International Encyclopedia of Communication Research Method*s. https://doi.org/https://doi.org/10.1002/9781118901731.iecrm0237

Fritsche, U. R., Henneberg, K., Hünecke, K., Thrän, D., Witt, J., Hennig, C., & Rensberg, N. (2009). *IEA Bioenergy Task 40: Country Report Germany*, 1–52.

Gajjar, J., Raizada, S., Kumar, V., Abraham, N., & Ghosh, S. (2019). Economic effect of rooftop photovoltaic penetration on retail rates of bangalore electricity supply company. *International Journal of Energy Economics and Policy, 9(1)*, 336–345. https://doi.org/10.32479/ijeep.6036

Galvan, J. L., & Galvan, M. C. (2017). Writing Literature Reviews: A Guide for Students of the Social and Behavioral Sciences. *Taylor & Francis.* Retrieved from https://books.google.com/books?id=YTUlDwAAQBAJ

Gao, X., & Rai, V. (n.d.). Local Demand-Pull Policy and Energy Innovation: Evidence from the Solar Photovoltaic Market in China. Retrieved from

https://ssrn.com/abstract=3127052

García-Alvarez, M. T., & Mariz-Pérez, R. M. (2012). Analysis of the Success of Feed-in Tariff for Renewable Energy Promotion Mechanism in the EU: Lessons from Germany and Spain. *Procedia - Social and Behavioral Sciences*, 65, 52–57. https://doi.org/10.1016/j.sbspro.2012.11.090

Geddes, A., Schmidt, T. S., & Steffen, B. (2018). The multiple roles of state investment banks in low-carbon energy finance: An analysis of Australia, the UK and Germany. *Energy Policy*, 115(August 2017), 158–170. https://doi.org/10.1016/j.enpol.2018.01.009

Ginsberg, M. (2018, January 1). Solar Power in the USA—Status and Outlook. A Comprehensive *Guide to Solar Energy Systems*, 53–80. https://doi.org/10.1016/B978-0-12-811479-7.00004-X

GIZ. (2016). Indian Rooftop Solar Photovoltaic Landscape-Business Models & Opportunities Content Rationale for Promoting Rooftop Solar Photovoltaic Projects Business Models & Opportunities Regulatory Aspects Status of Policy/Regulations in States Content.

Goel, M. (2016). Solar rooftop in India: Policies, challenges and outlook. *Green Energy & Environment.* https://doi.org/10.1016/j.gee.2016.08.003

Goldman, D. P., Mckenna, J., & Murphy, L. (2005). Financing Projects That Use Clean-Energy Technologies: An Overview of Barriers and Opportunities. *National Renewable Energy Laboratory, (October).*

Government of India, Central Eectricity Authority, M. of power. (2021). All India Installed Capacity (in MW) of Power Stations (As on 31-01-2021). *Central*

Eectricity Authority, Ministry of Power, 4, 1–7. Retrieved from http://www.cea.nic.in/reports/monthly/installedcapacity 2016 / installed_capacity-03.pdf

Government of India,Central Eectricity Authority, M. of power. (2020). All India Installed Capacity (in Mw) of Power Stations Installed Capacity (in Mw) of Power Utilities in the States / Uts Located in. *Central Eectricity Authority, Ministry ofpower(Vol.4)*.https://doi.org/http://www.cea.nic.in/reports/monthly/installedcapacity 2016 / installed_capacity-03.pdf

Hahn, E., & Fellow, R. (2014). The Japanese Solar PV Market and Industry-Business Opportunities for European Companies.

Hairat, M. K., & Ghosh, S. (2017a). 100 GW solar power in India by 2022 – A critical review. *Renewable and Sustainable Energy Reviews*, 73, 1041–1050. https://doi.org/10.1016/J.RSER.2017.02.012

Hairat, M. K., & Ghosh, S. (2017b). 100 GW solar power in India by 2022 – A critical review. R*enewable and Sustainable Energy Reviews*, 73, 1041–1050. https://doi.org/10.1016/J.RSER.2017.02.012

Hamwi, M., & Lizarralde, I. (2017). A Review of Business Models towards Service-Oriented Electricity Systems. *Procedia CIRP*, 64, 109–114. https://doi.org/10.1016/J.PROCIR.2017.03.032

Harrison, H., Birks, M., Franklin, R., & Mills, J. (2017). Case study research: Foundations and methodological orientations. *Forum Qualitative Sozialforschung*, 18(1). https://doi.org/10.17169/fqs-18.1.2655

Hoggett, R. (2014). Technology scale and supply chains in a secure, affordable and

low carbon energy transition. *Applied Energy, 123*, 296–306. https://doi.org/10.1016/j.apenergy.2013.12.006

Horváth, D., & Szabó, R. Z. (2018). Evolution of photovoltaic business models: Overcoming the main barriers of distributed energy deployment. R*enewable and Sustainable Energy Reviews, 90,* 623–635.https://doi.org/10.1016/J.RSER.2018.03.101

Hosenuzzaman, M., Rahim, N. A., Selvaraj, J., Hasanuzzaman, M., Malek, A. B. M. A., & Nahar, A. (2015). Global prospects, progress, policies, and environmental impact of solar photovoltaic power generation. *Renewable and Sustainable Energy Reviews, 41*, 284–297. https://doi.org/https://doi.org/10.1016/j.rser.2014.08.046

Howard, L., Tim, B., & Palie, S. (2013). The servitization of manufacturing: A systematic literature review of interdependent trends. *International Journal of Operations & Production Management, 33(11/12)*, 1408–1434. https://doi.org/10.1108/IJOPM-07-2010-0196

Huijben, J. C. C. M., & Verbong, G. P. J. (2013). Breakthrough without subsidies? PV business model experiments in the Netherlands. *Energy Policy, 56*, 362–370. https://doi.org/10.1016/J.ENPOL.2012.12.073

IBEF. (2020). *Indian Brand Equity Foundation.*Annual Report 2019-2020. www.ibef.org

IEA-Pvp. (2020). Snapshot of Global PV Markets 2020. *Www.Iea-Pvps.Org.* Retrievedfromhttp://www.ieapvps.org/fileadmin/dam/public/report/technical/PVPS_report__A_Snapshot_of_Global_PV_-_1992-2014.pdf

India, I. (2019). IEEFA. Institute for Energy Economics and Financial

Analysis.Vast Potential of Solar Rooftop in India. www.ieefa.org

Isaac, S., & Michael, W. B. (1995). Handbook in research and evaluation: A collection of principles, methods, and strategies useful in the planning, design, and evaluation of studies in education and the behavioral sciences, 3rd ed. *Handbook in research and evaluation: A collection of principles, methods, and strategies useful in the planning, design, and evaluation of studies in education and the behavioral sciences, 3rd ed*. San Diego, CA, US: EdITS Publishers.

Jacobsson, S., Sandén, B. A., & Bångens, L. (2004). Transforming the energy system-the evolution of the German technological system for solar cells. *Technology Analysis and Strategic Management, 16(1*), 3–30. https://doi.org/10.1080/0953732032000199061

James, T., Feldman, D., & Margolis DOE -Solar Program Washington, R. (2013). Japan's Solar Photovoltaic (PV) Market: An Analysis of Residential System Prices (Presentation), *NREL (National Renewable Energy Laboratory)*. Retrieved from http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=2&pid=27&aid=12&cid=r1,&syid=1990&eyid=2011&unit=BKWH.

Jha, A., & Leslie, G. (2020). Dynamic Costs and Market Power: Rooftop Solar Penetration in Western Australia. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3603627

Joshi, A., Kale, S., Chandel, S., & Pal, D. (2015). Likert Scale: Explored and Explained. *British Journal of Applied Science & Technology*, 7(4), 396–403. https://doi.org/10.9734/bjast/2015/14975

Kappagantu, R., Daniel, S. A., & Venkatesh, M. (2015). Analysis of Rooftop Solar

PV System Implementation Barrier in Puducherry Smart Grid Pilot Project. *ProcediaTechnology*,*21*,490–497. https://doi.org/10.1016/J.PROTCY.2015.10.033

Kar, S. K., Sharma, A., & Roy, B. (2016). Solar energy market developments in India. *Renewable and Sustainable Energy Reviews*, 62, 121–133. https://doi.org/10.1016/J.RSER.2016.04.043

Kazi, A. M., & Khalid, W. (2012). Questionnaire designing and validation Introduction and Objectives. *Journal of the Pakistan Medical Association*, 62(May).

Khanna, J. R., Magal, A., Karandikar, A., & Awalikar, A. (n.d.). *Best Practices Manual for Implementation of State-level Rooftop Solar Photovoltaic Programmes in India About.*

Kobashi, T., & Yarime, M. (2019). Techno-economic assessment of the residential photovoltaic systems integrated with electric vehicles: A case study of Japanese households towards 2030. *Energy Procedia*, *158(2018)*, 3802–3807. https://doi.org/10.1016/j.egypro.2019.01.873

Kollins, K., Speer, B., & Cory, K. (2010). *Solar PV Project Financing* : Regulatory and Legislative Challenges for Third-Party PPA. Contract, (February), 1–43.

Langham, E. (2013). Institute for Sustainable futures virtual Net Metering in Australia; *OPPORTUNITIES & BARRIERS*. Retrieved from www.isf.uts.edu.au

Li, Y., & Liu, C. (2017). Estimating solar energy potentials on pitched roofs. *EnergyandBuildings*,*139*,*101–107.* https://doi.org/10.1016/J.ENBUILD.2016.12.070

Lipiak, J., Kulesza, R., & Salwin, M. (2019). Product-service system - a literature review. *Research in Logistics & Production,* 9(1), 5. https://doi.org/10.21008/j.2083-4950.2019.9.1.1

Lopez, A., Roberts, B., Heimiller, D., Blair, N., & Porro, G. (2012). U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis. *National Renewable Energy Laboratory Document,* 1(7), 1–40. https://doi.org/NREL/TP-6A20-51946

Maleki, E., Belkadi, F., & Bernard, A. (2018). A Meta-model for Product-Service System based on Systems Engineering approach. *Procedia CIRP*, 73, 39–44. https://doi.org/10.1016/j.procir.2018.04.016

Manju, S., & Sagar, N. (2017a). Progressing towards the development of sustainable energy: A critical review on the current status, applications, developmental barriers and prospects of solar photovoltaic systems in India. *Renewable and Sustainable Energy Reviews,* 70, 298–313. https://doi.org/10.1016/J.RSER.2016.11.226

Manju, S., & Sagar, N. (2017b). Progressing towards the development of sustainable energy: A critical review on the current status, applications, developmental barriers and prospects of solar photovoltaic systems in India. *Renewable and Sustainable Energy Reviews*, 70(August 2015), 298–313. https://doi.org/10.1016/j.rser.2016.11.226

Margaret Diane LeCompte, M. A., & Schensul, J. J. (1999). *Analyzing & Interpreting Ethnographic Data. AltaMira Press.* Retrieved from https://books.google.com/books?id=_Rdq3PO_9PAC

Margolis, R., & Zuboy, J. (2006). Nontechnical Barriers to Solar Energy Use: Review of Recent Literature. *National Renewable Energy Laboratory, NREL/TP*-52(September), 1–30. https://doi.org/10.2172/893639

Marques, P., Cunha, P. F., Valente, F., & Leitão, A. (2013). A methodology for product-service systems development. *Procedia CIRP*. https://doi.org/10.1016/j.procir.2013.06.001

Matisoff, D. C., & Johnson, E. P. (2017). The comparative effectiveness of residential solar incentives. *Energy Policy, 108,* 44–54. https://doi.org/10.1016/J.ENPOL.2017.05.032

Meiklejohn, D., Bekessy, S., & Moloney, S. (2018). Shifting practices: How the rise of rooftop solar PV has changed local government community engagement. *Cogent Environmental Science, 4(1).* https://doi.org/10.1080/23311843.2018.1481584

Ministry of New and Renewable Energy; USAID; GERMI. (2016). *National Solar Mission Best Practices Guide*, (June), 60. Retrieved from https://mnre.gov.in/file-manager/UserFiles/Best-Practices-Guide-on-State-Level-Solar-Rooftop-Photovoltaic-Programs.pdf

Ministry of New and Renewable Energy. (2017). C*oncept Note on SRISTI* (Sustainable Rooftop Implementation for Solar Transfiguration of India), (December). Retrieved from https://mnre.gov.in/file-manager/UserFiles/comments-on_RTS.pdf

MNRE. (2015). Ministry of New and Renewable Energy, *Report of the export group on 175 GW RE by 2022. NITI Aayog.* https://mnre.gov.in

MNRE. (2018). *Ministry of New and Renewable Energy, Report. Overview. Annual Report.* https://mnre.gov.in

MNRE. (2019). *State {Rooftop} {Solar} {Attractiveness} {Index} ({SARAL}). SARAL Index*. Retrieved from pib.gov.in/Pressreleaseshare.aspx?PRID=1582543 https://mnre.gov.in

MNRE. (2020a). MNRE. (2020b). MNRE *Ministry of New and Renewable Energy, Report on Grid Connected Solar Pholovoltaic Capacity Addition.* https://mnre.gov.in

MNRE. (2021). *MNRE Ministry of New and Renewable Energy, Report on Grid Connected Solar Pholovoltaic Capacity Addition.* https://mnre.gov.in

Motocorp, H., & Energies, H. F. (2014). *Making Use of the Roof :* Employment Generation from Hero MotoCorp ' s 80 kW Rooftop Solar Project in Haryana India.

Narula, K., & Sudhakara Reddy, B. (2015). Will net metering model for residential roof top solar PV projects work in Delhi? A financial analysis. *International Journal of Renewable Energy Research, 5(2),* 341–353. https://doi.org/10.20508/ijrer.95132

NISE. (2013). NISA AR-18-19. National Institute of Solar. *Journal of Chemical Information and Modeling (Vol. 53).* https://doi.org/10.1017/CBO9781107415324.004

Noguchi, M. (2005). Japanese Manufacturers' "Cost-Performance" Marketing Strategy for the Delivery of Solar Photovoltaic Homes. *In Proceedings ISES 2005, Solar World Congress, Aug. 6-12, 2005, Orlando, USA*. Retrieved from

https://www.researchgate.net/publication/253367219

Osterwalder, A., Pigneur, Y., & Tucci, C. L. (2005). Clarifying Business Models: Origins, Present, and Future of the Concept. *Communications of the Association for Information Systems, 16(July)*. https://doi.org/10.17705/1cais.01601

Overholm, H. (2015). Spreading the rooftop revolution: What policies enable solar-as-a-service? *Energy Policy*, *84*, 69–79. https://doi.org/10.1016/J.ENPOL.2015.04.021

Palm, A. (2017). *Residential solar photovoltaics deployment: barriers and drivers in space.*

Parekh, A. P., & Modi, A. I. (2008). A Review of Renewable Energy Scenario in India. *International Research Journal of Engineering and Technology, 9001*. Retrieved from www.irjet.net

Pereira, V. R. (2013). *Product-service system – PSS : a study of business drivers, (JUNE).*

Pergande, B., Nobre, P. L. A., Nakanishi, A. C., Zancul, E. S., Loss, L., & Horta, L. C. (2012). Product-service system types and implementation approach. Leveraging Technology for a Sustainable World - *Proceedings of the 19th CIRP Conference on Life Cycle Engineering*, 43–48. https://doi.org/10.1007/978-3-642-29069-5_8

Philip, A. (2014). *Filling the Gaps: Rooftop Solar Projects in India (Vol. 49)*, Issue No. 10, 08 Mar, 2014 Annie. ISSN (Online) - 2349-8846

Pirayesh, A. E., Seregni, M., Doumeingts, G., Zanetti, C., Westphal, I., & Hans, C.

(n.d.). *A Conceptual Model for Product Service System (PSS).* https://doi.org/10.20944/preprints201802.0079.v1

Quirós, E., Pozo, M., & Ceballos, J. (2018). Solar potential of rooftops in cáceres city, spain. *Journal of Maps, 14(1),* 44–51. https://doi.org/10.1080/17445647.2018.1456487

Rai, V., & Zarnikau, J. (n.d.). *The Report Committee for Chihiro Takeda Government Policy and Innovation Activity:* A Patent Study of Solar Photovoltaic Balance of System in Japan APPROVED BY SUPERVISING COMMITTEE.

Ram, M., Abhishek Pratap, G., Anand Prabhu Pathanjali, G., & Abhishek Pratap, M. (2013). Rooftop Revolution: Unleashing Delhi's Solar Potential Rooftop Revolution: *Unleashing Delhi's Solar Potential AcknowleDgement*. Retrieved from http://www.greenpeace.org/india/Global/india/report/2013/Rooftop-Revolution.pdf

Ramalho1, M., Câmara, L., Pereira, G. I., Pereira Da Silva, P., & Dantas, G. (n.d.). *Photovoltaic energy diffusion through net-metering and feed-in tariff policies: learning from Germany, California, Japan and Brazil.*

Rogelio, O., & Robert, K. (2003). Managing the transition from products to services. *International Journal of Service Industry Management, 14(2),* 160–172. https://doi.org/10.1108/09564230310474138

Rohankar, N., Jain, A. K., Nangia, O. P., & Dwivedi, P. (2016). A study of existing solar power policy framework in India for viability of the solar projects perspective. *Renewable and Sustainable Energy Reviews, 56,* 510–518. https://doi.org/10.1016/J.RSER.2015.11.062

Rooftop Solar-Garnering Support from Distribution Utilities. (2016). *SHAKTI Sustainble Energy Foundation*. www.shatkifoundation.in

Sáez, C. A., & Requena, J. C. (2007). Reconciling sustainability and discounting in Cost–Benefit Analysis: A methodological proposal. *Ecological Economics, 60(4),* 712–725. https://doi.org/https://doi.org/10.1016/j.ecolecon.2006.05.002

Sahoo, S. K. (2016). Renewable and sustainable energy reviews solar photovoltaic energy progress in India: A review. *Renewable and Sustainable Energy Reviews.* https://doi.org/10.1016/j.rser.2016.01.049

Sahu, B. K. (2016). Solar energy developments, policies and future prospectus in the state of Odisha, India. *Renewable and Sustainable Energy Reviews, 61*, 526–536. https://doi.org/10.1016/J.RSER.2016.04.027

Salwin, M., Kraslawski, A., & Lipiak, J. (2020). State-of-the-Art in Product-Service System Design. *Lecture Notes in Mechanical Engineering*, 645–658. https://doi.org/10.1007/978-981-15-1910-9_53

Schmidt-Costa, J. R., Uriona-Maldonado, M., & Possamai, O. (2019). Product-service systems in solar PV deployment programs: What can we learn from the California Solar Initiative? *Resources, Conservation and Recycling, 140(August 2018)*, 145–157. https://doi.org/10.1016/j.resconrec.2018.09.017

Schmidt, T. S. (2014). *Low-carbon investment risks and de-risking*. Nature Climate Change, 4(4), 237–239. https://doi.org/10.1038/nclimate2112

Sharma, A. (2011a). A comprehensive study of solar power in India and World. *Renewable and Sustainable Energy Reviews.* https://doi.org/10.1016/j.rser.2010.12.017

Sharma, A. (2011b). A comprehensive study of solar power in India and World. *Renewable and Sustainable Energy Reviews*, 15(4), 1767–1776. https://doi.org/10.1016/j.rser.2010.12.017

Singla, S. (2018). *Rooftop Solar in India.PWC Report, Looking back, Looking ahead.* https://www.climateinvestmentfunds.org/knowledge-documents/rooftop-solar-india-looking-back-looking-ahead

Smart City; *Mission Statement & Guidelines. (2015). MoUD, (June).SNAs, P. order by. (2010).* Combined Summary of State Policies for - Solar Power Projects.

Sovacool, B. K. (2010). A comparative analysis of renewable electricity support mechanisms for Southeast Asia. *Energy, 35(4),* 1779–1793. https://doi.org/10.1016/j.energy.2009.12.030

Spieth, P., Schneckenberg, D., & Ricart, J. E. (2014). Business model innovation - state of the art and future challenges for the field. *R and D Management,* 44(3), 237–247. https://doi.org/10.1111/radm.12071

Srivastava, S. P., & Srivastava, S. P. (2013). Solar Energy and Its Future Role in Indian Economy. *International Journal of Environmental Science: Development andMonitoring,4(3),*81–88.Retrieved from https://www.ripublication.com/ijesdmspl/ijesdmv4n3_18.pdf

Steffen, B. (2020). Estimating the cost of capital for renewable energy projects. *Energy Economics, 88,* 104783. https://doi.org/10.1016/j.eneco.2020.104783

Sundaray, S., Mann, L., Bhattacharjee, U., Garud, S., & Tripathi, A. K. (2014a). *Reaching the sun with rooftop solar Ministry of New and Renewable Energy*

Government of India. Retrieved from www.teriin.org

Swanson, D. R., & Smalheiser, N. R. (1997). An interactive system for finding complementary literatures: a stimulus to scientific discovery. *Artificial Intelligence, 91(2)*, 183–203. https://doi.org/https://doi.org/10.1016/S0004-3702(97)00008-8

Tan, A. R., Mcaloone, T. C., & Gall, C. (n.d.). *Product/Service-System Development-An Explorative Case Study In A Manufacturing Company*. INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'07.

Tanesab, J., Parlevliet, D., Whale, J., & Urmee, T. (2018). Energy and economic losses caused by dust on residential photovoltaic (PV) systems deployed in different climate areas. *Renewable Energy, 120*, 401–412. https://doi.org/https://doi.org/10.1016/j.renene.2017.12.076

Tantisattayakul, T., & Kanchanapiya, P. (2017). Financial measures for promoting residential rooftop photovoltaics under a feed-in tariff framework in Thailand. *Energy Policy, 109*, 260–269. https://doi.org/10.1016/J.ENPOL.2017.06.061

Tarai, R. K., & Kale, P. (2018). Solar PV policy framework of Indian States: Overview, pitfalls, challenges, and improvements. *Renewable Energy Focus, 26(September 2018)*, 46–57. https://doi.org/10.1016/j.ref.2018.07.001

Tayal, D., & Rauland, V. (2017). Future business models for Western Australian electricity utilities. *Sustainable Energy Technologies and Assessments, 19*, 59–69. https://doi.org/10.1016/J.SETA.2016.11.007

Thompson1, A. W., Ny1, H., Lindahl1, P., Broman1, G., & Severinsson2, M. (n.d.). *Benefits of a Product Service System Approach for Long-life Products: The Case of Light Tubes.*

Trivedi, S., Ray, I., & Vulturius, G. (2018). A CPI, ICRIER, and SEI Report *Scaling up Rooftop Solar Power in India: The Potential of Solar Municipal Bonds 2 A CPI, ICRIER, and SEI Report Scaling up Rooftop Solar Power in India: The Potential of Solar Municipal Bonds.* Retrieved from www.climatepolicyinitiative.org

Trivedi, S., Ray, I., Vulturius, G., Goldar, A., Prakash, L., Sandeep, J., & Sagar, P. A. (2018). *Scaling up Rooftop Solar Power in India: The Potential of Municipal Solar Bonds.*

Tukker, A. (2004). Eight types of product-service system: Eight ways to sustainability? Experiences from suspronet. B*usiness Strategy and the Environment*. https://doi.org/10.1002/bse.414

Tyagi, V., Dwivedi, P., & Gupta, A. (n.d.). *Solar Rooftop PV Systems-markets, policies and future potential.*

USAID. (2016). White Paper on Gross Metering for Solar Rooftops in Karnataka.

Utterback, J. M., & Abernathy, W. J. (1975). *A dynamic model of process and product innovation. Omega, 3(6),* 639–656. https://doi.org/https://doi.org/10.1016/0305-0483(75)90068-7

Venkateswaran, J., Solanki, C. S., Werner, K., & Yadama, G. N. (2018). Addressing Energy Poverty in India: A systems perspective on the role of localization, affordability, and saturation in implementing solar technologies. *Energy Research and Social Science*, 40(February), 205–210. https://doi.org/10.1016/j.erss.2018.02.011

Vimpari, J., & Junnila, S. (2019). Estimating the diffusion of rooftop PVs: A real estate economics perspective. *Energy, 172,* 1087–1097.

https://doi.org/10.1016/j.energy.2019.02.049

Wasserbaur, R. (2018). Analysing interplays between PSS business models and governmental policies towards a circular economy. *Procedia CIRP*, 73, 130–136. https://doi.org/10.1016/J.PROCIR.2018.04.004

Webster, J., & Watson, R. T. (2002). *Analyzing the Past to Prepare for the Future:* Writing a Literature Review. MIS Quarterly, 26(2), xiii–xxiii. Retrieved from http://www.jstor.org/stable/4132319

Yannis, P., & Nikolaos, B. (2018). Quantitative and Qualitative Research in Business Technology: Justifying a Suitable Research Methodology. *Review of Integrative Business and Economics Research*, *7(1)*, 91–105. Retrieved from http://buscompress.com/journalhome.html%0Ahttps://search.proquest.com/docview/1969776018?accountid=10286&rfr_id=info%3Axri%2Fsid%3Aprimo

Yong, A. G. (2014). An exploratory study of factors affecting credit card brand and category selection in India. *Journal of Financial Services Marketing*, *19(3)*, 221–233. https://doi.org/10.1057/fsm.2014.17

Yousuf, M. I. (2007). *Using experts' opinions through Delphi technique.* Practical Assessment, Research and Evaluation, 12(4).

Zander, K. K., Simpson, G., Mathew, S., Nepal, R., & Garnett, S. T. (2019). Preferences for and potential impacts of financial incentives to install residential rooftop solar photovoltaic systems in Australia. *Journal of Cleaner Production*, *230*, 328–338. https://doi.org/https://doi.org/10.1016/j.jclepro.2019.05.133

Zott, C., Amit, R., & Massa, L. (2011). The Business Model: Recent Developments and Future Research. *Journal of Management*, *37(4)*, 1019–1042.

https://doi.org/10.1177/0149206311406265

APPENDICES

APPENDIX A: QUESTIONNAIRE SURVEY BASED ON LIKERT SCALE

1. All states should make the installation of Grid Connected RTS system mandatory on New Residential premises with connected load of 5KW and above:
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

2. Despite several initiatives by government for deployment of Grid-Connected rooftop systems, the adoption among residential consumers depends on ease of subsidy disbursement.
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

3. The Grid connected systems help in reduction of electricity costs, but residential consumers are encouraged by subsidies as incentives to install these systems.
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

4. Distribution Utilities play crucial role in success of Grid-Connected rooftop system market growth.
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

5. Lack of interconnection guidance for staff and adequate skilled personnel in Distribution Utilities leads to slow application and approval process.
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

6. Introduction of clear and detailed Metering regulations will significantly facilitate the growth of Grid-Connected rooftop systems in India.
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

7. Although many system providers are empaneled by state government, but Independent and reliable service providers are required for post installation experience and trust in market.
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

8. Adequate skilled manpower development for design, install and maintain the systems will reduce the burden of regulators in implementation process.
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

9. Availability of post installation O&M services and timely support from suppliers/vendors will lead to high paying tariff consumers opting for Grid-Connected rooftop systems.
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

10. Consumer awareness can be increased through advertisement and campaigns for better understanding of policies and process of installation of Grid-Connected RTS system.
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

11. Home improvement loans and ease of securing low interest bank loans would cover upfront solar system cost.
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

12. Rationalizing the online, single window clearance process for simple user-friendly interface of consumers with regulatory bodies needs to be developed for smooth process of installing systems.
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

13. Introduction of Innovative incentive schemes by government agencies would enable large scale deployment of Grid connected Rooftop systems on residential premises.
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

14. Installation of Grid Connected rooftop system on residential buildings would increase resale value of the house.
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

15. Elimination of government subsidies for installing rooftop systems on residential consumers would negatively impact the growth of rooftop sector.
    - Strongly agree.
    - Agree
    - Indifferent
    - Disagree
    - Strongly disagree.

APPENDIX B: QUESTIONNAIRE FOR EXPERT OPINION SURVEY

S. No.	QUESTIONS
1	Right Advertisement and campaign approach is required to reach residential audience and make them aware of RTS policies and schemes
2	Pre-defined financial assistance to be made available for consumers showing interest in RTS systems.
3	Availability of trained/expert staff from SNA/ DISCOMs side should be approachable to make residential consumers understand the scheme/policies and going forward procedure.
4	Online application portal for smooth application filing procedure to be made available for consumers to access.
5	To make the RTS scheme attractive and have mass acceptance, the government should provide rebates and tax incentives.
6	The empaneled suppliers and vendors list to be made available to consumers to choose their supplier.
7	Presence of retail sale and service network which is accessible to the consumers of RTS systems.
8	Reduction in the billing cycle for the adjustment of import/export of energy into the grid.
9	Impose of Renewable generation obligation (RGO) on multi story housing complexes and the residences having more than 10KW of connected load
10	Subsidy/Rebates disbursement procedures should be simple and time bound.

APPENDIX C: DETAILS OF THE EXPERT PANEL INTERVIEWED FOR EXPERT OPINION SURVEY

Experts	Designation	Department
1	SPE	SNA
2	CPO	SNA
3	Dy. CPO	SNA
4	EE	Utilities
5	CE (Commercial)	Utilities
6	EE	Utilities
7	Scientist	MNRE
8	Scientist	MNRE
9	Technical head	Albers
10	Director	Mittal
11	Consultants	Fidato consultants
12	Managing Partner	Ados Electronics
13	Manager	Tata solar power
14	Manager	Tata solar power
15	Senior Manager	Tata solar power
16	Senior Marketing Officer	Tata solar power
17	Vice President	Tata solar power
18	Associate Vice President	GMR Energy Trading
19	Sr. finance consultants	KPMG
20	Sr. Manager	Solar Solutions

APPENDIX D: BENCHMARKING OF THE RTS BUSINESS MODELS

Parameters	India	USA	JAPAN	Spain	Germany	Australia
Capacity Targets	By 2022, the solar rooftop installation target of 40 GW		63 GW by 2030 (cumulative installed capacity).	4669 MW solar PV installations by 2016.	PV Installations totaled 42 GW in 2017.	As of September 2018, Australia had over 10,131 MW of installed photovoltaic (PV) solar power.

Policy Enablers	Falling module cost, subsidy by government	There is a tremendous decline in solar price around 62.5 % over the years	As the result of the FIT arrangement, the RTS market segment is rapidly increasing. The residential market is the largest in the world.	Initial growth due to gov. policies and slowdown in the sector happened due to non-applicability of solar tax.	FIT arrangement and the reduction in solar prices are major reasons driving the RTS market.	Decreasing costs of solar systems and increasing prices of fossil fuels is anticipated to act as the opportunity to boost the industry growth over the forecast period.
Residential consu		The residential	Typical household	The residential segment	A typical household	

mer energy pattern		energy usage is 940 kWh/month (EIA 2013).	electricity consumption in Japan is about 300 kWh/month (Federation of Electric Power Companies 2013	consumes 2500-5000 kWh per year	ld has an annual power consumption of 3,900 kWh paid roughly 29,3 €-cts/kWh in 2016	
Business Models	CAPEX AND RESCO	The third-party ownership model has been attracting RTS market and driving the new	Few developments in leasing and PPA are occurring in the market, while FIT arrangement is not very famous.	Self-Financing model is common and it does not have a net metering (NM) or a net billing (NB) scheme.		

		expansion.				
Investment climate	Different for different states (50%-70%). Higher for special states categories.	Federal tax incentives, rebates, net-metering, renewable energy certificates, and feed-in tariff	Under the National cash subsidy program a cash subsidy for residential consumer was priced at $0.20/W is available for RTS systems		The producer can decide to sell its electricity in the market any period of time, instead of getting the fixed tariff. The producer receives an additional premium on top of the market price.	Supportive government policies and initiatives couple with increasing demand for solar systems mainly in residential applications is likely to surge the demand growth over

						the forecast period.
Metering arrangements	Net-metering, FITs		For the surplus power generate, a residential FIT of $0.40/kWh is given. The government targets a 3.2% annual return for system owners.	The exported energy fed into the grid does not get any cost benefits but the backup electricity charges are free for residential consumer.		In 2018, the Queensland government introduced the Affordable Energy Plan offering interest free loans for solar panels and solar storage in an effort to

						increase the uptake of solar energy in the state.
PV Manufacturing	Domestic modules for tax rebate	Since 2008, declining cost of solar modules and innovative business models have significantly expanded the residential rooftop solar installations in	Only 10% of modules are imported in Japan and most households install RTS using domestic brands. The domestic manufactured components and modules have standard technical			The price of photovoltaics has been decreasing, and in January 2013, was less than half the cost of using grid electricity in Australia

		the U.S, growing at an average annual rate of 55%	requirements.			
Bank Loans / Financing	Home improvement loans by banks, Third party financing	The financing of RTS projects id done through traditional method wherein Cash purchase is the least expensive option	Many local government bodies provide incentive for RTS installations. And in some cases the combination of national and local incentive are given sometimes in form of cash benefits			

			such as $500 per system.			
Cost of Capital		The capital expenditure for installing RTS is higher for residential consumer category. The major costs incurred are on site feasibility, supply chain, logistics, taxes, and	Very low cost of capital and bond of 10 year is about 0.7% which attracts PV as an investment option.	The residential segment consumes 2500-5000 kWh per year, electricity tariff 2.06, faces higher installation (€2.07 /Wp) and financing (6.71%) costs, and is able to self-consume a lower share of the total electricity	As the penetration of PV is more than 5 per cent of the electricity demand, the behavior of utilities can be seen as a mix of an opposition towards PV development and attempts	

		overhead costs, PV inverter and AC subsystem costs.		generated (33%)	to take part to the development of this new business.	
Challenges		The upfront cost of a PV system is significant and likely a barrier for most households. There are several financing options available to	Relatively small rooftop spaces compared to other countries. The cost of equipment is higher and the labor is not affordable	The main reasons for the decline were the 2008 economic crisis as well as a harsh regulatory environment for solar energy. In 2012 a moratorium for incentives for new renewabl	Spain has been known for its notorious "solar tax". The problem with the latter is that it taxes self-consumption PV installations even for the electricity they	

		homeowners who choose not to (or cannot) purchase a PV system with cash. interest rates are simple.		e energy installations was implemented.	produce for their own use and don't feed into the grid.	
PV system hardware		Generally lower PV equipment prices (buyer power).	Generally higher PV equipment prices (supplier power).			
Other Equipment		Most installers use ladders. The	System suppliers provide additional			

		additional equipment are installed to keep animals out of panel to avoid unnecessary damages.	materials to satisfy customer aesthetic request such as smoothing the corners of arrays. Few of the materials used are scaffolding as opposed to ladders.			
Taxes		Taxes often range from 0% to more than 7%.	Tax of 5% on all systems.		The tax on the sun, as Spain's royal decree (RD) 900/2015 was commonly	

					known, was actually a complex set of tolls and charges applied to grid-connected behind-the-meter distributed generation	
Approvals and time frame		The paper work takes approximately 3-10hours to finish, in some	The paper work takes less time than approval. The approval takes around 1-2 days.			

		cases electronic filing is not available. Many forms are not available online.	Mostly forms are available online to be filled.			
After Sale Services		Third-party companies are responsible for the operations of their systems; with customer-owned systems, service	The after sales representatives builds strong customer relationships by providing them with maintenance packages for around $100/per		In 2010, the top 10 system integrators in Germany were all German-based firms.153 German PV installers deliver	

		plans vary.	system. The consumer installing RTS on residential premises must obtain clearance certificate from Electrical utility in the country.		some of the lowest installed costs in the world in their home market	
Government support schemes and rebate plans		Homeowners have additional options for procuring solar energy via third-party	The model is similar to the Solar PPA model in the U.S. in that the developer installs and owns the		Spanish regulation is that a single installation is not allowed to supply electricity to several different	The Solar Homes and Communities Plan was a rebate provided by the Austral

		owners hip models, such as PPAs or solar leases, offered by multipl e local, regiona l, and national solar finance compan ies.	system and sells power to the site host. However, the differenc e lies in the source of fund. In addition to governm ent's source of fund, the company raised fund from individua ls who expect returns in dividends in 10-20 years. Surplus		end-consume rs, thus preventi ng installati ons in multi-family building s and hamperi ng the diffusio n of the technolo gy in urban areas	ian Govern ment of up to A$8,00 0 for installi ng solar panels on homes and commu nity use buildin gs (other than schools). This rebate was phased out on 8 June 2009, to be replace d by the

			power was purchased by Chubu Electric Company.			Solar Credits Program, where an installation of a solar system would receive 5 times as many Renewable Energy Certificates for the first 1.5 kilowatts of capacity under the Renewable Energy

						Target.

APPENDIX E: STATE WISE RTS SOLAR POLICIES IN INDIA

State	Metering	Capacity of Solar System	Subsidy	Loan availability	Ownership options	Others
Karnataka	Gross Metering	Limits in kW: HT Consumers: up to 1 MWp LT Consumers (Single Phase): up to 5 kW LT Consumers (Three Phase): Above 5 kW to 50 kW	30% subsidy on the cost of solar system from MNRE	Under the priority sector lending, bank loan up to 10lacs is available for consumers to install RTS.	Capital expenditure model (CAPEX) and Revenue energy service company model (RESCO)	Exempted from wheeling, banking, cross subsidy charges if applicable, VAT
Andhra Pradesh	Net Metering	Capacity =1MW	Additional 20% subsidy for installation of roof top	Under the priority sector lending, bank loan up to 10lacs is available	Capital expenditure model (CAPEX) and Revenue energy	

			system up to 5 kW capacity in domestic sector.	for consumers to install RTS.	service company model (RESCO)	
TELANGANA	Net Metering	Capacity of solar system 1MW	20% additional subsidy from Telangana State Govt. for installation of roof top system up to 3 kW capacity		Capital expenditure model (CAPEX) and Revenue energy service company model (RESCO)	No Distribution losses and charges, Electricity duty, Cross subsidy surcharge, VAT
TAMILNADU	Net Metering	Min 1 kW Max 1 MWp capacity in your area.	Subsidy of Rs. 20,000/kW from TN Govt. is availabl	Under the priority sector lending, bank loan up to 10lacs is available	Capital expenditure model (CAPEX) and Revenue energy	Exemption from wheeling & cross subsidy surcharge

			e for 1 kW system only for domestic consumers of Tariff category (LT-IA)	for consumers to install RTS.	service company model (RESCO)	
Maharashtra	Net Metering	1kW to 1 MW;	30% subsidy on the cost of solar system from MNRE	Under the priority sector lending, bank loan up to 10lacs is available for consumers to install RTS.	Capital expenditure model (CAPEX) and Revenue energy service company model (RESCO)	
Chhattisgarh	Net Metering	50 kW to 1 MW	30% subsidy on the cost of solar system from MNRE	Under the priority sector lending, bank loan up to 10lacs is available for	Capital expenditure model (CAPEX) and Revenue energy service	

				consumers to install RTS.	company model (RESCO)	
Gujarat	Gross Metering	Min 1 kW Max 1 MW	Subsidy of Rs.10,000 per kW through GEDA (Gujarat Energy Development Agency) after successful installation & commissioning of rooftop systems for Residential consumers only for 2 kW	Under the priority sector lending, bank loan up to 10lacs is available for consumers to install RTS.	Capital expenditure model (CAPEX) and Revenue energy service company model (RESCO)	Exempted from Transmission Charge, Transmission Loss, Wheeling Charge, Wheeling Loss, Cross Subsidy Surcharge, Electricity Duty

			systems only.			
Madhya Pradesh	Net Metering	Up to 112 kW	30% subsidy on the cost of solar system from MNRE	Under the priority sector lending, bank loan up to 10lacs is available for consumers to install RTS.	Capital expenditure model (CAPEX) and Revenue energy service company model (RESCO)	Exempted from banking, wheeling, cross-subsidy surcharges & electricity duty, no liability of property tax, exempted from VAT and entry tax.
Rajasthan	Net Metering	Size: Min 1 kW Max 1 MW	Subsidy is applicable as per SECI guidelines.	Under the priority sector lending, bank loan up to 10lacs is available for consumers	Capital expenditure model (CAPEX) and Revenue energy service company	Exemption from banking, wheeling & cross subsidy charges

				to install RTS.	model (RESCO)	
PUNJAB	Net Metering	Size: Min 1 kW Max 1 MW	Subsidy is applicable as per SECI guidelines.	Under the priority sector lending, bank loan up to 10lacs is available for consumers to install RTS.	Capital expenditure model (CAPEX) and Revenue energy service company model (RESCO)	Exemption from wheeling charges and cross subsidy surcharge
Haryana	Net Metering	Size: =1 MWp	Subsidy is applicable as per SECI guidelines.	Under the priority sector lending, bank loan up to 10lacs is available for consumers to install RTS.	Capital expenditure model (CAPEX) and Revenue energy service company model (RESCO)	Mandatory for new residential buildings having plot size more than 500 sq. yards to install 3% to 5% capacity of their Sanctioned load.

DELHI	Net Metering	Size: Min 1 kW Max 1 MW	GBI-An incentive of Rs. 2.00 per unit will be paid to you on gross energy generated from your rooftop system. The minimum eligibility criteria for GBI will be 1,100 solar energy units (kWh) generated per annum per kW.	Under the priority sector lending, bank loan up to 10lacs is available for consumers to install RTS.	Capital expenditure model (CAPEX) and Revenue energy service company model (RESCO)	Residential consumers opting to implement solar plants to sell power to the grid shall be exempted from the conversion charges requirement of house tax to commercial tax.

Uttar Pradesh	Net Metering	Size: Min 1 kW Max 1 MWp	An incentive of a maximum absolute amount of INR 30,000 rupees would be disbursed in subsidy/ customer; below which it would be disbursed at the rate of INR 15,000/ kW.	Under the priority sector lending, bank loan up to 10lacs is available for consumers to install RTS.	Capital expenditure model (CAPEX) and Revenue energy service company model (RESCO)	Exemption from wheeling & cross subsidy surcharge if applicable
Uttarakhand	Net Metering	Size; up to 500 kW	70% subsidy on the cost of	Under the priority sector lending,	Capital expenditure model (CAPEX)	Exemption from wheeling & cross

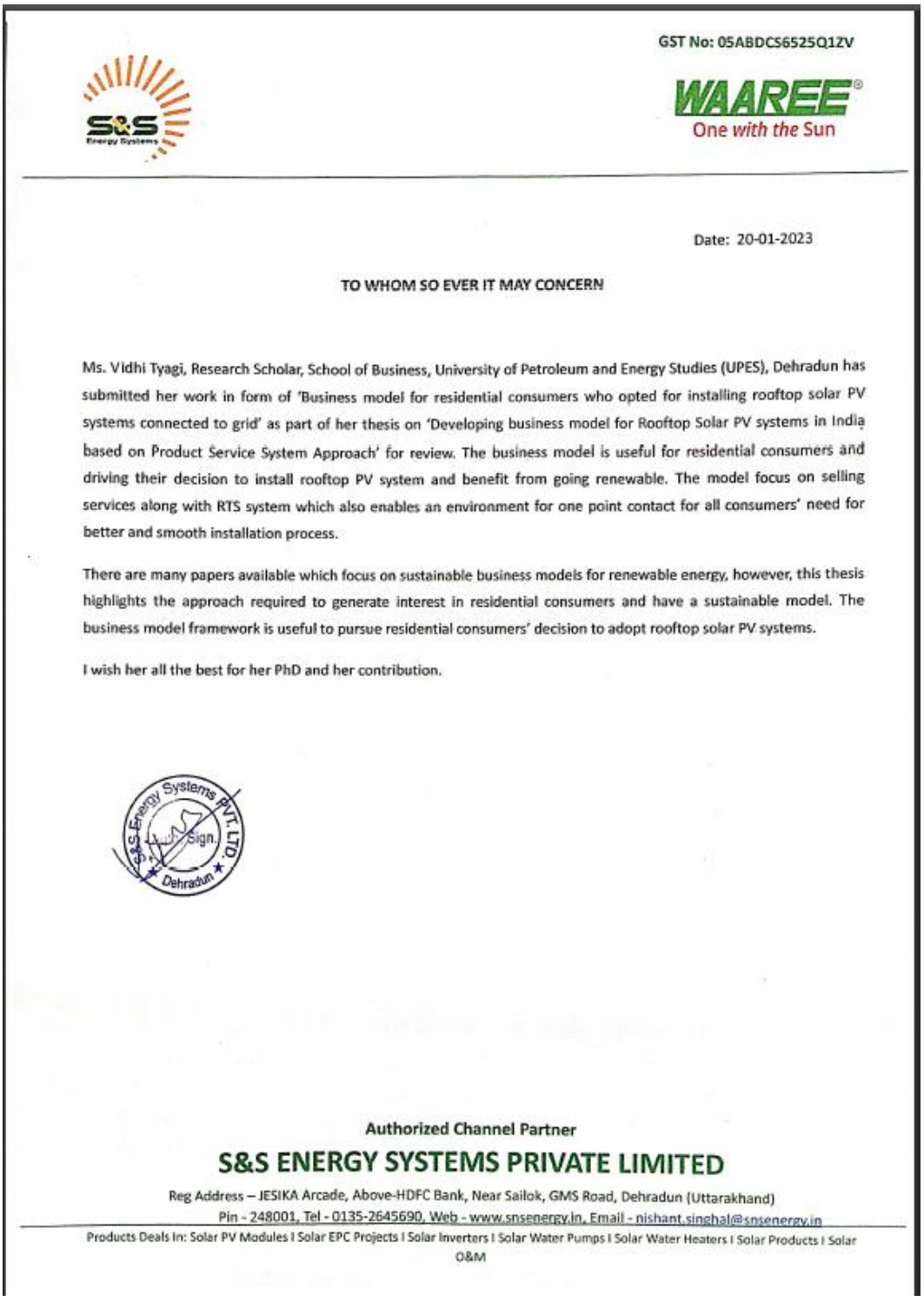
			solar system from MNRE	bank loan up to 10lacs is available for consumers to install RTS.	and Revenue energy service company model (RESCO)	subsidy surcharge
Himachal Pradesh	Net Metering	Size: Min 1 kW Max 1 MWp	Distributed generations by farmers and unemployed youths- With equity contribution of Rs. 50 lacs per MW. Subsidy- 70% subsidy on the cost of solar system	Under the priority sector lending, bank loan up to 10lacs is available for consumers to install RTS.	Capital expenditure model (CAPEX) and Revenue energy service company model (RESCO)	Exempted from wheeling, banking, and cross subsidy surcharge

			from MNRE (Central Gov.)			
Chandigarh		System size: Min 1 kW MAX 500 kW	30% subsidy on the cost of solar system from MNRE.	Under the priority sector lending, bank loan up to 10lacs is available for consumers to install RTS.	Capital expenditure model (CAPEX) and Revenue energy service company model (RESCO)	Exempted from wheeling, banking, and cross subsidy surcharge
BIHAR	Net Metering	Min 1 kW Max 1 MWp	30% subsidy on the cost of solar system from MNRE, (Central Government) through State Nodal Agency	Under the priority sector lending, bank loan up to 10lacs is available for consumers to install RTS.	Capital expenditure model (CAPEX) and Revenue energy service company model (RESCO)	Exemption from wheeling charges and cross subsidy surcharge.

			subject to approval & availability of funds.			
WEST BENGAL	Net Metering	Rooftop Mandatory for all large housing complexes (500 kW)	30% subsidy on the cost of solar system from MNRE			
Jharkhand	Net Metering	Min 1 kW Max 1 MWp	30% Capital subsidy (Central Financial Assistance) from MNRE	Under the priority sector lending, bank loan up to 10lacs is available for consumers to install RTS.	Capital expenditure model (CAPEX) and Revenue energy service company model (RESCO)	Exempted from wheeling charges, cross subsidy surcharges, electricity duty, VAT
ODISHA	Net Metering	Min 1 kW Max 1 MWp	30% Capital subsidy (Central	Under the priority sector lending,	Capital expenditure model (CAPEX)	Electricity generated by the

			Financial Assistance) from MNRE (Central Government) through State Nodal Agency subject to approval & availability of funds.	bank loan up to 10lacs is available for consumers to install RTS.	and Revenue energy service company model (RESCO)	rooftop solar system shall not be more than 90% of the electricity consumption at the end of the settlement period.
KERELA	Net Metering	Min 1 kW Max 1 MWp	30% Capital subsidy (Central Financial Assistance) from MNRE	Under the priority sector lending, bank loan up to 10lacs is available for consumers to install RTS.	Capital expenditure model (CAPEX) and Revenue energy service company model (RESCO)	Exempted from banking, cross subsidy charges, electricity duty

APPENDIX F- Letter for Validation of Business Model



GST No: 05ABDCS6525Q1ZV

WAAREE®
One with the Sun

Date: 20-01-2023

TO WHOM SO EVER IT MAY CONCERN

Ms. Vidhi Tyagi, Research Scholar, School of Business, University of Petroleum and Energy Studies (UPES), Dehradun has submitted her work in form of 'Business model for residential consumers who opted for installing rooftop solar PV systems connected to grid' as part of her thesis on 'Developing business model for Rooftop Solar PV systems in India based on Product Service System Approach' for review. The business model is useful for residential consumers and driving their decision to install rooftop PV system and benefit from going renewable. The model focus on selling services along with RTS system which also enables an environment for one point contact for all consumers' need for better and smooth installation process.

There are many papers available which focus on sustainable business models for renewable energy, however, this thesis highlights the approach required to generate interest in residential consumers and have a sustainable model. The business model framework is useful to pursue residential consumers' decision to adopt rooftop solar PV systems.

I wish her all the best for her PhD and her contribution.

S&S Energy Systems PVT. LTD. Auth. Sign. Dehradun

Authorized Channel Partner

S&S ENERGY SYSTEMS PRIVATE LIMITED

Reg Address – JESIKA Arcade, Above-HDFC Bank, Near Sailok, GMS Road, Dehradun (Uttarakhand)
Pin - 248001, Tel - 0135-2645690, Web - www.snsenergy.in, Email - nishant.singhal@snsenergy.in

Products Deals In: Solar PV Modules I Solar EPC Projects I Solar Inverters I Solar Water Pumps I Solar Water Heaters I Solar Products I Solar O&M

DEVELOPING BUSINESS MODEL BASED ON PRODUCT SERVICE SYSTEM APPROACH FOR SUCCESSFUL IMPLEMENTATION OF ROOFTOP SOLAR PV SYSTEMS IN INDIA

ORIGINALITY REPORT

10%	8%	5%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	en.wikipedia.org Internet Source	<1%
2	www.pace-d.com Internet Source	<1%
3	thaisolarpvroadmap.org Internet Source	<1%
4	www.vikramsolar.com Internet Source	<1%
5	doaj.org Internet Source	<1%
6	www.tricoliteenergy.in Internet Source	<1%
7	www.itsmysun.com Internet Source	<1%
8	shoes.snupigood.com Internet Source	<1%
	www.mnre.gov.in	