Consumer Adoption of Rooftop Photovoltaic Solar Power in India and Policies for its Faster Adoption

A Thesis submitted to the
University of Petroleum and Energy Studies

For the Award of
Doctor of Philosophy
in
Management

By
Amitabh Satapathy

July 2020

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Department of General Management
School of Business (SOB)
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DECLARATION

I declare that the thesis entitled "**Consumer Adoption of Rooftop Photovoltaic Solar Power in India and Policies for its Faster Adoption"** has been prepared by me under the guidance of Dr. A. K. Jain, Sr. Associate Professor and Dr S Barthwal, Sr. Associate Professor's, School of Business, University of Petroleum & Energy Studies. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

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DECLARATION

I certify that, Amitabh Satapathy has prepared his thesis entitled "**Consumer Adoption of Rooftop Photovoltaic Solar Power in India and Policies for its Faster Adoption**" , for the award of PhD degree of the University of Petroleum & Energy Studies, under our guidance. He has carried out the work at the School of Business, University of Petroleum & Energy Studies.

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Abstract

India is the fifth largest economy of the world and also one of the fastest growing large economies. India's share of the entire global economy is around 4% whereas its share of the total population is around 18%. Sustainability of this economic growth is key to elevate the standard of living of millions of Indians still living under abject poverty. One of the major challenges to this sustainable economic growth is meeting the demand for energy. The most vital is the growth in electricity sector. India's current installed generation capacity of electricity is around 365 GW, which is third largest in the world behind China and USA. In terms of per capita electricity consumption India will be ranked almost at the bottom which is less than 10% of per capita consumption in developed nations like USA and Germany and one third of global average. Indian power sector is ill famous for all the wrong reasons like frequent black outs, many people not having access to grid power and poor financial health of utility companies. This indicates that India needs to add almost twice the current installed capacity to become a large economy. The challenge is not only to add large units of installed capacity, but also to change the generation mix. Currently close to three quarters of the electricity generated in the country come from coal that is extremely polluting the environment. Apart from the polluting nature of fossil fuel, the other problem is that India doesn't have significant reserve and so depends on import. So, the future addition of electricity must come from cheap and renewable sources.

In the recent years, the government of India has made remarkable progress in improving the people's access to electricity and clean cooking. During the period

from year 2000 to 2018, around 700 million people in India gained access to electricity. Under its Jawaharlal Nehru National Solar Mission, it has set an ambitious target of 175 GW of renewable energy capacity by year 2022, with 100 GW coming from solar energy, 60 GW from ground mounted solar plants and 40 GW from rooftop installed systems. Considering almost year around solar radiation that the country receives, even a target of 100 GW installation by year 2022 sounds very low. Even the long-term target of installing 523 GW capacity from renewable sources by year 2030 seems possible with proper planning and proactive measures. So far, the growth in solar PV has been spectacular, but surprisingly the entire growth is coming from the ground mounted solar plant segment and the rooftop segment has been a laggard. In a populous country like India where land availability is scarce, and transmission and distribution section of the power sector is one of the worst in the world, importance of rooftop solar PV gets further enhanced.

The researcher attempts to identify various barriers and challenges to the growth in adoption of rooftop Solar PV in India. Despite certain obvious barriers, rooftop solar PV has been very successful in a few countries like Germany and even in India, a very small number of people have adopted it. The researcher tries to find out the important factors that lead to its adoption in India. On these important factors the difference in perception of adopters from non-adopters is found out. The researcher found out differences between adopters and non-adopters on demography and psychography and finally the researcher attempts to find out the suitable government policies that will trigger the adoption of this rooftop solar PV in India. The research was carried out in two states, Kerala and Odisha.

An extensive review of literature was carried out by the researcher to find out various barriers and challenges and also factors of adoption of rooftop solar PV across various countries. The researcher studies government policies across all major countries and in India across each state. It is evident from the entire review that although Government of India has taken various initiatives to promote solar energy across the country but only few states have shown encouraging results. It provides the base for the business problem.

Slow adoption of rooftop solar power system in India has dented the country's ambitions to provide reliable power to all its consumers, reduce the import bill of more than one lakh crore rupees on account of fossil fuel and reduce around 320 million tons of CO_2 emission per year.

The objectives of the study are:

1. To identify the important factors leading to adoption of rooftop solar PV in India.
2. To explore the perceptions of adopters and non-adopters towards rooftop solar PV in India.
3. To examine the demographic and psychographic differences between the adopters and non-adopters of rooftop PV in India.
4. To analyze government policies in countries like USA, China, and Germany, where rooftop solar PV adoption has been successful and find out the suitable policies for India.

The first three objectives use quantitative research whereas the last objective uses qualitative research. For quantitative research primary data were collected through questionnaire survey in the states of Kerala and Odisha.

The first objective of study was achieved through identifying five factors that are important for adoption of rooftop solar PV. These factors were extracted through factor analysis, with the help of 200 responses on 39 variables. The five important factors identified are Complexity, Financial Attractiveness, Environmental Benefits, Social Image and Trialability. For the second objective of study, researcher collected primary data through questionnaire from 150 randomly chosen respondents and hypotheses testing tool is used to arrive at the conclusion. It is found that adopters carry better perception about rooftop solar PV on two important factors, Complexity and Financial attractiveness. On other three factors the difference in perception is not significant.

The third objective was carried out from the data extracted for the second objective and hypothesis testing is done as analysis. On important demographic factors like education, income, occupational status and social class, the adopters are superior to the non-adopters. However, contrary to the wide belief that adopters should be younger than non-adopters, the findings prove the other way. For the fourth objective, qualitative research is followed. Data was collected through FGD. Using thematic analysis, the data was analysed, and it is found out that the most important policy that would drive adoption of rooftop solar PV in India is implementation of net metering scheme across all the states in the country.

The researcher checked the validity and reliability of the tests and also clearly spells out the scope for future research on this.

ACKNOWLEDGEMENT

The success and final outcome of my research required a lot of guidance and support from many people and I feel myself extremely privileged to have got this continuously throughout the completion of my project. I attribute the success of this research considerably to such supervision and assistance and I would not forget to thank them.

I owe my deep gratitude to my research guides Dr Arvind Kumar Jain, Sr Associate Professor, School of Business, UPES, Dehradun and Dr Sunil Barthwal, Sr Associate Professor, School of Business, UPES, Dehradun. They took keen interest on the research work and guided me throughout the journey. Despite their busy schedule, they could still take time out and put their invaluable guidance, without which the research would have never taken the desired shape. It was indeed an honour and privilege to work with both of them. It was an unforgettable learning experience with some incredible and precious inputs by both the guides.

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Finally my acknowledgement note would be incomplete without mentioning the contribution made by my little daughter Dhreety, my wife Debajani, my sister Sanghamitra, my mother Prabhabati Satapathy and above all the blessings from my late father Shri Bhagaban Satapathy, who spent his entire life in this noble field of education.

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1. Introduction

India is right now the fifth largest economy in the world and is also one of the fastest growing large economies [103]. As per World Bank, the real GDP of India has grown at an average 6.8% during the period between year 2000 and 2018 [104]. Despite this phenomenal growth, per capita GDP of the country is one of the lowest in the world. Even many African and Asian countries have higher per capita GDP than India. Although India's contribution to the global economy is less than 4%, it contributes nearly 18% to the global population [105]. This indicates that it is still one of the poorest countries in the world with millions of people living below poverty line. Sustainability of this faster growth of India's economy is the key to elevate the lives of millions of people who live under utter poverty and don't have access to basic amenities.

But sustainability of this faster economic growth of a large country like India has multitude of challenges, and the most important is meeting the growing energy need. Energy is central to the country's ambition of becoming one of the largest economies of the world. Steps taken in India in terms of energy mix will increasingly influence the global energy scenario. The challenges of meeting the growing energy demand include adhering to climate commitments of significantly reducing carbon emissions proportionate to its GDP by 33-35% by 2030 from 2005 level and reducing country's reliance on imported energy [7]. Experts feel that such challenges warrant an accelerated transition to a lower cost, domestically available, low-emission, less water intensive energy economy and it should begin with the greening of the electricity sector and then progressively moving on to electrify transport and other major industries. In the energy sector, power sector has got the maximum correlation with the growth in economy. In the recent years, the government of India has made remarkable progress in improving the people's access to electricity and clean cooking. During the period from year 2000 to 2018, around 700 million people in India gained access to electricity. In the pursuit of producing clean energy, India has set an ambitious target of 175 GW of renewable energy capacity by year 2022, with 100 GW coming from solar energy [7]. The growth in installed capacity of renewable energy over the last few years has been spectacular. But the share of renewable sources in total electricity generation continues to be insignificant. As of March 2019, renewables were providing only 9.2% of total generation [1]. The country has got massive potential in both wind energy and solar energy. Considering almost year around solar radiation that the country receives, even a target of 100 GW installation by year 2022 sounds very low. Even the long term target of 523 GW capacity addition from renewable sources by year 2030 seems easily within reach with proper planning. However, it needs to prepare a proper roadmap, identify the possible barriers and set up plans to mitigate those barriers and reach the target. Globally electricity from wind energy and solar PV is witnessing phenomenal growth and the technology is also fast improving. Improvement in technology has helped integration of electricity generated from these sources with the national grids receiving electricity from conventional sources like coal. In tropical countries like India, electricity from solar PV holds extreme significance as the potential is enormous due to higher solar radiation almost throughout the year. Solar PV is generally categorized into two segments, one is the ground mounted grid connected plants and the other is rooftop solar PV that is either grid connected or operating off grid. In a populous country like India where land availability is scarce, and transmission and distribution section of the power sector is one of the worst in the world, importance of rooftop solar PV gets further enhanced. Going forward, tapping this massive energy source from the Sun will be the key to the sustainability of economic growth of the country. It will also significantly impact the steps taken worldwide for protection of the environment.

Solar or coal? the energy India picks may decide Earth's fate

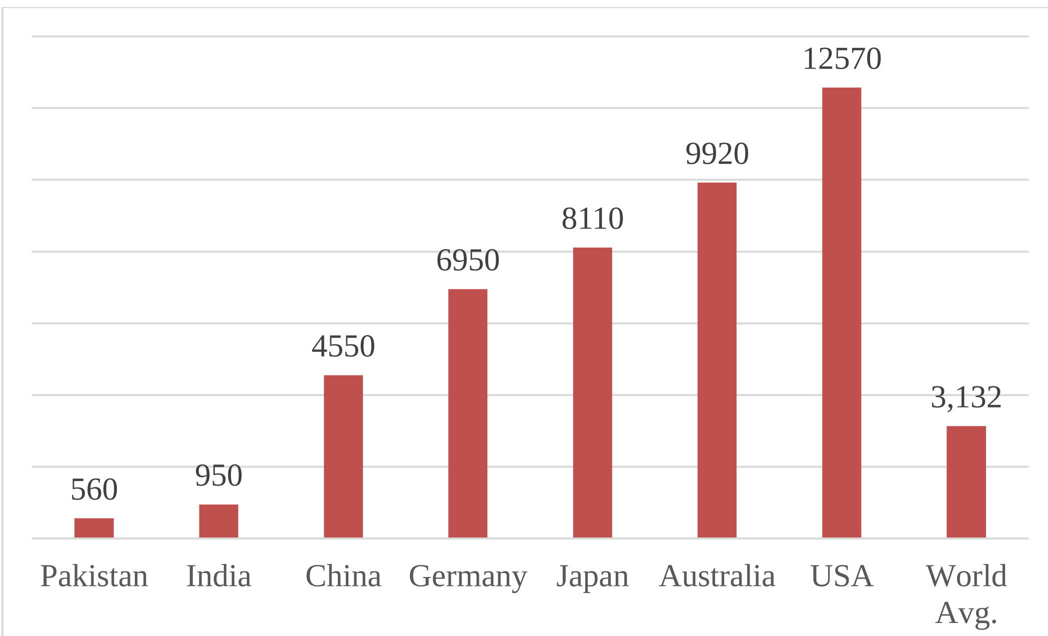
Charles C. Mann

1.1 Power Sector Scenario in India

Indian power sector is at a crossroad. At one end, the country needs to install massive amount of new power projects and at the other end it has ratified the Paris climate change agreement at the UN [2]. The Paris deal is the world's first comprehensive climate agreement involving all the major countries with CO2 emissions believed to be the driving force behind this agreement. Under the deal, India has committed that it would ensure 40% of its electricity generated from non-fossil sources by year 2030. India accounts for about 4.5% of the greenhouse gas (GHG) emissions around the world [6]. So, the only option for the country is to switch from the traditional fossil fuel based power generation to renewable energy. Lion share of the renewable sources should come from solar PV.

India is the third largest producer and consumer of electricity in the world behind China and USA. It has currently 349 GW of power generation capacity (CEA as on September 30, 2019) [3]. This compares to 1,223 GW of installed capacity in China and 1,110 GW in the USA [4]. Similarly, the per capita electricity consumption at 1181 KWh (CEA, 2018-19) is almost one third of the world average and less than 10% of the average in developed countries like the U.S., Canada or Australia [4]. Since independence, the power sector in India has been one of the worst performing sectors for almost six decades. The entire sector right from generation to distribution was being managed by the government. The generation, distribution and transmission were carried out by state electricity boards. The power sector situation remained so bad that for decades millions of Indians lived without electricity and those having access to electricity were also in no better situation. Frequent power cuts were very common and growth in generation was abysmally low as most of the state electricity boards were financially in dire straits. Transmission and distribution losses were extremely high, and adoption of modern technology was very rare. Most of the power plants were highly polluting the environment. Such poor condition of the power sector not only adversely affected lives of millions of Indians, it also affected industrialization and so the economic growth of the country. The introduction of Electricity Act 2003 was the game changer for the sector. The act brought in disruptive changes to the sector like unbundling of generation from distribution and delicensing of power generation. Since the introduction of this electricity act and subsequent revisions, the sector has witnessed phenomenal developments.

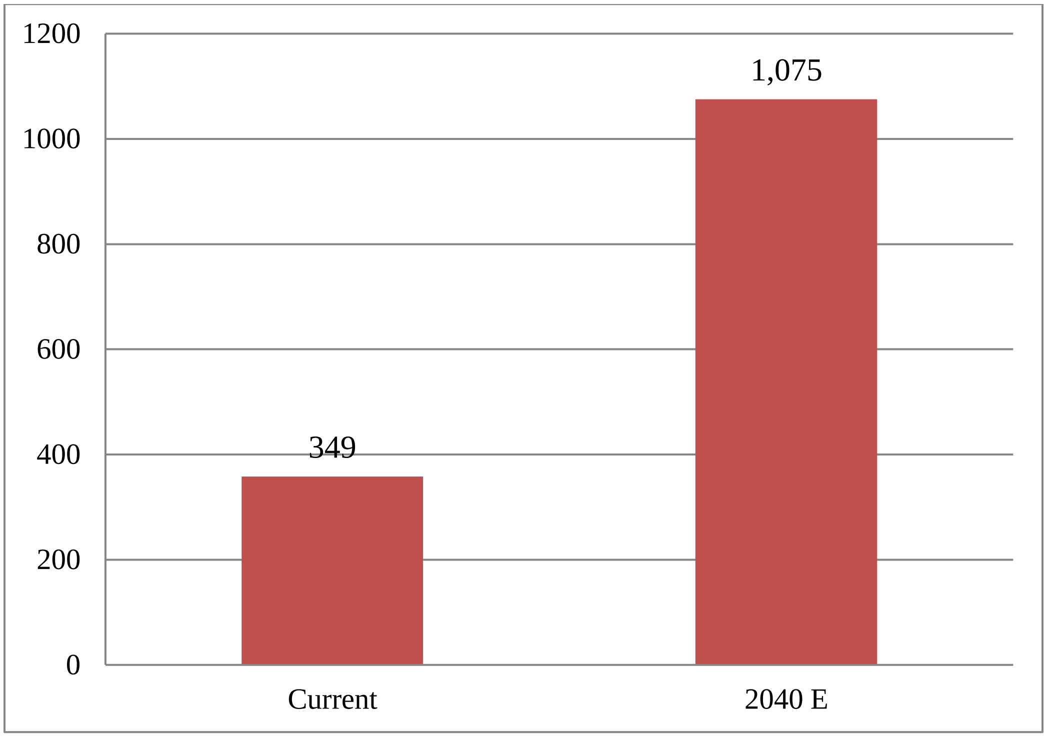
Figure 1.1: Country wise annual electricity consumption in KWh/Capita



Source: IEA and World Bank for Year 2017

Looking at these statistics, potentially India should witness massive growth in not only installed capacity of electricity but also generation and consumption. Electricity has a very positive correlation with economic growth. To provide electricity to the entire Indian population and keep pace with economic growth, there is need to add close to 900 GW of electricity generation capacity by 2040 [5], but resources are limited.

Figure 1.2: India's Current and Forecast Installed Electricity Capacity (GW)

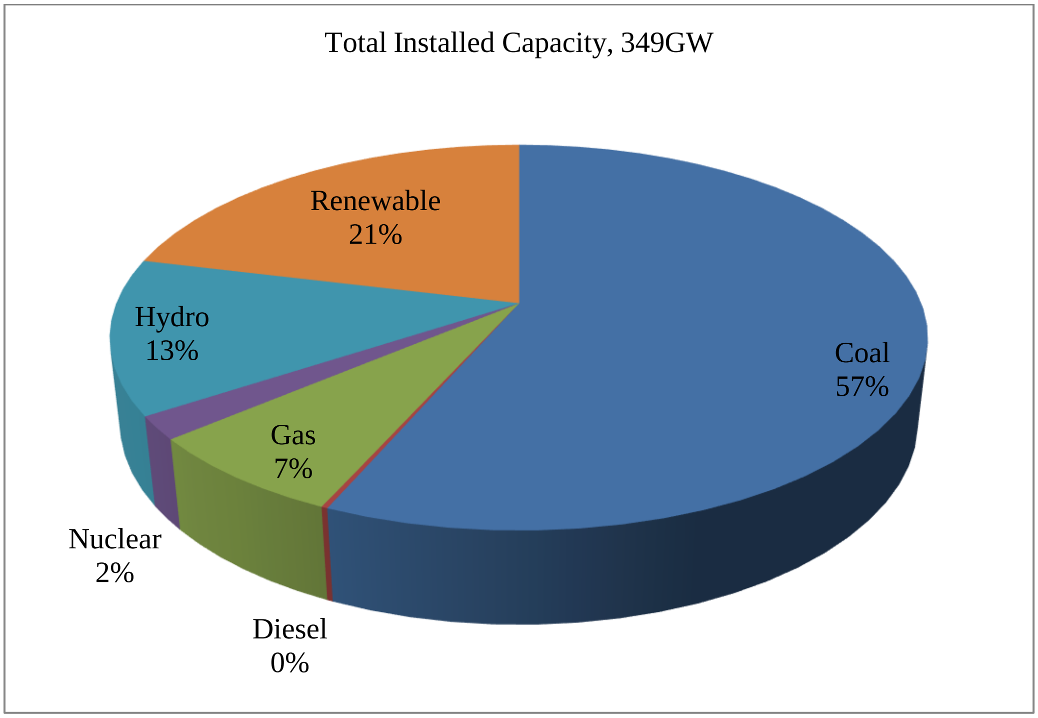


Source: IEA & CEA

A recent report on Washington Post says that almost a quarter of the population in India live without electricity. Another quarter which is connected to the grid, remain in dark for 10-15 hours a day due to unscheduled power cuts and load shedding. Contrary to this, Germany maintains grid down time of only 17 minutes per year [99].

Apart from the need to generate more electricity, one more critical issue for the country is its dependence on fossil fuel, especially coal. In terms of Carbon Dioxide emissions, India is the third most polluting country in the world, nearly half of which is contributed by power sector [6]. So, the massive future need for electricity, if comes from fossil fuel, will not only be destructive for India, but also for the entire world. If India follows a path similar to the one followed by China, that will add another eight billion tons of carbon to the atmosphere each year, more than total U.S. emissions in 2013 [6]. Even if for a moment we ignore the environmental issues, India doesn't have fossil fuel reserve to support the demand. In 2014-15, the country spent more than Rs 1 lakh crore for importing coal [7]. A major reason for the existing power sector crisis is its heavy reliance on centralized power generation [8]. Higher reliance on commercial fuels like coal and oil as a short-term measure for meeting increasing demand is disturbing in view of depleting fossil fuels and pollution [9]. This heavy reliance of Indian power sector on fossil fuel like coal, gas and oil is because of faulty energy policy. It is imperative to note that India depends on import from foreign countries for these fuels [10]. Because of this over dependence on fossil fuel and the country not having sufficient reserve, the annual additions of new power projects took a major hit during the previous few years [7]. As of March 2019, the country had 200.7 GW of coal fired generation capacity which was 56.3% of the total installed capacity. Share of this coal fired capacity in total electricity generation was an unsustainably high 74.3% [1]. During the same time, renewables were providing 77.8 GW of capacity, which was 21.8% of the total generation capacity and only 9.2% of total generation [1]. Going forward there is no surprise that both installed capacity mix and generation mix of Indian electricity are going to witness transformations with the share of coal expected to drop significantly.

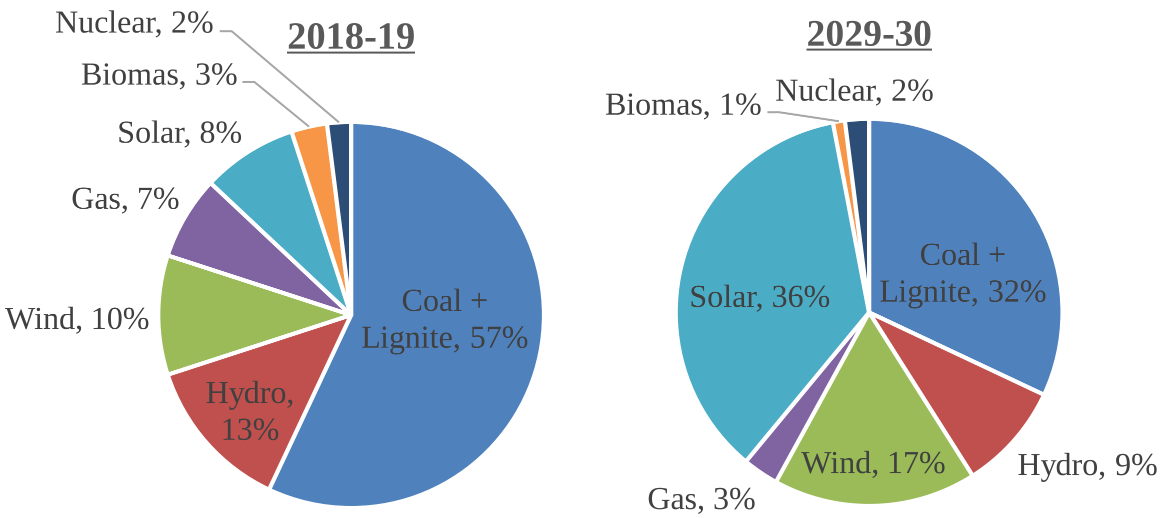
Figure 1.3: Fuel wise break up of India's electricity installed capacity



Source: CEA as on September 30, 2019

Over the last few years, India has added huge electricity generation capacity. This resulted in an impressive drop in both energy and peak deficits to just 0.4% and 0.6% respectively by June 2019. This is a very significant achievement as electricity demand has grown 5-6% annually. The outlook for the sector is still clouded by the uncertain financial situation of distribution companies and huge transmission and distribution losses. Although the country's electricity supply has historically been largely coal-dominated, in the last 2-3 years, the share of solar and wind generation has been increasing fast, although in absolute volume is still low. CEA has estimated the expected change in both installed capacity mix and generation mix over the next decade and share of solar and wind energy will significantly increase.

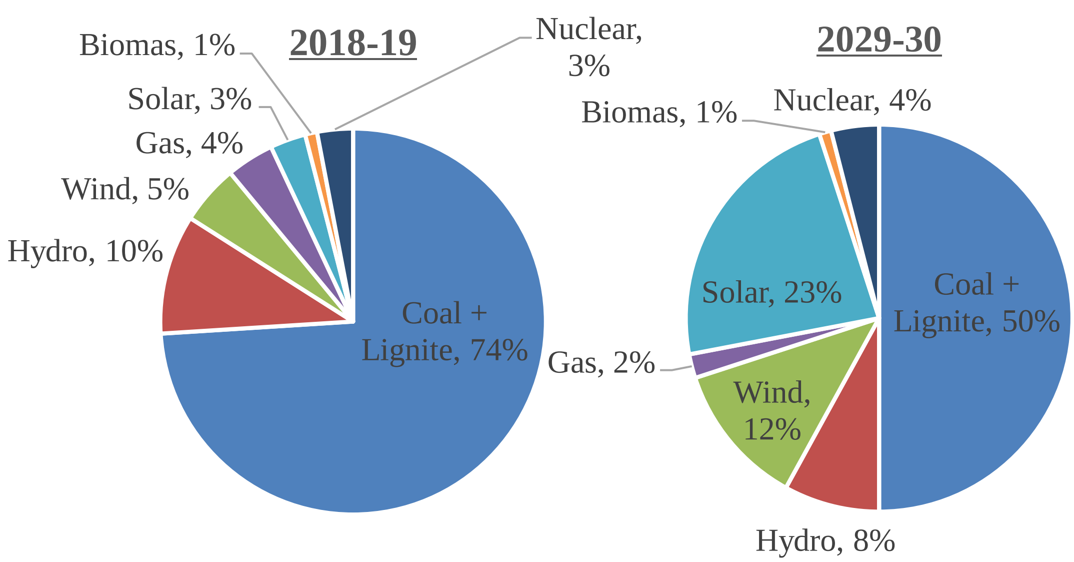
Fig 1.4: Electricity Installed Capacity Mix in India



Source: IEEFA

In terms of installation capacity, solar PV is expected to have the largest share within the next ten years. Share of coal and lignite will witness the largest drop. Nuclear energy has got large potential in India, but its share is not expected to change much due to the risk involved in having nuclear plans in a densely populated country like India. The world has still not forgotten the nuclear disasters at Chernobyl or Fukushima. Another issue with nuclear plants is availability of fuel as India will have to depend on countries like France, USA, Canada for supply of enriched uranium. India has got large potential of hydro energy. However, getting environmental clearance for setting up large hydro dams is extremely difficult. Apart from environmental clearances, setting up large dams require displacement of thousands of people from nearby locations, which is not an easy task for the government.

Fig 1.5: Electrcity Generation Mix in India



Source: IEEFA

Although solar PV will provide the largest share of installation capacity, coal and lignite will continue to have the largest share of electricity generation. The reason behind this is higher efficiency of thermal plants compared to the solar PV.

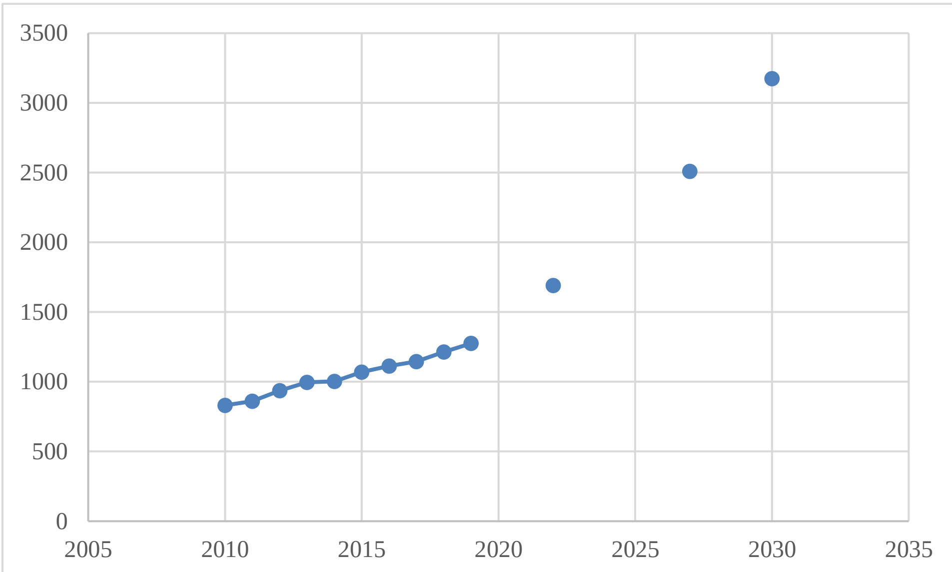
The growth in demand for electricity is expected to continue not only due to the expected economic growth but also due to factors like urbanization, expanding access to electricity, and faster adoption of electric vehicles in India. A recent study by TERI (The Energy and Research Institute) indicates that electricity demand in India is expected to reach 1,692 BU (billion unit) in year 2022, 2,509 BU in 2027 and 3,175 BU in 2030 from the present demand of 1,275 BU in 2018-19

[11]. The rise in demand will pose several challenges. To meet these future challenges, peaking capacity and flexible power plants need to be set up to meet demand at any time, bring improved reliability and quality of supply, and integrate variable renewable energy technologies in the system. Finding the appropriate generation mix is crucial that should address energy security, affordability, and environmental compatibility.

The rise in demand puts severe stress on the environment. CO2 emission from power generation in India reached more than 2.5 giga tonnes in 2016 from around 1 GT in 2013 [100]. However, the share of power sector in total emission is expected to drop to around 45% in 2040 from around 50% at present (IEA)[5]. This expected drop will be because of more renewable energy deployment and improvement in coal technology.

One of the major advantages that India has today and going forward is the vast potential of renewable energy that is mostly untapped, especially solar energy. Estimates show that the country's solar potential is more than 750 GW and wind potential is around 302 GW [12]-[13]. Even there is considerable potential in biomass and hydro energy. A quick transition to renewable energy will have several macro-economic benefits, like reduction in import bill on fossil fuel, creation of local employment opportunities, investment inflows and reduction in pollution. However, to tap this massive potential of renewable energy, the country needs to make available the necessary capital and more importantly manage the uncertainty and variability of power generation from renewable energy while integrating with the generation from conventional sources.

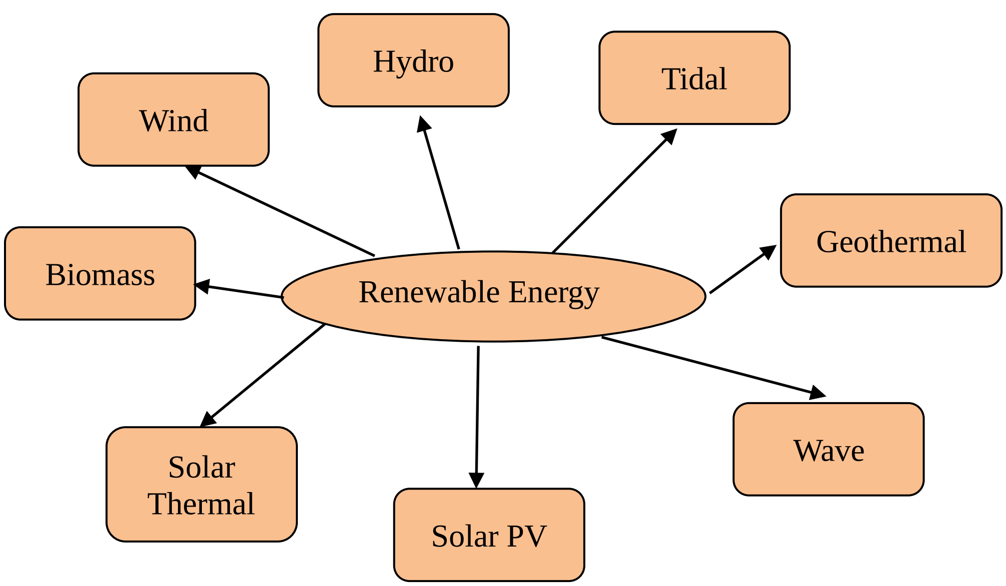
Figure 1.6: Electricity Demand Forecast in India in billion unit



Source: Ministry of Power, GoI and TERI

Power from renewable energy should be the new norm all over the world. Globally hydro, wind and solar energy are the major renewable sources of energy.

Figure 1.7: Renewable Energy Sources (RES)

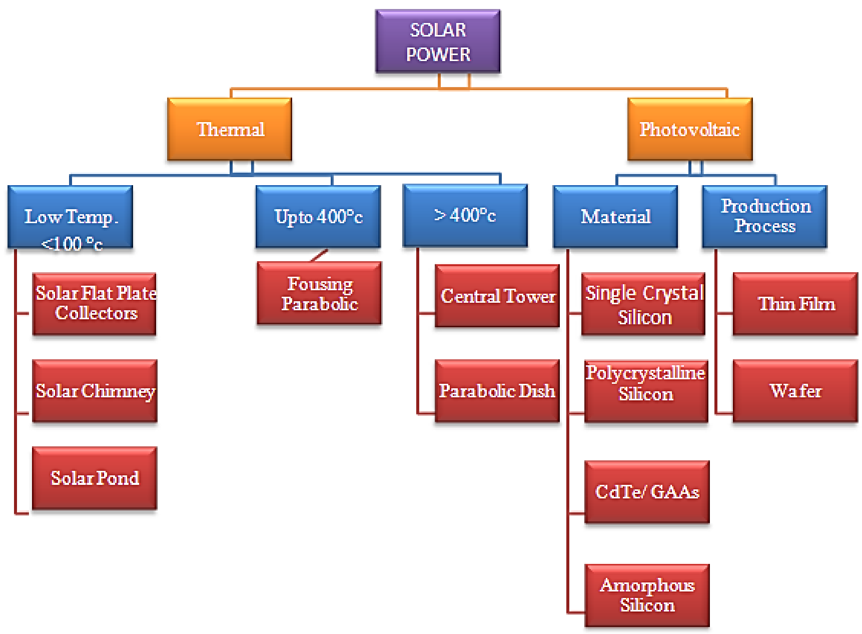


In countries like India, among all the renewable sources, solar PV will lead the pack as the country is blessed with almost year-round solar radiation. Although India entered late into the solar space, the country has been witnessing phenomenal growth in solar PV installation over the last few years, especially in the ground mounted solar plants segment. Study of the solar PV status reveals that surprisingly the rooftop PV segment has not been growing as desired. A study of solar PV status in India and a comparison with other countries throws open a few more questions than answers.

1.2 Solar PV Status

Different technologies are available in converting solar energy into electricity and other useful form of energy. Among the various technologies known, a few like Solar Pond and Solar Chimney are still under demonstration stages. Solar PV has been the most adopted technology across the globe for tapping solar and converting it into useable form of energy in the form of electricity.

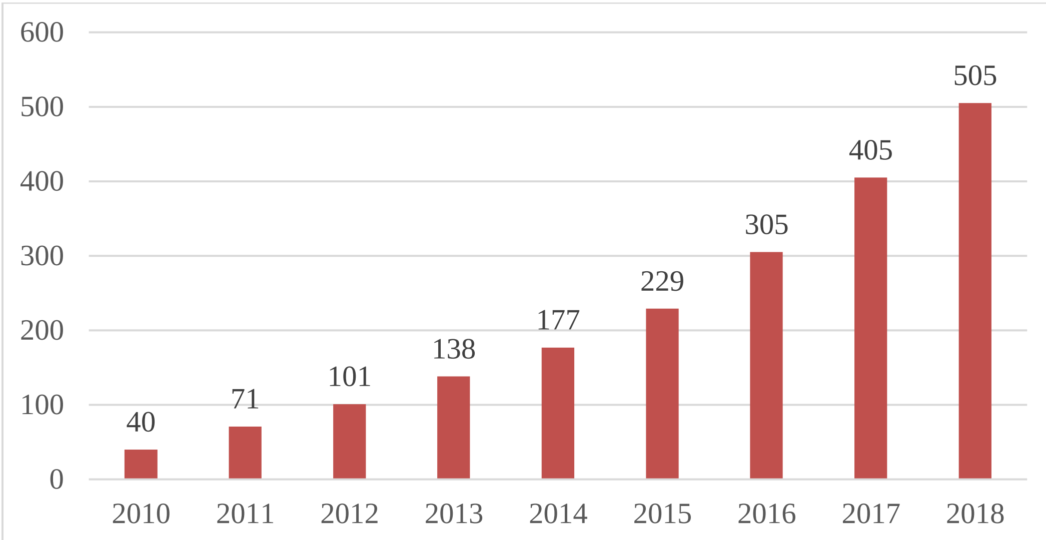
Figure 1.8: Different Solar Energy Technologies



Worldwide, each year electricity generated from renewable energy is more than the electricity generated in the previous year. Hydro has still the biggest share of electricity production from renewable energy globally, contributing 58% in 2019 [14]. Wind contributes 22% and solar PV 10%. Overall, in 2019, renewable energy produced 27.3% of total electricity produced globally [14]. The popularity of renewable energy can be seen from the fact that more than 90 countries have installed capacity of at least 1 GW of renewable. A few countries have achieved some glorious milestones in this field of power generation from renewable energy. Costa Rica powered itself for 300 days completely from renewable energy, USA is producing electricity from renewable energy that is almost equal to what it produces from coal, Portugal generated more than half of its electricity consumption in 2018 from renewable sources and there are many such examples [14]. A few countries generated significant portion of electricity from variable wind energy and solar PV. In 2019, share of electricity generated from such wind energy and solar PV in Denmark was 60%, Uruguay 33%, Ireland 32%, Germany 30%, and Portugal 26% [14]. This rising share of electricity from variable wind energy and solar PV has given confidence to other countries in integrating this generation into power grids. It helped in reducing the apprehension about the difficulty in managing the grid when significantly higher share of electricity production comes from variable wind energy or solar PV. Globally, governments focused their policy attention primarily on power generation from renewable sources. Over the years due to factors like new enabling technologies, cost reduction and developments in energy storage systems, these government policies have evolved a lot. Many countries focused on policies to facilitate integration of power from renewable energy with the national grids. It was also observed that in many countries competitive bidding through auctions for new solar PV and wind energy caused bid levels to reach record lows. One major reason for the current widespread deployment of solar PV and wind energy is years of steady decline in levelized cost of electricity, making the technologies competitive with conventional form of energy.

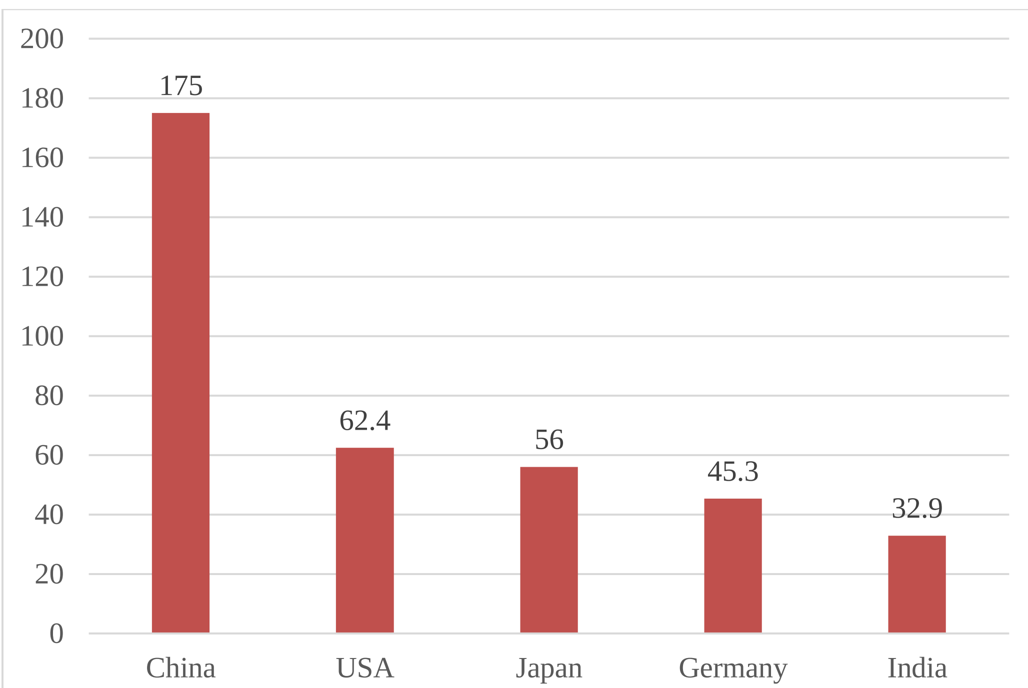
Solar PV has become world’s fastest growing energy technology with its demand expanding to many countries [14]. It has become the most competitive option for generating electricity in several countries. The direct conversion of sunlight into electricity by solar photovoltaic (PV) technology presents large untapped potential and offers a technically and commercially viable, and sustainable solution to the problem of growing energy demand worldwide. By the end of year 2018, at least 32 countries have installed solar PV capacity of 1 GW or more [14]. There still remain challenges that prevent solar PV from becoming a major electricity source worldwide. These challenges are mainly policy and regulatory instability, financial issues, and the need to integrate solar PV into electricity markets and system. Solar PV is already a significant and growing source in electricity generation in many countries like Honduras where its share is 10.7% of total generation. Other such countries are Italy (nearly 8.6%), Greece (8.3%), Germany (8.2%) and Chile (8.1%) [14]. By the end of 2019, it is estimated that electricity generated worldwide from solar PV is around 2.8% of annual electricity generation [14]. Leading countries in terms of cumulative installed capacity of solar PV are China, USA, Japan, Germany, and India. China accounts for nearly half of annual addition of solar PV worldwide.

Figure 1.9: Growth in global installed capacity of solar PV in GW



Source: REN21Renewables 2020 Global Status Report

Figure 1.10: Country wise solar PV installed capacity in GW (2018)

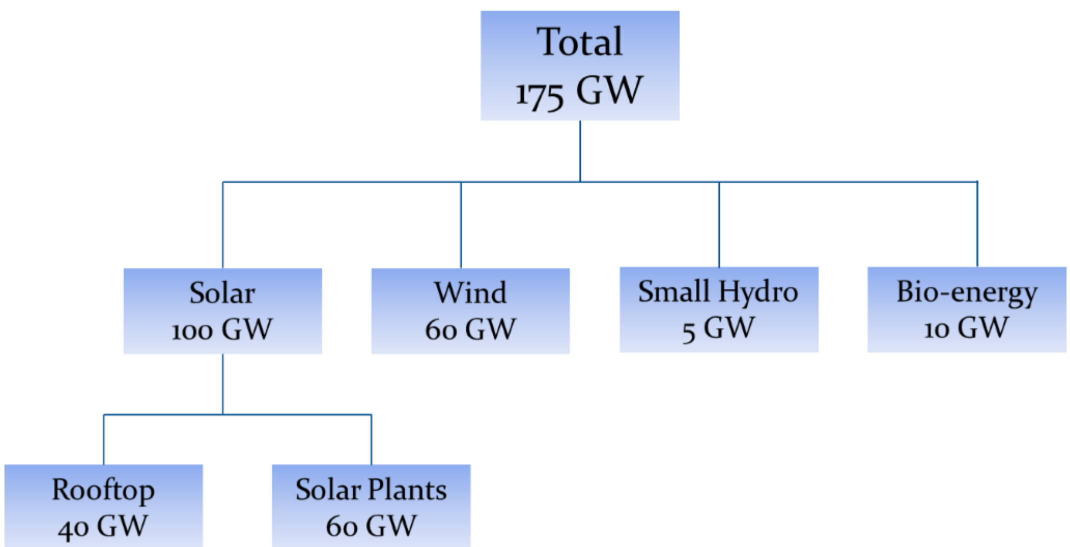


Source: REN21Renewables 2020 Global Status Report

Government of India has realized the current situation and the importance of switching to renewable energy to meet the electricity demand.

“The world must turn to (the) sun to power our future,” Prime Minister of India, Narendra Modi said at the historic COP21 climate conference in Paris last year. Unveiling its own bold initiative, India pledged that it would derive at least 40% of its energy needs from renewable sources by 2030 [2]. The government has put forward an ambitious 175 GW renewable energy by year 2022 [7].

Figure 1.11: Renewable energy plan by GoI

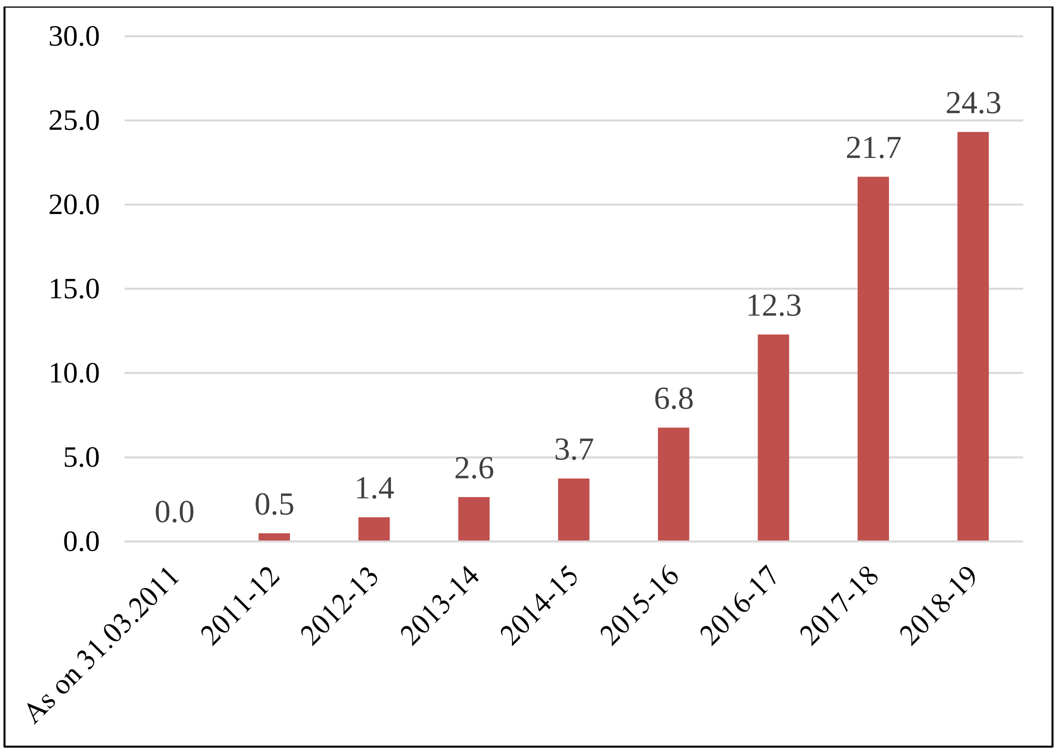


Source: Report on the expert group on 175 GW RE by 2022 by Niti Ayog

Under the Jawaharlal Nehru National Solar Mission (JNNSM), India is aiming to generate 100 GW solar power by 2022, comprising of 40 GW Rooftop and 60 GW of Large and Medium Scale Grid Connected Solar Power.

This plan sounds highly ambitious considering the current status of solar power in India. Despite massive potential for solar power in India, its contribution to the overall growth of Indian power sector has been abysmally low. The photo voltaic penetration in percentage of electricity demand in India is less than even 1% as of 2015 compared to almost 8% in countries like Italy or Germany [16]). The installed capacity of solar PV in India was a meager 2% of the world's total installed capacity as of December 31, 2015. However, it has increased to around 5% by year 2018 [14].

Figure 1.12: Progress in solar power installed capacity in India in GW



Source: MNRE Report 2019 [13]

As we can see, India has been extremely slow in catching up with the growth in solar PV across the world despite having very favourable climatic condition with high solar radiation almost throughout the year.

India lies in a sunny tropical belt with good solar radiation. The total theoretical potential annually is more than 5,000 trillion kWh [17]. The intensity of solar radiation per day in India is around 4 – 7 kWh per square meter. India receives an average 250 to 300 clear sunny days every year. A research pointed out that theoretically entire electricity demand of the country can be met from energy produced from only 3,000 km2 land area, which is only 0.1% of the total land area of India [18].

As it can be seen that over the last few years, growth in solar PV in India has been satisfactory. However, most of the growth has come from ground mounted large size solar plants. The rooftop solar PV segment that has got many advantages, especially in a densely populated country where land is scarce, has not been growing. This is contrary to what is observed in countries like Germany, USA, Japan, Australia etc which have been very successful in adoption solar PV.

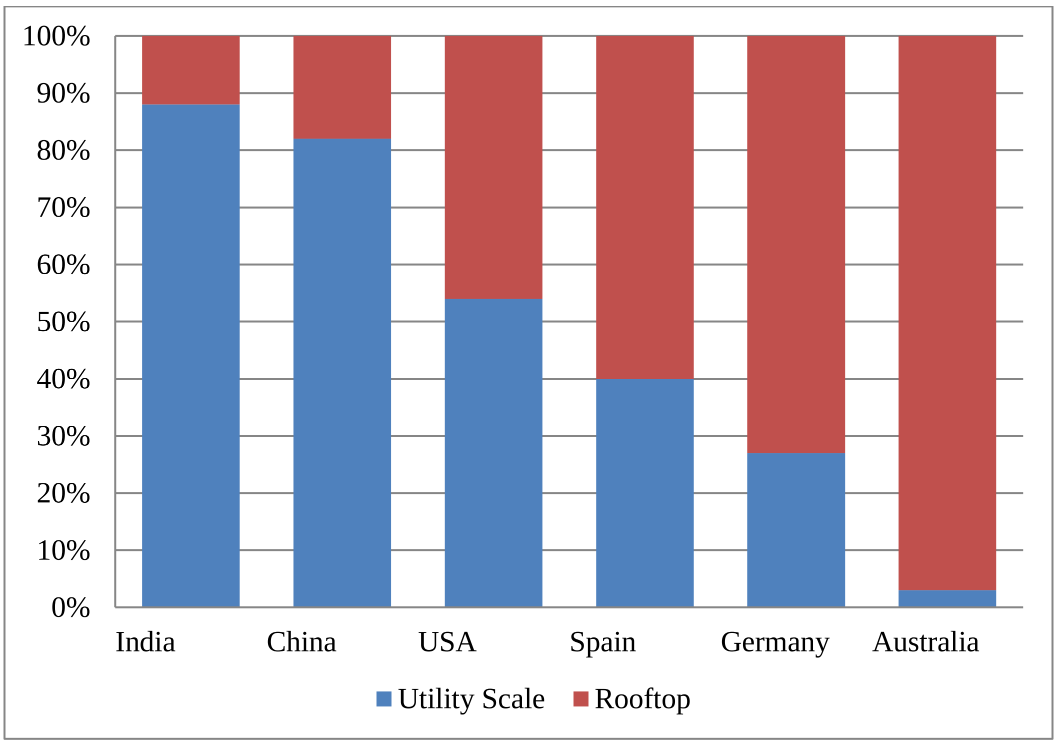
1.3 Rooftop Solar PV in India

Rooftop solar PV systems are photovoltaic panels installed on rooftops of buildings used for residential, commercial, or industrial purposes. Such systems are either having grid connectivity or operate off the grid. For grid connected systems, electricity generated from rooftop PV systems are either entirely fed into the grid at regulated FIT (feed-in-tariffs) or used for own consumption with net-metering approach. A net-metering mechanism is an approach wherein the consumer is billed only for the ‘net’ electricity supplied by the DISCOM. Net electricity is the difference between total consumption and electricity generated from rooftop PV. Rooftop solar PV systems are installed with or without battery storage. Rooftop solar PV systems have several advantages, mainly reduction in T&D (transmission and distribution) losses, low gestation time, absence of requirement of additional land, improvement of the grid voltages, improvement in system congestion because of higher self-consumption of solar electricity, and local employment generation. Around 62.5% of the total area of India, translating into roughly 2.0 million square kilometres, have annual average Direct Normal Insolation of more than 5.0 kW h/m2 /day. In most parts of the country, the building structures are of low height, so having more horizontal spread. So, there is likely to be a significant potential for rooftop solar photovoltaic electricity generation in India [19].

Rooftop solar power holds considerable significance considering the shortages of free land in heavily populated countries like India. “Down To Earth” magazine on September 29, 2016 reported that Electricity for all can be achieved only through rooftop solar power and it is possible by adding only 50GW rooftop solar power [103]. A recent report by A T Kearney (Solar Power and India’s Energy Future, 2013) [101], mentions that solar will become a crucial component of India’s energy portfolio in the next decade because of several factors: (a) Coal is becoming more difficult to obtain, (b) Sources of domestic gas are shrinking and (c) The urgent need to reduce carbon.

A news article on April 22, 2016 published in the Business Line mentioned the apprehension shown by CEOs about the possibility of India missing its solar power target. It cited the major hurdle coming from the rooftop solar power segment. Against a target of 40 GW of rooftop solar power installation by year 2022, the current installation is only around 2 GW. When the contribution of rooftop solar PV is more than 50% of the total solar PV in countries like Germany, in India the corresponding figure is less than 10% [12]-[20].

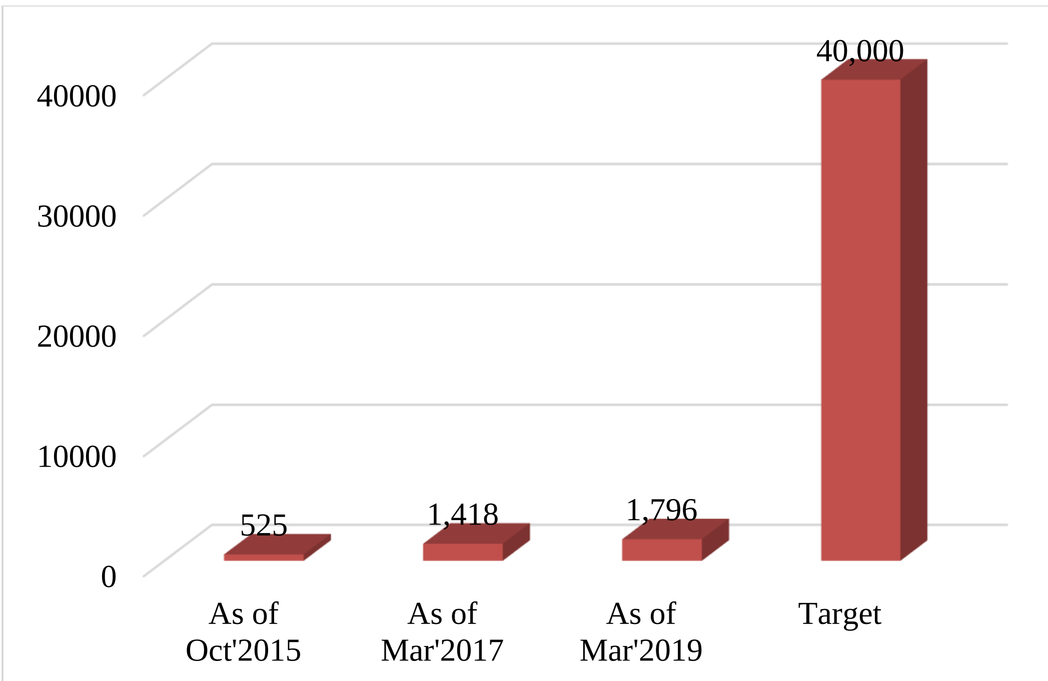
Figure 1.13: Share of rooftop in total solar PV installation



Source: Poonnavich Suppanich, Weerin Wangjiraniran (2015) and Bridge to India Annual Report 2016 [12]-[20]

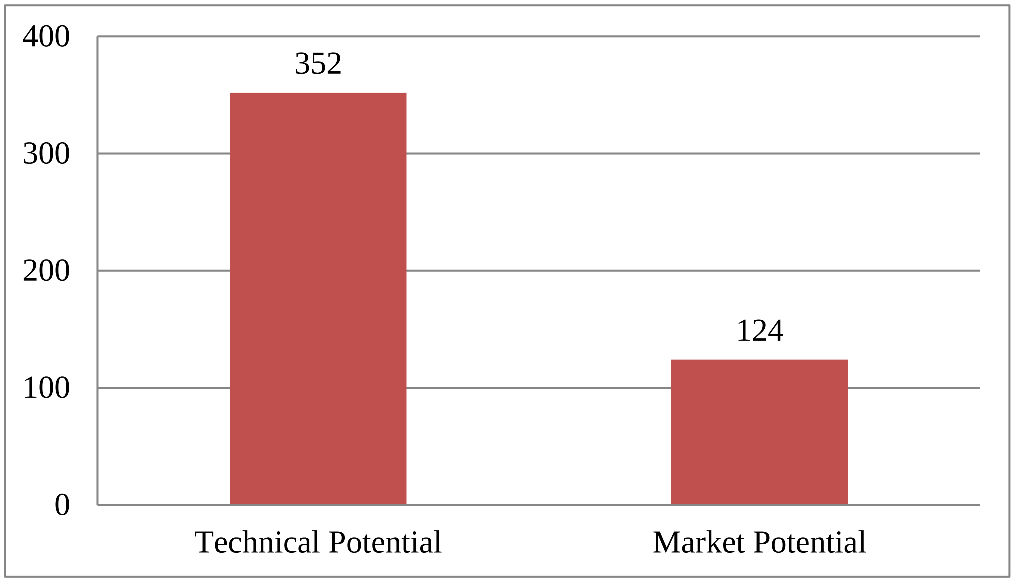
As of March 2019, the total rooftop solar PV installed in India is only 1,796 MW. This is miniscule if we look at the potential and the 2022 target of 40 GW set by the government.

Figure 1.14: Rooftop PV scenario in India (in MW)



Source: Bridge to India

Figure 1.15: Solar Rooftop PV potential in India in GW



Source: Report of the expert group on 175 GW RE by 2022 by Niti Ayog

Considering its significance in providing electricity to households in remote locations and also its contribution in providing clean energy, growth in this segment holds extreme criticality in the over-all success of the Indian power sector. As availability of land is always a big question mark due to several reasons, there would be limitation in the growth of large ground mounted solar PV plants. Rooftop solar PV system has all the ingredients to witness sustainable growth over a very long period. So, it is an irony that this arm of the entire solar PV system is actually a laggard in India. The situation is same across all the states, except to some extent the state of Gujarat. Cost of rooftop solar PV system is one of the lowest in India and there are various government sponsored financial incentives for consumers to adopt it. However, nothing seems to be working for the improvement in the adoption of rooftop solar PV system in India

Table 1.1: State wise solar PV target and achievement Dec 30, 2019

	Target (MW)	Utility (MW)	Rooftop (MW)
Maharashtra	11926	1663	216
UP	10697	1045	141
AP	9834	3559	88
Tamil Nadu	8884	3788	156
Gujrat	8020	2764	302
Rajasthan	5762	4844	120
Karnataka	5697	7275	132
MP	5675	2237	49
West Bengal	5336	109	43
Punjab	4772	947	68
Haryana	4142	249	118
Delhi	2762	156	110
Bihar	2493	149	7
Odisha	2377	398	14
Jharkhand	1995	38	14
Kerala	1870	142	42
Chhatisgarh	1783	231	10
NE States	1205	58	41
J & K	1155	19	11

Uttarakhand	900	315	76
Telengana	0	3621	73
Total	100,000	33,730	1,889

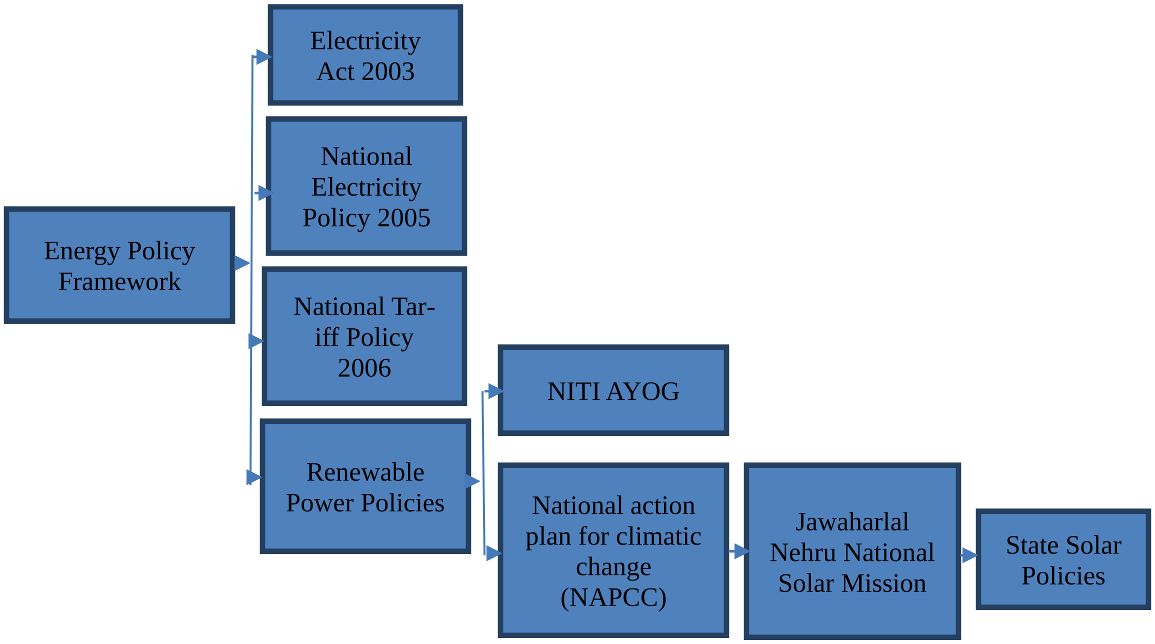
Source: MNRE

Since the new Electricity Act, 2003 was introduced, the platform was set for changes in the Indian power sector. After that a few important policies were introduced that helped the growth seen in solar energy in the country.

1.4 Act and policies in India

Electricity Act 2003 can be considered as the steppingstone for the growth of solar PV or any renewable energy in India. Figure 1.13 depicts the energy policy framework of solar energy in India. All these acts, plans, or policies have taken cues from each other and are closely interlinked. This framework plays a vital role in any policy development of the states.

Figure 1.16: Energy Policy Framework of India



1.4.1 Electricity Act 2003

The first seed of change to Indian power sector was sown through electricity act that was established in 2003. The objective was to bring revolution to the power sector with the introduction of a new framework and limiting the role of the Government in many of the activities. The objective of the Electricity act was not only framing laws for a generation, transmission, sharing and consumption of electricity, but also to stimulate and streamline electricity policies and tariff in the country through launching central electricity board and restructuring the SEBs (state electricity boards). Section 61 of the Act enforces the state electricity boards to line up encouraging tariff rates that would result in promotion of Renewable energy resources. The act envisaged rural electrification, setting up a national tariff policy, precaution against theft of electricity and protection of consumers.

The policy through another section (section 86) ensures generation of electricity from renewable energy through a provision of mandating a certain percentage of electricity fed to the grid coming from renewable sources. As per the act, the state boards were assigned one primary function promoting generation and co-generation of electricity from renewable energy sources and there should be facilities for intra-state transmission and wheeling. Various steps like open access on payment of surcharges on successive tranches of purchase coupled with issues like cross-subsidies would pave the way for determining the intrastate wheeling charges. The act provides appropriate measures for any power plants with grid connectivity, to be able to sale electricity, which in turn gave a boost to the prospective players in the field of power generation.

1.4.2 National Electricity Policy 2005

The National electricity policy was amended in 2005 with an objective of supplying quality and reliable power of specified standards to the whole of India at improved efficiency and reduced tariffs. The policy introduced state wise open access transmission to encourage participation from the private sector in the power sector. Application of Supervisory Control and Data Acquisition (SCADA) and data management systems were enforced for improving the efficiency of the distribution network. In an attempt to augment the electricity generation in the country, the policy tried to reduce the capital cost requirement by encouraging competition among generation companies. Apart from fixing up the tariff rates, the policy mandates the SEBs (state electricity boards) to fix targets for installation and production of renewable energy.

1.4.3 National Tariff Policy 2006

The national tariff policy was announced in 2006 by the Ministry of Power, Government of India. The policy introduced the role of an appropriate electricity commission that would fix the tariff at which the distribution companies would procure the minimum percentage of electricity from renewable sources. Such procurement would be done through competitive bidding process. The objective of the policy were: (a) to ensure availability of electricity to all the consumers at competitive and reasonable tariff, (b) improve financial viability of the power sector to attract investment, and (c) endorse transparency and consistency in the system by reducing regulatory intervention.

1.4.4 National Action Plan on climatic change (NAPCC)

In 2008, government of India introduced the NAPCC to thwart the challenges posed by climatic changes and attain sustainable growth in India. It aims at creating awareness about this threat among the entire community; different government agencies, scientists, industry, and public representatives to bring in the realization among us about the responsibility of protecting the earth. The plan has eight missions and one of those is the national solar mission of implementation and execution of Jawaharlal Nehru National Solar Mission (JNNSM). Other missions are National Mission for Enhanced Energy Efficiency, national mission on sustainable habitat, national water mission, national mission for sustaining the Himalayan ecosystem, national mission for a green India, national mission for sustainable agriculture and national mission on strategic knowledge for climate change.

1.4.5 Jawaharlal Nehru National Solar Mission (JNNSM) 2010

NAPCC points out that India is a tropical country that receives sunshine not only for longer hours but also with good intensity. So solar energy has great potential here and this type of distributed generation is suitable for providing electricity to people living in remote locations. Based on this vision, in year 2010, government of India announced the Jawaharlal Nehru National Solar Mission (JNNSM) to encourage substantial growth of solar power to provide energy security in India that would be economically and ecologically sustainable. The mission had an initial target of installing 20 GW capacity of solar energy by year 2020 in three phases. The target was subsequently revised by NITI Aayog. The revised target for the first phase of JNNSM was set at installation capacity of 1 GW by March 2013 and it was accomplished in 2012. The second phase of the target was set at 10 GW that was scheduled to continue till March 2017. The final targeted capacity as per the last phase was 20 GW on or before March 2022. Another important objective of JNNSM is to make the country a leading country worldwide in solar energy by boosting confidence of power developers, encouraging manufacturing activities in solar sectors, and introducing large-scale goals supported by adequate policy framework.

The key factor identified by the mission to promote solar energy would be through a Renewable Purchase Obligation (RPO) set-up for power utilities. The RPO energies the utility-scale power generation and increases the Solar Purchase Obligation because of drop in tariff fixed for Solar power purchase. Putting in solar power demonstration plants along with bidding process would facilitate better price discovery, which in turn would determine tariff for solar energy. The mission aims to drive down costs of electricity from solar power and bring it towards grid parity, through rapid increase in installed capacity and technological innovation.

JNNSM offers opportunities for not only decentralized but also off-grid solar PV that is suitable for remote locations where grid penetration is difficult as well as very expensive. The mission, through providing 90% subsidy for the off-grid solar systems, encourages rural communities to set up stand-alone solar power plants in special category states and inaccessible locations. MNRE plans to provide solar lighting systems covering about 10,000 villages and hamlets through its remote village electrification program. In urban locations, JNNSM promotes setting up of the rooftop solar PV, solar park, and other small solar power plants.

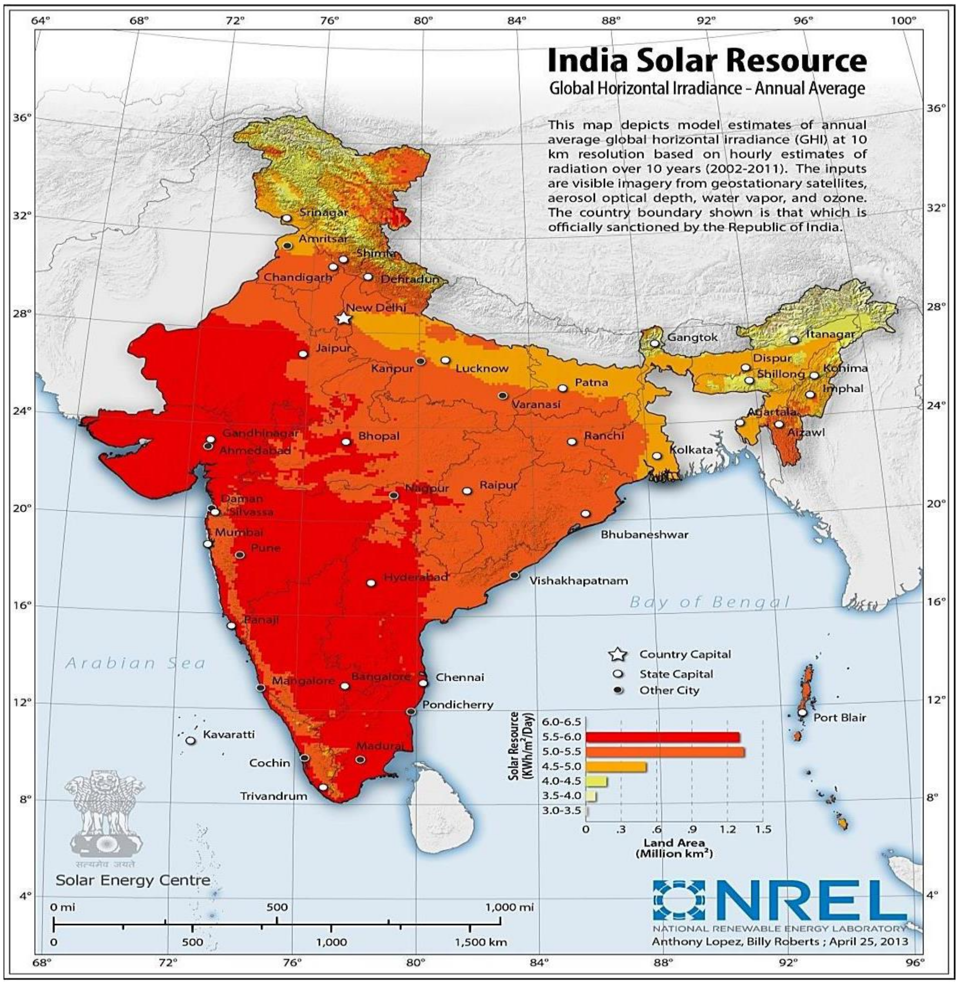
1.4.6 National Institution for Transforming India (NITI) Aayog

On 1st January 2015, government of India abolished its 65-year-old Planning Commission and established NITI Aayog. NITI Aayog was set up with the purpose of coming up with strategic plans for a long-term policy, form program frameworks, and monitor the progress and efficiency.

India witnessed significant growth in solar PV installation since the introduction of national solar mission. This growth coupled with around 60% drop in the price of solar PV between year 2010 and 2014, encouraged NITI Aayog to revise the current solar target of India. The Aayog amended the renewable energy roadmap and increased the target for solar power installation capacity to 100 GW by 2022 from the earlier estimate of 20 GW.

NITI Aayog focuses on upgradation of technology and capacity building for successful implementation of programs throughout the country. NITI Aayog additionally addresses the issue of proper planning and managing of the grid to ensure system reliability that is too important considering the fluctuation and uncertainty in the output of solar photovoltaic power plants.

Figure 1.17: Solar Radiation in India



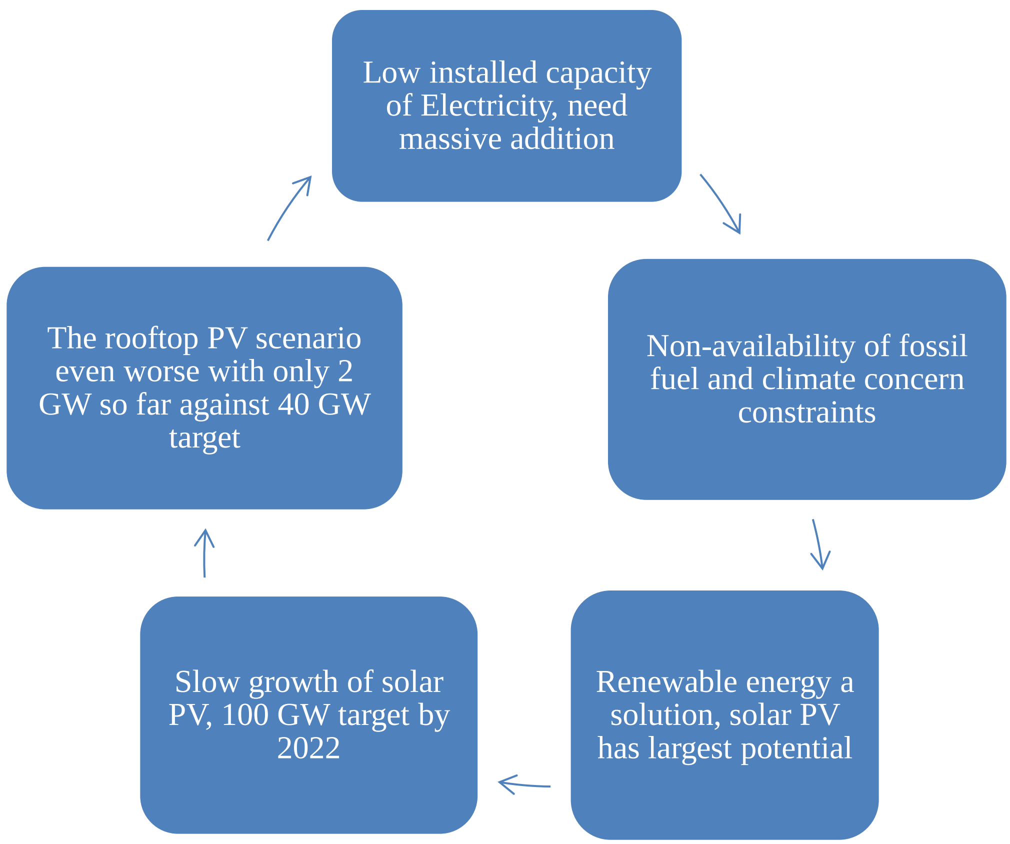
Source: NREL

This slow growth in rooftop solar PV will certainly dent India's ambition of migrating to a generation mix comprising mainly renewable sources in future. Without that, providing quality power to all its citizens along with reducing greenhouse gas emissions would be difficult to achieve. Continuing dependence on fossil fuel for electricity generation will also not help the country reduce its import bill on account of importing fossil fuel like coal and oil.

1.5 Problem Statement

Slow adoption of rooftop solar power system in India has dented the country's ambitions to provide reliable power to all its consumers, reduce the import bill of more than one lakh crore rupees on account of fossil fuel and reduce around 320 million tons of CO2 emission per year.

Figure 1.18: Schematic Representation of the Problem



Source: Own representation

1.6 Summary

This section discusses the potential of India as an emerging economy which is one of the fastest in the world too. For sustainability of the growth in economy, the major challenge is meeting the growing energy need from green sources. The power sector in India is currently one of the worst in the world, in terms of per capita consumption, frequent blackouts, and people not having access to grid power. Most of the power plants in India are coal fired and highly polluting the environment.

Government of India has drafted a future plan of installing 175 GW of renewable energy by year 2020, of which 100 GW will come from solar PV. 40 GW of this 100 GW solar power would be from rooftop segment. India is a densely populated country and so land is scarce. In view of this rooftop solar PV will be ideal for India. The country is also blessed with almost year around good solar radiation. However, the growth in rooftop solar PV in India has been very poor. Against a target of 40 GW by year 2022, the country has managed to install only 2 GW so far. Compared to countries like Germany, USA, China, or Italy, this is significantly lower. This slow growth of rooftop solar PV will severely dent country's plan to gradually shift to renewable energy to meet the energy demand. This study helps the researcher finalize the business problem, which is slow growth in rooftop solar PV in India.

2. Literature Review

Review of various literature, referred journals and articles related to the area of problem statement, is a key element of any research. A thorough and exhaustive review of available literature provides all kinds of work already done on the subject and a lot of data and information. Understanding of the literature helps the researcher find the research gap corresponding to the identified problem. Here the researcher prepared a few themes on which search for available literature began. A lot of emphasis was given to find world class journals and articles of repute. The themes on which the researcher studied the literature are

a. Solar energy
b. Advantages of rooftop solar PV
c. Barriers of rooftop solar PV
d. Solar PV adoption
e. Government policies in different countries and across important states of India that encourage adoption of rooftop solar PV

2.1 Solar Scenario

In general, solar energy technologies can be classified into two broad categories, photovoltaic (PV) and concentrating solar power (CSP). Photovoltaic cells convert sunlight into electric current, whereas CSP uses reflective surfaces to focus sunlight into a beam to heat a working fluid in a receiver. The contribution of CSP is extremely negligible and it is PV that is going to be the major technology for solar power. The total worldwide installed capacity of solar power was only 512 GW by the end of 2018 [14]. This is less than even 2% of the total solar power potential across the world. Over 22 countries in the world are meeting more than 1% of their power requirements from PV. Italy, Greece and Germany are the leading countries in the world in terms of percentage of their power generation coming from PV with shares of 8.6%, 8.3% and 8.2% respectively [14].

2.2 Advantages of Rooftop Solar PV

Solar PV has many advantages, a few important ones are: (a) involves no greenhouse gas emission, (b) operation is noise free, (c) system has long life of around 25 years, (d) there is low maintenance cost, and (e) it is easy to install [9]. A research on reviewing solar energy policies has identified key advantages of solar energy and those are: (a) no emission of GHG or other toxic gases, (b) reclamation of degraded land, (c) reduction in requirement for transmission lines, (d) improvement in quality of water resources, (e) improvement in energy independence,

(f) diversification of energy supply and so more energy security, and (g) faster electrification of rural and remote locations of developing nations [22]. A study in Hong Kong identified the advantages as saving in fossil fuel, and reduction in GHG emission and other pollutants [23].

In India wind energy took off much earlier than solar energy, but the later has significant advantages over wind energy. Solar energy is more abundantly available and more predictable [10]. Another study in India found out many advantages of PV and those are: (a) the country receives very high solar radiation with daily incidence ranging from 4 to 7 kWh/m2 and 2300 to 3200 hours of sunshine per year, (b) low marginal cost of generation, (c) can increase energy security by diversifying supply, (d) reduces import dependence, (e) mitigates fuel price volatility, (f) can be an important tool for spurring regional economic development [24]. A research paper in Tajikistan confirmed that solar PV energy had great potential to improve the sustainable development and livelihoods of communities living in remote mountainous regions [25]. In Bangladesh, it was observed that the growing popularity of Solar PV was because of a number of advantages. These advantages are: (a) no requirement for additional resource like water and fuel, (b) no moving parts, and (c) low maintenance requirement [26]. In Hong Kong the drivers of solar PV are Climate change and environmental hazards [23].

Among all sources of renewable energy, solar energy has the highest potential. For example, buildings in the US city of San Francisco receives yearly sum of solar radiation ranging from 967 to 2,110 kWh/m2 [27]). A study in Lebanon indicated that by tapping only 12.5% of the total rooftop surfaces of the residential buildings, it would be able to supply electricity to the whole country which is around 2.3 GW. So, this will eliminate use of any fossil fuel based power plant [28]. Despite the massive potential of solar energy, the energy is absolutely clean. A recent research in Denmark suggested that the world could shift to entire 100% renewable energy and if done so, GHG could be reduced to 10.2% of 2000 level by year 2050. Also, this will have socio-economic benefits as well, especially significant increase in local employment generation and savings of huge health care cost as improvement in environment due to more use of renewable energy will improve health issue [29]. A 5 MW solar PV plant studied in Saudi Arabia suggested that it would result in preventing an average 914 ton of greenhouse gases each year entering the atmosphere [30]. Another such 5 MW solar PV plant studied in Oman suggested that total of 7025 and 5944 tons of GHG could be avoided each year if the 5MW PV plant replaced diesel and natural gas based generations respectively [31].

Rooftop PV has another benefit which is very important in the present context when the world is getting warmer. It reduces the load required for cooling the buildings. A study in the US indicated that rooftop PV reduced the peak load demand due to reduction in cooling load of the buildings [32]. Another study in Canada also supported this claim [33]. A study in India based on a computer simulation, demonstrated that the energy required for roof-induced cooling load decreased between 73% and 90% after installation of the PV system [34]. A research in Greece confirmed that building integrated PV applications not only saved conventional energy use, but also offset the ‘‘peak’’ electricity generation from fossil fuel, like coal and oil. For building installing rooftop solar PV, electricity is generated at the point of use and therefore transmission and distribution losses are avoided leading to reduction in utility company’s capital and maintenance costs [35].

Solar PV offers a sustainable way of producing electricity to provide the growing need of the society. The major advantages are: (a) no pollution through greenhouse gas emissions or harmful waste generation like radioactive waste, (b) as this is a form of distributed electrical generation, adoption of this reduces the dependence and pressure on the national or state grids and so eliminates to a large extent the possibility of blackouts and overloads, (c) it helps in national energy security, and (d) it provides sustainable and long term economic growth prospects for any country. Because of such enormous benefits, it not only attracted international cooperation but also investment in technology over the past so many years. Such cooperation and investment in technology resulted in tremendous gains in performances of solar PV system [36]. Although there are issues related to grid problems due to increase in electricity generation from rooftop solar PV systems, researchers in the US found that the excess energy generated by solar panels helped reduce the pressure on electric grids during summer season, when demand increases significantly forcing utilities to buy substantial power at high rates. A few experts mentioned that the shift to solar energy was significantly helping the states meet requirements put forward by the federal to reduce greenhouse gas emissions. Solar PV is also generating thousands of new jobs [37].

A study in Phoenix and Tucson metropolitan areas in the United States showed that deployment of cool roofs and rooftop solar photovoltaic panels reduced air temperature near the surface across the diurnal cycle and decreased daily cooling energy. During the day hours, cool roofs are more effective at cooling than rooftop solar photovoltaic systems, but during the night, solar panels are more efficient at reducing the urban heat island effect. It was found that while cool roofs reduced daily citywide cooling energy demand by 13–14 %, rooftop solar photovoltaic panels reduced the same by 8–11 %. These benefits didn't include the additional benefits derived from the electricity production. The results demonstrated that deployment of both roofing technologies had several benefits for the urban environment. Also, solar photovoltaic systems provide additional value as they reduce the dependence on fossil fuel consumption for electricity generation [38].

A research in South Korea demonstrated that almost 30% of the annual electricity consumption of the city of Seoul could potentially be met from widespread installation of rooftop solar PV systems [39]. The research emphasized the importance of rooftop solar PV at a time when rapid urbanization around the world is causing massive increase in energy requirements across all the major cities. The largest 35 cities in China are home to about 18% of the global population. These cities account for 40% of the country´s energy consumption and CO2 emissions. If we look at the worldwide situation, all the cities account for around 67% of global energy consumption and 71% of CO_2 emission from energy related emissions around the world. So, strategy like meeting a considerable portion of the cities' energy demand from electricity produced from rooftop solar PV would be critical to the sustainability of these major cities.

In the city of Ontario, Canada, potentially 30% of the city's annual energy demand can be met through electricity generated from rooftop solar PV [40]. Falling capital costs and growing emissions reduction ambitions are foreseen to result in solar PV playing a major role in future power systems [41].

2.3 Barriers of Rooftop Solar PV

Despite growth of rooftop solar PV across the globe, there are barriers to its adoption. Several research are available both in India and other countries in finding out the barriers to adoption of rooftop solar PV.

A white paper published by MNRE and TERI in 2014 [106] identified some key barriers to large scale adoption of rooftop SPV across various consumer categories in India and those are:

(a) high upfront cost,

(b) limited financing schemes by banks,

(c) lack of awareness among consumers,

(d) availability of limited standardized rooftop solar PV systems,

(e) inadequate supply chain for rooftop solar PV systems,

(f) inadequate experience of grid connectivity at low voltage,

(g) limitations of solar systems to function during power outage, and

(h) higher cost of dual function inverter (which allows consumption of solar electricity during power outage).

A study in Puduchery, India found out some barriers to rooftop solar PV and those are: (a) lack of consumer awareness about rooftop solar technology, (b) high initial cost of installation, (c) higher payback period, (d) lack of clarity on subsidy, (e) suitability of rooftops, (f) requirement of storage battery [54]. Higher capital cost as a barrier was again confirmed by another research in India [56].

Malti Goel (2016) in her paper “Solar rooftop in India: Policies, challenges and outlook” identified the key challenges for India in growth of rooftop solar PV. Those are: (a) consumer awareness and acceptance (b) manufacturing of solar cells and R&D, (c) installation technology and skilled worked force, (d) need for new business model, (e) micro and mini grid development for distributed generation, (f) integration of solar energy into national grid, and (g) challenges in regulatory framework [55].

Similar type of barriers were indicated by one more study in India and these were: (i) lack of awareness among prospective users, (ii) limited outlets for procurement, (iii) unavailability of different models catering to varying needs among various user segments, (iv) high price, and (v) limited hours of usage possible for solar systems [49]-[57]. One more study in India stated that some of the key limitations of PV were its high capital cost and inability to support large load [9]

A study conducted in Indore, Madhya Pradesh on adoption of solar energy products like solar inverters, solar water heating systems, solar lights, etc. identified the major barriers to the adoption of solar products as perceived high cost, financial constraints, lack of awareness about government initiatives, and absence of promotional activities [74]. A research in India highlighted benefits of raising awareness through demonstration of PV and facilitating financing of PV systems to the end-users in the developing countries [49]-[53]. Higher temperature is not good for PV. The highest PV output condition occurs at the worst-case condition expected (coldest temperature and highest incident irradiance) [58]. This is not a favourable situation in India.

Although cost of solar rooftop PV is coming down, it is still debatable whether or not it can compete with fossil fuel under different circumstances and at different locations. In India, IRR of a small rooftop SPV of capacity 2.5 kW was found to be around 9% without any financial subsidy by the government and 13% with subsidy [144]. Another study In India done in 2013 estimated that grid parity could happen in the period of 2017–19. This was because of the falling prices of PV panels, not only from China but also from the U.S., and growing cost of grid power in India [68]. A study of an on-site solar PV plant (without land and battery cost) in the Indian city of Jaipur found the levelized cost of electricity at Rs. 14.94 [69]. A research on solar energy in India predicted PV module price to fall continuously due to over-capacity and predicted that by 2016, the cost of solar power could be as much as 15 percent lower than that of the most expensive grid-connected conventional energy supplies. Project execution, financing, and localization were stated to be crucial [70].

It can be noticed from all these research in India that there is considerable overlap among the barriers found out in each research. The important barriers can be summarized as: (i) financial unattractiveness, (ii) lack of awareness among consumers, (iii) technical limitations in both installation and usage, (iv) absence of effective promotional schemes and (v) supply chain problems.

Just like India, considerable research is available in other countries in finding out major obstacles to adoption of rooftop solar PV.

A study in Bangladesh classified the determining factors for solar PV adoption as geo-physical, economic & socio-political, and environmental [48]. Geo-physical factors are location, sunshine, solar radiation, and available surface area. Economic & socio-political factors are capital investment, technology support, political commitment, and social acceptance. Environment factors are GHG emission reduction, and environment protection.

A recent study in China finds out major barriers to solar PV as: (a) difficulty in identifying suitable rooftops, (b) short life span of many rooftops in China, which are often designed to last only 10 to 15 years instead of usual life span of 20 to 30 years, (c) lower residential electricity tariff compared to commercial and industrial tariffs, making the self-consumption Feed-In-Tariff less attractive for residential systems, (d) China’s relatively weak legal and institutional mechanisms for en-forcing contracts and contract payments, (e) difficulty in financing, (f) absence of standards for connecting PV to the grid at different voltages, (g) government time lag in policy implementation, and (h) labour availability [63]. Another research in

China confirmed that the cost of PV power generation was the most obvious barrier [44].

One of the major reasons for the slow adoption of PV domestic systems in Asia and Pacific region is the use of very broad terms of administrative criteria [49]-[51]. Broad terms of administrative criteria indicated the hassle of getting the procedural clearance as well as receiving government incentives for installing rooftop solar PV. In Pakistan the major barriers found out were: (a) high initial cost, (b) inadequate renewable energy policy, (c) lack of awareness in local communities, and (d) inadequate availability of technical knowledge [22]. A research done in Nepal found that cost of electricity from solar PV was higher than grid price and that was the hindrance to its growth [60]. In Honk Kong major challenges were high initial cost, large installation space and heavily obstructed external environment [23].

A study in Saudi Arabia mentioned key barriers for renewable energy as: (a) huge public subsidies for fossil fuels, (b) government preferences to large scale and centralized projects, (c) investment risks, (d) lack of administrative experience with renewable technologies, and regulatory issues [21].

Although, rooftop solar PV has very long life of around 25 years, a research in

South Africa indicated that its performance degrades over time [42]. The efficiency at which the solar PV operates gradually drops over the period. Research in Zimbabwe showed the presence of a finance scheme acting as a catalyst for PV growth [49]-[52]. A study in Bahrain confirmed that high capital cost, lack of necessary information on PV, and apprehension about maintenance related issues were the major barriers [143].

A study in Egypt suggested higher initial investment is a major barrier to PV [46]. A study in Greece supported this claim. It found out that although the barrier was delay in getting approval, higher growth was witnessed during a period because of 55% of initial cost given as incentive and high FIT [47]. The study emphasized the necessity for a simplified licensing procedure and a better coordination through institutions for environmental approvals. Experience from Mexico indicated technology-user interaction as a more critical problem for adoption of PV than cost, efficiency, or other purely technological issues [49]-[50].

Research highlighted the unavailability of skilled technicians required for promotion and installation of the systems as a barrier in developing countries [49]-[66]. Similarly lack of investments and financing, high transaction costs, subsidies to conventional fuels and lack of awareness about PV systems at all levels were found to be market barriers for PV in Least Developing Countries [49]-[67].

In their paper “Solar energy: Markets, economics and policies” carrying out research in Australia, the authors classified the barriers to solar energy into technical, economic, and institutional barriers. The paper also discussed various policy instruments that support PV [45].

Technical barriers are: (a) low efficiency of PV modules, (b) performance limitations of other system components, (c) inadequate supply of raw material, (d) incompatibility of the existing electrical system with conventional energy.

Economic barriers are: (a) initial system cost, (b) high cost of electricity generated from PV, and (c) financing problem owing to higher risk.

Institutional barriers are: (a) lack of effective and appropriate laws such as Renewable Portfolio Standards or RPS for utilities, (b) limited ability to train adequate number of technicians to effectively work in a new solar energy infrastructure, (c) limited understanding among key national and local institutions of basic system and finance factors, and (d) procedural problems such as the need to secure financing from multiple sources and approvals from several agencies.

A research in the United States identified the barriers to the growth in adoption of rooftop solar PV as: (a) lack of awareness by the end users and major stakeholders, (b) extreme levels of risk aversion, worries about the system performance, and (c) absence of suitable rooftop space for installations. However, the greatest obstacle perhaps is the combination of all these barriers [71].

Contrary to general belief, a research opined that cost was not a significant barrier in China [43]. Grid connected distributed generation in the form of roof-top installations contribute significantly to the overall market in Japan and Germany [49].

A 5 MW solar PV plant studied in Saudi Arabia offers an IRR (Internal Rate of Return) mean value of 13.53% while the minimum and maximum varied between 10.73% and 16.65% [30]. In Korea electricity from solar PV was found more expensive than other sources [59]. In Oman, one study on a 5MW solar PV plant indicated PV Cost of Electricity to be higher than that from gas, but lower than diesel [31]. A research in Canada suggested that without drop in installation cost, LCOE was not at par with grid price. The high initial upfront cost of solar PV still seems to be a hurdle to adoption, despite declining cost of systems [61]. In his research the author C.Yang (2010) determined that a realistic examination of grid parity would suggest that solar PV was much further away from becoming cost-effective in distributed (residential) systems than what was normally claimed. The main problems identified were: (a) many analysts were not amortizing all of the cost to the end consumers, and (b) wrongfully considering $1/Wp manufactured cost instead of retail installed cost when calculating grid parity [63]-[62]. A study in Bangladesh noticed that an IRR of 10.62% could be obtained in any location in Bangladesh for a grid connected PV power plant [64]. A study in UK indicated that larger size solar PV plants were financially more competitive. Rooftop solar installations of 50 to 250 kW returned positive NPVs, while some of the smaller capacity installations at some sites returned negative NPV [65].

There are some research indicating barrier to rooftop solar PV from utilities side.

The rooftop solar PV systems share certain proportions of loads connected at the mains of residential households, depending on their capacity. As rooftop PV systems take care of a portion of the loads locally, pressure on the distribution feeder is reduced and system performance is improved by means of reducing feeder loss and releasing system capacity. At the same time, integration of rooftop solar PV systems at a high penetration level can impose number of challenges for distribution network operators and one major problem is voltage rise in the network [26].

The rapidly growing technological competitiveness of solar PV, along with other forms of renewable energies, has resulted in a new era of infrastructure provision and a paradigm shift in energy policy. While considerable debates are going on about urban and rural development along with infrastructure policy, the public is taking it for granted the integration of different disciplines (geographic information system, environmental modelling, urban planning, different branches of engineering) and their roles in the delivery of utility services. People believe that within each single discipline, the task should be left to engineers, network operators and national utility regulators. As a result, there has been hardly any research carried out on the urban and regional impacts of utility restructuring and the changing environment for urban and regional governance with this possible large-scale adoption of solar PV. To take advantage of solar PV technology's steady drop in price, a thorough understanding of the urban local potential of solar PV is critical for utility planning, accommodating grid capacity, deploying financing schemes and formulating future adaptive policies [36].

Difficulty in accurate projection of rooftop solar PV potential is a barrier to the adoption of this technology [40]. To accommodate large number of rooftop solar PV systems and integrating that with the grid, proper grid planning is unavoidable.

Without proper planning of the grid capacity, sudden spurt in electricity generation from solar PV system will lead to grid imbalance in terms of voltage fluctuation. Estimation of rooftop solar PV potential doesn't end with estimating the total roof area only. It requires other factors such as orientation of rooftops, efficiency of solar PV panels, solar insolation in the region, and shading because of some obstacles. One more issue with rooftop solar PV is the mismatch in timing of peak load demand and peak generation form solar PV. In countries like India, generally peak demand in electricity occurs during evening hours whereas peak generation from rooftop solar PV happens during hours around noon. This mismatch requires storage of electricity generated by the rooftop solar PV when the demand for electricity is low.

2.4 Solar PV Adoption

There is not much research available in the field of adoption of rooftop solar PV, especially in India there has not been any so far. However, a few studies have been done on adoption of solar energy products. A study in Punjab identified five major factors that determine the acceptance of solar energy products and these are benefits, attitude, awareness, investment, and promotion. The study also identified lack of financial support by the government and high initial cost as major barriers to the diffusion of solar energy products [72]. Another study in Telengana state in India indicated that perceived benefits combined with demographic variables played a major role in the adoption of solar energy products [73].

A very old research in USA on adoption residential solar energy revealed significant differences between adopters and non-adopters, both on attribute perceptions of solar energy systems and demographic characteristics. The study confirmed that adopters perceived certain key attributes of solar energy system more favourably than non-adopters. These attributes are relative advantage, complexity, compatibility, perceived risk, observability, and trialability. Also, on demographic factors, the adopters were found to be younger, more highly educated, higher in income, higher in occupational status, and earlier in the family life cycle [126].

A study in San Diego county, USA applied a data driven agent-based modelling framework to analyse residential rooftop solar adoption [43]. The study found out that peer effect measured in terms of number or density of adopters in any location was vital to consumers adopting it.

Another study in Texas, USA, surprisingly indicated that influence of others in the neighbourhood or close acquaintance was not an important factor in adoption of solar PV [142]. Rather, factors like financial attractiveness and environmental benefits were more important for adopters. However, another research again in USA confirmed a strong relationship between adoption of rooftop solar PV and number of nearby installed systems [119]. It also suggested a strong relationship between adoption and environment and policy variables.

In Thailand, despite its National Energy Policy Commission adopting new feed-in tariff in 2013 to support rooftop and community ground-mounted solar installations, the goal of the residential rooftop solar couldn’t be achieved [20]. The study found out the 20 critical factors each for acceptance as well as rejection of rooftop PV.

Table 2.1: Critical factors to acceptance and rejection of solar PV

Factor	Definition	Acceptance	Rejection
Global warming	Solving climate change situation	1	16
Technology Development	Solar power technology will be developed steadily in the future	2	19
Unlimited Power	Infinite power from the sun	3	4
Environmental Protection	Reduction in GHG emission	4	20
Building Location	Solar radiation potential of the location	5	3
Social Value	Solar energy is decent technology for their social value	6	17
Land Use	The area consumed by the system effect on living of installer	7	13
Power System	Effect of the new system on the recent power system.	8	18
Solar Energy Knowledge	System installation will make people know how to use it	9	8
Global Trends	Renewable energy's worldwide	10	14

	popularity		
Power Production Monitoring	Power generation can be monitored	11	11
Building Structure	Strength of the roof and building structure for system installation	12	7
Installation Space	Area suitability for installation of solar PV	13	5
GHG Reduction Monitoring	GHG emission can be monitored	14	10
Neighbor Attitude	Attitude about environmental protection image	15	15
Maintenance	Difficultly of maintenance	16	2
Income Statistics Monitoring	Income from selling electricity can be monitored	17	12
Availability of Service Providers	Difficultly of access to the service providers	18	6
Installation Cost	The installation cost is too high and effect to living cost	19	1
Revenue	Sell solar electricity	20	9

Source: Suppanich and Wangjiraniran, 2015

2.5 Solar PV Policies

Government policies are important for faster adoption of rooftop solar PV and across the globe, different policies are in place. As per a study by Govinda R. Timilsinaa, Lado Kurdgelashvilib, and Patrick A. Narbel (2012) [45], various policy instruments that support PV and are in place in many countries, are

i) Feed-in-tariff (FIT): This policy has been implemented in more than 75 jurisdictions around the world as of early 2010, including Australia, EU countries, Brazil, Canada, China, Iran, Israel, the Republic of Korea, Singapore, South Africa Switzerland, the Canadian Province of Ontario and some states in the United States. It played major role in success in Germany and Italy.

ii) Investment tax credit: Despite their instrumental role in promoting solar energy, investment tax credits schemes are criticized for their impacts on government revenue

iii) Subsidies: Subsidies are the primary instrument to support solar energy development in almost every country around the world.

iv) Renewable energy portfolio (RPS): In the United States, 31 out of 50 States have introduced RPS. Many countries, particularly developed countries, have set penetration targets for renewable energy in total electricity supply mix at the national or state or provincial levels

v) Financing facilitation: In India, the Shell Foundation worked with two leading banks in India, viz. Canara Bank and Syndicate Bank, to develop renewable energy financing portfolios. In Bangladesh, the Rural Electrification and Renewable Energy Development Project established micro-credit financed facilities that resulted in the installation of over 970,000 solar–home systems (SHS) between 2003 and May 2011.

vi) Public Investment: The rapid development of the PV industry and market in China is mainly due to government support, implemented through number of rural electrification programs

vii) Net metering: It has been implemented in Australia, Canada, United States and some European countries including Denmark, Italy and Spain

viii) Government mandates and regulatory provisions: In Germany, all renewable energy generators are guaranteed to have priority access to the grid.

Here is a summary of policies that made solar PV successful in different countries [22].

Country	**Policies**
USA	Renewable portfolio standard, incentive like PURPA 1978, investment tax credit, and production tax credit
Canada	Feed-in-tariff, government incentives, and subsidy
Germany	Feed-in-tariff, credit terms, and tax incentives
Spain	Feed-in-tariff and targets
France	Feed-in-tariff, green loans, and tax incentives
China	Renewable energy law

Pakistan	National Renewable Energy Policy
Australia	Feed-in-tariff, subsidy, and targets
Malaysia	Increase in research & development, and subsidy

A research finds out the hierarchy of the priorities of criteria in a variety of technology alternatives, and the hierarchy is useful in policy formulation. Among technical, political or social, and economic factors, surprisingly political or social factors have overwhelmingly low importance [75].

A research paper by European Wind Energy Association concluded that FIT mechanisms were the most suitable policies for introducing renewable energy technologies to the market, and an investment grants tendering system is suitable for supporting immature technologies. (European Wind Energy Association EWEA), Wind energy facts: a guide to the technology, economics and future of wind power. London: Earthscan Publications Ltd.; 2009 [102].

A study in China identified the drawback of upfront subsidy on the growth of solar PV. First, an upfront subsidy provides an incentive to install PV but does not provide a strong incentive for the systems to produce electricity, which resulted in concerns about the installation of low-quality PV projects and cheating the subsidy programs. Since 2013 government instead has been following a performance-based incentive or Feed-in-tariff [63]. Authors carrying out a case study on solar PV in Taiwan suggest that at the formative phase when the new technology is to emerge, supply of resources in the form of research, and development of demonstration programs are critical to success. The existing schemes in Taiwan include demonstration system, subsidy, financial assistance, and subsidy o purchasing electricity. For further growth in PV, three measures are recommended and those were: (a) implement pricing policies which are powerful, predictable and persistent, (b) design different prices for different renewable energy, (c) form further market expand programs in the medium and long-term [76].

Experiences from many European countries confirm the importance of financial incentives in the growth of solar PV [77]. When Spain witnessed a drop in installation of solar PV due to change in incentive policy in 2011, other countries like Greece, Israel and Turkey noticed significant increase in solar PV market due to introduction of new incentives. In all these countries including Germany and Italy, role of Feed-in tariff was extremely critical. Germany's spectacular success in solar PV can be attributed to the "Thousand roofs programme" in 90's as it demonstrated technical feasibility and sent a positive signal to the PV industry. It provided an important impulse for the further development of the technology [77].

Thailand introduced feed-in tariff to support growth of solar rooftop PV. The FIT was 6.96 Thai baht (THB) per kilowatt hour for small-to-medium-sized systems and households producing not more than 10 kW, while for those that generate 11 to 250 kW, the rate was 6.55 baht, and 6.16 baht for those making 251 kW or more. The government promised to provide FIT for 25 years [78].

Germany's successful FIT policy has been replicated elsewhere in the world and countries like Italy, Japan, Spain, UK and USA have also seen their PV market rapidly flourish. Since 2010, UK, for example, has seen its PV capacity grow exponentially due to conducive policies like FIT and renewable obligation certificates (ROC) [21]. In Brazil high tax on PV equipment and absence of incentives for this form of generation prevented large-scale use [79].

A research in Dominican Island raised the negative implications of subsidizing PV market and recommended an R&D strategy as compared to market push strategy for developing PV markets for rural electrification in developing countries [49]-[80].

On the basis of lessons on dissemination of PV systems in India, market development of PV based on product features rather than on subsidies was recommended [49]-[57].

Experience from China suggests that the development of a local free market seems more successful than donor or government subsidy driven programmes for a widespread deployment of decentralized PV technologies [49]-[81].

A study in Nigeria indicated that PV markets could be boosted by providing fiscal and financial incentives such as tax holiday, tax-free dividend, abolition of excise duty, etc. to industrialists and investors [49]-[82]. A research on net metering in India noted that some of the most popular support mechanisms for promoting PV systems around the world included capital subsidies, FIT, tax exemption and VAT reduction, and net metering [56]. However, grid characteristics and distribution sector were not fully ready for implementation of Net Metering. Malti Goel (2016) in her paper "Solar rooftop in India: Policies, challenges and outlook" identified the key factors in growth of solar PV in countries like Germany, USA, Italy, Japan etc. Those were Feed-in tariff, Tax Credit, Subsidies, Soft loans and Renewable Purchase Obligations. Among all these schemes, Fee-in tariff has been found to be the most important factor in the growth of solar PV [55].

A research by Vanderbilt University in Nashville, TN, USA and Sandia National Laboratories in Albuquerque, NM, USA observed that the rooftop solar market in the US, and especially in California, had experienced explosive growth in last few years [63]. The research noticed that at least a part this growth could be attributed to the incentive programs introduced by the government that effectively reduced the system costs. One of the most assertive incentive programs was the California Solar Initiative (CSI). CSI is a rooftop solar subsidy program initiated in 2007 and the goal of this programme was to create 1940 megawatts of installation capacity by 2016. However, the authors feel that in a rigorous sense, it would be advisable to measure this success in comparison to some baseline or benchmark. So, the policy should be evaluated in comparison to the same world, but in the absence of any incentives. Such an experiment to measure the success of any policy is almost impossible. But it is also critical to understand how success of any policy should be evaluated with respect to its stated goals or objectives, so that it can be learnt from past experience and better and effective policy alternatives in future settings with similar goals can be identified.

An extensive research was carried out in Thailand to find out effective business models and financing options for a rapid growth in adoption of rooftop solar PV in the country [83]. As we know suitable business models and financing options play a critical role in growth of rooftop solar PV in any country. The researchers observed that in Thailand, even though there was currently a pause in feed-in tariff support for rooftop solar systems, the adoption of rooftop solar PV was still doing well. It was primarily because of new business models and financing options for rooftop solar PV. The paper reviewed four business models and one financing option for customers to adopt rooftop solar PV system in Thailand. The four business models that were analysed are:

a. **Roof Rental:** Under this business model there are three key players: (a) the roof owner, (b) the developer company which would install and operate the rooftop solar PV, and (c) the utility company. In this model, the roof owner first gets into a 25-year rental contract with the developer company at an agreed rental fee to be received by the roof owner. The developer company enters into a 25-year power purchase agreement (PPA) with the utility. The developer then installs and operates the solar PV system from the rooftop. Mainly rooftops of commercial establishments like factories, shopping malls, industries were preferred in this business model because of larger roof area, stronger roofs that could withstand the extra loads of solar panels for 25 years and ease of getting into the contract. The major drivers under this model are: (a) the roof owners receive regular rental income for the roof without taking any risk of solar PV installation, and (b) the solar panels keep the roofs coolers, thus reducing the power requirement for the building. The major barriers in this model are the limitation or quota on PPA that the utilities offer and drop in feed-in-tariff.

b. **Solar shared saving through PPA:** Compared to the roof rental model, this model eliminates the uncertainties over quota over PPA and possible lowering of FIT by the utilities. The key players are again the roof owner, the developer and the utility company, although the role of the utility is significantly lower. The objective of this model is for the roof owner to receive electricity from rooftop solar PV installed on his/her roof with a developer taking the responsibility of installing and operating the system. The developer company gets into a long term agreement with the roof owner through which the developer installs, owns, and operates the solar PV system and sells the electricity generated to the roof owner at a price little less than the retail grid electricity tariff. The major drivers for such business model are: (a) Roof owners are assured of lowering the electricity bill without having the hassle of installing or operating the rooftop solar PV system, (b) The developer doesn't have to rely on the utility for buying the generated power, so scaling up the mode is easy, and (c) Stress on central grid is reduced, so government expenditure on electricity infrastructure also reduces. The major barrier to the growth of this model is lack of clarity on legal issues involving a third party other than the utility company selling power to the consumers. Like most of the countries, Thailand also has this concept of only the utilities selling power to the consumers and there is no clarity about another player acting as a utility company competing with the existing utilities. So, the developers are apprehensive about being pushed into legal complications by the utilities. Also, another barrier is the quantum of benefits the roof owners receive, which is significantly lower at around 5% to 10% of the existing retail grid power tariff. In both these roof rental and solar shares saving models, system sizing is important to ensure that most of the power generated through solar PV is consumed rather than being fed to the grid.

c. **Solar Leasing:** Solar leasing is a business model that allows the roof owners or consumers to install the rooftop solar PV without incurring the high upfront cost and pay the cost over a longer period. The players in this model are the roof owner, the leasing company and the utility. The leasing company (or lessor) gets into a leasing contract with the roof owner or the customer (lessee). The lessor installs, owns and operates the rooftop solar system on the customer's roof. The lessee makes the payment for the solar system through a combination of initial down payment and monthly instalments. The roof owner consumes the electricity produced from solar PV or sells it to utility at the existing feed-in tariff. This way the consumer enjoys benefits from the rooftop solar PV system in the form of energy saving or feed-in tariff income without facing the hardship of self-financing the initial installation cost. The major drivers of this business models are: (a) business opportunity for leasing companies and financial institutions to expand through a new area, and (b) Roof owners getting the opportunity to get benefits of rooftop solar PV without facing the difficulty of financing the installation cost. This resolves one major problem where millions of interested consumers are not adopting rooftop solar PV just because it is not affordable. One major barrier to this model is that it may not be feasible for small consumers. Leasing companies or financial institutions would not be interested to go for small residential buildings that won't sound attractive. Another barrier is the absence of legal formalities for third party registration of rooftop solar PV systems.

d. **Community Solar:** This the fourth business model that the researchers discussed. There are a few instances worldwide where groups or cooperatives set up solar PV systems to generate electricity for either own consumption or selling to the grid. Although growth of such model has been extremely negligible, it has got a good potential in future. This particular business model is like project financing. The community receives financing from different institutions in the form of loans having low interest and a long-term tenure. The equity investors offer around 15% of the total investment cost. Electricity generated is sold at feed-in-tariff and the income is used to pay back the investors, the lenders, and a small portion is kept for O&M cost and profit. One major driver of this model is the community mind set of people in rural areas and the bigger scale of operation. However, the barriers are the difficulty in forming groups of people who approve the model and then arranging low cost capital for financing the project.

The paper analysed the attractiveness of the first two business models, roof rental and solar PPA compared to the traditional approach of the roof owner buying and installing the solar PV. Basic financial parameters like NPV (Net Present Value), IRR (Internal Rate of Return), LCOE (Levelized cost of electricity) and Payback period. As it was not possible to calculate IRR and Payback period for solar PPA model due to zero initial investment, on parameters like LCOE and NPV, the solar PPA business model was found to be more attractive for the consumers. However, similar analysis indicated the solar leasing model not to be very attractive for the consumers unless it is supported by some government incentives.

The research concluded that rooftop solar PV in Thailand was at the formation stage and without government support it could not take off and expand on its own. But the critical suggestion was that the government support programmes should be different for different scales of operation. If government initiates various support programmes, more and more business models will emerge. Among the business models discussed here, the solar PPA model can sustain for commercial rooftop segments even without government incentives. The policies that it recommended were: (a) implementing net metering regulations, (b) providing financial incentives for residential rooftop PV segment and (c) simplification of permit or any other formalities. Sometimes, certain policies even deter growth of renewable energy. For example, in Bulgaria, the protection of arable land for farmers was a policy that deterred growth of solar PV because, ground-mounted photovoltaic modules reduced the total amount of arable land [84].

2.5.1 Policy Landscape in India:

The Indian government is offering several tax and financial incentives to support the rooftop solar market. The most important ones are:

- Capital subsidy: 30% subsidy for residential and institutional consumers
- Accelerated depreciation: 80% depreciation
- Tax holiday: 10 year tax holiday (MAT payable)
- Low cost funding: $1.5 billion funding from World Bank, ADB and KFW

2.6 Different Support Schemes for Rooftop PV in selected countries

Table 2.2: Renewable energy Policies in different countries

Schemes	Australia	Germany	India	Italy	Japan	USA
Direct capital subsidy		✓	✓	✓	✓	✓
Green electricity schemes (Customer has the option to buy green energy)	✓	✓		✓		✓
PV specific green electricity scheme						✓

Renewable Portfolio Standard (RPS)	✓	✓	✓		✓	✓
Solar set aside RPS target			✓			✓
Financing scheme	✓	✓	✓		✓	✓
Tax credits or tax benefits	✓	✓	✓	✓	✓	✓
Net metering or net-billing or self consumption incentives	✓	✓	✓	✓	✓	✓
Sustainable building requirements					✓	✓

Source: MNRE White Paper, 2014

2.7 Timeline for GOI's journey towards Renewable energy

Creation of CASE or Commission of Alternate Sources of Energy	CASE became an independent Department of New Energy Sources (DNES)	DNES became a full-fledged ministry	Electricity Act 2003 that provides a framework for overall growth of electricity sector in India. Mandatory for Distribution Licensees to procure renewable energy	National Electricity Policy 2005 that allowed preferential tariff for electricity produced from renewable energy sources	Tariff Policy 2006, allowed special tariff for solar energy, Integrated Energy Policy 2006, set specific targets for capacity addition
1981	1982	1992	2003	2005	2006

National Action Plan on Climate Change (NAPCC) 2008, advised that RPO's be set at 5% of total grids purchase, and be increased by 1% each year for 10 years	Generation based Incentives (GBI) for Solar introduced	Jawaharlal Nehru National Solar Mission (JNNSM) 2010, set targets of 20 GW of grid connected and 2 GW of off-grid solar power capacity by 2022. The present government later amended the target to 100 GW.	Renewable Energy Certificates (RECs) introduced	MNRE brought back the 30% capital subsidy for residential consumers
2008	2009	2010	2011	2015

So far 15 states have notified the State Solar Policies and those are Andhra Pradesh, Chhattisgarh, Gujarat, Haryana, Jharkhand, Himachal Pradesh, J & K, Karnataka, Kerala, Madhya Pradesh, Odisha, Rajasthan, Tamil Nadu, Telengana, Uttar Pradesh and Uttarakhand.

2.8 Summary of state level policies in India [107]-[108]-[109]

A thorough analysis of policies implemented in different states is critical to recommending the suitable policies that would help in growth of rooftop solar PV in India. Although very specific solar only policies are not in existence in a number states, comprehensive policies covering all the renewable energy sources are implemented across the states. The researcher looked at a few important issues like:

a) Various incentives and schemes

b) Tariff and sale of power generated

c) Banking and wheeling schemes

d) Power evacuation and grid connection

e) Eligibility of producers

2.8.1 Incentives and Schemes

In India, one could notice a lot of commonality as well as difference between states about various incentives and schemes in place for the power producers.

Table 2.3: State level Schemes and Incentives

Andhra Pradesh	Bihar	Chhattisgarh
- No cross subsidy on producers, either for captive use or third party sale - Electricity duty exempted, both for captive use and third-party sale within the state. - Value added tax (VAT) will be refunded. - Stamp duty and registration charges on any land purchase to be refunded. - These are in addition to prevalent REC (renewable energy certificate) benefits. - Incentives will be offered for	- Electricity duty exempted. - Entry Tax on the devices, equipment, and machinery is removed. - Financing supported by the government is available. - Apart from incentives specific to solar energy and renewable energy, the developers can avail the facilities available under Industrial Incentive Policy	- Non-conventional sources of electricity generation are recognized as a priority industry. - Subsidy on interest payment, capital investment, project report preparation and technical patent - Electricity duty and stamp duty are exempted - Exemption or concession while acquiring land - Exemption of VAT or value added tax. - Open Access is available to all at a fee decided by CSERC

a duration of seven years. - The developers are eligible to sell RE (Solar) certificates - Reactive Power drawn will be charged at a price decided by the APERC.	and other policies of the state government.	- No cross subsidy surcharges while selling electricity to third parties within the state. - These are in addition to prevalent REC (renewable energy certificate) benefits.

Gujarat	Haryana	Jharkhand
- Developers to share 50% of the gross benefit of clean development mechanism (CDM) with the distribution licensee - Various incentives would be available for only 25 years – No cross subsidy surcharges while selling to third parties within the state - Electricity duty exempted for selling to third par-	- Various charges on account of conversion, change of land use, external development, scrutiny fee and infrastructure development, are exempted - All new solar power projects are recognized as industry, thus enjoying all the incentives that any industrial unit is offered. - CDM Benefits available	- 50% of the electricity duty and cess are exempted for 10 years. Reduced to 5 years for captive use plants. - For cat. I project, transfer to another party before commissioning not allowed - All new solar power projects are recognized as industry, thus enjoying all the incentives that any industrial unit is offered. - Value added tax and entry tax on purchase of equipment are ex-

ties or licensee or captive use.	- Selection of IPPs through competitive Bidding	empted. - CDM benefits available - Open access available.

Jammu & Kashmir	Karnataka	Kerala
- Various incentives would be available for only 25 years - Entry tax on purchase of any equipment is exempted - No stamp duty on mortgage deed in favour of financing institution - No court fee on lease agreement for land. - No royalty in the form of free power. - Electricity duty @ 4 paisa /unit for captive use or sale to third party or licensees. - No demand cut of 50% of installed capacity.	- Different taxes like entry tax, stamp duty and registration charges exempted. - Industrial consumers using solar power can have pro-rate reduction in contract demand. - Environment clearances not needed for solar - Reactive power can be drawn from grid for solar plants. - Other central gov-	- Free open access facility. - Electricity duty exempted. Consumers opting for electricity from solar PV are offered tariff incentive. - Government promotions for solar plants and street lighting using solar power. - Mandatary for large consumers to meet certain percentage of electricity from solar called Solar Procurement Obligation (SPO). Share of solar as per SPO is about to increase every year. Plan to even include domes-

- The CDM benefits to be transferred to the distribution licensee. - Pay for drawing reactive power as per JKSERC order. - Using old or used plant and machinery not allowed.	ernment incentives in place	tic consumers into SPO.

Madhya Pradesh	Manipur	Meghalaya
- Electricity duty and cess exempted for 10 years from the date of commissioning. - Using old plant or machinery not allowed for installation. - Benefits under industrial promotion policy applicable to solar projects. - VAT and entry TAX exempted. - CDM benefits applicable - Transfer of project is not allowed before its commis-	- On monthly basis, transactions involving wheeling, banking or sale of power will be settled with the developers. - Electricity duty exempted for 5 years from the date of commissioning. - All new solar power projects are recognized as industry and so avail all the incentives that any industrial unit is offered. - All central government in-	- Electricity duty exempted for 5 years from the date of commissioning. - All new solar power projects are recognized as industry and so avail all the incentives that any industrial unit is offered. - All central government incentives are applicable. - Sales tax is exempted to help grant of loans by IREDA and MNRE. - Project clearance within 2

sioning. - No license needed for solar plants in rural areas.	centives are applicable	months from the date of submission of application

Mizoram	Odisha	Punjab
- On monthly basis, transactions involving wheeling, banking or sale of power will be settled with the developers. - Electricity duty exempted for captive use or third party sale - All new solar power projects are recognized as industry and so avail all the incentives that any industrial unit is offered. - All central government incentives available. - Equipment and materials to	- Solar power plant installed after the effective date is considered as an industrial unit and is exempted from paying electricity duty. - OREDA acts as the nodal agency for single window clearance of solar projects. Every proposed solar project, except those through competitive bidding process, needs to be registered with OREDA. - Sale of power through	- Electricity duty exempted on captive use. - Octroi duty on both electricity generated and equipment or machinery needed while setting up the plants is exempted. - No levy of VAT and cess. - Entry tax on any equipment or raw material exempted - Stamp duty and registration fee on purchase or leasing of land exempted - All new solar power projects are recognized as in-

be used for setting up the plants are exempted from State sales tax	open access is allowed under REC mechanism	dustry and so avail all the incentives that any industrial unit is offered. - NOC from pollution board not required.

Rajasthan	Tripura	Tamil Nadu
- All new solar power projects are recognized as industry and so avail all the incentives that any industrial unit is offered. - The developers need to intimate estimated water requirement and also the source of water. They need to bear the cost of modifying the existing canal system, if such a re-	- All new solar power projects are recognized as industry and so avail all the incentives that any industrial unit is offered. - Vat and Sales tax exempted. - Central government incentives available - 10% CDM benefit in first year. It drops to 90% in the second year with 10% given to beneficiaries. It drops by 10% every year	- Tax incentives to all solar projects. - CDM benefits to all solar power developers. - Entire power generated from solar plants used for captive purpose or sale to utility is allowed for 5 years. - Captive plants are exemption from demand cut to the extent of 100% of the installed capacity. - Use of old plant and machineries not allowed.

quirement arises.	up to 50% and then shared equally between developer and beneficiary. - 2.5% of the estimated project cost to be deposit-ed as a security. - All transactions between the producers and TSECL will be settled on monthly basis.	- Single window clearance in 30 days so that the plants can be commissioned in less than 12 months. - Solar water heating system is made mandatory for new buildings, marriage halls, hotels etc.

Uttar Pradesh	Uttarakhand	West Bengal
- All new solar power projects are recognized as industry and so avail all the incentives that any industrial unit is offered. - Government bears cost of constructing transmis-sion line as well as sub-station in the Bundel-	- Entire CDM benefits will be passed to the de-velopers - Projects are for a period of 40 years from the date of award, - A committee headed by chief secretary of the state will accord approv-	- Developers of projects installed for captive con-sumption are exempted from demand cut up to 50% of the installed ca-pacity - The state and distribu-tion utilities will provide revolving Letter of Credit

khand region. - Time frame for commissioning for solar PV projects is within 13 months.	als / clearances through a single window mechanism	for all RE projects - Government support for projects in remote locations - All central government incentives available. - CDM benefits for generating company.

2.8.2 Evacuation and Grid Connection

Table 2.4: State wise evacuation and grid connection rules

Andhra Pradesh	Bihar	Chhattisgarh
- Andhra Pradesh DISCOM or APTRANSCO will lay the evacuation line from inter-connection point to grid substation, however the cost will be borne by the project developer. If it's done by the	- Developers have to offer 25% of the electricity generated to Distribution Licensee. This provision is not applicable to captive projects. - If Developers plan to sell full or part of the	- Electricity generated form solar projects should be fed into the nearest substation of either the state Transco or a distribution licensee honouring the Grid code. - Laying down the evac-

developers, they need to pay the supervision fee to APTRANSCO or DISCOM. - To speed up the process, the technical feasibility for evacuation will be granted by APTRANSCO/DISCOMs within 21 days of applying.	electricity generated to either the grid or third parties using the grid, they need to design the system at their own cost - BSEB will bear the capital cost of the transmission, only if the developer commits to supply at least 50% generation to the grid and there should be a minimum of 2MW	uation line till the grid substation from the interconnection point can be done by either the state TRANSCO or DISCOM, or the developer. The cost will be borne by the developer. No supervision fee to Chhattisgarh Transco or Discom. - Technical feasibility for evacuation within 21 days.

Gujarat	Haryana	Jharkhand
- Electricity generated from solar projects will be fed into the grid at 66 kV. - Evacuation facility from the interconnection point to the grid substation of	- For grid connected rooftop solar PV, developers have the responsibility of arranging power evacuation as per technical specification, guide-	Laying down of transmission lines from the switchyard of the generating unit to substation will be carried out by JSEB for category I and

GETCO will be approved and laid by GETCO - There would be joint metering by GEDA/GETCO for the electricity generation.	lines and regulations of HERC.	category IV projects. The same needs to be done by the developers for category II and category III projects. - Power to fed into the grid at 33 KV.

Jammu & Kashmir	Karnataka	Kerala
- The developer is required to develop the necessary infrastructure from the generating point to the interconnection point - In accordance with policy of the central government, connectivity synchronisation with the grid for remote areas will be facilitated	- The developers to connect the generating station with the nearest grid substation or interconnection point at their own cost. - On request, KPTCL/ ESCOMs may take up construction and maintenance of the evacuation infrastructure on cost basis, which the developers need to bear. - No network augmenta-	- For accessing grid connectivity, the utility will assess the feasibility and if found suitable, will provide the connectivity. - KSEB acts as single window service provider to all grid connected solar plants. - KSEB establishes the required evacuation facility from the generating plants beyond the pooling

	tion charges on the developers on account of system augmentation beyond interconnection point. - The developers need to develop and maintain the generating unit substation as per the grid code at their own cost and select voltage levels of 400 / 220 / 110 / 66 / 33kV.	station. This offer is limited only to projects of 10MW or lower capacity. - For higher than 10 MW capacity plants, KSEB will carry out the construction work on deposit work basis.

Madhya Pradesh	Manipur	Meghalaya
- The developer to lay transmission line and switchgear for evacuation from generating station to the nearest substation or interconnection point. MPPTCL or MP Discom offers the service of carrying out this task, but	- The developers to connect the generating station with the nearest grid substation or interconnection point at their own cost. They need to take care of maintenance as well. - On request, the state	- The developers to connect the generating station with the nearest grid substation or interconnection point at their own cost. They need to take care of maintenance as well. - On request, the state

cost will be borne by the developer. - For the construction work, MPPTCL or Discom, need to be paid supervision charges	power department can take up this task on cost basis, which the developers need to bear. - Cost of expansion of substation capacity at 33/ 11 kV or higher and transmission lines will be borne by the discom.	power department can take up this task on cost basis, which the developers need to bear.

Mizoram	Odisha	Punjab
- The developers to connect the generating station with the nearest grid substation or interconnection point at their own cost. They need to take care of maintenance as well.	- Grid interfacing arrangements to be prepared by solar project developers/OPTCL/DISCOMs. - Substation for the generating unit will be developed and maintained by the developer. - The developer will install a remote terminal unit (RTU) for injecting the power to the grid.	- The developers to connect the generating station with the nearest grid substation or interconnection point at their own cost. Subsequent maintenance also is to be take care of by the producers. - Punjab State Power Corporation

- On request, the state power department can take up this task on cost basis, which the developers need to bear. - Cost of expansion of substation capacity at 33/ 11 kV or higher and transmission lines will be borne by the discom.	- Solar power producers will ensure the average power factor between lagging 0.95 and 1.0. - Developer needs to carry out T&D extension work for grid interfacing at its own cost. - Maintenance can be done by GRIDCO or DISTCOS on payment of fees	Ltd./Licensees will provide transmission link, required switchgear and check meter for the developers to sell power to them - PSPCL/PSTCL/Licensee will provide jumpers at interconnection point

Rajasthan	Tripura	Tamil Nadu
- RVPN / Discoms will develop and expand the T&D network necessary to evacuate the power from receiving substation,	It is the responsibility of the developers to connect the generating station with the nearest grid substation or	Solar projects need to evacuate power at suggested voltages: <10kWp : 240V <10kWp to <15kWp:

- For the solar plant to getting connected to the receiving grid substation, it should be at least of 5 MW capacity and the voltage level at 33 kV. For smaller than 5 MW, the developer needs bear the cost of line bay. - A number of developers can pool together and construct a common substation. - Producers need to pay grid connectivity charges	interconnection point at their own cost and this includes maintenance also. - Expanding the capacity of substation capacity at 3/11 kV or higher and transmission lines will be borne by the government	240V/415V <15kWp to <50kWp: 415V <50kWp to <100kWp: 415V >100kWp : 11Kv

Uttar Pradesh	Uttarakhand	West Bengal
- The developers need to connect the generating station with the nearest grid substation or interconnection point at their own cost. - This transmission line shall be constructed by the STU or	T&D lines from generation site to be provided by UPCL/PTCUL	- The state electricity distribution company limited (WBSEDCL) and the distribution licensee will jointly create evacuation infrastructure. - The evacuation infrastruc-

Discom who owns the "feed in substation". - Entire cost of construction of the line, wheeling charges, losses etc to be borne by the developer.		ture cost beyond the interconnection point will be borne by the licensees, with this to be gradually recovered from consumers. - The developers need to develop and maintain interfacing equipment and associated switchgear at their own cost.

2.8.3 Banking and Wheeling

Table 2.5: State wise power banking and wheeling schemes

Andhra Pradesh	Bihar	Chhattisgarh
Wheeling: Developers will bear the wheeling and transmission losses. - Charges for selling electricity outside the state. But no charges for captive use or sale to third parties within the state through 33KV system.	**Wheeling:** The state electricity board offers the wheeling facility through its transmission and distribution system to the developers only	**Wheeling:** Wheeling is allowed for the developers at a fee as determined by CSERC. **Banking:** Banking facility is allowed

Banking: 100% banking allowed from January to December. No carry forward is allowed. - The electricity banked is not allowed to be consumed or redeemed during the period between February and June or any day during peak hours of consumption. - Baking fees is 2% of the units banked	if the power available is in excess of 1 MW. **Banking:** NA	at mutually agreed terms

Gujarat	Haryana	Jharkhand
Wheeling: It is available, and rules are determined by GERC and keep changing from time to time. **Banking:** NA	**Wheeling:** Wheeling facility is provided to the developers at a fee as per HERC Regulation 2010 with amendments **Banking:** Banking is allowed for one year and no carry forward option is available. Also banking	**Wheeling:** Wheeling facility is available. The state government provides grant of 4% of the wheeling charges and the rest will be borne by the developer. **Banking:** Banking facility is available for a period of one financial year and no carry

	electricity can't be used peak hours.	forward option is available at the end of the period. Fee is 2% of the banked energy

Jammu & Kashmir	Karnataka	Kerala
Wheeling: Wheeling facility is available. - One trading RE certificate would be issued to the projects for every 1000 units of electricity (1MWH) wheeled to either the utility or any other licensee. **Banking:** Banking facility is available for a period of two months.	**Wheeling:** Wheeling facility is available. - Any transaction involving wheeling or sale of power will be settled on monthly basis **Banking:** Banking facility is available. Banking and cross subsidy charges will be determined by KERC.	**Wheeling:** Wheeling facility is available. For plants installed with the clear purpose of captive consumption, there is no T&D losses or wheeling charges. **Banking:** Banking facility is available only for captive generators.

Madhya Pradesh	Manipur	Meghalaya
Wheeling: Available at a fee. For wheeling, the	**Wheeling:** Wheeling of electricity generated from	**Wheeling:** Wheeling facility is available for

state government provides grant of 4% in the form electricity fed. The balance, if any, to be borne by the developer. **Banking:** 100% banking facility available for one financial year. At the end of the period, banked energy will be purchased by state Discom or state power trading company. - Banking charge is 2% of the banked electricity	solar projects is allowed using the grid owned by the power department. Wheeling charge for own captive use, or selling to any third party within the state is 2% of the electricity fed to the grid, - For selling electricity to third party, it must be a HT consumer of power. **Banking:** Banking is allowed for a period up to one year and no carry forward is allowed.	the developers and the wheeling charges will be determined by STU. Developers can wheel electricity for captive use or selling to a third party within the state. - Third party procuring power from developer needs to be HT consumer, unless relaxed by the DISCOM. **Banking:** NA

Mizoram	Odisha	Punjab
Wheeling: Wheeling facility is available for the developers and the wheeling charges are 2% of the electricity fed to	**Wheeling:** Available through T&D network of GRIDCO/DISTCOS at a fee. - Developers can transmit power outside the	**Wheeling:** Wheeling facility is available for the developers and the wheeling charges is 2% of the energy fed to the

the grid. Developers can wheel electricity for captive use or selling to a third party within the state. - Third party procuring power from developer needs to be HT consumer. **Banking:** Electricity generated can be banked for a period up to 1year	state. **Banking:** • Banking facility is available for plants set up only for captive use and the period is for one financial year. There will be banking charges. - The total unutilized electricity for the year, will be paid at a price mutually agreed.	grid. **Banking:** Banking of electricity is allowed for a period of 1 year. However, energy banked during non-paddy season and non-peak hours is not allowed to be drawn during paddy season and peak hours respectively.

Rajasthan	Tripura	Tamil Nadu
Wheeling: Wheeling facility is available at a fee. Wheeling is available even for selling electricity to third parties. **Banking:** Banking of	**Wheeling:** Wheeling facility is available, and the charges are 2% of the electricity fed to the grid. **Banking:** Banking of electricity is available for a period of one financial year. Unutilised banked	**Wheeling:** Allowed **Banking:** Banking facility is available at a charge as per the orders of the TNERC.

electricity is available as per the RERC regulations	electricity at the end of each financial year will be settled at a price specified in the PPA.	

Uttar Pradesh	Uttarakhand	West Bengal
Wheeling: NA Banking: NA	**Wheeling:** Available at a fee for captive use or third party sale within/ outside the state. - Wheeling charges will be announced in advance **Banking:** Banking of electricity generated from solar plants is allowed at mutually agreed terms	**Wheeling:** Allowed **Banking:** NA

2.8.4 Sale of Power and Tariff

Table 2.6: State wise sales of power and tariff

Andhra Pradesh	Bihar	Chhattisgarh
Electricity generated from these projects will be purchased by the state	Developers can consume the electricity for captive use or sell to third parties	State DISCOM will buy the electricity through a bidding process for tariff

DISCOMs at a price determined by APERC from time to time using pooled cost of PPA.	using BSEB network by paying open-access charges. For selling to a third party, it must be an HT consumer procuring a minimum 1 MW of electricity. After captive use, developers can sell excess power to the grid only if excess power available is more than 1 MW	to meet the RPOs finalized by the government. - State utilities have the choice of purchasing electricity from solar projects at pooled cost finalized by the designated commission from time to time.

Gujarat	Haryana	Jharkhand
- Open access facility is provided to the developers for selling the generated electricity to third parties - Developers don't have to bear the burden of cross subsidy	- The government has finalized RPO targets and is encouraging setting up solar plants of 1-10 MW capacity, so that they don't have to buy it from outside the state.	Category I Projects: - Power purchase agreement to be signed between the state electricity board and the developers who are allotted projects under tariff based competitive bidding for sale of electricity to JSEB for category I projects.

surcharges while selling electricity to third parties within the state. - Electricity that will be sold to Distribution licensees will fetch levelized fixed tariff for both Solar PV and solar thermal.	- IPPs are encouraged to install solar plants for captive use as well as third party sale. - Major thrust is given for setting solar plants of capacity up to 50 MW on barren village land and on canals, grid connected rooftop solar PVs. Entire electricity generated from these sources will be purchased by DISCOM.	For category II projects, the power purchase agreement will be signed between producer and the procurer on mutually agreed rates. For category III projects, PPA is to be signed between the producer and the procurer as per the existing CERC or JSERC regulations. For category IV projects, PPA is to be signed between the electricity producer and the procurer mentioned as Solar Corporation of India/ JSEB/ Discoms as per Guidelines under JNNSM

Jammu & Kashmir	Karnataka	Kerala
- Electricity from solar plants can be consumed for captive use or sold to power development department (PDD) of the	- The government plans to achieve minimum target of 1,600 MW of grid connected utility scale solar power projects.	- Electricity generated from solar plants will be sold to KSEB at a tariff that will be decided by KSERC, or at the pooled

state or sold to any third party in or outside state. - The state SERC will decide the tariff for sale of electricity generated to PDD. - Open access facility would be provided to the developers - Developers need to bear the T&D losses - The government has mandated that the distribution licensees need to purchase the electricity generated as specified by JKSERC.	Electricity generated from these projects will be sold to state ESCOMs or third parties or used for captive consumption. - The policy to encourage farmers owning land to install solar plants with capacity range from 1 MW to 3 MW per farmer. Electricity generated from such plants will be sold to ESCOMs at KERC tariff rates. - Government plans to include various HT category consumers having minimum load of 50 kVA under Solar Purchase Obligation (SPO)	cost of the power purchase of the utility or net metering. - KSEB has the first right to refuse for the power from the solar plants established in the state except the plants setup with the purpose of captive consumption. - KSERC will notify the Pooled Cost of Power Purchase every year. - Energy charges for the grid connected plants will be settled on a monthly basis between developer and the utility.

Madhya Pradesh	Manipur	Meghalaya

- MPPMCL will enter into an agreement (PPA) with the developer for purchase of electricity generated and this will be under REC mechanism. The tariff would be the average power purchase cost. - The developers can sale the electricity to any third party within the state or outside. - For selling part or the entire electricity generated to third parties, the developers needs to pay a fee to MPPMCL on monthly basis which is equal to half of the difference between third party sale rate and prevailing APPC rate of MPPMCL for that year. - There is mechanism for finalizing the tariff in the power purchase agreement. For category I projects, PPA will be executed between MPPMCL or MP Discoms and successful bidders. The tariff is the one arrived during the tariff based bidding process, but it should not be more than the	- There will be a power purchase agreement between the state power department and the solar project developer to buy electricity at a minimum price of Rs.2.25 per unit. The tariff will be increased every year for 10 operational years. - Subsequently the rate of increase to be mutually agreed between the developer and power department. - Duration of the	DISCOM will purchase power at tariff fixed by state electricity regulatory commission (SERC) and on mutually agreed terms and conditions

rates specified by MPERC. - For category II projects, PPA will be executed between the solar project developer and the procurer on mutually agreed tariff. • For category III projects, PPA will be executed between the solar project developer and the procurer as per regulations/orders of CERC/MPERC. • For category IV projects, PPA will be executed between the solar project developer and the procurer which is MPPMCL or MP Discom or NVVN as per guidelines under JNNSM	PPA is standard for 20 years, however it can me changed if developer prefers shorter period	

Mizoram	Odisha	Punjab
- State power department will purchase power at a minimum price of Rs. 3.50/unit with annual increase at 5% for 10 operational years. - After the initial 10	- Developer can enter into a power purchase agreement (PPA) to sell electricity to bulk buyers or distribution licensees approved by Orissa Electricity Regulatory Commission (OERC). - Developers who set up solar	- The tariff for solar power will be as per Punjab state electricity regulatory commission (PSERC) RE regulations.

years, rate of increase in tariff will be mutually agreed between the power department and the producer. - It is not mandatory for the power producers to sell power to the power department - Developers can sell electricity to a third party within and outside the State with permission of the power department. The price will be mutually settled between them. - PPA will be for minimum duration of 10 years unless the developer wants shorter duration	plants for their own captive use and fail to consume the electricity generated during the year, enjoy the benefit of that energy treated as sold to grid corporation of Odisha (GRIDCO). The price will be negotiated between them and approved by OERC. - If the developers fail to sell power in open access, they can sell to GRIDCO or Discoms or any third party within the state. The tariff is mutually agreed and needs approval by OERC. - Electricity generated from solar projects and purchased by GRIDCO or Discoms, the applicable tariff is the average pooled power cost finalized by OERC from time to time.	

Rajasthan	Tripura	Tamil Nadu
The Discoms need to honour the renewable purchase obligation (RPO) and so buy a certain percentage of total power from solar energy. For this RERC decided the tariff through competitive bidding process. - All the solar plants need to provide bank guarantee equal to Rs 10 lakh / MW as security - For projects set up to sale electricity through REC mechanism, PPA needs to be executed - For solar plants set up to sale electricity to Discoms, security deposit will be regulated by provision in the bid document and PPA	- Tripura state electricity corporation ltd. (TSECL) will purchase power at a tariff decided by Tripura electricity regulatory commission (TERC). - After the initial 10 years, rate of increase in tariff will be mutually agreed between the buyer and the producer. - It is not mandatory for the power producers to sell power only to TSECL, produc-	- Trading of solar power is promoted through renewable energy certificate (REC) mechanism with the objective of meeting solar purchase obligations (SPO). - All the related parties committed to meet SPO have basically three options. One is to produce solar power for own consumption, second is to buy solar power from Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO), and the third option is to purchase solar renewable energy certificates through the power exchange from the holders of renewable energy certificates for an equivalent quantity.

- Developers who set up solar projects to sale electricity to parties other than state Discoms, need to contribute a sum of Rs 1 lakh / MW of installed capacity every year towards Rajasthan Renewable Energy Development Fund.	ers can sell electricity to a third party. The price will be mutually settled between them. - PPA will be for minimum duration of 10 years unless the developer wants shorter duration	- Under this mechanism, solar power promoters are eligible to possess one tradable RE Certificate per every 1000 units of electricity (1 MWh) wheeled to the distribution utility or to any other licensee. - Tamil Nadu targets 6% SPO for various categories of HT / LT consumers. It starts with 3% till December 2013 and 6% from January 2014.

Uttar Pradesh	Uttarakhand	West Bengal
- Electricity generated from solar power plants commissioned during the policy period, can be used for captive consumption, sold to any third party or sold to distribution utility of UP power corporation limited (UPPCL).	- Uttarakhand power corporation limited (UPCL) will have the first right to purchase electricity generated from solar	- All the electricity generated from the renewable energy projects established within the State of West Bengal are to be preferably sold to the distribution licensees within

- Developers interested in selling the generated electricity to a distribution utility of UPPCL, need to participate in competitive bidding for the capacity they intend to offer, subject to the approval by UP energy regulatory commission (UPERC). - UPPCL will sign the PPA with the successful bidders for a period of 10 years. - Developers, who plan to sell the generated electricity to third parties, can set up plants under this policy. However, they will not be allowed to sign a PPA with the distribution utility of UPPCL, even in future.	plants. - Price of electricity will be determined by Uttarakhand energy regulatory commission (UERC). - The state government will provide guarantee for payments to be made by UPCL for purchase of electricity.	the state. - All transactions between the developer and the state electricity transmission company (WBSETC) or distribution licensee involving wheeling or sale of power will be settled on monthly basis as per PPA and transmission service agreement executed.

2.9 Overview of State net metering guidelines

Table 2.7: State wise net metering guidelines in India

State	Policy Scope	System Size Limit	Grid penetration % of dist. Transformer capacity	Excess Electricity sale price	Eligibility
Andhra Pradesh	Upto 1 MWp	100% of annual consumption	Not mentioned	APPC	All Consumers
Assam	1kWp to 1MWp	40% of contracted load	Not mentioned	APPC	All Consumers
Bihar (Draft)	Upto 1 MWp	90% of annual consumption	15%	Not mentioned	Not mentioned
Chhattisgarh	50 kWp to 1 MWp	49% of annual net generation	Not mentioned	50% of regulated solar tariff	Not mentioned
Delhi	>1 kWP	100% of contracted Load	20%	APPC	All Consumers
Goa and UTs	1 kWp to 500 kWp	Not mentioned	30%	As per regulated solar tariff	All consumers

Gujarat	Not Mentioned	50% of contracted load	Not mentioned	APPC/ 85% of APPC for REC projects	All consumers
Haryana	1kWp to 1 MWp	90% of annual consumption	15%	NA	All consumers
Himachal Pradesh	1 kW to 5 MW	80% of contracted load	30%	M5.00/ unit	All consumers
Karnataka	Upto 1 MWp	Not mentioned	80%	M9.56/ kWh (without subsidy), M7.20/ kWh (with 30% subsidy)*	All consumers
Kerala	1kWp to 1MWp	Not mentioned	50%	APPC	All consumer categories, up to 11kV
Madhya Pradesh	Up to permissi-	Not mentioned	15%	APPC	All consumers

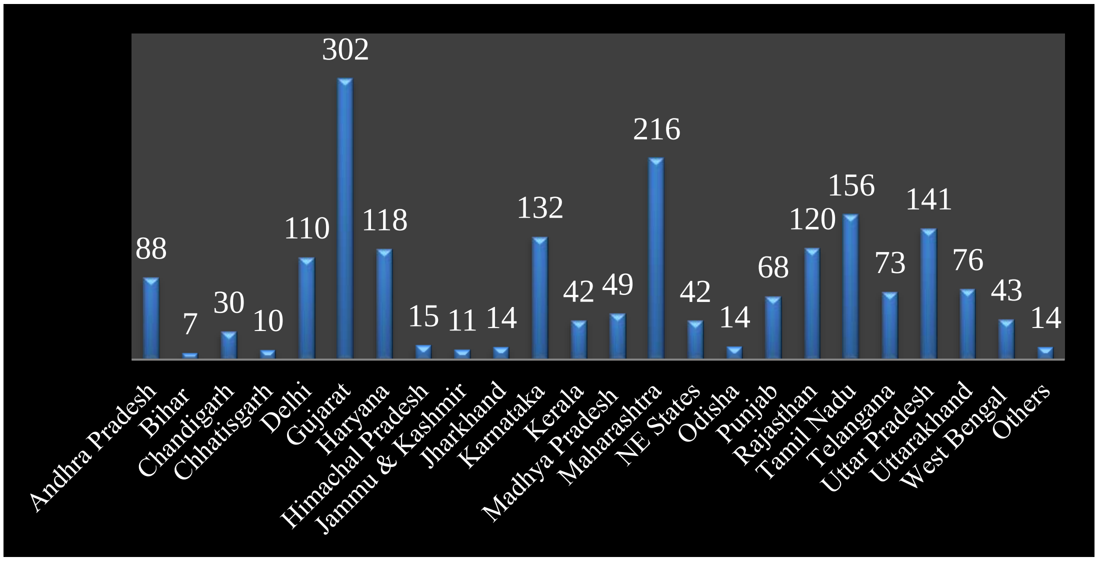
	ble individual rated capacity of 112 kW at LT				
Maha-rasthra	Upto 1 MWp	100% of con-tracted load	40%	APPC	All con-sumers
Meghalaya	Upto 1 MWp	<90% of annual consumption	15%	No pay-ment	All con-sumers
Odisha	Not Men-tioned	<90% of annual consumption	30%	No pay-ment	All con-sumers
Punjab	1kWp to 1MWp	<80% of con-tracted load	30%	As per re-tail supply tar-iff of the con-sumer category	All con-sumers
Rajasthan	1 kWp upto 1MWp	<80% of con-tracted load	30%	As per reg-ulated solar tariff	All con-sumers
Tamil Na-	Not men-	<90% of annual	30%	No pay-	All con-

du	tioned	consumption		ment	sumers
Uttar Pradesh	>1 kWp	100% of contracted load	15%	M0.50/ kWh	All consumers
Uttarakhand	Upto 500kWp	Upto 500kWp	Not mentioned	M9.20/kWh (with subsidy)	All consumers
West Bengal	>5 kWp	<90% of annual consumption	Not mentioned	APPC	Only for institutional consumers
Telengana	Not Mentioned	Not Mentioned	Not Mentioned	APPC	All consumers

Source: Bridge to India Solar Handbook 2016

Note: APPC is Average Pooled Purchase Cost

Figure 2.1: State wise rooftop PV installed capacity (MW), De 30, 2019



Source: MNRE

After careful analysis of all the possible barriers and comparison of policies in India with that of other countries, it is noticed that the major reasons attributed to this slower adoption of rooftop solar PV in India are: (a) Higher upfront cost, (b) Financially unattractive business model, (c) Lack of standardization in rooftop solar PV, (d) Unavailability of skilled manpower providing installation and maintenance services, (e) Lack of awareness among consumers about rooftop solar PV, (f) Unsuitability of roof top for installation of solar PV, (g) Poor quality assurance of the solar PV systems available, (h) Lack of concern for environment among consumers, (i) Lower than required or absence of Feed-in tariff, and (j) Difficulty in receiving the financial benefits from the government and permission from local authorities. The other variables are Income statistics monitoring, Neighbor attitude, Installation space, Existing power system, global trends, building structure, social value, unlimited power, global warming, lack of administrative experience with renewable technologies, public subsidies for fossil fuels, government preferences to large scale and centralized projects, political commitment, social acceptance, the limited ability to train adequate number of technicians to effectively work in a new solar energy infrastructure, inadequate supply of raw material, ad government time lag in policy implementation

2.10 Theory Underpinned

Theory of Adoption

It is always intriguing to know how and why individuals adopt innovations. Rogers' innovation diffusion theory is a landmark in this field. As defined by Rogers (1995) [85] Innovation is "an idea, practice or object that is perceived as new by an individual or group of people". It is not necessary that innovation should be better or more beneficial to an individual. Despite genuine attempts, all the innovations are not successful. Over 30 years of research comes to a commonly agreed conclusion that one third of all innovations fail (Cooper and Kleinschmidt 1987; Poolton and Barclay 1998; Suwannaporn and Speece 2003) [82]. So, it is very important to find out the factors that cause any innovation to fail. Rich literature is available with theoretical models to address issues in the field of innovation adoption. A few notable theories are Diffusion of Innovations theory (DOI) (Rogers 1962), Theory of Reasoned action (TRA) (Fishbein and Ajzen 1975), Theory of Planned Behaviour (TPB) (Ajzen 1985; Ajzen and Fishbein 1980), Technology Acceptance Model (Davis 1989), decomposed Theory of Planned Behavior (Taylor and Todd 1995), extended Technology Acceptance Model (TAM) (Venkatesh and Davis 2000) and Unified Theory of Acceptance and Use of Technology (Venkatesh et al. 2003) [8]. Among all these aforementioned theories, Rogers' Diffusion of Innovation Theory is the most well established and used theory [86]. As per Rogers there are five attributes most important for adoption of innovation. These five known as perceived attributes of innovations are – Relative advantage, Observability, Trialability, Compatibility and Complexity. Apart from Rogers' DOI theory, two other such theories are also considered good as far as finding attributes leading to adoption of innovations are concerned. One is Meta-Analysis by Tornatzky and Klein (1982), where 30 attributes (five of which were Rogers') were identified; and the other Perceived Characteristics of Innovating theory by Moore and Benbasat (1991), where five attributes (two of which were Rogers') were identified [86]. In the paper 'Examining consumer acceptance of green innovations using innovation characteristics: A conceptual', Kapoor et al. (2013) recommended a brilliant theoretical framework taking into consideration all the three important aforementioned theories [86].

Table 2.8: Framework by Kapoor et al.

Attributes	Definitions	Sources
Relative advantage	Degree to which an innovation is better than the	Rogers (2003)

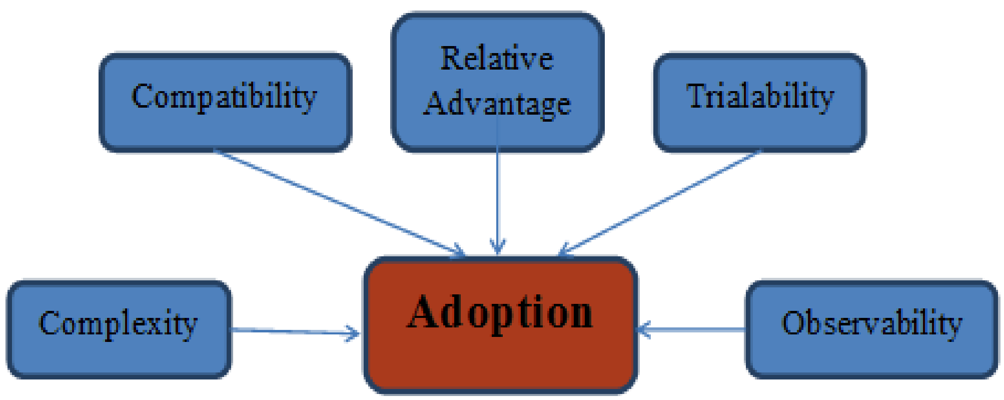
	idea it supersedes	
Compatibility	Degree to which an innovation is consistent with existing values, past experiences and needs of potential adopters	Rogers (2003)
Complexity	Degree to which an innovation is relatively difficult to understand/use	Rogers (2003)
Trialability	Degree to which an innovation may be experimented with on a limited basis	Rogers (2003)
Observability	Degree to which the results of an innovation are visible to others	Rogers (2003)
Cost	Costs associated with the use of an innovation	Tornatzky and Klein (1982)
Risk	Multidimensional component involving perfor-	Tornatzky and Klein (1982)

	mance, financial, social, physical, psychological and other types of risks	
Ease of use	Degree to which an individual believes that using a system is free of physical/ mental effort	Davis (1986); Moore and Benbasat (1991)
Image	Degree to which the use of an innovation is perceived to enhance one's image in society	Tornatzky and Klein (1982)
Visibility	Degree to which the use of a particular innovation is apparent	Tornatzky and Klein (1982)
Voluntariness	Degree to which use of an innovation is perceived as being voluntary/free will	Tornatzky and Klein (1982)
Result Demonstrability	Tangibility of the results of using an innovation, including their observabil-	Moore and Benbasat (1991)

	ity and communicability	
Social Approval	Non-financial aspect of reward	Tornatzky and Klein (1982)
Communicability	Degree to which an innovation can be clearly and easily understood	Tornatzky and Klein (1982)

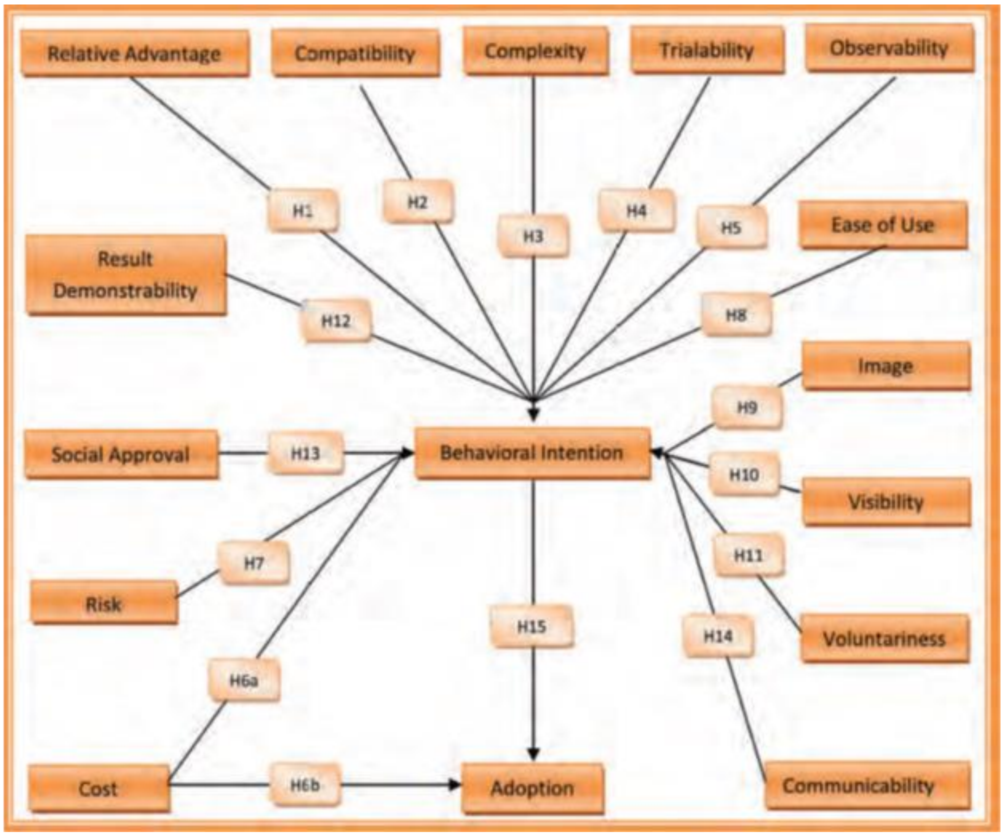
Source: Kapoor et al., 2013

Figure 2.2: Rogers' adoption attributes



Source: Rogers Adoption Factors

Figure 2.3: Adoption model by Kapoor et al.



Source: Kapoor et al. (2013), Examining consumer acceptance of green innovations using innovation characteristics: A conceptual'

Rogers defines diffusion as "the process in which an innovation is communicated thorough certain channels over time among the members of a social system". So from the definition, it can be seen that innovation, communication channels, time, and social system are the four key components of the diffusion of innovations. As per his theory, the decision process to adopt any innovation involves five steps: (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation. Rogers suggested a few important attributes of innovations that help to reduce uncertainty about the innovation. He came up with five major factors : (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability and mentioned that that the perceptions of these characteristics predict the rate of adoption of innovations. Rogers did admit there was lack of research on the effects of the perceived characteristics of innovations on the rate of adoption. It is observed that 49-87% of the variance in the rate of adoption of innovations is explained by these five attributes. Apart from these attributes, the innovation-decision type, communication channels, social system, and change agents may increase the predictability of the rate of adoption. Rogers also classified the adopters into different categories: innovators, early adopters, early majority, late majority, and laggards.

A study on adoption of a new technology by faculty members classified the faculty members based on Rogers' five categories of innovation adoption and compared them on the demographic variables of age, gender, race/ethnicity, teaching experience, and highest degree attained. While a significant relationship emerged between Rogers' adopter categories and their years of teaching experience and highest degree attained, the results did not show an important difference between faculty adopter categories and age, gender, and race/ethnicity. No significant difference existed between users and non-users in demographic characteristics of age, gender, race/ethnicity, teaching experience and highest degree attained [127].

A few more researches are done to analyze user demographics (e.g. Laukkanen et al., 2007; Lee et al., 2005) such as age, gender, education etc. to predict.

Here is the summary of the gaps observed in the underlying theory, Rogers' Diffusion of Innovation.

1. Lack of research on the effects of the perceived characteristics of innovations on the rate of adoption
2. How perception of adopters towards the innovation is different from the non-adopters.
3. The theory suggests only six adopter characteristics; the interaction with change agents, training, cosmopolitanism, age, gender and income level that affect adoption. It doesn't explain other characteristics like social class, occupational status.
4. The theory also doesn't explain adopter characteristics on psychographic factors.

Table 2.9: List of Independent Variables from Literature Review

Possible Increase in Electricity Tariff	Freedom from future increase in electricity tariff
Electricity Tariff	Current electricity tariff is high
ROI	High return on investment
FIT	Attractive feed-in-tariff
Capital Requirement	Cost of installation
Operating Cost	Cost of operating solar PV

Unlimited Power	There is no limit to the power that can be generated from rooftop solar PV
Subsidy	Subsidy from the government to finance installation cost
Tax Benefits	Tax benefit due to favorable depreciation
Image in the society	Enhances social image
Ease of Financing	Ease of getting financing of initial cost
Ease of getting government incentive	Ease of getting all government incentives
Environment Concern	Your concern for the environment
Difficulty in maintenance	Maintaining the rooftop solar PV
Trialability	Easy to take up a trial project on smaller scale
Ease of understanding Technology	The concept of rooftop solar PV can be understood easily
No requirement of additional resources	Doesn't need any additional resources like water
Building cooling load	Lowers cooling load requirement of the building as it keep the roof cool
Better peak load management	Helps in better peak load management
Independence	Provides independence from utility provider or oth-

	ers
Environmental Benefits	Good for the environment
Helping others to Install	Helps others to install due to sharing of knowledge
Environment Concern Image	Helps create an "Environment Concern Image" for you
Global trends	There is trend globally to go with rooftop solar PV
Long term FIT	Clarity over long term future FIT (feed in tariff)
Investment Horizon	The life of the project
Compatibility of Equipment	Compatibility of all equipment with Solar PV system
Compatibility of Building	Compatibility of building for solar PV installation
Ease of Use	Ease of operating the solar PV system
Availability of Rooftop Space	Availability of sufficient unused rooftop space
Availability of Service Providers	Availability of plenty of PV service providers
Building location	Location of the building in terms of receiving solar radiation
Ease of dealing with utility provider	Easy to deal with utility provider
Monitoring of Electricity	Ease of monitoring electricity generation and usage

Usage	
Visibility	Benefits from use of rooftop solar PV is visible
Demonstrability	Ease of seeing a demonstration of rooftop solar PV
Safety	No health hazards
Quality of system available in the market	Quality of rooftop solar PV system available in the market for installation
Social Value	PV installation is compatible with your social value

2.11 Research Gap

Development of solar PV sector in India has been visible, through different initiatives, ever since independence. Since 2009 solar saw a transition from a mere obligation to uplift society to a stronger socio-economic growth opportunity in India. Through this review, the researcher has tried to showcase the evolution of solar energy in India along with the initiatives to promote solar PV in the country. The study has tried to list out various organizations and institutions involved in promoting solar PV technology.

Further, researcher has discussed various central and state policies and regulations to promote rooftop solar PV in the country.

Based on the literature reviewed, researcher has identified the following research gap, which further motivates researcher to carry out the proposed research.

- No research is available to understand why the adopters have adopted the rooftop solar PV in India. Starting from the widely accepted Rogers theory of Adoption and diffusion of Innovation, several researches are available. No research is done to find out the application of this theory to understand low adoption of rooftop solar PV in India and find out the important factors for adoption of rooftop solar PV in India.
- There is no research done to find out the perception of consumers in India towards adoption of rooftop solar PV
- Rooftop solar PV adopter characteristics are not known and no research is done to find out how are the adopters different from non-adopters in terms of demography or psychography?
- No research is done to check the effectiveness of government policies to foster the adoption of rooftop solar PV in India.
- So, factors affecting adoption of a technology where government policies are important need to be explored along with better understanding of adopters and non-adopters in terms of differences on perception, demography and psychography factors

2.12 Research Problem

How adopters of rooftop PV in India evaluate adoption, how are they different from non-adopters and what policies can facilitate better adoption.

2.13 Research Questions

1. What are the important factors leading to adoption of rooftop solar PV in India?
2. What are the perceptions of adopters and non-adopters towards rooftop solar PV adoption in India?
3. What are the demographic and psychographic differences between adopters and non-adopters of rooftop PV in India?
4. Which of the policies that facilitated growth in successful countries like Germany, China and USA are apt for India?

2.14 Research Objectives

1. To identify the important factors leading to adoption of rooftop solar PV in India.
2. To explore the perceptions of adopters and non-adopters towards rooftop solar PV in India.
3. To examine the demographic and psychographic differences between the adopters and non-adopters of rooftop PV in India.
4. To analyze government policies in countries like USA, China, and Germany, where rooftop solar PV adoption has been successful and find out the suitable policies for India.

2.15 Scope of Research:

Consumer of adoption of rooftop solar PV in India. The research is done only considering the consumers. Other participants like government, utilities, power producers are not included within the scope of the research. The consumers considered are residential and commercial rooftop solar PV adopters and non-adopters in the states of Odisha and Kerala.

2.16 Summary

This section discusses various scholarly work published in refereed journals and other articles from reputed sources. The review was done on five themes

a. Solar energy

b. Advantages of rooftop solar PV

c. Barriers of rooftop solar PV

d. Solar PV adoption

e. Government policies

Solar PV has got number of advantages as well as barriers. The importance of solar PV goes up manifold in the present context when the entire world is facing unprecedented environment crisis. The world needs to switch from fossil fuel based power and solar with enormous potential is expected to be a major alternative. In populous countries like India, rooftop solar PV will be a major contributor due to land scarcity and many other benefits. A number of countries like Germany, Italy, USA, Japan etc tried to overcome the barriers through suitable government policies and have been successful in doing so. The review also focussed extensively on policies introduced by government of India and different states. This exercise helped researcher prepare an exhaustive list of variables leading to adoption of rooftop solar PV. These 39 variables found are clubbed into a few important factors through factor analysis. From various literature studies, the researcher zeroed in on the research gap. The section starts with identifying the research gap. From research gap, research problems and research objectives are clearly spelled out. The researcher has identified four research objectives.

1. To identify the important factors leading to adoption of rooftop solar PV in India.
2. To explore the perceptions of adopters and non-adopters towards rooftop solar PV in India.
3. To examine the demographic and psychographic differences between the adopters and non-adopters of rooftop PV in India.
4. To analyze government policies in countries like USA, China, and Germany, where rooftop solar PV adoption has been successful and find out the suitable policies for India.

3. Research Methodology

Research methodology is considered the most important part of the entire research process. Research methodology starts with identifying the research gaps. Once research gaps are identified, the researcher finds out the research questions and research objectives and scope of research. Here the researcher narrowed down to only four research objectives, for each objective the researcher designs the process. The research design clearly spells out

i. Research approach
    - Qualitative research methodology
    - Quantitative research methodology
    - Mixed research methodology
ii. Data collection plan
iii. Target Population
iv. Population Size
v. Sampling plan
vi. Data Analysis tool

3.1 Research Design

Research design can be defined as the method for collection, analysis, and interpretation of data. Research objectives are the key factor behind choosing the type of research design. Research design can be classified as quantitative, qualitative, or mixed research.

The four research objectives that the researcher has identified are:

1. To identify the important factors leading to adoption of rooftop solar PV in India.
2. To explore the perceptions of adopters and non-adopters towards rooftop solar PV in India.
3. To examine the demographic and psychographic differences between the adopters and non-adopters of rooftop PV in India.
4. To analyze government policies in countries like USA, China, and Germany, where rooftop solar PV adoption has been successful and find out the suitable policies for India.

The researcher has used mixed research methodology, quantitative research methodology for the first three objectives and for the fourth objective, qualitative research is used.

Quantitative Research	Objective 1 Objective 2 Objective 3

Qualitative Research	Objective 4

3.1.1 Quantitative Research

Quantitative research methods use numbers as data [87] and generally statistics is used to analyse those data. Quantitative methods are used when the researcher intends to study the effect of a specified variable on another while the effects of other variables are disregarded. Creswell (2003) described that such a method is suitable in the sciences, and quantitative methods have been in use in the sciences for long time compared to the other research methods. This method can be further classified into two types: (a) Descriptive Design, and (b) Experimental Design. Experimental design allows the researcher control over the situation. Here the researcher used descriptive design for Objectives 1, 2 and 3.

Objective 1 of the research is to find out the important factors that lead to adoption of rooftop solar PV. The researcher found out 39 variables and intends to come up with a few important factors that explain the reason behind adoption of rooftop solar PV. The data required for factor analysis needs to be quantitative and so a scale is designed to capture importance of each variable on a numerical scale and using that factor analysis is done to identify the important factors.

Objective 2 of the research finds out perception of adopters as well as non-adopters of rooftop solar PV to verify if there exists any significant difference. Perception is captured on numerical scale and hypothesis testing is done.

Objective 3 of the research verifies demographic and psychographic differences between adopters and non-adopters. Using numerical data, both hypothesis testing and descriptive statistics are used for analysis and so verification of demographic and psychographic factors.

3.1.1.1 Data Collection Method

Survey technique is used to collect primary data for objectives 1,2 and 3. This technique is generally used to collect data from large sample size and statistical tools are used to analyze them. Survey technique applies to studies which uses deductive approach for exploratory and descriptive research. It is commonly used to answer questions like what, where, how much and how many [88]. The survey was conducted twice, once for objective 1 and then once more for objectives 2 and 3.

3.1.1.2 Target Population

The target population for survey includes organizations or individuals associated with rooftop solar PV in India. The focus was on those who have already installed solar PV on their rooftops and those who have not adopted rooftop solar PV despite having awareness about the technology.

3.1.1.3 Sampling Frame

Houses with rooftop solar PV installed in Odisha & Kerala were identified as part of the sampling frame. Just like most of the Indian states, these two states, despite having very good solar radiation, have witnessed very low adoption of rooftop solar PV. In fact, Kerala was one of the few first movers in India. So, it would be intriguing to know the reason why these two states still have such low adoption of rooftop solar PV. It would be equally interesting to find out those few adopters and the reason behind their decision to adopt rooftop solar PV. For Objectives 2 and 3, respondents who have access to grid power and have not yet installed rooftop solar PV, were considered as part of sampling frame.

3.1.1.4 Sample Size

Objective 1: 200 respondents who have adopted rooftop solar PV

Objectives 2 & 3: 75 adopters from the same sample chosen for Objective 1 and 75 respondents wo have not adopted rooftop solar PV.

To decide the sample size for carrying out factor analysis, it depends on the number of variables and there is a wide range of recommendations available. The minimum sample size suggested is 3 to 20 times the number of variables with absolute number ranging from 100 to over 1,000 [89]. Comrey and Lee (1992) offered a kind of rating scale for sample size and it is like 100: Poor, 200: Fair, 200: Good, 500: Very good and 1000 or more: Excellent [110]. It is also found out that, more than finding the sample size before carrying out the test, it is more appropriate to find out the suitability of data at the time of carrying out factor analysis. Keiser-Meyer-Olkin (KMO) test for sampling adequacy indicates the proportion of variances in the variables that may be caused by underlying factors [111]. A KMO score is a good indicator of sampling adequacy and roughly, the interpretation of the score is as follows. Although the researcher would have preferred aa higher sample size, it was not possible owing to small population size. As the adoption of rooftop solar PV has been very low, that severely limits the sample size. So, the researcher finalized the sample size to be 200, which meets all the criteria for an accurate factor analysis.

KMO Score	Adequacy
Greater than 0.9	Superb
0.8 – 0.89	Great
0.7 – 0.79	Good
0.5 – 0.69	Mediocre
Less than 0.5	Not acceptable

Similarly, Barlett's test of sphericity indicates how unrelated are the variables and so not suitable for factor analysis. A low score (<0.05) indicates that the sample is good for factor analysis.

For Objectives 2 & 3, 150 respondents were chosen, 75 each from adopters and non-adopters. Sample size depends on the required accuracy of result with a higher sample size reducing the probability of missing a hypothesis that actually exists, that means the Type II error reduces. Also depending on the size of the sample, different statistical tools are recommended to test the hypotheses. A sample size of greater than 30 is considered large enough when random sampling is used. However, sample size was calculated using the formula

n = (Zσ/E)^2 ,where

Z = Value from Z table for a confidence level, considered 95% here

σ is the standard deviation found through a sample of 30

E = Margin of error acceptable, considered 5% here

The standard deviation of the sample found was 0.36. With 5% margin of error, the sample size found out was 140.

3.1.1.5 Sampling Design

Snowball Sampling was used by the researcher, as the population of rooftop solar PV adopters is not explicitly available, and so participants are hard to find. So, in both these states, constructing a sampling frame is difficult. Snowball sampling technique is ideal under such scenarios [113]. Through snowball sampling, effort was made to reach out to the entire population as the population is very small. As snowball sampling technique is a non-probability sampling method, it has a major disadvantage that the sample may not represent the entire population [113]. Other disadvantages of snowball sampling technique are correlations between network size and selection probabilities, reliance on the subjective judgments of informants, and confidentiality concerns [153]. To overcome the issue of missing out certain section of the population, the researcher continued the process till a point when new respondents almost stopped coming.

Once the population was identified using snowball sampling, random sampling was used for objectives 2 and 3. This sampling method provides equal probability of everyone in the population to be picked up in the sample. This particular property makes this sampling technique one of the most preferred techniques in research. The weakness in this technique is that the sample may not reflect the population if the population is not uniform and is a composition of few specific groups [145].

3.1.1.6 Questionnaire Design

Questionnaire survey is a very structured data collection method. The same set of questions are put across to large number of respondents. Questionnaire is nothing but the list of questions printed legibly that respondents are requested to answer [90]. The questionnaire begins with seeking the respondents' basic information followed by 39 questions pertaining to variables identified by the researcher, requesting the respondents to give a score on an interval scale indicating importance of each variable (Annexure 1). At the end of the questionnaire respondents were requested to mention any other factor that they may think important. For the second survey, the questionnaire begins with different demography and psychography details and then 5 questions pertaining to five factors on which the respondents are requested to give a score about what they perceive (Annexure 2).

Another important aspect of questionnaire is the scale. There are four types of scales available, Nominal, Ordinal, Interval and Ratio. The researcher preferred to select interval scale as most of the statistical tools can be applied on data from interval scale. The responses were collected on a seven-point interval scale [1 as the least important factor to 7 as the most important factor for the first survey. For the second survey, 1 means the Strongly disagree to 7 as strongly agree]. Using pilot testing, the researcher modified the wording and language to ensure that the questionnaire conveys exactly what is intended precisely without any blurred interpretation. The researcher made sure that the questions were precise, clear, easy to understand, and unambiguous [91].

3.1.1.7 Administering Questionnaire

The questionnaires were administered through mainly personal contacts. As the researcher followed snowball sampling, the initial few contacts proved critical as through them more and more prospective respondents could be traced. Apart from personally administering it, the researcher also relied on responses through email and google form. It requires intense follow up and personal visits to complete the data collection.

3.1.1.8 Data Analysis Tools

Objective 1	Factor Analysis
Objective 2	Hypothesis Testing
Objective 3	Hypothesis Testing and Descriptive Statistics

For objective 1, factor analysis was applied to find out important factors from the list of identified variables. For factor analysis, importance of each variable on a scale of 1 to 7 were captured and factor analysis was done using ‘r’.

Factor Analysis: Responses to questionnaire were collected from 200 respondents. The questionnaire was designed to find the importance of 39 variables the researcher identified from literature review. The importance of each variable was captured on an interval scale of 1 to 7. The responses from all the respondents were fed to the factor analysis software ‘r’. ‘r’ is an open source data analysis software.

The main aim of carrying out factor analysis is to reduce the large number of variables to smaller number of factors. The reduction of the number of variables depends on the number factors extracted. If the number of factors extracted is large, then interpretation of the results becomes difficult, whereas lesser number of factors extracted can result loss of important information. So, having the optimum number of factors is the key. For conducting the analysis, criteria of eigenvalues, percentage of variance explained criteria, Scree Test criteria, were combined and used to determine the appropriate number of factors,

For objective 2, hypothesis testing was done. Hypotheses testing is a systematic way of testing claims or ideas about the population. As per Rogers’ theory of adoption, any innovation is evaluated on five key factors and that holds key in its adoption or rejection. From Objective 1, five key factors that lead to adoption of rooftop solar PV in India were identified. These five factors are Complexity, Financial Attractiveness, Environmental Benefits, Social Image Building and Trialability. Findings from previous researches are used to formulate hypothesized directions of beliefs concerning rooftop solar PV.

Hypothesis Formulation (Objective 2): H1: Adopters and nonadopters differ on the basis of their perceptions of rooftop solar PV system. As compared to non-adopters,

i. adopters rate such system as lower in complexity, both complexity in installation as well as operation **(H1a)**

ii. greater in financial attractiveness **(H1b)**,

iii. greater in environmental benefits **(H1c)**,

iv. better in social image building **(H1d)**

v. more possible to try on a limited basis **(H1e)**.

The Roger and Shoemaker (1971) indicated that individual perceptions of major attributes affect the adoption of any innovation [149]. Even another research by Ostlund (1974) reiterated correlations between adoption of innovation and individual perceptions about important attributes [148]. Perception is defined as the act of apprehending by means of the senses and/or the mind. Perception relates to both basic senses such as visual, flavour and taste attributes, and formed learning or experiences [150]. A research on adoption of residential solar energy system in the US measured the perceptions on important attributes on a seven-point Likert scale [126]. One more research about consumer perception on southeast Asian restaurants in Minnesota, USA used a five-point scale to measure perception [151]. A study to find a scale to measure consumer perception of CSR indicated Likert type scales appropriate to measure consumer perception [152].

For Objective – 2, on a scale of 1 to 7, perception of adopters as well as non-adopters on the five factors were captured through a questionnaire.

From the captured data, the hypotheses formed were tested with a significance level of 5%. Both “z” tests and Chi-square tests were conducted to test the hypotheses.

For Objective 3, hypothesis testing for demographic variables and descriptive Statistics for psychographic variables were applied. Demographic data on age, education, income, occupation and social class, and psychographic data on decision making swiftness, respect for rules and regulation, and preference for cars were captured. For demographic variables of non-adopters, data for the entire Indian population was considered as almost all except a negligible number are non-adopters.

Hypothesis Formulation (Objective 3):

The following hypotheses were formed.

H2: Adopters and nonadopters of rooftop solar PV system differ on the basis of selected demographic measures.

H2a: Compared to non-adopters, adopters of rooftop solar PV in India are younger.

H2b: Compared to non-adopters, adopters of rooftop solar PV in India are higher educated

H2c: Compared to non-adopters, adopters of rooftop solar PV in India have higher income

H2d: Compared to non-adopters, adopters of rooftop solar PV in India have higher occupational status

H2e: Compared to non-adopters, adopters of rooftop solar PV in India are higher on social class

3.1.2 Qualitative Research

Unlike quantitative research, qualitative research has been in existence only for a few decades [92]. In this research method, open ended questions are generally asked, unlike close ended questions in quantitative questions. The researcher, if interested, can be a part of the research instruments. As per Creswel (2003), qualitative research is broadly inductive with the researcher generating meaning from the data collected [92]. This method is generally applied when the researcher is not certain of which variables to control. Qualitative research methods are useful where the researcher intends to gather a general idea from the subjects with an objective to explore, interpret and describe a situation. The objective is to review government policies in countries where rooftop solar PV adoption has been successful and expert view on their effectiveness in India. Qualitative research is not generally hypothesis driven [115]. This methodology is ideal where quantitative data is not available or no null hypothesis can be formed. For objective 4, researcher found out that qualitative research method would be ideal.

3.1.2.1 Data Collection Plan

Literature Review and Focus Group Discussion (FGD) are used for collecting data. Through literature review government policies in countries like Germany, China and USA were studied.

3.1.2.2 Focus Group Discussion (FGD)

Focus group discussion is one of the most popular qualitative research methods. It involves a discussion among a group of people, and it is guided by a moderator according to a prepared guidelines or protocol. FGD aims to obtain data from a purposely selected group of individuals rather than from a statistically representative sample of a broader population. The method gradually developed as a qualitative data collection approach that helped form a strategy for scientific research and local knowledge [93]. As rooftop solar PV is a relatively new technology, FGD is an appropriate technique to collect quality data. The researcher ensured that FGD members were from this field and had considerable knowledge on various aspects of rooftop solar PV. FGD technique is a proven methodology for qualitative data analysis that has got many advantages. As the discussion is open ended, FGD leads to collection of very wide range of data. So, the researcher here preferred this particular technique for objective 4.

Through literature review, important variables for adoption of rooftop solar PV were identified. These variables could be categorized into a few important factors; financial attractiveness, environmental benefits, complexity, trialability, and social image. The researcher established a link between those important factors and various policies implemented across various countries. That link helps navigate the focus group discussion with a clear approach of finding out those policies that would augment the rooftop solar PV adoption in India. A Focussed Group Discussion was conducted on November 17, 2017 at Bhubaneswar to discuss the government policies in India and find out the effectiveness.

3.1.2.3 FGD Members

The researcher adopted non-random convenient way of choosing the participants. The group was chosen in a way that the participants have good subject knowledge, but not known to each other. The researcher avoided random selection of participants as the discussion required people with good subject knowledge that was not very common. Also, the researcher preferred participants who were known to him, but bring diverse views. Ideally a group size should be between 5 and 8 (Sagepub). The participants were:

1. GM Electrical, GRIDCO, Odisha
2. Manager - RE Cell, PP, GRIDCO, Odisha
3. President, CCPPO, Bhubaneswar
4. Chief GM, SLDC, OPTCL, Odisha
5. Ex-Director - Commercial, GRIDCO
6. Additional General Manager, BHEL, New Delhi

The researcher played the role of the moderator.

3.1.2.4 FGD Questions

The researcher prepared two engagement questions and five exploration questions. The two exploration questions were prepared to make the participants comfortable with the topic of discussion. These two questions are:

1. How is the power sector situation in the country?
2. What will be the future of solar PV in India?

Five exploration questions were prepared to be discussed in the FGD.

1. Why Rooftop Solar PV adoption in Germany is so high and how it's catching up first in countries like USA or China?

2. How important is the role of the government in the adoption of rooftop solar PV?

3. What are the major reasons for slow adoption of rooftop solar PV in India?

4. What are the government policies in India to promote adoption of rooftop solar PV?

5. What is the most important government policy that would effectively be the game changer?

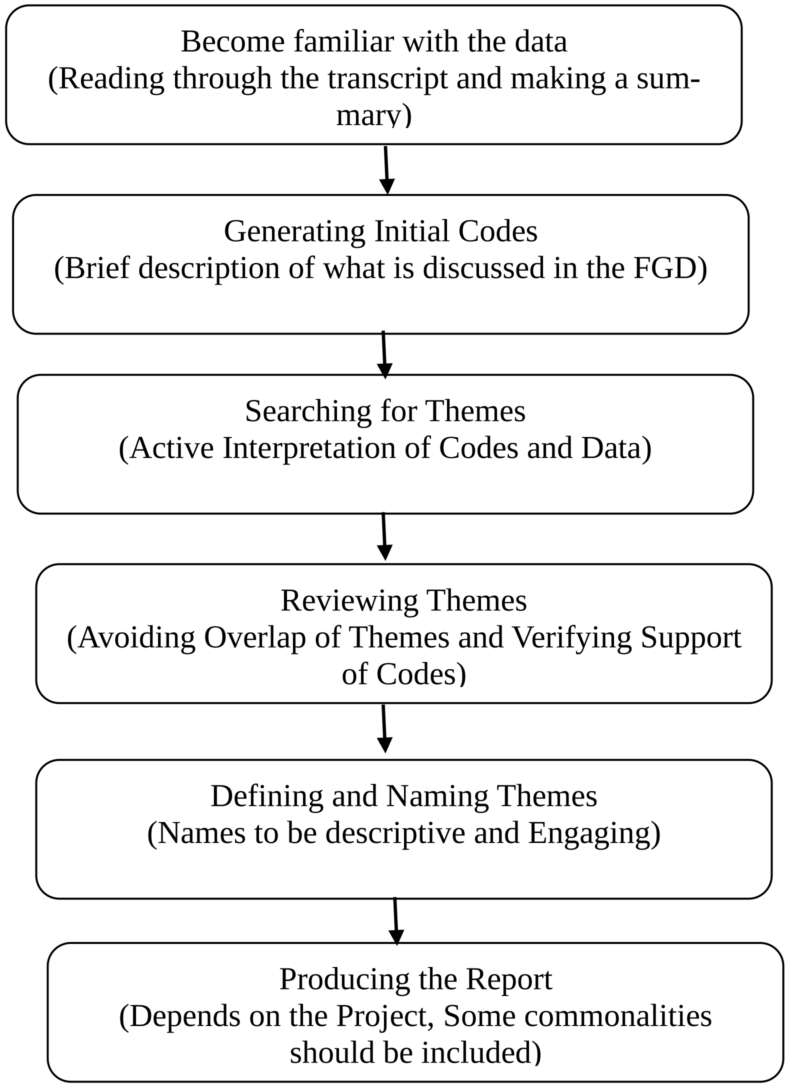
3.1.2.5 FGD Data Collection

The researcher arranged a person to take note of all the discussions. After the discussion was over, the researcher verified the transcript with the participants. The discussion started with understanding the success story of rooftop solar PV in Germany and the reasons behind the success. Then the discussion included the success of rooftop solar PV in USA and China. From the discussion, the team decided to jot down the important policies that helped the adoption of rooftop solar PV in these three countries. Moderator spelled out clearly those policies identified through extensive literature review. The researcher, as moderator, also brought out the important factors for adoption of rooftop solar PV and the corresponding policies broadly addressing those factors. However, the discussion was kept open to include any other policy that might not have been implemented in those countries. Over the course of the discussion the group discussed the pros and cons of each policy from an Indian context. However, it became very difficult to zero in on any particular policy that should be chosen as the most suitable policy for India. Although feed-in-tariff is considered as a very important policy worldwide, the group unanimously agreed that in India offering a generous FIT is almost impossible considering the financial health of distribution companies in all the states.

3.1.2.6 Data Analysis Tool

Thematic analysis approach was used to analyse the qualitative data. Thematic Analysis is the process of identifying patterns or themes in a qualitative data [94]. There are many different approaches to thematic analysis (Alhojailan, 2012; Boyatzis,1998; Javadi & Zarea, 2016). However, one of the popular approaches is suggested by Braun & Clarke’s 6-step framework. The six steps suggested are: 1. Become familiar with data, 2. Generate initial codes, 3. Search for Themes, 4. Review Themes, 5. Define themes, 6. Write-up.

Data analysis process:



From the FGD conducted, a transcript was prepared, and the researcher acted as the moderator. The transcript was analyzed using thematic analysis to address the research question.

3.2 Summary

This section described in detail the research methodology. The researcher has identified four research objectives.

1. To identify the important factors leading to adoption of rooftop solar PV in India.
2. To explore the perceptions of adopters and non-adopters towards rooftop solar PV in India.
3. To examine the demographic and psychographic differences between the adopters and non-adopters of rooftop PV in India.
4. To analyze government policies in countries like USA, China, and Germany, where rooftop solar PV adoption has been successful and find out the suitable policies for India.

For these four research objectives, research design is elaborately explained. For the first three objectives, the researcher employs quantitative research and for the fourth objective, qualitative research is employed.

For quantitative research, survey method is applied for data collection. Data collection is done in two steps. For the first objective data was collected from adopters of rooftop solar PV in the states of Kerala and Odisha. A sample size of 200 is finalized and for this snowball sampling technique is applied. Factor analysis is applied for data analysis. For objectives 2 and 3, data was collected again from the states of Kerala and Odisha and the respondents were both adopters and non-adopters. A sample size of 150 is finalized that is chosen using random sampling method. Hypothesis testing and descriptive statistics are the analysis tools used. Both ‘z’ test and ‘Chi-square’ tests are conducted for hypothesis testing. The analysis is done to find out: (a) perception of both adopters and non-adopters towards rooftop solar PV and (b) demography and psychography difference between adopters and non-adopters of rooftop solar PV.

For objective 4, qualitative research method is applied that includes conducting a focus group discussion. Thematic analysis approach is applied for analysing the qualitative data collected through literature review and then the FGD.

4 Data Analysis and Findings

For all the four objectives relevant data are collected. As defined in the research design, the data thus collected are analyzed to get the hidden meaning of those data, which in turn helps us arrive at the conclusion of our research.

4.1 Factor Analysis for Consumers

Objective 1: To find out the important factors leading to adoption of rooftop solar PV in India

Factor analysis has been conducted to determine the important factors for adoption of rooftop solar PV in India. Factor analysis is a technique researcher uses to condense the data in many variables into just a few important factors.

From the exhaustive literature review, 39 variables were identified that contribute to the possible adoption of rooftop solar PV. A questionnaire was prepared to find out the importance of each such variable on a scale of 1 to 7 in the adoption decision, with 1 indicating the least important and 7 the most important. The researcher received responses from 200 respondents through physically visiting the respondents, google form, telephone, Email and WhatsApp, with first two methods contributing most of the responses.

From these responses, a factor analysis was done using “r”.

4.1.1 Test of data adequacy

The researcher checked various factors to find out the fitness of the factor analysis and found that the model fits well.

KMO (Kaise-Meyer-Olkin) Test Score: 0.93

- Interpreting KMO Score
  - 0.9+ :Superb
  - 0.8 – 0.89 : Great
  - 0.7 – 0.79 : Good
  - 0.5 – 0.69 : Mediocre
  - <0.5 : Unacceptable

KMO score indicates the proportion of variance in the test that may be caused by underlying factors. High values generally suggest that a factor analysis is likely to be useful with the data

Barlett Test of Sphericity

- Chi-Square : 5741.4
- Degrees of Freedom : 741
- p value: <2.2 e-16

Bartlett's test of sphericity tests the hypothesis that the correlation matrix is an identity matrix. This tests to what extent the variables are unrelated to each other and therefore unsuitable for factor analysis. Small p-values indicate that a factor analysis would be useful with the data as the variables are related to some extent.

Table 4.1: Measure of Sampling Adequacy (MSA) of each variable

Variable	**MSA**
Freedom from future increase in electricity tariff	0.83
Current high electricity tariff	0.90
High return on investment	0.94
Attractive feed-in-tariff	0.94
Low cost of installation	0.92
Low Operating Cost	0.89
Access to unlimited power	0.81
Attractive subsidy from the government	0.92
Attractive tax incentives	0.96
Enhances social image	0.91
Ease of getting financing of initial cost	0.93
Ease of getting all government incentives	0.92
Concern for the environment	0.71
Ease of maintenance	0.91
Ease of taking up a trial project on smaller scale	0.88
Ease of understanding the concept of rooftop solar PV	0.95
Absence of requirement for any additional resources like water	0.75
Lowering of cooling load requirement of the building as it keep the roof cool	0.71
Supports in better peak load management	0.84

Independence from utility provider or others	0.81
Good for the environment	0.69
Helps others to install due to sharing of knowledge	0.94
Helps create an "Environment Concern Image"	0.93
It is a global trend	0.96
Clarity over long term future FIT (feed in tariff)	0.96
Longer investment horizon	0.81
Compatibility of all equipment with Solar PV system	0.88
Compatibility of building for solar PV installation	0.91
Ease of operating the solar PV system	0.95
Availability of enough unused rooftop space	0.72
Availability of plenty of PV service providers	0.95
Suitability of building location for rooftop solar PV installation	0.95
Easy to deal with utility provider	0.94
Ease of monitoring electricity generation and usage	0.95
Visibility of benefits from use of rooftop solar PV	0.97
Ease of seeing a demonstration of rooftop solar PV	0.96
No health hazards	0.94
Availability of good quality rooftop solar PV system	0.95
Compatibility with your social value	0.97

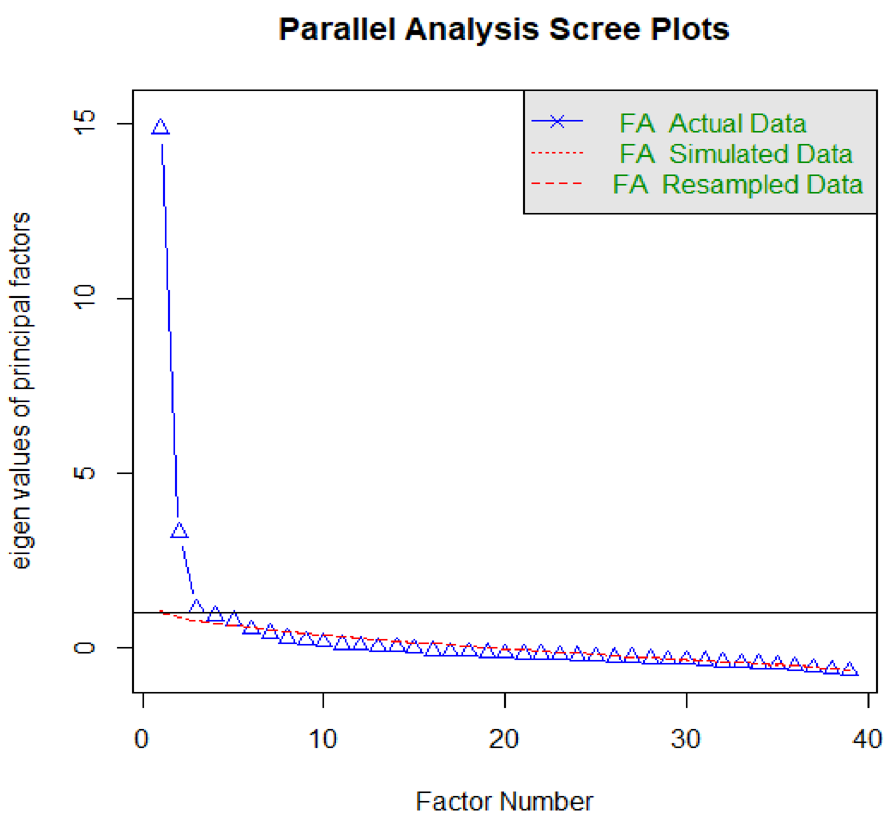
Measure of data adequacy for each variable is more than 0.7, so that indicates that the variables are good for factor analysis.

4.1.2 Factor Extraction

Selecting the number of factors to represent all the variables is an important step in factor analysis. Using the data analysis tool 'r', the number of factors was selected using Parallel Analysis method. Parallel analysis method suggested five factors to be considered.

A scree plot was drawn to further verify the ideal number of factors.

Figure 4.1: Parallel analysis scree plots of factor analysis



In the scree plots, the blue line shows eigenvalues of actual data and the two red lines show that for simulated and resampled data. It can be observed that eigenvalues of actual data show a large drop initially and then the line make more sideway movement. Also, the researcher located the point of inflection which is the point where the gap between simulated data and actual data is likely to be minimum. The eigenvalues for each factor represent the variance explained by that factor. The scree plots with the point of inflection also confirms the parallel analysis indication to use extract five factors.

Table 4.2: Correlation Matrix of Factor Analysis

	MR1	MR3	MR2	MR4	MR5
Freedom from future increase in electricity tariff	0.09	0.48	0.13	-0.05	-0.22
Current high electricity tariff	0.13	0.46	0.1	0.23	-0.32
High return on investment	0.15	0.7	0.06	0.09	-0.12
Attractive feed-in-tariff	0.22	0.57	-0.09	0.28	-0.1
Low cost of installation	0.18	0.64	-0.04	-0.28	0.12
Low Operating Cost	0.06	0.54	0.26	-0.17	-0.05
Access to unlimited power	-0.13	0.23	0.47	-0.37	0.13
Attractive subsidy from the government	0	0.68	0.01	0	0.07

Attractive tax incentives	0.16	0.7	-0.1	0.06	0.05
Enhances social image	-0.06	0.26	0.13	0.42	0.07
Ease of getting financing of initial cost	-0.14	0.75	-0.07	0.2	0.11
Ease of getting all government incentives	0.02	0.62	0.08	0.01	0.27
Concern for the environment	-0.26	-0.01	0.69	0.27	0.16
Ease of maintenance	0.53	0.22	0.11	-0.02	0.25
Ease of taking up a trial project on smaller scale	0.19	0.13	0.21	0.02	0.45
Ease of understanding the concept of rooftop solar PV	0.4	0.1	0.18	0.25	0.29
Absence of requirement for any additional resources like water	0.05	-0.02	0.49	0.1	0.04
Lowering of cooling load requirement of the building as it keep the roof cool	0.07	0.02	0.61	-0.22	0.04
Supports in better peak load management	0.3	0.02	0.53	0	0.05
Independence from utility provider or others	0.63	0.06	0.23	-0.21	-0.17
Good for the environment	0.08	-0.17	0.65	0.24	0

Helps others to install due to sharing of knowledge	0.25	0.14	0.15	0.06	0.56
Helps create an "Environment Concern Image"	0.14	0.18	0.01	0.69	0
It is a global trend	0.22	0.12	-0.05	0.61	0.11
Clarity over long term future FIT (feed in tariff)	0.37	0.4	-0.01	0.24	0.09
Longer investment horizon	0.21	0.41	0.11	-0.01	-0.07
Compatibility of all equipment with Solar PV system	0.55	0.1	0.22	-0.05	-0.23
Compatibility of building for solar PV installation	0.88	-0.02	0.09	0	-0.12
Ease of operating the solar PV system	0.73	-0.01	0.05	0.14	0
Availability of enough unused rooftop space	0.38	-0.04	0.23	-0.2	-0.04
Availability of plenty of PV service providers	0.5	0.26	-0.01	0.07	-0.03
Suitability of building location for rooftop solar PV installation	0.63	0.02	0.11	0.03	0.16
Easy to deal with utility provider	0.64	0.07	-0.1	0.05	0.24
Ease of monitoring electricity gener-	0.57	0.16	-0.23	0.23	0.16

ation and usage					
Visibility of benefits from use of rooftop solar PV	0.61	0.19	-0.14	0.18	0.1
Ease of seeing a demonstration of rooftop solar PV	0.44	0.32	0.14	0.22	0.09
No health hazards	0.46	0.15	0.18	-0.05	0.23
Availability of good quality rooftop solar PV system	0.6	0.26	-0.07	0.03	0.16
Compatibility with your social value	0.21	0.18	-0.1	0.45	0.18

This matrix shows the loading of each variable into each of the five factors. Loading in excess of 0.4 were considered by the researcher and no double loading of any variable was noticed.

4.1.3 Adequacy Test

Mean item complexity = 1.8

Barlett test: X-squared = 5741.4, df = 741, p-value < 2.2e-16

The degrees of freedom for the null model are 741 and the objective function was 31.06 with Chi Square of 5752.11

The degrees of freedom for the model are 556 and the objective function was 5.97

The root mean square of the residuals (RMSR) is 0.04

RMSEA Index is 0.076 which is acceptable. MSEA values less than 0.05 are good, values between 0.05 and 0.08 are acceptable, values between 0.08 and 0.1 are marginal, and values greater than 0.1 are poor [114].

The df corrected root mean square of the residuals is 0.04

The harmonic number of observations is 200 with the empirical chi square 447.82 with prob < 1

The total number of observations was 200 with Likelihood Chi Square = 1084.78 with prob < 1.9e-36

Tucker Lewis Index of factoring reliability = 0.856

RMSEA index = 0.076 and the 90 % confidence intervals 0.063

BIC = -1861.08

Fit based upon off diagonal values = 0.99

Tucker Lewis Index of factoring reliability is 0.856 which is again acceptable.

Table 4.3: Factor analysis summary

	MR1	MR3	MR2	MR4	MR5
SS loadings	7.05	6.09	3.5	3.55	1.84
Proportion Var	.18	.16	.09	.09	.05
Cumulative Var	.18	.34	.43	.52	.56
Proportion Explained	.32	.28	.16	.16	.08
Cumulative Proportion	.32	.60	.76	.92	1

4.1.4 Identified Factors

Table 4.4: Factors with factor loading

Factors	Variables	Loading	Factor Name
Factor 1	Ease of maintenance	0.53	Complexity
	Ease of understanding the concept of rooftop solar PV	0.4	
	Independence from utility provider or others	0.63	
	Compatibility of all equipment with Solar PV system	0.55	
	Compatibility of building for solar PV installation	0.88	
	Ease of operating the solar PV system	0.73	
	Availability of enough unused rooftop space	0.38	
	Availability of plenty of PV service providers	0.5	
	Suitability of building location for rooftop solar PV installation	0.63	
	Easy to deal with utility provider	0.64	
	Ease of monitoring electricity generation and usage	0.57	

	Visibility of benefits from use of roof-top solar PV	0.61	
	Ease of seeing a demonstration of rooftop solar PV	0.44	
	No health hazards	0.46	
	Availability of good quality rooftop solar PV system	0.6	
Factor 2	Freedom from future increase in electricity tariff	0.48	Financial Attractiveness
	Current high electricity tariff	0.46	
	High return on investment	0.7	
	Attractive feed-in-tariff	0.57	
	Low cost of installation	0.64	
	Low Operating Cost	0.54	
	Attractive subsidy from the government	0.68	
	Attractive tax incentives	0.7	
	Ease of getting financing of initial cost	0.75	
	Ease of getting all government incentives	0.62	
	Clarity over long term future FIT (feed in tariff)	0.4	

	Longer investment horizon	0.41	
Factor 3	Access to unlimited power	0.47	Environmental Benefits
	Concern for the environment	0.69	
	Absence of requirement for any additional resources like water	0.49	
	Lowering of cooling load requirement of the building as it keep the roof cool	0.61	
	Good for the environment	0.65	
	Supports in better peak load management	0.53	
Factor 4	Enhances social image	0.42	Social Image
	Helps create an "Environment Concern Image"	0.69	
	It is a global trend	0.61	
	Compatibility with your social value	0.45	
Factor 5	Ease of taking up a trial project on smaller scale	0.45	Trialability
	Helps others to install due to sharing of knowledge	0.56	

From the factor analysis, the researcher found out five important factors that decide the solar rooftop PV adoption among the adopters. And these five factors are:

1. Complexity
2. Financial Attractiveness
3. Environment Benefits
4. Social Image
5. Trialabilty

Three of the five factors from Roger's theory of adoption; Relative Advantage, Complexity and Trialability got included. Social image is a surprise inclusion as one of the factors.

4.1.5 Reliability of Factor Analysis

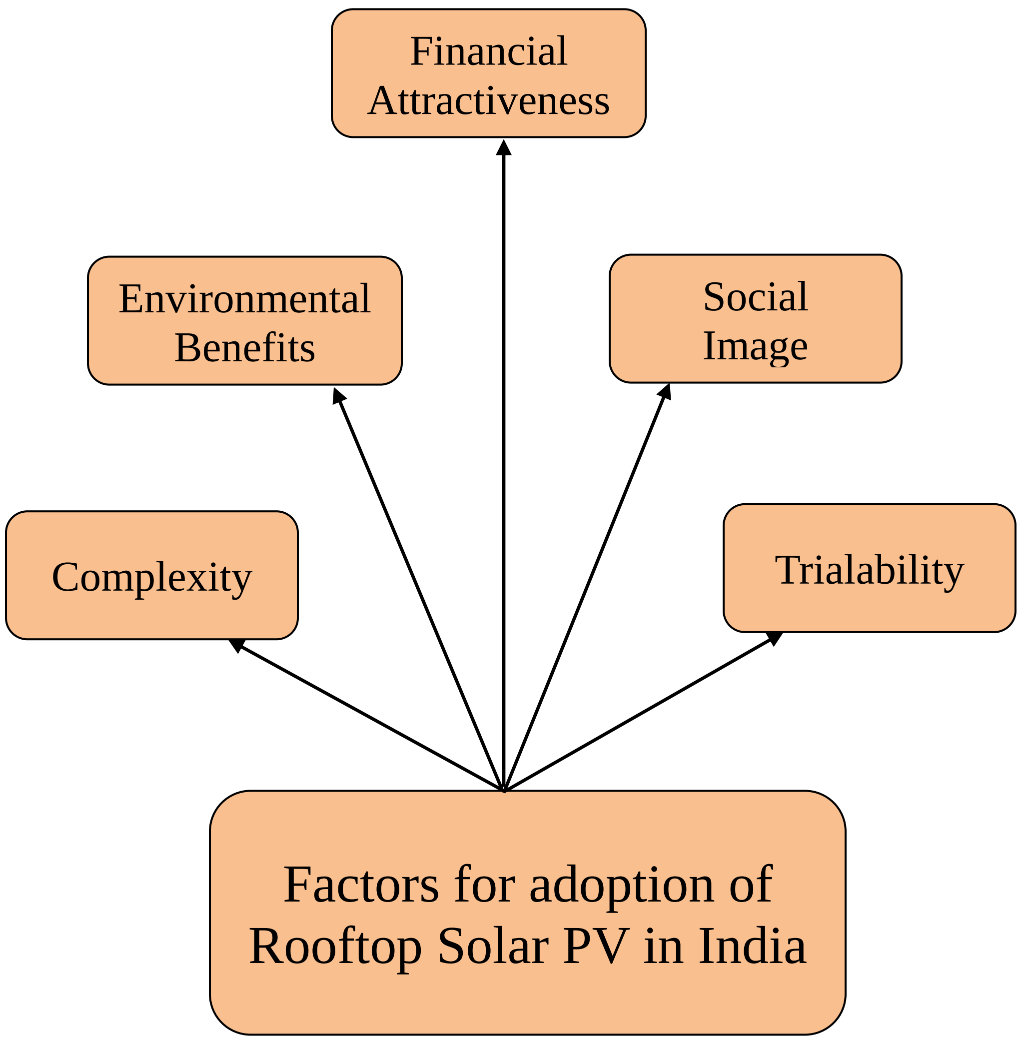
Cronbach's alpha is a good measure of assessing the reliability or internal consistency of a set of test items. It is a function of the number of items in any test and calculated as the average of covariance between the items and total variance.

Table 4.5: Cronbach's alpha of each factor

Factor 1	Factor Name	Cronbach's Alpha
Factor 1	Complexity	0.93
Factor 2	Financial Attractiveness	0.89
Factor 3	Environmental Benefits	0.73
Factor 4	Social Image	0.88
Factor 5	Trialability	0.57

The overall Cronbach's alpha for the whole set of variables was found to be 0.95. Cronbach's alpha, if more than 0.5, is a good indication for internal consistency or reliability.

Figure 4.2: Factor of adoption for rooftop solar PV in India



4.2 Consumer perception

Objective 2: To find out the consumer perception of adopters and non-adopters towards rooftop solar PV in India.

From Objective – 1, factors for adoption of rooftop solar PV were identified and those are:

1. Complexity
2. Financial Attractiveness
3. Environment Benefits
4. Social Image
5. Trialability

Once the critical factors that adopters consider while deciding about adopting rooftop solar PV are found out, it is important to verify the perception of prospective adopters or those who have evaluated and decided against adoption. If the non-adopters perceive rooftop solar PV poorly on these parameters, that explains a major reason behind their not adopting the technology. A comparison between adopters and non-adopters on how they perceive will provide further insight. Poor perception by non-adopters compared to the adopters indicates lack of awareness among consumers and more is required to educate them on different important factors. The findings will help the policy makers take corrective measures to improve the perception of consumers, if found poor.

On these five factors, perception of both adopters and non-adopters towards roof top solar PV was captured. On a scale of 1 to 7, where 1 indicates strongly disagree and 7 strongly agree, perception on each of these factors were taken.

4.2.1 Hypothesis test on Complexity

Hypothesis

H01: Adopters perceive rooftop solar PV less complex to install than non-adopters

H1a: Adopters do not perceive rooftop solar PV less complex to install than non-adopters

Table 4.6: “z” test result for installation complexity

Adopters		Non-Adopters					
Mean	Std. Dev	Mean	Std. Dev	S.D of both variables	"Z" Value	Acceptable "z" value	Hypotheses
3.16	1.49	3.93	1.61	0.25	-3.07	1.645	Failed to reject

“z” value of this two-sample variable = $(3.16-3.93)/\sqrt{(1.49^2/75+1.61^2/75)} = -3.07$.

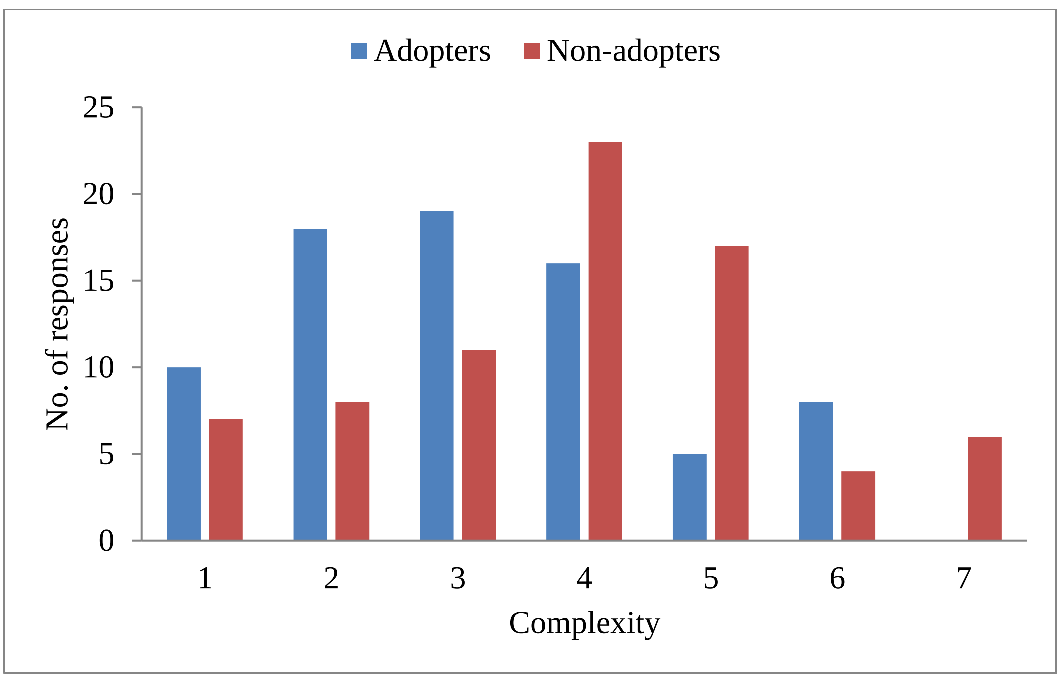
On complexity of installation the mean score among adopters is 3.16 whereas it is 3.93 among non-adopters. Acceptable “z” value is 1.645 for a 95% confidence level. From the means of the sample of adopters and non-adopters, the “z” value found out is -3.07. As the “z” value is less than the acceptable value of 1.645, the null hypothesis couldn’t be rejected.

Table 4.7: Chi-square test summary for installation complexity

Adopters		Non-Adopters				
Mean	Std. Dev	Mean	Std. Dev	Chi Square Value	Acceptable Value for p=0.05	Hypothesis
3.16	1.49	3.93	1.61	21.64	12.592	Failed to reject

Chi-square test proves that the difference in perception of adopters and non-adopters towards installation complexity of rooftop solar PV is statistically significant. But the difference is as expected as per hypothesis, and so the hypothesis couldn't be rejected

Figure 4.3: Perception of adopters & non-adopters on installation complexity



As it can be seen, most of the respondents among adopters of rooftop solar PV chose low score on installation complexity, whereas a large of non-adopters chose high score like 4 or 5. None of the adopters gave the highest score of 7 on complexity whereas a sizeable chunk among non-adopters opted for a score of 7 indicating the installation process is highly complex. The findings support the belief that one possible reason behind people not adopting rooftop solar PV, is that they perceive the process to install it is very complex.

Hypothesis

H02: Adopters perceive rooftop solar PV less complex to operate than non-adopters

H2a: Adopters do not perceive rooftop solar PV less complex to operate than non-adopters

Table 4.7(a)

Adopters		Non-Adopters					
Mean	Std. Dev	Mean	Std. Dev	S.D of both variables	"Z" Value	Acceptable "z" value	Hypotheses
2.39	1.51	3.76	1.67	0.26	-5.26	1.645	Failed to reject

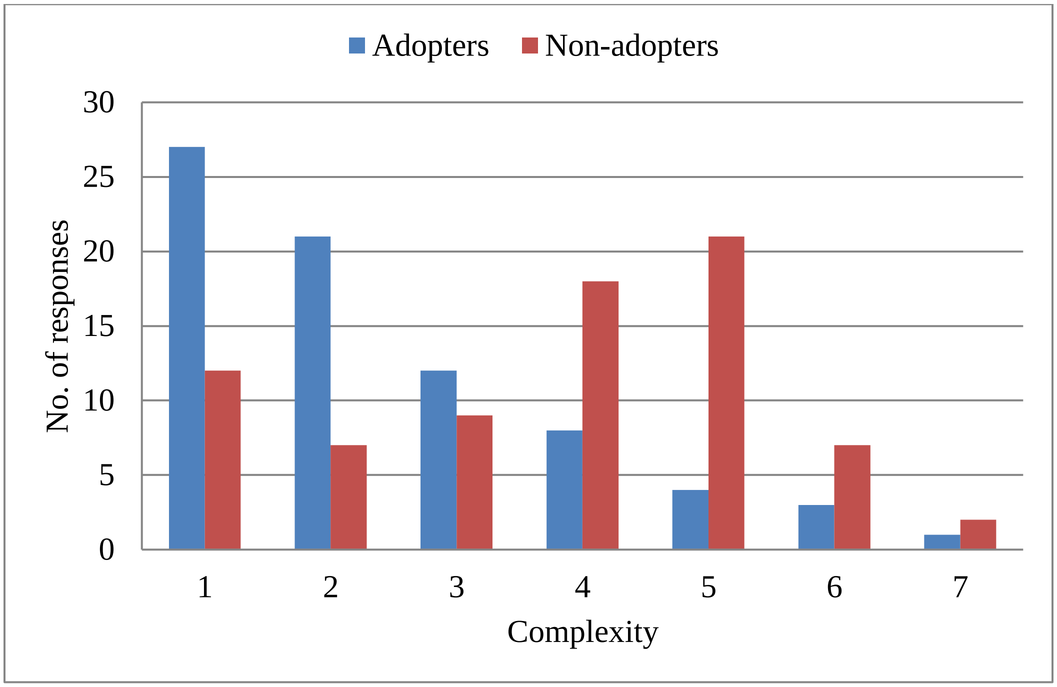
On complexity of operation the mean score among adopters is 2.39 whereas it is 3.76 among non-adopters. Acceptable “z” value is 1.645 for a 95% confidence level. From the means of the sample of adopters and non-adopters, the “z” value found out is -5.26. As the “z” value is less than the acceptable value of 1.645, the null hypothesis couldn’t be rejected.

Table 4.8: Chi-square test summary for operation complexity

Adopters		Non-Adopters				
Mean	Std. Dev	Mean	Std. Dev	Chi Square Value	Acceptable Value for p=0.05	Hypothesis
2.39	1.51	3.76	1.67	30.54	12.592	Failed to reject

Chi-square result indicates the difference in perception towards operating rooftop solar PV in India between adopters and non-adopters is statistically significant and is as per hypothesis. This reiterates the hypothesis that adopters of rooftop solar PV in India perceive the rooftop system to be less complex to operate than what the non-adopters perceive.

Figure 4.4: Perception of adopters and non-adopters on operating complexity



A large number of adopters responded with a very low score of complexity for operating the rooftop solar PV whereas the number of non-adopters providing such low scores is significantly lower. The result demonstrates that only after consumers start operating the rooftop solar PV system in India, they realize that it is not complex to operate. The difference in perception between adopters and non-adopters is quite significant on this factor of complexity to operate.

4.2.2 Hypothesis test on Financial Attractiveness

Hypothesis

H03: Adopters perceive rooftop solar PV financially more attractive than non-adopters

H3a: Adopters do not perceive rooftop solar PV financially more attractive than non-adopters

Table 4.9: "z" test result for Financial attractiveness

Adopters		Non-Adopters					
Mean	Std. Dev	Mean	Std. Dev	S.D of both variables	"Z" Value	Acceptable "z" value	Hypoth-eses
4.88	1.31	4.09	1.53	0.23	3.39	-1.645	Failed to reject

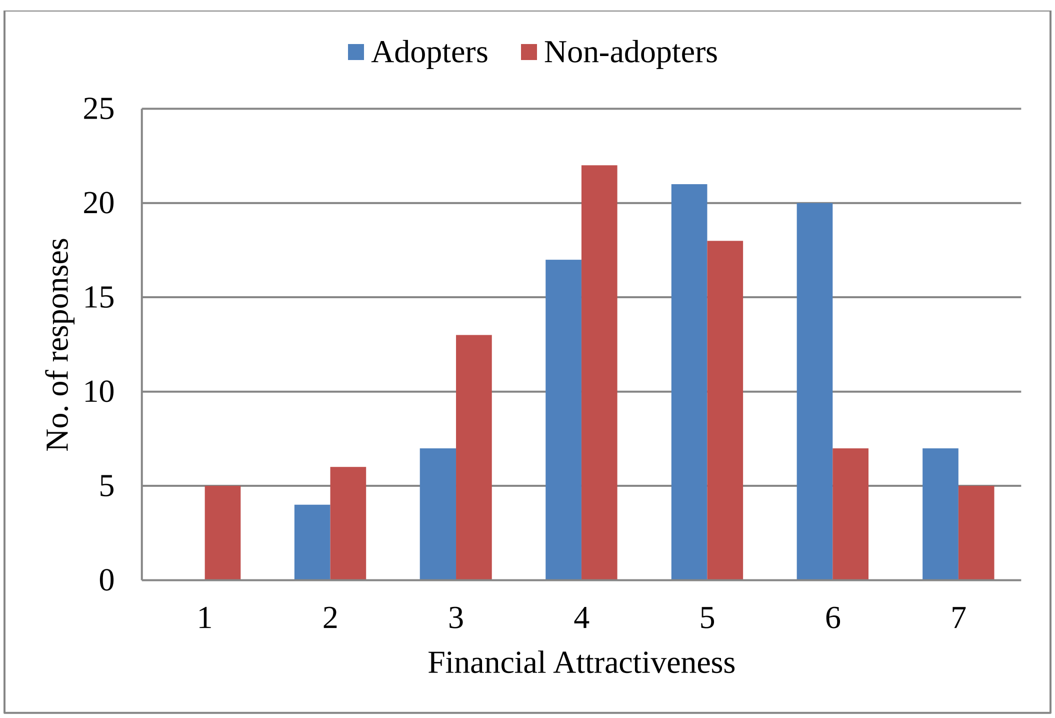
On financial attractiveness of rooftop solar PV in India, the mean score among adopters is 4.88 whereas it is 4.09 among non-adopters. Acceptable "z" value is -1.645 for a 95% confidence level. From the means of the sample of adopters and non-adopters, the "z" value found out is 3.39. As the "z" value is higher than the acceptable value of -1.645, the null hypothesis is accepted. This is a very surprising revelation as there are different financial incentives that government provides to the consumers and government does try to propagate that through different platforms. As financial attractiveness is one of the most important factors, more study can be carried out to find out the reason behind such poor perception. The problem can be either the existing incentive schemes are not effective or awareness about such schemes is not reaching the people.

Table 4.10: Chi-square test summary for financial attractiveness

Adopters		Non-Adopters				
Mean	Std. Dev	Mean	Std. Dev	Chi Square Value	Acceptable Value for p=0.05	Hypothesis
4.88	1.31	4.09	1.53	14.66	12.592	Failed to reject

Chi-square test proves that the difference in perception of adopters and non-adopters towards financial attractiveness of rooftop solar PV is statistically significant. So, the hypothesis that adopters perceive rooftop solar PV to be financially more attractive than how non-adopters perceive couldn't be rejected.

Figure 4.5: Perception of adopters & non-adopters on financial attractiveness



On perception about financial attractiveness of rooftop solar PV, the average scores of both adopters and non-adopters are more than 4. Not surprisingly, among adopters there is no one giving a score of 1. A certain number of non-adopters gave the lowest possible score, perceiving the rooftop solar PV to be financially not attractive at all. This is a very surprising revelation as there are different financial incentives that government provides to the consumers.

As financial attractiveness is one of the most important factors, more study can be carried out to find out the reason behind such poor perception. The problem can be either the existing incentive schemes are not effective or awareness about such schemes is not reaching the people.

4.2.3 Hypothesis test on Environmental Benefits

Hypothesis

H04: Adopters perceive environmental benefits of rooftop solar PV higher than what non-adopters perceive

H4a: Adopters do not perceive environmental benefits of rooftop solar PV higher than what non-adopters perceive

Table 4.11: "z" test result for Environmental Benefits

Adopters		Non-Adopters					
Mean	Std. Dev	Mean	Std. Dev	S.D of both variables	"Z" Value	Acceptable "z" value	Hypotheses
5.92	1.58	5.98	1.41	0.24	-0.27	-1.645	Failed to reject

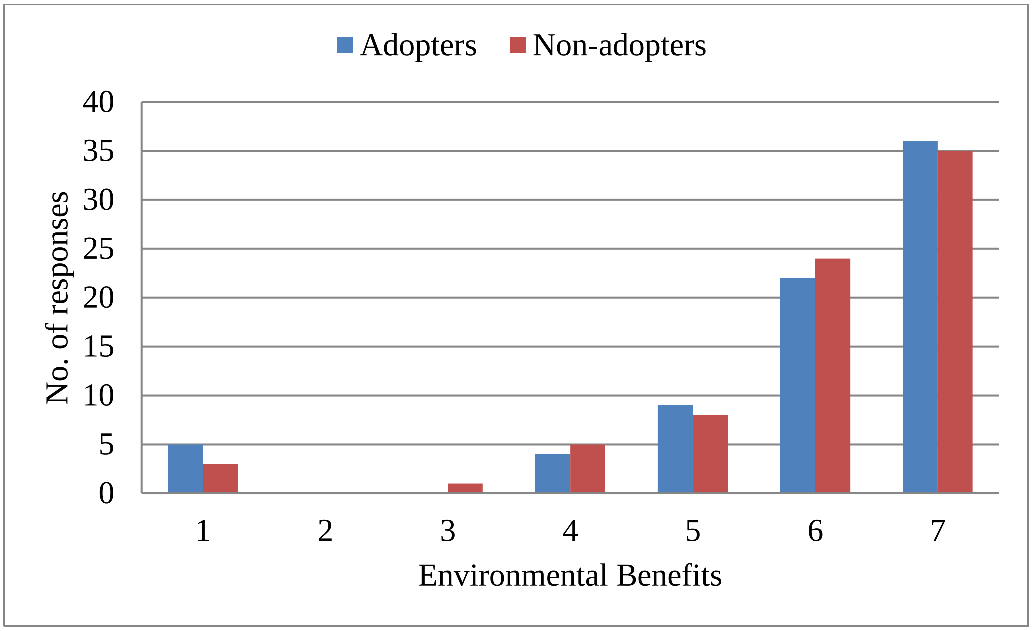
On environmental benefits of rooftop solar PV in India, the mean score among adopters is 5.92 whereas it is 5.98 among non-adopters. Acceptable “z” value is -1.645 for a 95% confidence level. From the means of the sample of adopters and non-adopters, the “z” value found out is -0.27. As the “z” value is higher than the acceptable value of -1.645, the null hypothesis couldn’t be rejected.

Table 4.12: Chi-square test summary for Environmental Benefits

Adopters		Non-Adopters				
Mean	Std. Dev	Mean	Std. Dev	Chi Square Value	Acceptable Value for p=0.05	Hypothesis
5.92	1.58	5.98	1.41	1.77	12.592	Failed to reject

Chi-square test proves that the difference in perception of adopters and non-adopters towards environmental benefits of rooftop solar PV is statistically not significant and so the null hypothesis couldn’t be rejected.

Figure 4.6: Perception of adopters & non-adopters on environmental benefits



From analysing the responses, it is easily noticeable that both adopters and non-adopters perceive rooftop solar PV system to have considerable environmental benefits. This is one factor where it seems both adopters and non-adopters are highly appreciative about the environmental benefits of rooftop solar PVs. The findings are not very surprising as benefits of rooftop solar PV or any other renewable energy, to the environment is very well known among people across the world.

4.2.4 Hypothesis test on improving Social Image

Hypothesis

H05: Adopters perceive adoption of rooftop solar PV improves social image more than what non-adopters perceive

H5a: Adopters do not perceive adoption of rooftop solar PV improves social image more than what non-adopters perceive

Table 4.13: “z” test result for improvement in social image

Adopters		Non-Adopters					
Mean	Std. Dev	Mean	Std. Dev	S.D of both variables	"Z" Value	Acceptable "z" value	Hypoth-eses
4.12	1.58	4.28	1.8	0.28	-0.57	-1.645	Failed to reject

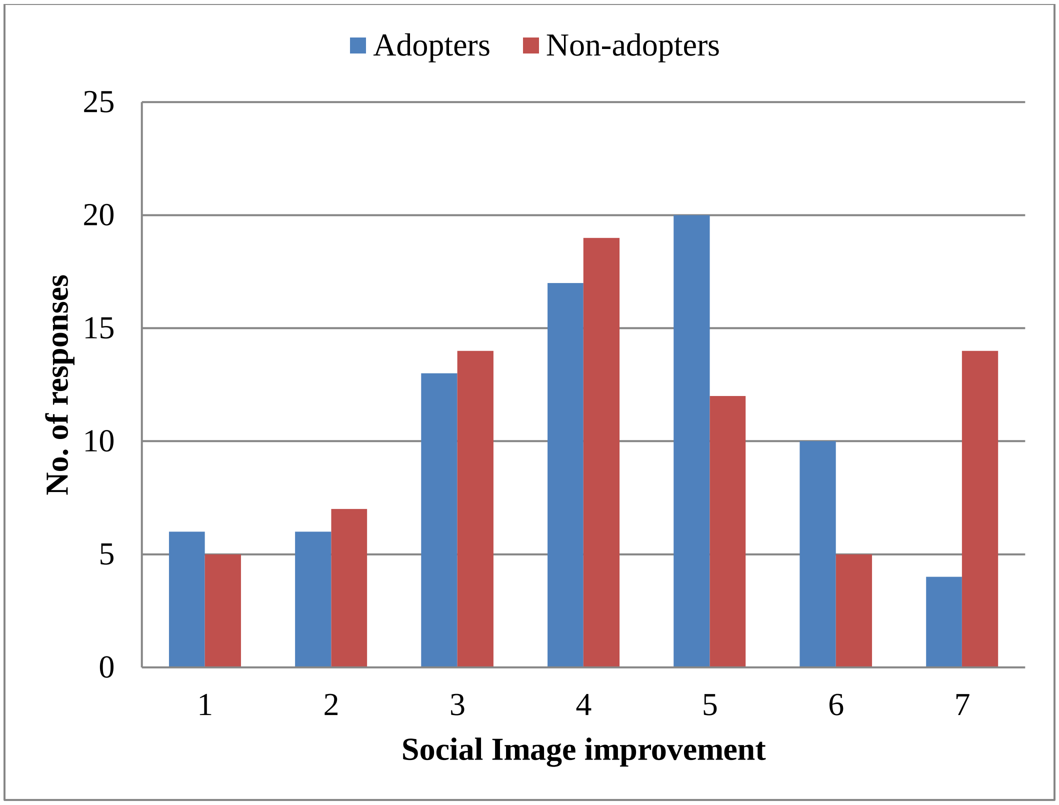
On improvement of social image due to adoption of rooftop solar PV in India, the mean score among adopters is 4.12 whereas it is 4.28 among non-adopters. Acceptable “z” value is -1.645 for a 95% confidence level. From the means of the sample of adopters and non-adopters, the “z” value found out is -0.57. As the “z” value is higher than the acceptable value of -1.645, the null hypothesis couldn’t be rejected.

Table 4.14: Chi-square test summary for improvement in social image

Adopters		Non-Adopters				
Mean	Std. Dev	Mean	Std. Dev	Chi Square Value	Acceptable Value for p=0.05	Hypothesis
4.12	1.58	4.28	1.8	9.54	12.592	Failed to reject

Chi-square test proves that the difference in perception of adopters and non-adopters towards environmental benefits of rooftop solar PV is statistically not significant and so the null hypothesis couldn't be rejected.

Figure 4.7: Perception of adopters and non-adopters on social image



It is noticed from the chart that both adopters and non-adopters are not very clear about the improvement in social image due to adoption of rooftop solar PV. Surprisingly, non-adopters are believing a little more than the adopters that adoption of the system will improve the social image.

4.2.5 Hypothesis test on Trialability

Hypothesis

H06: Adopters perceive trialability of rooftop solar PV system is higher than what non-adopters perceive

H6a: Adopters do not perceive trialability of rooftop solar PV system is higher than what non-adopters perceive

Table 4.15: "z" test result for Trialability

Adopters		Non-Adopters					
Mean	Std. Dev	Mean	Std. Dev	S.D of both variables	"Z" Value	Acceptable "z" value	Hypotheses
3.97	1.65	3.95	1.68	0.27	0.09	-1.645	Failed to reject

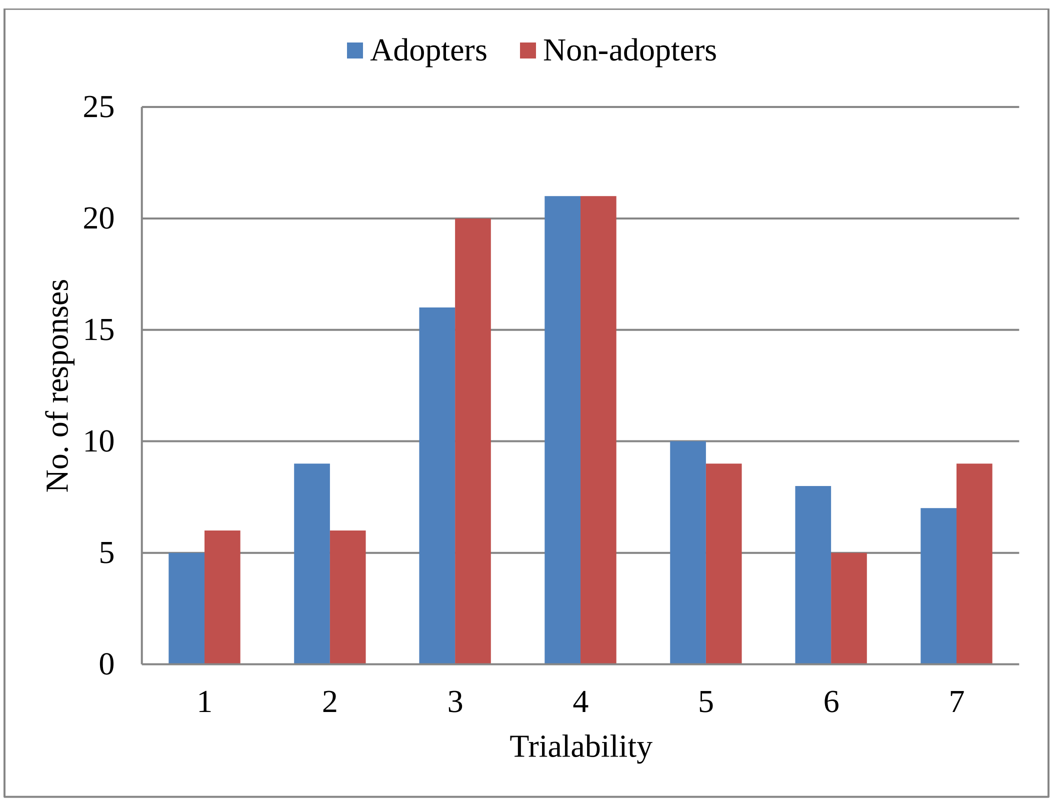
On trialability of the rooftop solar PV in India, the mean score among adopters is 3.97 whereas it is 3.95 among non-adopters. Acceptable "z" value is -1.645 for a 95% confidence level. From the means of the sample of adopters and non-adopters, the "z" value found out is 0.09. As the "z" value is higher than the acceptable value of -1.645, the null hypothesis couldn't be rejected.

Table 4.16: Chi-square test summary for improvement in social image

Adopters		Non-Adopters				
Mean	Std. Dev	Mean	Std. Dev	Chi Square Value	Acceptable Value for p=0.05	Hypothesis
3.97	1.65	3.95	1.68	2.13	12.592	Failed to reject

Chi-square test proves that the difference in perception of adopters and non-adopters towards trialability of rooftop solar PV is statistically not significant and so the null hypothesis couldn't be rejected

Figure 4.8: Perception of adopters and non-adopters on trialability



It is noticed from the chart that both adopters and non-adopters are not very clear about the trialability of rooftop solar PV. The mean scores of both adopters and non-adopters are almost identical. This is one more major concern as people will feel that adopting rooftop solar PV can turn out to be a trap for very long period. This is where demonstration projects come handy as we could see its impact in the growth of rooftop solar PV in Germany.

4.2.6 Summary of Perception

Here is the summary of response we received and the “z” test results for the hypotheses. The “z” tests were conducted with 95% significance level.

As the data was discrete, chi-square tests were also conducted to test the null hypotheses.

Table 4.17: Perception against attributes

Mean Score on a scale 1 – 7		
	Adopters	Non-Adopters
Installation Complexity	3.16	3.93
Operating Complexity	2.39	3.76
Financial Attractiveness	4.88	4.09
Environmental Benefits	5.92	5.98
Social Image Building	4.12	4.28
Trialability	3.97	3.95

<u>Hypotheses Test Result Summary from “z” test</u>

Table 4.18: “z” test result

	Adopters		Non-Adopters					
	Mean	S.D	Mean	S.D	S.D of both variables	"Z" Value	Acceptable "z" value	Hypotheses
Installation Complexity	3.16	1.49	3.93	1.61	0.25	-3.07	1.645	Failed to reject
Operating Complexity	2.39	1.51	3.76	1.67	0.26	-5.26	1.645	Failed to reject
Financial Attractiveness	4.88	1.31	4.09	1.53	0.23	3.39	-1.645	Failed to reject
Environmental Benefits	5.92	1.58	5.98	1.41	0.24	-0.27	-1.645	Failed to reject
Social Image Improvement	4.12	1.58	4.28	1.8	0.28	-0.57	-1.645	Failed to reject
Trialability	3.97	1.65	3.95	1.68	0.27	0.09	-1.645	Failed to reject

<u>Chi-Square Test</u>

Table 4.19: Chi square test summary

	Adopters		Non-Adopters				
	Mean	S.D	Mean	S.D	Chi Square Value	Acceptable Value for p=0.05	Hypothesis
Installation Complexity	3.16	1.49	3.93	1.61	21.64	12.592	Failed to reject
Operating Complexity	2.39	1.51	3.76	1.67	30.54	12.592	Failed to reject
Financial Attractiveness	4.88	1.31	4.09	1.53	14.66	12.592	Failed to reject
Environmental Benefits	5.92	1.58	5.98	1.41	1.77	12.592	Failed to reject
Social Image Building	4.12	1.58	4.28	1.8	9.54	12.592	Failed to reject
Trialability	3.97	1.65	3.95	1.68	2.13	12.592	Failed to reject

Using "z" test results, all five null hypotheses were accepted with a 95% confidence level. So, hypotheses as compared to nonadopters, adopters rate rooftop solar PV system as lower in complexity, both complexity in installation as well as operation, greater in financial attractiveness, greater in environmental benefits, better in social image building and more possible to try on a limited basis hold true. However, looking at Chi-square summary, it can be noticed that regarding perception about environmental benefits, social image building and trialability, both adopters and non-adopters have almost similar kind of perceptions.

It is also important to notice that regarding complexity in installation, the average score even among the adopters is not highly favourable. The average score is 3.16 with 1 being the best and 7 being the worst. So there seems to be a scope to eliminate a few hassles involved in installation process.

Similarly, on financial attractiveness, even the adopters feel it is attractive, but not highly attractive with an average score of 4.88 with 7 being the best and 1 the worst. Among non-adopters the score is very close to neither attractive nor non-attractive.

Both adopters and non-adopters are not very comfortable at the ease of taking up a small project on trial. But, on the factor of environmental benefits, it seems both adopters as well as non-adopters are very clear about the benefits.

So, from the hypothesis tests, it was found out that it is not true that both adopters and non-adopters believe the complexity and financial attractiveness of rooftop solar PV to be similar. The non-adopters believe that the complexity of both installation and operation of rooftop solar PV is more. Similarly, financial attractiveness of rooftop solar PV seems less to the non-adopters compared to the adopters.

The findings are significant revelations in theory of adoption of any technology. There was no confirmation from literature that while adopting any new technology, perception between adopters and non-adopters differ. However, through this research it was found out that one possible reason for non-adoption of rooftop solar PV could be due to poor perception about the system by non-adopters compared to adopters.

Table 4.20: Objective 2 output

Factor	Finding
Complexity	Non-adopters are more sceptical
Financial Attractiveness	Non-adopters perceive this to be less attractive
Environmental Benefits	Perception of both similar
Social Image	Perception of both similar
Trialability	Perception of both similar

4.3 Demography and Psychography analysis

Objective 3: To find out the demographic and psychographic difference between adopters and non-adopters of rooftop solar PV

The demographic factors on which adopters were compared with non-adopters are

1. Age
2. Income
3. Education
4. Occupational Status
5. Social Class

A clear understanding of demography of the people who adopt rooftop solar PV can go a long way in identifying the target prospective consumers. This helps policy makers reach out to those people are increase the success rate as understanding the parget customers makes strategy formulation a lot easier.

4.3.1 "z" test for age

Hypothesis

H07: Adopters of rooftop solar PV in India are younger than non-adopters

H7a: Adopters of rooftop solar PV in India are not younger than non-adopters as s

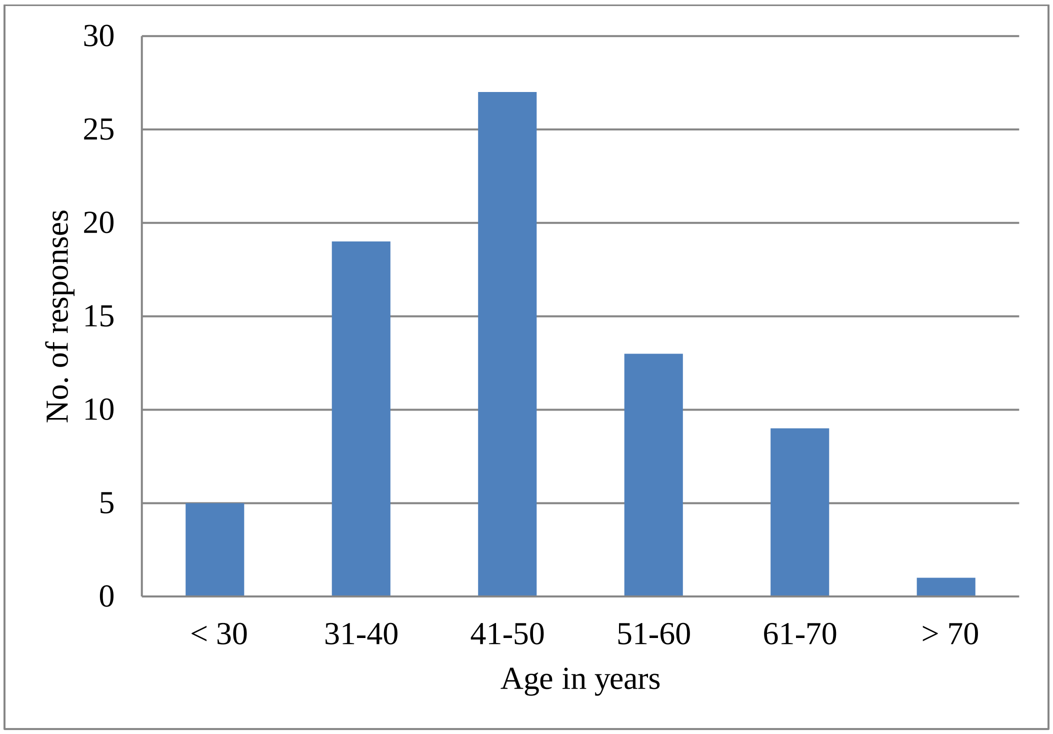
Table 4.21: "z" test for Age

Mean	Std. Dev	Std. Error	Pop. Mean	"z" Val.	Acceptable "z" value	Hypothesis
45.7	11.07	1.29	43	2.1	1.645	Rejected

Average age of the sample adopters was found to be 45.7 years with standard deviation of 11.07 years and standard error of mean as 1.29 years. Average age of population over 25 years in India is 43 years which is nothing but the average age of the non-adopters. From the means of the sample of adopters and non-adopters, the "z" value found out is 2.1. Acceptable "z" value is 1.645 for a 95% confidence level. As the "z" value is higher than the acceptable value of 1.645, the null hypothesis is rejected.

So, it is not true that the adopters of rooftop solar PV in India are younger. Generally, the younger people around the world adopt any technology faster that older people. It is surprising to notice that the same doesn't hold good for rooftop solar PV in India.

Figure 4.9: Age of adopters



4.3.2 "z" test for income level

Hypothesis

H08: Adopters of rooftop solar PV in India have higher income than that of non-adopters

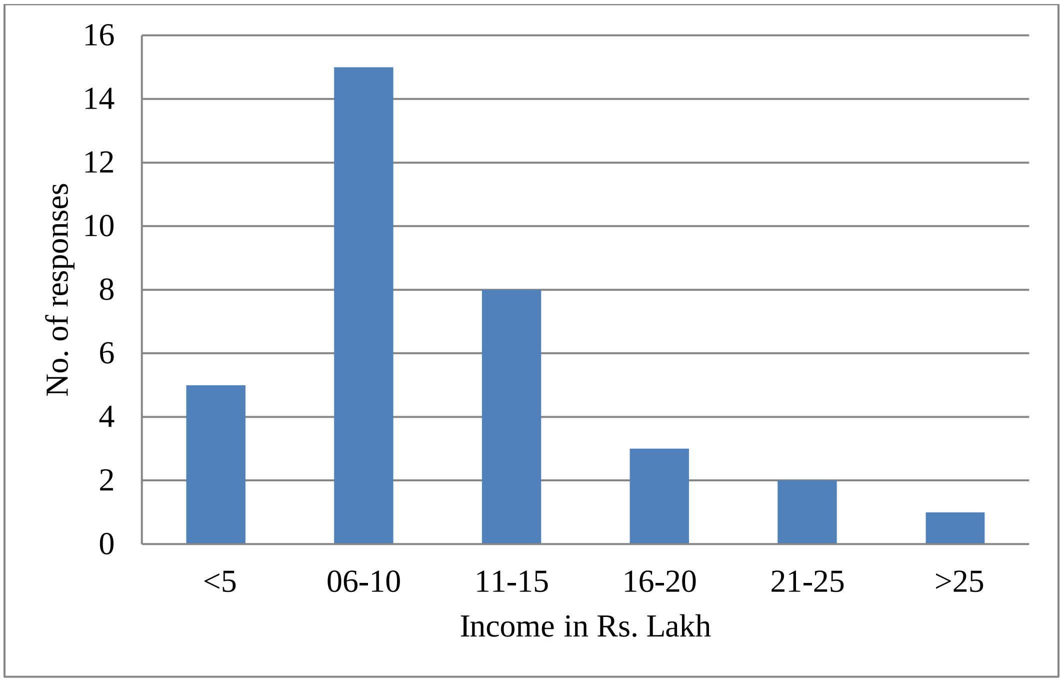
H8a: Adopters of rooftop solar PV in India do not have higher income than that of non-adopters

Table 4.22: "z" test for Income level

Mean	Std. Dev	Std. Error	Pop. Mean	"z" Val.	Acceptable "z" value	Hypothesis
13.1	6.13	1.07	0.8	11.5	-1.645	Failed to reject

Average income level of the sample adopters was found to be Rs. 13.1 lakh per year with standard deviation of 6.13 lakh years and standard error of mean 1.07 lakh. Average income level of non-adopters is only Rs. 0.8 lakh per year. Even the average income of the state of Kerala at Rs. 1.45 lakh or that of Orissa at Rs. 0.55 lakh is far below the average income of the adopters. From the means of the sample of adopters and non-adopters, the "z" value found out is 11.5. Acceptable "z" value is -1.645 for a 95% confidence level. As the "z" value is higher than the acceptable value of -1.645, the null hypothesis couldn't be rejected.

Figure 4.10: Income level of adopters



It can be easily seen from the graph that people with higher income prefer to adopt rooftop solar PV. In a country where millions of people live at income of less than a dollar a day, it is not feasible for them to arrange initial capital cost for the installation. It also puts a question mark on the availability of financing schemes. If easy and cheap financing is made available, penetration among low income group could be higher.

4.3.3 "z" test for Educational level

Hypothesis

H09: Adopters of rooftop solar PV in India have higher education than that of non-adopters

H9a: Adopters of rooftop solar PV in India do not have higher education than that of non-adopters

A scale is used for quantifying education level as given below:

Below High School : 0

High School : 1

Diploma / Intermediate : 2

Graduate : 3

Post Graduate / Professional : 4

Table 4.23 "z" test for Educational level

Mean	Std. Dev	Std. Error	Pop. Mean	"z" Val.	Acceptable "z" value	Hypothesis
3.75	0.46	0.05	0.5	60.3	-1.645	Failed to reject

The mean score for education using the aforementioned scale is found to be 3.75 whereas the same for non-adopters is only 0.46. From the means of the sample of adopters and non-adopters, the "z" value found out is 60.3. Acceptable "z" value is -1.645 for a 95% confidence level. As the "z" value is higher than the acceptable value of -1.645, the null hypothesis couldn't be rejected.

Table 4.24: Chi-square test for Educational level

Mean	Std. Dev	Std. Error	Pop. Mean	Chi Square Value	Acceptable Value for p=0.05	Hypothesis
3.75	0.46	0.05	0.5	146.6	7.815	Failed to reject

The Chi-square test indicates that the difference in educational levels of adopters and non-adopters is statistically significant, but in the same direction as per hypothesis. So, the hypothesis that adopters of rooftop solar PV in India are higher educated than the non-adopters couldn’t be rejected.

Figure 4.11: Education level of adopters

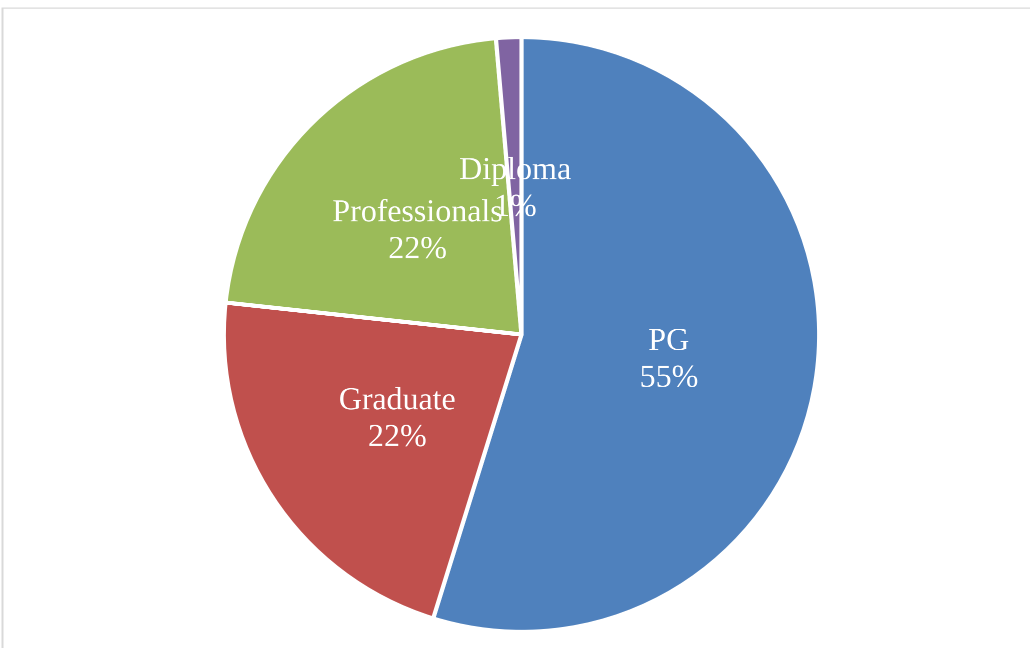
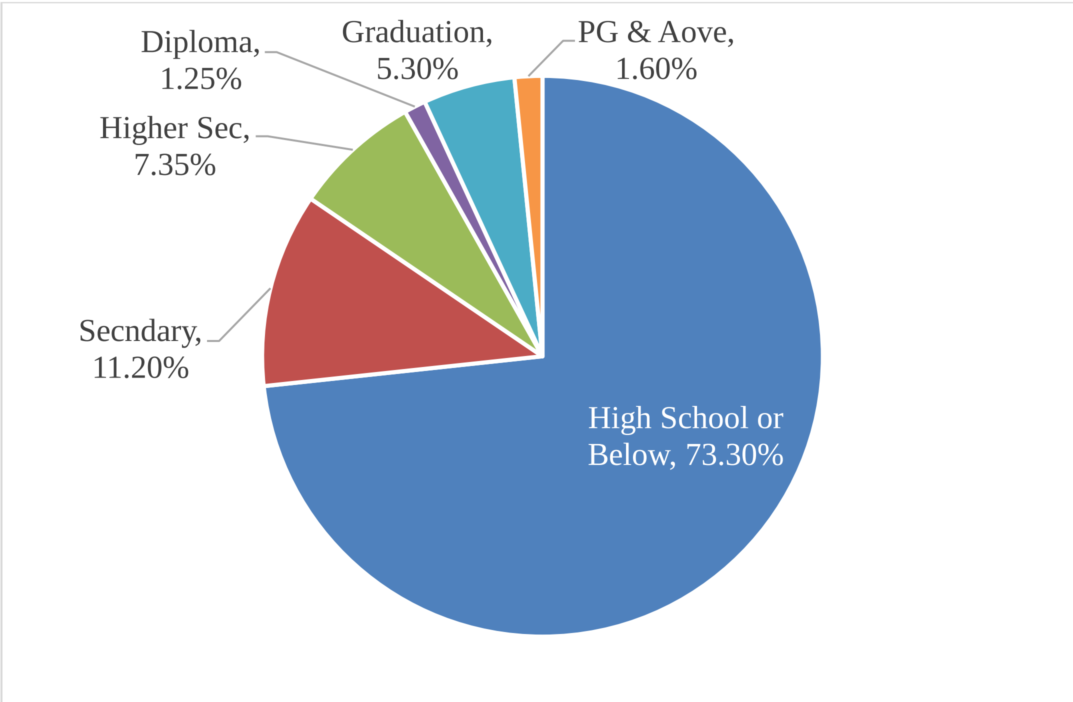


Figure 4.12: Education Level of Non-adopters



It can be easily seen that the difference in educational level of adopters from that of non-adopters is quite prominent. Nearly 80% of the adopters have either post-graduation or professional qualification, whereas nearly three quarter of the non-adopter population have educational level or high school or below. This is one area where a lot of work must be done for spreading the awareness among people who are not very educated but are potential adopters. May be the platform needs to be different or the target population and its traits need to be understood properly.

4.3.4 "z" test for Occupational Status

Hypothesis

H010: Adopters of rooftop solar PV in India have higher occupational status than that of non-adopters

H10a: Adopters of rooftop solar PV in India do not have higher occupational status than that of non-adopters

A scale is used for quantifying occupational status as given below:

Unskilled manual (USM) : 1

Skilled manual (SM) : 2

Lower Non manual (LNM) : 3

Middle Non manual (MNM) : 4

Higher Non manual (HNM) : 5

Table 4.25: "z" test for Occupational Status

Mean	Std. Dev	Std. Error	Pop. Mean	"z" Val.	Acceptable "z" value	Hypothesis
4.26	0.9	0.15	1.12	20.3	-1.645	Failed to reject

The mean score for occupational status using the scale is found to be 4.26 whereas the same for non-adopters is only 1.12. From the means of the sample of adopters and non-adopters, the “z” value found out is 20.3. Acceptable “z” value is -1.645 for a 95% confidence level. As the “z” value is higher than the acceptable value of -1.645, the null hypothesis couldn’t be rejected.

Table 4.26: Chi-square test for Occupational Status

Mean	Std. Dev	Std. Error	Pop. Mean	Chi Square Value	Acceptable Value for p=0.05	Hypothesis
4.26	0.9	0.15	1.12	126.6	9.488	Failed to reject

The Chi-square test indicates that the difference in occupational status of adopters and non-adopters is statistically significant, but in same direction as per hypothesis. So, the hypothesis that adopters of rooftop solar PV in India have higher occupational status than the non-adopters couldn’t be rejected.

Figure 4.13: Occupational Status of adopters

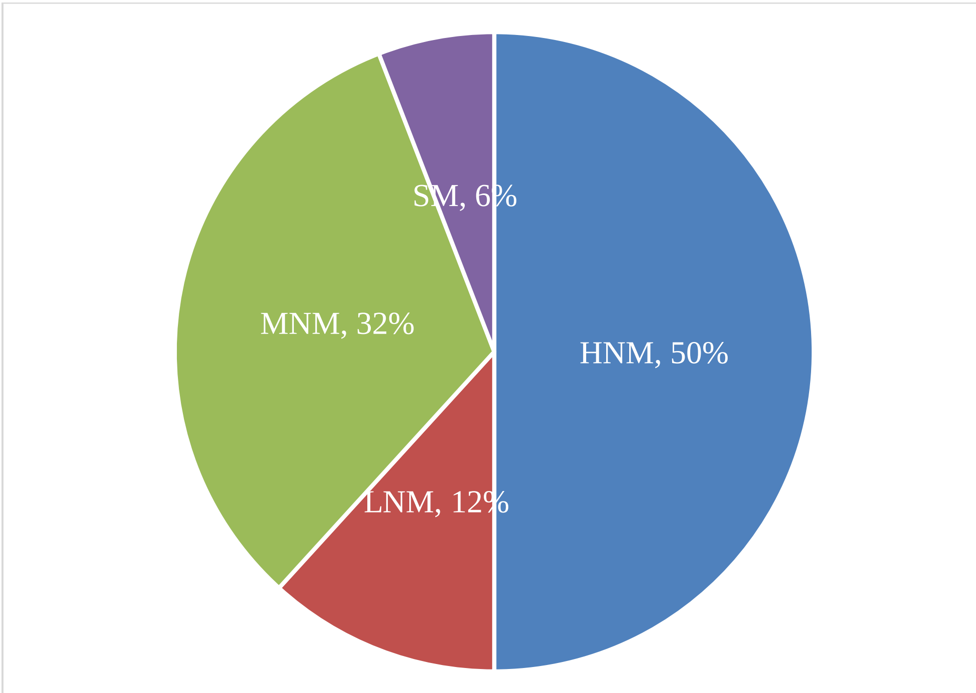
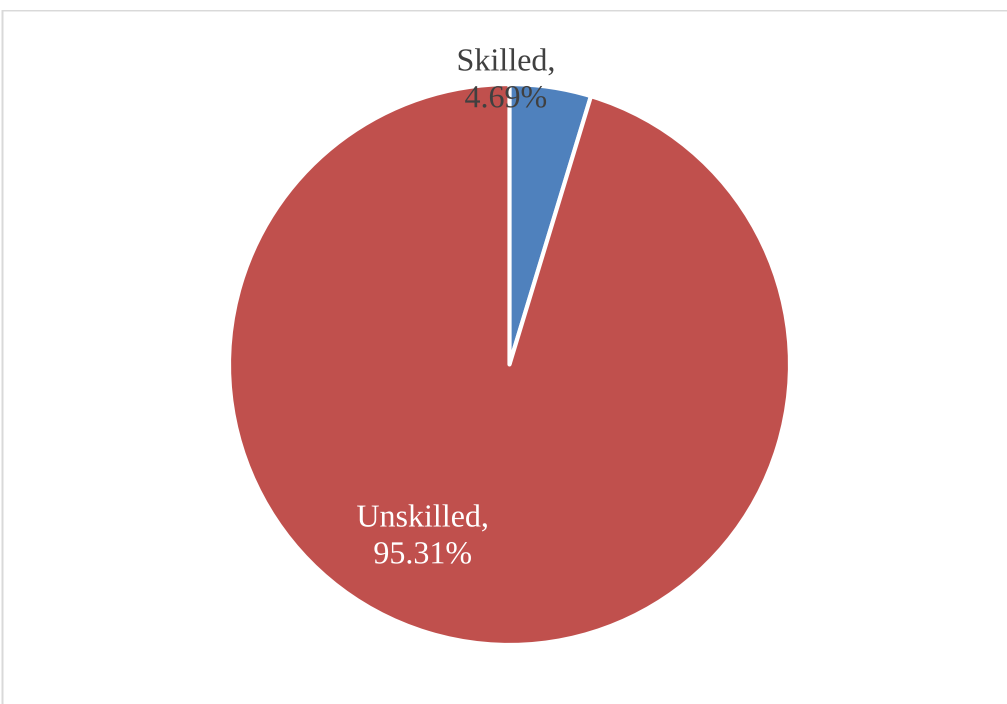


Figure 4.14: Occupational Status of Non-adopters



Occupational status of the adopters is significantly higher than that of non-adopters. When around 95% of the non-adopter population are unskilled, there is absolutely no unskilled person among the adopters. Almost 95% of the adopters are skilled and don't do manual jobs.

4.3.5 "z" test for Social Class

Hypothesis

H011: Adopters of rooftop solar PV in India have higher social class status than that of non-adopters

H11a: Adopters of rooftop solar PV in India do not have higher social class than that of non-adopters

A scale is used for quantifying social class as given below:

Lower lower (LL)	: 1
Middle lower	: 2
Higher lower	: 3
Lower Middle	: 4
Middle middle	: 5
Higher middle	: 6

Lower higher : 7

Middle higher : 8

Higher higher : 9

Table 4.27: "z" test for social class

Mean	Std. Dev	Std. Error	Pop. Mean	"z" Val.	Acceptable "z" value	Hypothesis
5.09	1.06	0.18	2.79	12.6	-1.645	Failed to reject

The mean score for social class using the scale is found to be 5.09 whereas the same for non-adopters is only 2.79. From the means of the sample of adopters and non-adopters, the "z" value found out is 12.6. Acceptable "z" value is -1.645 for a 95% confidence level. As the "z" value is higher than the acceptable value of -1.645, the null hypothesis couldn't be rejected.

Table 4.28: Chi-square test for Social Class

Mean	Std. Dev	Std. Error	Pop. Mean	Chi Square Value	Acceptable Value for p=0.05	Hypothesis
5.09	1.06	0.18	2.79	55.07	9.488	Failed to reject

The Chi-square test indicates that the difference in social class of adopters and non-adopters is statistically significant, but in the same direction as per the hypothesis. So, the hypothesis that adopters of rooftop solar PV in India have higher social class than the non-adopters is correct.

Figure 4.15: Social Class of adopters

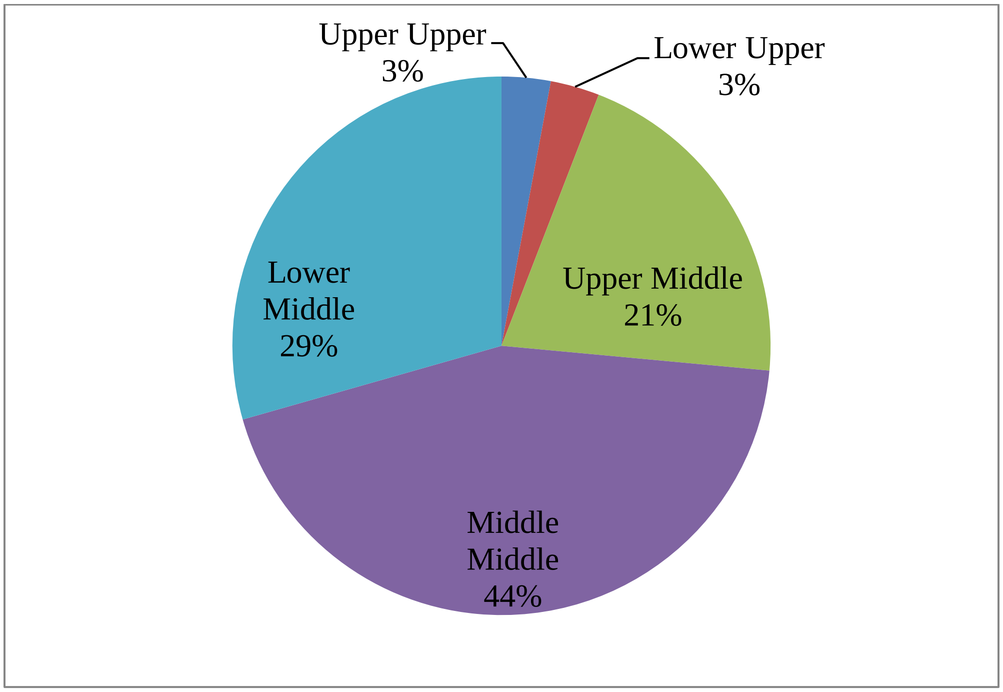
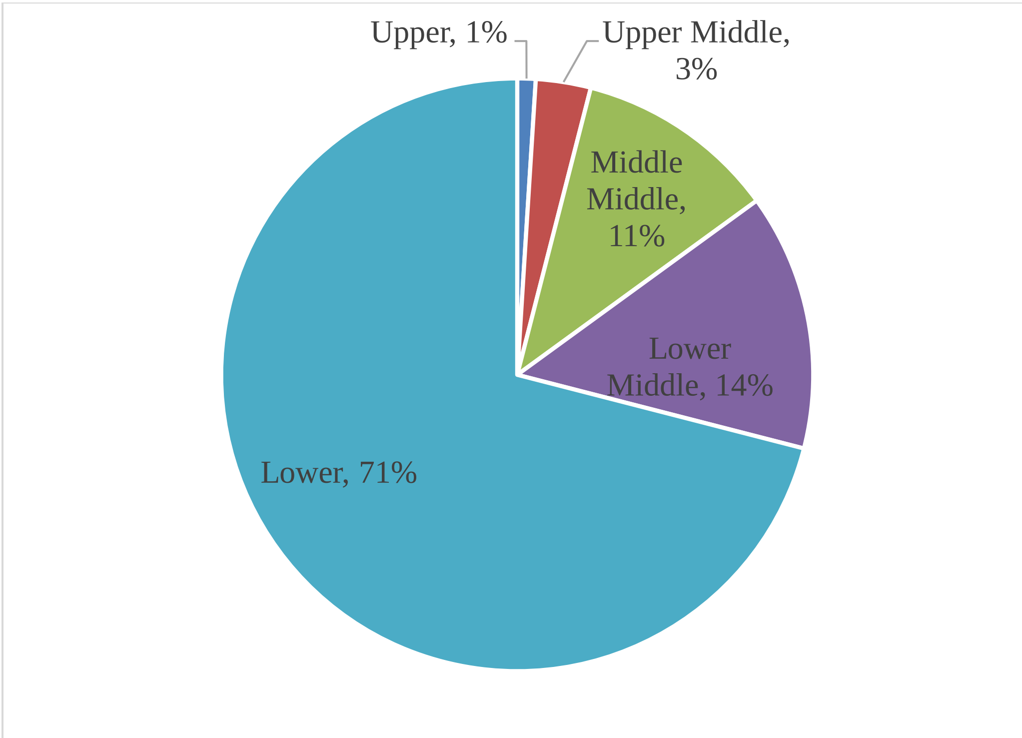


Figure 4.16: Social Class of Non-adopters



Social class of the adopters is prominently higher than that of non-adopters. When around 71% of the non-adopter population are from lower class, there is absolutely no lower class person among the adopters. Almost 95% of the adopters are from middle class and the rest from upper class.

4.3.6 Demographic differences summary

The researcher found out the demographic differences between the adopters and non-adopters of rooftop solar PV in India. The demographic factors considered to evaluate the differences are Age, Education, Income, Occupational Status and Social Class. Hypotheses testing was done to arrive at the conclusion. As the number of adopters of rooftop solar PV in India is negligible, demographic information about the entire population of India is a good indicator of demographic factors for non-adopters of rooftop solar PV. The researcher found out that there were significant differences between adopters and non-adopters on these factors.

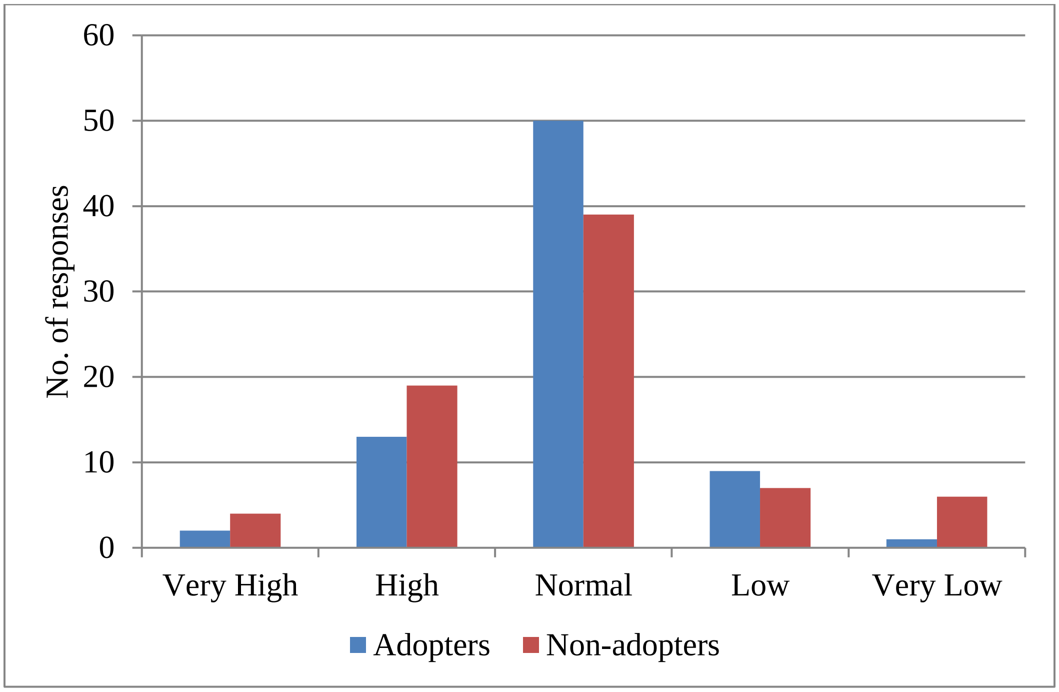
Contrary to the belief that adopters of rooftop solar PV in India are younger than non-adopters were proven wrong.

However, on all other factors, Income, Education, Occupational status and social class, the adopters are significantly superior than the non-adopters.

4.3.7 Psychographic Factors

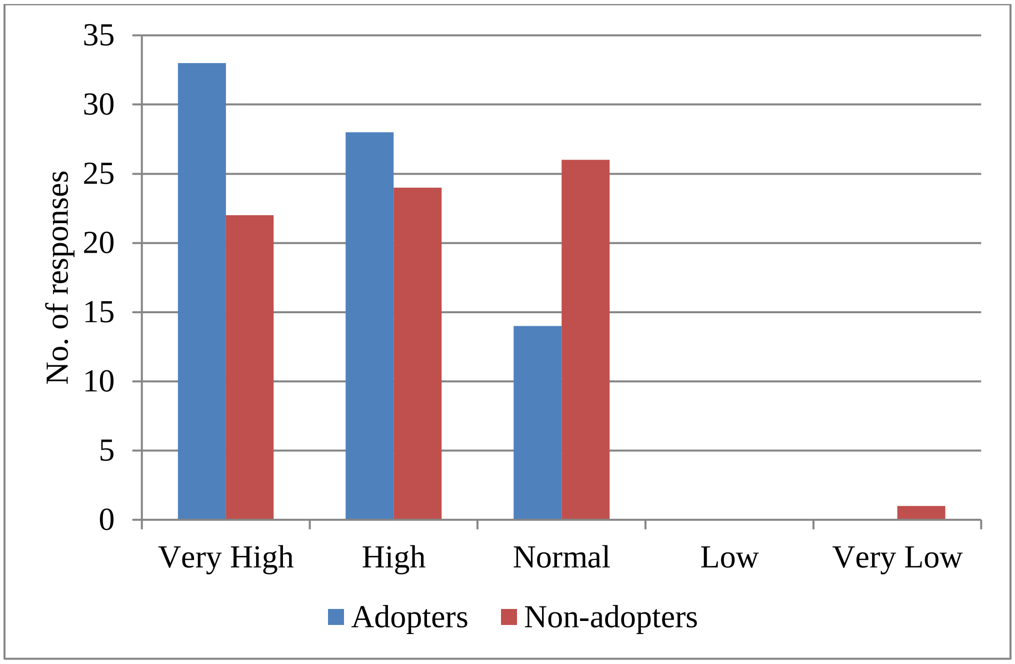
The researcher found out the psychographic differences between the adopters and non-adopters of rooftop solar PV in India. Three important factors, swiftness in decision making, Adhering to rules and regulations, and concern for environment through importance of cars.

Figure 4.17: Time for taking important decisions



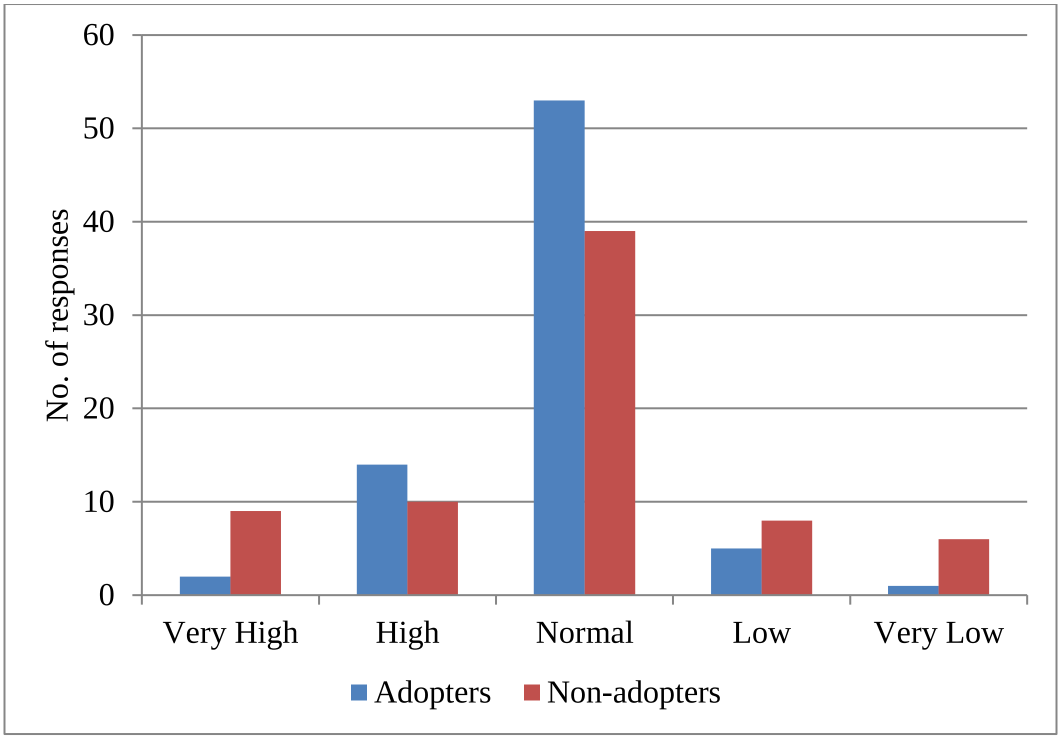
From the chart it can be seen there doesn't exist much difference between adopters and non-adopters in their swiftness in taking important decisions.

Figure 4.18: Importance of Rules & Regulations



On this factor of adhering to the rules and regulations, the difference between adopters and non-adopters is clearly visible. It can be seen that the adopters seem to be more law abiding.

Figure 4.19: Importance of Cars



On this parameter there again doesn't seem to be much difference between adopters and non-adopters. Rather the adopters of rooftop solar PV seems to be slightly keener to own cars. This is surprising as adopters are expected to have concern for the environment and should try to avoid buying cars.

4.3.8 Objective 3 Findings Summary

Demography

Factor	Finding
Age	Adopters are not younger
Income	Adopters have higher income
Education	Adopters have higher education
Occupation Status	Adopters have superior occupation
Social Class	Adopters are higher in social class

The findings on one demographic factor is surprising as from literature it is believed that younger people are expected to adopt any new technology. However, the findings here proved that wrong in case of adoption of rooftop solar PV. On other factors, the findings are in line with what is expected.

Psychography

Factor	Finding
Decision making	No significant difference exists in swiftness
Law abiding	Adopters seem to be more law abiding
Care for environment	No significant difference exists between them

4.4 Ideal Policy for fostering growth

Objective 4: To review government policies in countries where rooftop solar PV adoption has been successful and expert view on their effectiveness in India

4.4.1 Literature on major policies

Extensive literature review was done to find out important policies that facilitated growth of rooftop solar PV in Germany, China and USA. These policies are

- Feed-in-Tariff or FIT
- Renewable Portfolio Standard or RPS
- Capital Subsidy on the initial installation cost
- Tax benefits: Providing tax benefits on the capital expenditure on rooftop solar PV installation
- Ease of financing: Making arrangement to easily finance the installation cost
- Net metering: Allowing the electricity generated from solar PV to be fed to the grid and draw it whenever required by the customer and a meter giving the net consumption by the customer
- Green electricity scheme: Option given to the consumers to buy electricity generated from renewable energy sources
- Public investment: Government making significant investment in the concept

- Demonstration project: Setting up a few rooftop solar PVs that would act as demonstrations for any prospective consumer
- R&D: More funding and emphasis on research and development [45]

Major policies that drive growth in Germany are: (a) fixed feed-in-tariffs to be paid over a period of 20 years, (b) Purchase guarantees, and (c) Priority feed-in of renewable electricity into the grid. Other favourable policies are reduced interest loans, long term financing up to 20 years [115]. The policies that made solar PV successful in countries are:

USA - Renewable Portfolio Standard, Incentive like PURPA 1978, Investment Tax Credit, Production Tax Credit

Germany - Feed-in-tariff, Credit terms, and tax incentives

China - Renewable energy law [22]

Experience from China suggests that the development of a local free market seems more successful than donor or government subsidy driven programmes for a widespread deployment of decentralized PV technologies [49]-[81]. In the USA, at the federal level, there are incentives in the form of 30% solar investment tax credit and rules that mandate utilities to interconnect sources of distributed generation. Many local and state governments provide a wide range of subsidies like rebates, low cost loans, performance based incentives, grants, and various tax incentives. Twenty-nine states, Washington DC and three other territories have renewable Portfolio Standards (RPS) that require that a certain percentage of electricity sold in the state generated from approved renewable resources with targets of generation from renewable sources varying between 2% and 25% of total generation [120].

4.4.2 Focus group discussion

A transcript was prepared for the entire discussion in FGD. A thematic analysis approach was followed to analyse the qualitative date on the transcript.

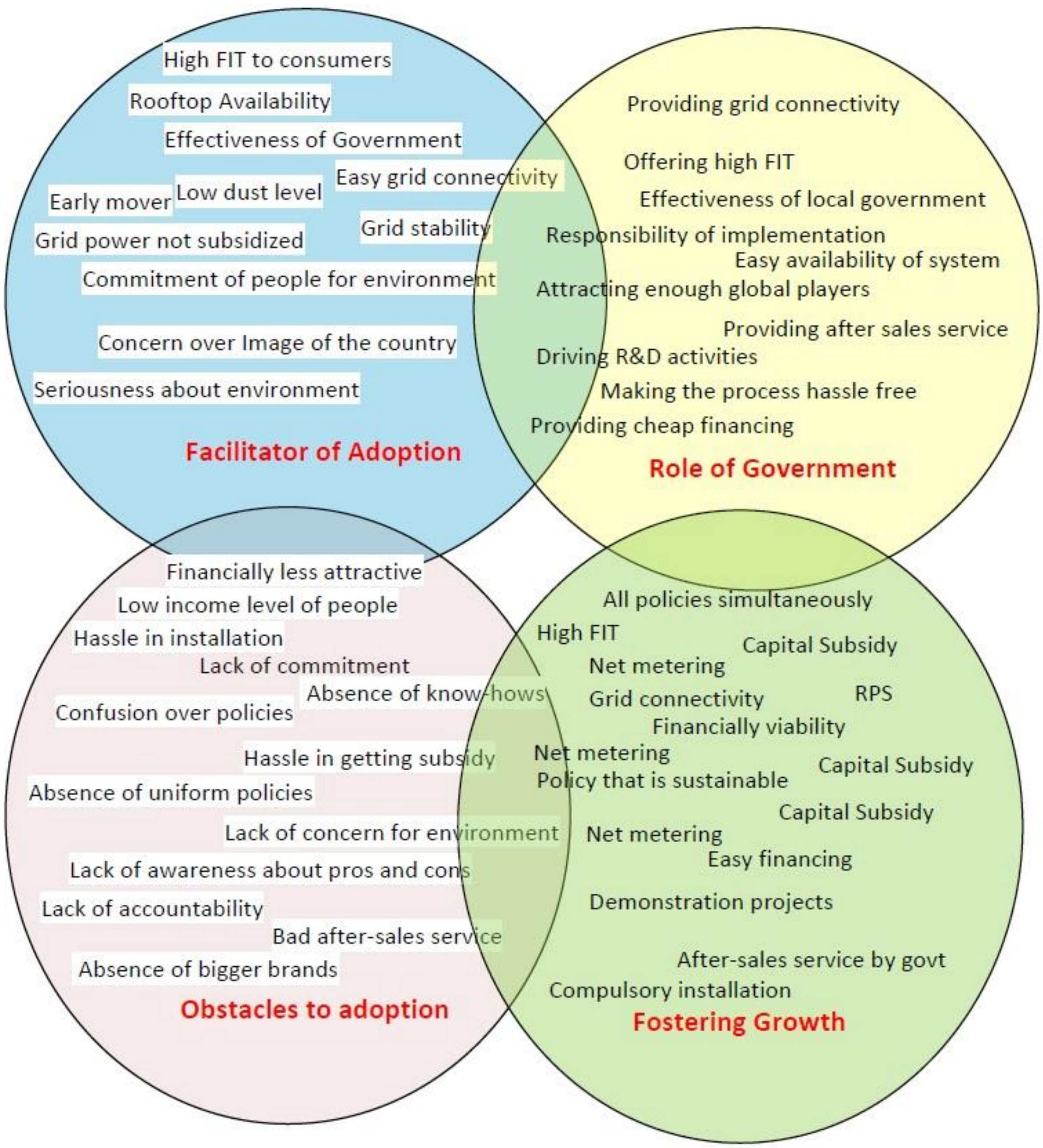
4.4.3 Thematic Analysis

Using the transcript prepared from the focus group discussion, thematic analysis approach was followed to analyse the qualitative data. The transcript through coding was divided into distinct themes and those four themes are:

- Facilitator of adoption
- Fostering growth
- Role of government
- Obstacles to adoption

A thematic map is prepared for analysing the data.

Figure 4.20: Thematic Map of FGD



From the thematic map, it can be clearly observed that policies involving grid connectivity is appearing under various themes and hold extreme criticality in the growth in adoption of rooftop solar PV. Looking at all such policies, Net metering is the most important policy that Indian government should implement across all the states for the faster growth in adoption of rooftop solar PV. Over the last few years, most of the states in India have introduced net metering scheme for their consumers. Many technical problems, especially possible grid imbalance is the major bottleneck in introduction of this scheme. Policy makers have tried to find out solutions to this problem either through technology upgradation or limiting the number of net metering connections for any region. A stable and reliable grid is a major component in encouraging people to generate electricity from solar PV installed in rooftops. A stable and reliable grid eliminates the need for the consumers to have batteries for storing the electricity generated from solar PV. It not only reduces the total cost, but also reduces the hassle of operating the battery supported storage system. Net metering doesn't create financial burden on the utilities, unlike gross metering schemes. So net metering scheme with a stable and reliable is expected to play a major role in growth of rooftop solar PV in India.

4.5 Summary

This section describes the data analysis and findings for each of the four research objectives. From the factor analysis, five key factors are identified that explain adoption of rooftop solar PV. The five factors thus found out are

1. Complexity

2. Financial Attractiveness
3. Environment Benefits
4. Social Image
5. Trialability

On these five factors perception of adopters and non-adopters are found out and it was noticed that there exists significant difference in perception between the two groups.

On demography and psychography factors, the difference is found out. Contrary to what literature says, it is noticed that adopters of rooftop solar PV are not younger. However, on all other demography factors, the hypotheses drawn from literature hold good.

Using the thematic analysis, the qualitative data collected from FGD are coded and put into different themes. A detail study of the themes and the codes confirmed that Net metering is the most important policy that government of India should implement for faster adoption of rooftop solar PV.

5 Conclusion

5.1 Factors of Adoption

The adoption of rooftop solar PV in India has been pretty disappointing so far. Rogers' diffusion of innovation theory identified five key factors that explain 49-87% of the variance in the rate of adoption of any innovations. However, this research, through factor analysis, identified five key factors that explain specifically the adoption of rooftop solar PV in India. These key factors are:

1) Complexity
2) Financial Attractiveness
3) Environmental Benefits
4) Social Approval
5) Trialability

A close analysis reveals that these five factors retain three of the factors proposed by Rogers and those three factors are Complexity, Relative Advantage and Trialability. Contrary to most of the adoptions of new technology, adoption of rooftop solar PV does not happen at the expense of the existing technology of grid electricity. Here the situation is that of co-existing and one complementing the other. That could be the reason why two important factors "Compatibility" and "Observability" are missing from the list of important factors identified in this research. As can be seen, complexity and financial attractiveness turn out to be two major factors that explain adoption of rooftop solar PV. So, steps to remove hassles during installation and operations of rooftop solar PV system would pave the way for better adoption of this technology. Although government of India has introduced various schemes to incentivize rooftop solar PV system, the effort has not been fully successful in improving the perceived financial attractiveness. Not only innovative schemes should be introduced to enhance the financial attractiveness in a sustainable manner, but also efforts should be made to ensure that those reach the consumers in a hassle free manner.

5.2 Attribute Perceptions

Understanding adoption of any technology is an intriguing task. For adoption of any innovation, a few important factors explain the reason behind adoption. Although Rogers's theory of adoption confirmed five key factors behind adoption of any technology, these attributes could explain only 49% to 87% of the variance in the rate of adoption. So, the authors through literature review found out five attributes that are specific to adoption of rooftop solar PV and could better explain the adoption.

Three of the five factors from Roger's theory of adoption; Relative Advantage, Complexity and Trialability got included. Relative advantage was more specifically defined by the author in terms of financial benefits and environmentally benefits. Compatibility and observability are two factors removed from Roger's proposed factors. The five factors thus selected that better explain adoption of rooftop solar PV are: complexity, financial attractiveness, environmental benefits, trialability, and social image.

A favourable perception of consumers on these five attributes should lead to widespread adoption of rooftop solar PV and similarly negative perception can lead to rejection.

The study confirmed the hypotheses that on the five critical parameters, perceptions of adopters were more favourable than the non-adopters.

An old study done in USA to understand perception difference between adopters and non-adopters of residential solar energy system (solar home heating and water heating systems) confirmed that adopters perceived the technology more favourably than non-adopters. On Roger's proposed five parameters, compared to non-adopters, adopters rated the technology as greater in relative advantage, lower in financial and social risk, lower in complexity, more compatible with personal values, more observable, and more possible to try on a limited basis [126]

A similar study in Indonesia indicated that consumers perceived price at which electricity from solar PV exported to the grid was not profitable [146].

From the research it was noticed that on five key attributes of rooftop solar PV, perception of adopters of rooftop solar PV in India varies from that of non-adopters. Especially on the key factors of complexity and financial attractiveness, perception of adopters is more favourable. Compared to non-adopters, adopters perceive rooftop solar PV to be less complex to install and operate. Also, adopters perceive financial benefits to be more attractive. On other three factors, environmental benefits, social approval and trialability, difference in perceptions of both adopters and non-adopters is not very apparent.

Another key take-away is that even among adopters, the perceptions about financial attractiveness and complexity are not very encouraging. The mean score on financial attractiveness is only 4.88 on a scale where 4 indicates neither attractive nor unattractive with a possible best score of 7. In several countries around the world, governments tried to incentivize the rooftop solar PV through various schemes like offering attractive feed-in-tariff, providing subsidy on installation cost, providing tax incentives, or offering low cost financing.

In India poor financial health of the distribution companies made offering attractive feed-in-tariff almost impossible. Still with an IRR of around 13% with government subsidy, more needs to be done to put across the financial benefits to consumer in a more effective manner.

On one more key factor, complexity, even the adopters don't think the installation process is hassle free. With a mean score of 3.16 by adopters, it indicates a perception of neither very complex nor very easy. So, a lot of efforts to remove procedural hassles for the prospective consumers are needed.

As similar type of research to find our perception of adopters and non-adopters of rooftop solar PV on critical factors has not been carried out anywhere to the best of my knowledge, a comparison with other countries is not possible. However, looking at overall perception of consumers in a country like Australia, perception of consumers in India needs to improve. A survey in Australia found that about two-thirds of the respondents would be willing to install a photovoltaic system [147].

5.3 Demographic Findings

On demographic factors, adopters are found to be significantly different than the non-adopters. Compared to non-adopters, adopters are found to have higher income, better education, higher occupational status, and higher social class. Surprisingly, contrary to the wide belief that adopters of new technology are younger, the researcher found that it was not true in case of adoption of rooftop solar PV in India. It was found out that average age of adopters was higher than non-adopters. On psychographic factors, adopters and non-adopters don’t seem to have significant differences. On factors like promptness in decision making or love for cars, adopters are not different than non-adopters. However, adopters are more law abiding and they respect rules and regulations.

5.4 Policy Review

Considering complexity and financial attractiveness are two most important factors explaining adoption of rooftop solar PV, government policies offering financial incentives and hassle-free installation hold key to widespread adoption of rooftop solar PV. A review of policies in countries like Germany, USA and China throw a lot of commonality. Policies that make adoption of rooftop solar PV financially attractive are implemented across geography. Policies like Gross Metering or Net metering, Fixed feed-in-tariffs, Purchase guarantee, Capital Subsidy, Attractive financing schemes are a few policies that have driven the adoption of rooftop solar PV. Through a FGD involving experts, a very healthy and fruitful discussion helped finding out critical policies from Indian context. From the discussion, one key factor emerged that many of the schemes offering financial incentives are possible only when the electricity from rooftop solar PV can be connected to the grid. A thematic analysis approach was followed to identify the most important policies that government should implement to foster the growth of rooftop solar PV in India. Form the analysis, it clearly came out that Net Metering scheme is the most important policy, without which adoption of rooftop solar PV would be severely impeded. Apart from Net Metering, subsidy on initial capital requirement as well as ease of financing are also very important.

5.5 Contribution to Literature

It is intriguing to find out reason behind adoption of innovation. Although several theories tried to explain it, Roger's theory of adoption is very widely followed theory in the field of adoption of any new technology. The theory doesn't explain the adoption of any technology in its entirety. The variance that is explained by Rogers's theory sometimes drops to even lower than 50%. The researcher through factor analysis, found out little more insight into adoption of a specific technology, rooftop solar PV. The factors found out are more relatable and better explains adoption of rooftop solar PV. The theory can be tested in other locations or for other renewable energy adoption,

For adoption of innovation, the available theory was silent on importance of two important demographic factors, social class and occupational status. However, from the research it is clearly established that these two factors are positively correlated with adoption of innovation.

Also, it is proved that perception of innovation by adopters is clearly different from the perception of innovation by non-adopters. Perception about any new technology is vital to its adoption, and so poor or negative perception will certainly hinder the adoption.

5.6 Contribution to Practice

A suitable framework for adoption of rooftop solar PV in India was developed. Rogers Theory of adoption was modified to explain the factors leading to adoption of this new technology, rooftop solar PV. Knowing the important factors that consumers consider while adopting rooftop solar PV makes it easy for the policy makers address the actual problems rather than spending resources on issues that won't yield desired result. The identified factors can be used to find out perception of non-adopters in different parts of the country and work on improving the perceptions.

The finding on perception of adopters as well as non-adopters is extremely important as that should usher in taking measures to improve the perception of perspective consumers. The study revealed that on certain important factors like complexity and financial attractiveness, despite innumerable measures by the government, consumers still don't have highly positive perception. So may be certain changes in the approach itself will do wonders.

The study identified the demography and psychography factors of adopters. That will help identify the perspective consumers and thorough understanding of the target consumers is very important in facilitating growth in adoption of any new technology.

As we know for adoption of any new technology, government policies are important enablers. In some countries like Germany, certain favourable government policies lead to unprecedented growth in adoption of rooftop solar PV. This research identified a few key policies that policy makers in India can explore and implement that should help faster growth in adoption of rooftop solar PV in India. Government, regulators can use findings to work on important factors and policies for better adoption of rooftop solar PV in India.

5.7 Quality of Research and Validity

Sl. No	Criteria	Indicators	Assessment
Reliability	Test-Retest	Consistency across time	Pilot testing done
	Internal Consistency	Consistency of people's responses across the items	Cronbach's alpha of 0.91
Validity	Content/ Construct Validity	Measures all aspects of the construct and what is intended	Questions carefully assessed with expert opinion and feedback taken
	External Validity	Ability to generalize	Sample carefully chosen to represent wider population

5.8 Validity Summary

Objective 1:

Content Validity: Questionnaire was verified by experts and a pilot survey was done before the final data collection was undertaken.

Construct and Criterion Validity: RMSEA Index is 0.076 which is acceptable. MSEA values less than 0.05 are good, values between 0.05 and 0.08 are acceptable, values between 0.08 and 0.1 are marginal, and values greater than 0.1 are poor.

Tucker Lewis Index of factoring reliability is 0.856 which is acceptable.

Objective 2 and Objective 3:

Content validity: Questionnaire was verified by experts and a pilot survey was done before the final data collection was undertaken.

Construct Validity: The output has significant similarity with theoretical propositions. Also, hypotheses testing done using different statistical tools, “z” test and Chi-Square test, yielded same result.

Criterion Validity: Output has correlation with similar studies conducted at different geography at different times.

Objective 4:

As a moderator, the researcher ensured proper preparation and did a thorough study of all policies. Also, the researcher selected FGD members having a lot of expertise and experience in the field of solar energy. The outcome was checked with the same set of experts who participated in the FGD and compared with results from literature review.

5.9 Limitations and Future Work

Research Limitations

- Sample was drawn from only two states in India
- Due to very negligible adoption of rooftop solar PV in India, the sample

size was only 200 for factor analysis

- Snowball sampling technique was followed for the first objective and as the technique follows non-probability method, it may not represent the entire population.

Further Scope of Study

- The proposed framework mentioning important factors for adoption of rooftop solar PV can be tested at other locations.
- The framework can be tested for adoption of new technology in other renewable energy sources.
- Different in perception of adopters and non-adopters of any new technology in the area of renewable energy can be studied further.

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Appendices

Annexure:1

Questionnaire 1

On a scale of 1 to 7 please rate the importance of each of these factors that leads to your adopting rooftop solar PV with 7 being most important and 1 least important.

Least Important ⟷ Most Important

	1	2	3	4	5	6	7
Freedom from future increase in electricity tariff							
Current electricity tariff is high							
High return on investment							
Attractive feed-in-tariff							
Low cost of installation							
Low Operating Cost							
Access to unlimited power							
Attractive subsidy from the government							
Attractive tax incentives							
Enhances social image							
Ease of getting financing of initial cost							
Ease of getting all government incentives							
Your concern for the environment							
Easy maintenance							

Easy to take up a trial project on smaller scale							
The concept of rooftop solar PV can be understood easily							
Doesn't need any additional resources like water							
Lowers cooling load requirement of the building as it keep the roof cool							
Helps in better peak load management							
Provides independence from utility provider or others							
Good for the environment							
Helps others to install due to sharing of knowledge							
Helps create an "Environment Concern Image" for you							
It is a global trend							
Clarity over long term future FIT (feed in tariff)							
Longer investment horizon							
Compatibility of all equipment with Solar PV system							
Compatibility of building for solar PV installation							
Ease of operating the solar PV system							
Availability of sufficient unused rooftop space							
Availability of plenty of PV service providers							
Building location good for rooftop solar PV installation							
Easy to deal with utility provider							
Ease of monitoring electricity generation and usage							
Benefits from use of rooftop solar PV is visible							

Ease of seeing a demonstration of rooftop solar PV							
No health hazards							
Availability of good quality rooftop solar PV system							
PV installation is compatible with your social value							
Any other factor you would like to mention with the importance score:							

Please mention your age	21-30	31-40	41-50	51-60	>60
Annual Income in Rs Lakhs	<5	5-10	10-15	15-20	>20
Education	High School	Intermediate	Graduate	Post Graduate	Professional
Gender	Male	Female			
Housing Location	Rural	Semi Urban	Urban Outskirt	Central Urban	
No. of residents	1	2	3	4	>4
Time to take important decisions	Very Low	Low	Normal	High	Very High
Importance of climate changes	Very Low	Low	Normal	High	Very High
Importance of Environment Friendly Practices	Very Low	Low	Normal	High	Very High
Importance of rules	Very	Low	Normal	High	Very High

and regulations	Low				
Preference for cars	Very Low	Low	Normal	High	Very High
Preference for Electric/ Hybrid Cards	Very Low	Low	Normal	High	Very High
What you do in your leisure	Reading	Travelling	Playing	Watch TV/ Movies	a) Doing Nothing b) other outdoor activity

Your Name:	
Address:	
Profession:	
Average monthly in electricity consumption in units:	
Area of your roof top (in Sq Ft)	

Annexure: 2

Questionnaire 2

On a scale of 1 to 7 please mention your view about rooftop solar PV with 7 being Strongly Agree and 1 Strongly Disagree.

Strongly Disagree Strongly Agree

	1	2	3	4	5	6	7
The entire process of installation is very complex							
It is very complex to operate the system							
It is financially attractive							
It is good for the environment							
Its installation improves your social image							
It is easy to install smaller system for trial							

Please mention your age					
Annual Income in Rs Lakhs					
Education	High School	Intermediate	Graduate	Post Graduate	Professional
No. of residents	1	2	3	4	>4
Time to take important decisions	Very Low	Low	Normal	High	Very High
Importance of Environment and its protection	Very Low	Low	Normal	High	Very High

Importance of rules and regulations	Very Low	Low	Normal	High	Very High
Preference for cars	Very Low	Low	Normal	High	Very High
Preference for Electric/ Hybrid Cards	Very Low	Low	Normal	High	Very High
What you do in your leisure	Reading, Travelling, Playing, Watch TV/ Movies, Doing Nothing, other outdoor activity				

Your Name: Profession:	
Address:	

Annexure : 3

FGD Transcript

1. Why Rooftop Solar PV adoption in Germany is so high and catching up first in countries like USA or China.

A: Germany and USA are rich countries and also they are actually serious about the environment. China although not in that league, is trying to build an image of a developed country which is serious about global issues.

C: In each of these three countries governments are very effective, unlike India.

B: We can't ignore the people too. Yes, governments are more effective there, but people are also equally concern about the environment.

A: But I feel commitment of people will not work unless government drives it properly and makes it sound beneficial to the public.

F: High feed in tariff was a major reason for the adoption in Germany. They were offering around Rs. 30 per unit to solar PV producers. And that too, without any hassle to running from pillar to post like in India.

C: In all these countries, grid connectivity is very high. So power generated from rooftop solar PV can be easily fed to the grid.

F: Grid stability is also another reason

D: I feel USA and China are still not that effective like Germany considering their size.

F: These countries are technically much superior and the grid power is not highly subsidized. They don’t discriminate the industrial users by cross subsidizing domestic consumers.

E: All these three countries started very early. Germany is almost at saturation now. The dust level is low there, so maintaining the panels not a difficult task.

Mod: I would like to mention that the major policies implemented in these countries are

- Feed-in-Tariff or FIT
- Renewable Portfolio Standard or RPS
- Capital Subsidy on the initial installation cost
- Tax benefits: Providing tax benefits on the capital expenditure on rooftop solar PV installation
- Ease of financing: Making arrangement to easily finance the installation cost
- Net metering: Allowing the electricity generated from solar PV to be fed to the grid and draw it whenever required by the customer and a meter giving the net consumption by the customer
- Green electricity scheme: Option given to the consumers to buy electricity generated from renewable energy sources
- Public investment: Government making significant investment in the concept
- Demonstration project: Setting up a few rooftop solar PVs that would act as demonstrations for any prospective consumer
- R&D: More funding and emphasis on research and development

2. How important is the role of the government in the adoption

B: This is one area where role of the government is crucial. It has to be effective, make the whole process hassle free and facilitate the adoption.

A: Very critical, government has to drive the show. Providing grid connectivity to rooftop PV is critical

E: I feel the local governments are more important. The central government can provide guidance, but the local governments have to play the major role of implementing it. Also making the system easily available and attracting players to participate both in equipment manufacturing as well as aftersales service facilities are important.

C: Government holds the key with its policy formulation and incentivizing the schemes.

D: Government also can drive the R&D activities. It can attract major global players.

F: I feel success in adoption of rooftop solar PV depends 90% or more on government. We should not forget that in India electricity is completely government controlled.

B: Without the involvement of government financing won't be easy or cheap.

F: Just see the very quick growth we saw in Gujarat few years ago for offering high FIT to solar power. So Government is the major player.

3. What are the major reasons for slow adoption in India

A: I believe it is lack of commitment, nobody was actually serious except the last couple of years. Also our people are poor, for many it is too expensive.

D: I strongly feel lack of education. How many Indians even do know about climatic issues like GHG effect?

C: I feel low domestic electricity tariff is a major issue.

B: How about the financial attractiveness, I don't think rooftop solar PV is financially a good idea for many consumers.

F: I feel one major problem is lack of clarity in government policies, across states policies are different and confusing. If subsidy is offered on installation, people don't know when it is offered and when withdrawn.

E: Installation is still very difficult. Getting the permission from grid requires a lot of follow ups and even bribing. So the entire effort may not be worth taking.

A: Many are still not aware about its pros and cons. People even don't know the basics are how much area it requires, how to operate it, whether it needs a battery or not etc etc.

C: I feel people are not too worried about the environment. They think it is government's job.

A: People are apprehensive about after sales service, in India there is no big reliable brand offering this service.

C: Paper work is the major obstacle.

F: Some people are worried about future, what if government changes its policies and doesn't allow solar power to be fed into the grid.

4. What are the government policies in India to promote adoption of rooftop

solar PV.

C: In India we have almost all the important policies implemented except the green electricity scheme where the customer has the option of buying electricity produced only from green sources. But policies are not uniform across states. Even net metering is not implemented yet across all the states.

B: Some of the major policies in India are renewable portfolio standard, gross metering, net metering, subsidy, providing financing, tax incentives,

F: The incentives consumers receive are different in different states.

5. What is the most important government policy that would effectively be the game changer?

B: Very difficult to figure out one policy as each policy has its importance and in the absence of one such policy another policy becomes ineffective.

F: I strongly feel net metering. If I install rooftop solar PV I should be able to give it to the grid, otherwise why would I install the panels?

A: I feel the FIT is key, if government gives a high tariff, that would be a big incentive.

F: Even to do that, net metering is the basic requirement.

A: That is right.

C: Subsidy on installation cost is critical. At the present cost of installation, without subsidy the initial cost would be more and that would make the solar PV installation financially unviable.

D: One thing is all the policies are virtually useless in the absence of net metering.

Gross metering is even better, however looking at the current financial conditions of discoms, I don't think it is sustainable.

E: In my opinion, net metering, subsidy and financing in that order.

B: Renewable portfolio standard was a good policy that mandates the discom to have a certain percentage of electricity production from renewable. However corrupt practices killed that scheme.

A: I agree with E. Net metering is the key followed by subsidy and financing.

F: Most of consumers don't like battery attachment as it increases the cost and it requires frequent maintenance and replacement. So option of connecting the solar PV to the grid is the prime requirement.

C: It is kind of Net Metering is the base and other policies are add-ons. So without the base, the add-ons are useless.

A: That is just spot on as told by A

F: I remember years back Gujrat introduced gross metering at a very high tariff, close to Rs. 20 per unit and that immediately attracted number of consumers adopting rooftop solar PV. But the rising billing pressure forced the government to scrap it. So policies should be made in such a way that it is win-win for all, otherwise too much sugar coating makes it unsustainable.

A: Although I agree that Net Metering is the most important policy as without that many other measures become ineffective, in terms of importance, I am not sure if capital subsidy will be of higher priority or not. I have seen many consumers plunging into it just because the subsidy component is very significant.

F: In my opinion, there should be a few government run projects purely for demonstration so that prospective consumers can visit the site without any hassle and physically check the operations and also clarify any doubt. Till now most of us have a lot of doubts and so apprehension.

A: So, we can say that ease of financing, capital subsidy and net metering are the three most important policies that government should not only enact but implement in such a way that consumers can avail those quiet easily.

B: One more policy can be government setting up an aftersales service centre that can resolve any problem that consumers face after installation.

C: A policy through which they can force rooftop solar PV on any new building would be good. Also, for bigger buildings where consumption is high, they should make it mandatory for generating a certain percentage from solar, otherwise approval won't be given.

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