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Implications of Governmental Policies on the Solar Photovoltaic Market Growth in India

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Declaration by the guide

This is to certify that Mr MOBI MATHEW, a student of Master of Business Administration in Power Management, SAP ID 500070771 of University of Petroleum and Energy Studies, Dehradun, has successfully completed this dissertation report in "**Implications of Governmental Policies on the Solar Photovoltaic Market Growth in India**" under my supervision.

Further, I certify that the work is based on the investigation made, data collected, and analyzed by him and it has not been submitted in any other University or Institution for award of any degree. In my opinion, it is fully adequate in scope and utility, as a dissertation towards the partial fulfillment for the award of degree of Master of Business Administration.

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Contents

List of tables

List of figures

Abstract

India being in the tropic of cancer, is blessed with tremendous solar radiation that helps in implementation of the solar based electricity generation technologies like solar PV and solar thermal systems. Solar PV systems are employed in more numbers as the price of solar PV panels reduce gradually. Not only the reduction in the installation cost of the PV system and the rising concern for the environment have resulted in the wide spread installation of the PV system in the country, the governmental policies, both at the centre and states have significant role in promoting the same. In this dissertation report, the effects of governmental policies on the PV market in India is analysed. Various policies of the central government and the state governments are discussed along with few recommendation to enhance the policy structure and the effectiveness of the adopted policies in the country.

Chapter 1
Introduction

1.1 Background

Energy has evolved as a basic necessity of the mankind today. Considering the ever increasing demand for the electrical energy, the generation has to be increased. Increasing the generation through conventional power plants such as coal fired are least recommended considering the environmental impacts they pose to the world. Increasing temperature as a result of climate change also causes more burden on the electrical system and requires more energy to meet the demand [1, 2]. This promotes the renewable energy based electricity generation like solar and wind technologies. Solar PV technology turns out to be the most efficient means of harnessing the solar energy and for the generation of the electricity. There are mainly three categories of solar PV panels that are generally used. They are monocrystalline, multi-crystalline, and thin film solar cells. Around 85% of the solar PV market is occupied by the crystalline solar cells [3]. Each technology has their own advantages and disadvantages while PV systems focus on the decarbonisation of the energy sector. Being the third largest emitter of carbon dioxide (CO_2), India needs to take significant action to reduce the same and PV is the best to achieve this goal [4]. Figure 1 depicts the comparison of the CO_2 mission by different means of energy generation.

1.2 Motivation

The growth of PV market in the world had a slow pace till 2014. It had achieved a growth rate of 25% in 2015 resulting in a total installed capacity of 227 GW in the world, ten times higher than the total installations in 2009. Also, PV plants contribute to around 3% of the total electricity generation in the world [5]. The major share of PV installation in the world are in China, Germany, Japan, and USA with a total cumulative capacity of 43 GW, 39.6 GW, 33.3 GW, and 27.3 GW respectively [6]. With a total installed capacity of 15 GW, China acquired the prime position in the PV installations in 2015. As per the National Energy Administration of China, it is expected to have an installed capacity of 50 GW by the end of 2020. As a result of the new policy that enhances the domestic solar PV companies, the minimum installed capacity was raised to 10 MW per installation [7].

Germany accounted for the highest capacity of solar PV in 2012 by having 28 TWh of electricity, which is 45% more than the previous year. The target of Germany is to have 51 GW of solar PV installations by the end of 2020 [7]. Revision of the solar policy of Japan has resulted in the grid integration of the 99% of the installed solar PV farms in the country. Japan has an admiring target of achieving 28 GW and 53 GW of solar PV installations by the end of 2020 and 2030 respectively.

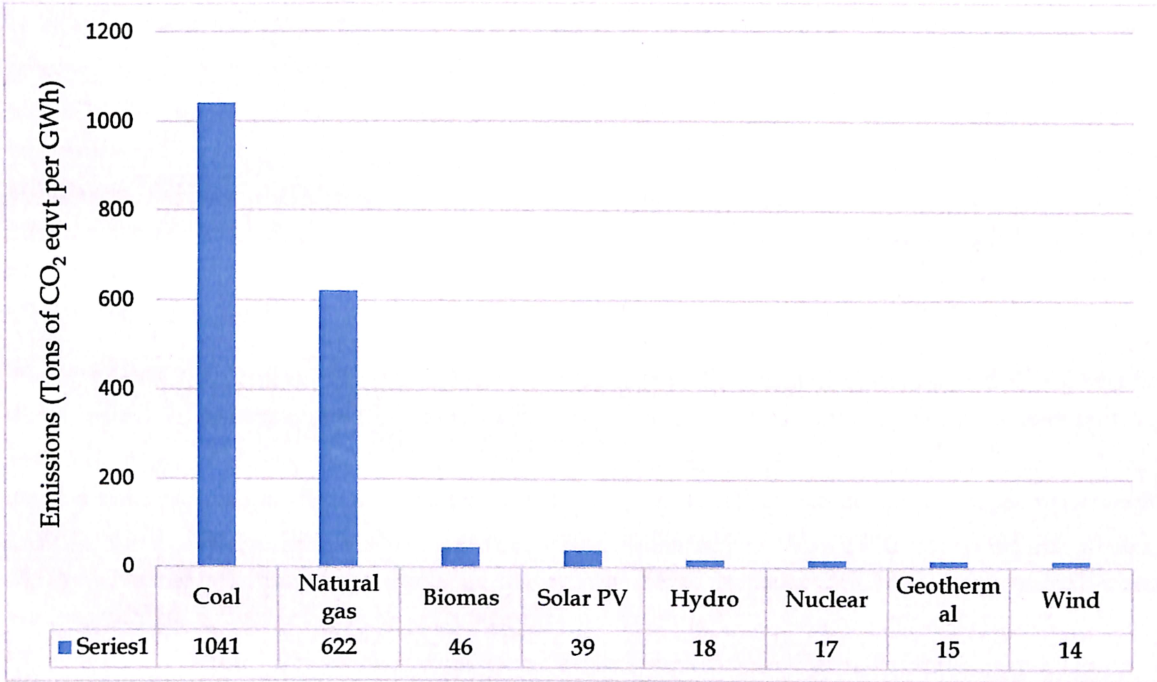

Figure 1.1: Comparison of emissions of different means of energy generation for the complete life cycle of the systems in tons of CO_2 equivalent per GWh.

Apart from the high solar insolation received by Italy, the solar PV market expands because of the incentive based policies that encourages the renewable energy utilization. Exceptional growth of Japan and China in the solar PV installations pushed to the fourth position. One of the critical policy that the US has developed is the 'investment tax credit'. This policy resulted in the reduction of the tax liability for the solar technology purchase, encourage the investment and ignites the growth in solar PV installations [7]. These studies and figures indicate a close relation between the market growth of solar PV and the governmental policies and this served as the cause to identify the same in India through this dissertation.

1.3 Literature review

The research and development in the solar PV field was initiated in 1980s with main focus manufacturing sector i.e., on developing better quality materials for the solar cells [8]. Ministry of new and renewable energy (MNRE) was formed in order to enhance the field of renewable energy. MNRE was the first of its kind in the world, set up exclusively for this purpose. Main aim of the MNRE is to develop policies and strategies for the enhancement of the utilization of different renewable energy sources [9]. In 1995 itself, I has become the third largest consumer of the solar energy, utilizing mainly for the off-grid applications like street lighting, solar pumps, and telecommunication sector.

It is projected that the electricity requirement of India would be 90 GW in the next seven years. Also, as per the study by the IEA, India will be the second largest contributor in the global energy demand by 2035 [3, 10]. In order to enhance the use of renewable energy resources, most of the governments have introduced subsidy schemes. Studies show that the subsidized renewable energy schemes are still 50% more expensive than the conventional means of electricity generation [11]. There are numerous works detailing the techno-economics of the solar PV systems and different other aspects [12-23].

To enhance the solar energy utilization through PV, the government of India has developed numerous policies and schemes. Electricity Act 2003, was the first among them that included the development of different tariff schemes like feed in tariff (FiT), renewable purchase obligations (RPO) [24, 25]. Few other major policies include tariff policy 2006, integrated energy policy 2006, national action plan on climate change 2008, generation based incentives for solar 2009, Jawaharlal Nehru national solar mission 2010.

Even though the technological advancements bring better productivity and improved lifestyle, these changes may get opposed by the people [26]. The four key factors that affect the Indian energy strategy are grid parity, cost competitiveness, cost effectiveness, and proper awareness [27]. Hence proper awareness is essential in order to enhance the widespread use of solar PV systems. This can be achieved by governmental policies and strategies that aim at the enhancement in the solar PV utilization as well as eliminates the negatives thoughts about the same among the general public. This study focusses on the implications of these governmental policies on the PV market in India.

1.4 Problem statement

Technological advancement results in the reduced price of the solar PV materials and accessories which in turn results in the decrease in the cost of energy generated through solar PV systems. This would result in the enhancing the use of solar PV systems. In addition, government of India has developed multiple policies to enhance the same. Hence a study on the implications of the governmental policies on the market growth of PV modules is necessary. It would help in identifying the key factors that enhances the market of PV modules and the factors or policies that reduced the same.

1.5 Need for the research

Governmental policies and measures have a vital influence on the market of any goods and services especially in an economy like India where public sector industries still has a significant share in the total market. So is the case of solar PV, that has got great importance in the present times considering the energy security and environmental sustainability. Hence a study that investigates the positive and negative impacts of the governmental policies and the changes made to them on the market growth of solar PV in a potential and developing economy like India emerges as the need of the hour. This dissertation attempts to study the renewable energy targets set by the government and analyse how the current policies aid in achieving the same. In addition, the impacts of the policies on the market growth of solar PV is also studied in this work.

1.6 Objectives of the study

This study considers the following as the objectives.

- Analysis of the trend of solar PV installations in India.
- Analysis of the different policies and plans developed by the government of India for enhancing the solar PV systems.
- Study the impacts of these policies on the growth of PV market in India.

1.7 Research methodology

The research methodology that would be adopted in this study initiates with a deep survey of available literature focussing on the policies and plan developed by the Government of India for the purpose of promoting the use of solar PV systems in India. Based on the literature review, the key gap i.e. the necessity of the study of implication of these policies and plans on the market growth of PV system accessories is essential apart from the technological and economic evaluation of the same. Different internet based data sources like scientific repositories, reports of companies and government will be used to collect the data. Suitable analysis would be carried out to figure out the implication of policies on the solar PV market growth. This will be followed by the development of the report of the dissertation.

1.8 Sources of data

The main objectives of this study include the analysis of the solar PV trend of India and the different policies developed for enhancing the solar PV. It also focuses on studying the implications of governmental policies on the market growth of solar PV materials and accessories in India. The data necessary for the study would be collected through internet and web based surveys. Published articles and conference papers from different scientific repositories like IEEEXplore.com, sciencedirect.com, springer digital library, etc. would be used as the primary source of information. Scientific reports, reports of different companies, newspaper articles, and government reports also would serve the purpose of data collection.

1.9 Organization of the report

This report is structured as follows: chapter 2 presents an overview of the Indian electricity sector as well as the status of different solar PV systems in India. Status of the solar PV market in India is briefly discussed in chapter 3. Chapter 4 discusses different policies adopted by the Indian government and the state government that enhances the use of solar PV systems. Chapter 5 presents the solar PV market and the relation with the governmental policies. Key barriers to the implementation of solar PV systems and the solar PV market is also discussed in this chapter. Chapter 6 concludes this dissertation report.

Chapter 2
Overview of electricity sector and solar PV systems in India

The unit energy demand of an economy has evolved as a pivotal index in determining the development achieved by the same. As per the recent studies, the coming decades would witness a threefold increase in the demand for the fundamental energy sources [28]. One of the latest reports published by the international energy agency (IEA) suggests that this acceleration in case of India could be pertained to the population explosion in certain areas, making it most populated at global level by 2050, that the country would experience [29]. Apart from this, an increment in the population, an exponential advancement in the GDP of the nation would also act as a significant element in causing a humungous impact on the nation's energy requirement in future, which as per the Greenpeace report is estimated to surge beyond 200% by 2040 - 50 [30]. According to the aforementioned reports, this hike in following decades is projected to be in oil demand and utilization of natural gas. Such a demand could be overcome though with an expansion in the size of the power system of the nation, hitting a quadruple size of the present. In addition to the projections of demand for the energy sources, these reports also present estimations of plausible renewable sources by the year 2050. The PV system is expected to increase in usage, as per the Greenpeace report, which proposes the same to consist 20 - 40% of the entire renewable source based installation across India [30, 31].

Numerous criteria such as income generation, social development and severe health related problems arisen as a consequence of dependency on firewood, charcoal etc. affect the quantity of energy supply required, in developing countries. Even though, the graphs in the past showed a proportional relation between the degree of economic advancement and greenhouse gas (GHG) emission, the trend has reversed as per recent studies [32]. Various alternative energy sources have been introduced to replace the conventional ones to curb the existing issues related to its usage such as hydro-power, wind, solar, nuclear and bio-energy. Moreover, fossils fuels are being replaced by gaseous ones in several zones including transportation, residential and industries. Though this is the scenario with hydro power and natural gas being the most apt and clean ones for energy production, such remedial measures face hindrances such as agitation, delay in clearances, lack of supply and implications on environment due to construction of hue dam structures [33].

India too has undergone remarkable improvisation in the power production, through adoption of myriad strategies which has paved way for the implementation of replenish-able sources of energy.in 1974, the total energy generation of the country amounted for 16.7 GW, owned both by the central and state authorities [33, 34]. This production comprised of various fuels, with coal contributing more than half i.e. 51%, large hydro accounting for 42%, nuclear sources consisting of 4% and 2% being gas, while that using alternative forms were nil [34]. The 1970's oil crisis demanded a better approach in the region from the side of the governments leading to formulation of policies triggering a favour for renewable sources over the others old forms. The above said reason along with the economic crash in 1990, revolution in industrial sector aided by private sector, a consequence of liberalization and industrialization parameters of Indian economy, assisted the growth of the same [35].

India has a very favourable geographical existence in terms of solar energy availability over a larger area of the nation, being a tropical country. The forecasting information gathered from all over the nation through satellites, subsequently verified utilizing ground data illustrates that India receives 500000 TWh of electrical energy, which a majority of the zones receiving 4-7 kWh [36], with Rajasthan and Gujarat being receptors of highest global horizontal irradiance.

Several elements such as necessity for electrification in rural regions, understanding of the significance of solar power, in addition to surplus availability of the same has helped in formulating relevant major policies over the previous years. The above mentioned statement is clearer when an in-depth look into comparison of the progress achieved, by India, in the implementation of solar and wind energy is taken into consideration as of 2017. While India finds a place among the world leaders being 6th in position to produce solar electricity and 4th in the case of wind energy, Indonesia presents a lesser favourable scenario. Both the countries have set higher horizons for renewables implementation.

In 2014, a humungous target of 175 GW electricity production from renewable resources by 2022, with solar energy contributing a 100GW and wind a 60 GW. Apart from this, a significant amount of 275 GW of renewable resources was declared as the target by the central electricity Authority (CEA) in 2018. India has committed to a contribution of 40% of its electricity production from non-fossil sources by 2030 to the

Paris agreement as part of its national policy, with an aid from low-cost international finance and technology transfer.

In this chapter, the overview of Indian electricity sector and the status of solar PV systems in India is presented.

2.1 Overview of Indian electricity sector

India is the sixth largest country in terms of power generation. The Indian electricity sector is mainly governed by the Ministry of Power (MoP). The MoP started its functionality on 2nd July 1992. The three major sections of the power sector are the generation, transmission, and distribution. There are three sectors of electricity generation in India, viz. central sector, state sector, and private sector. The central sector power generation constitute 29.78% i.e., 62.82 GW of the total installed capacity of India. Few of the major central sector undertakings involved in the power generation include national hydel power corporation (NHPC), national thermal power corporation (NTPC), nuclear power corporation of India (NPCI), etc. In addition to the central sector undertakings there are state level corporations that constitute for about 41.10% of the overall generation. Few of them are Kerala state electricity board (KSEB), Maharashtra state electricity board (MSEB), etc. About 29.11% of total installed capacity is generated by private sector. The power grid corporation of India is the organization responsible for the interstate transmission of the electricity.

2.1.1 Electrification

According to the World Bank, India belongs to a lower-middle income economy [37]. An impressive progress has occurred in the electrification of the country. By the end of 2016, 82% of the country is electrified that includes off-grid and limited connections too. The per capita electricity consumption in India is growing with a rate greater than 5% per annum. This is achieved because of the enhanced economic growth of the country. Figure 2.1 shows the per capita electricity consumption of India from 1971 to 2016. The electricity use in India is around 900 kWh per person per year in 2016. This is very less when compared to the world average of 3.1 MWh per person per year [38]. Even though the electricity access in India has been improved, there is still 239 million people in India without access to electricity [39].

2.1.2 Electricity quality

As there is continuous progress in the electrification of the country, a similar progress can be seen in quality of electricity supplied. Transmission and distribution losses in

Indian electricity system has reduced from 27% to 12% in a span of 14 years, i.e., from 2000 to 2014. Blackout and grid instability also reduces the power quality. India has improved the score of quality of electricity supply from 3.1 in 2007 to 4.7 in 2017 on a scale on 7 [40]. Another issues that electricity sector of India faces is the power theft. Even though the severity of the same has reduced over the period of time, still it persist in some areas of the country [41].

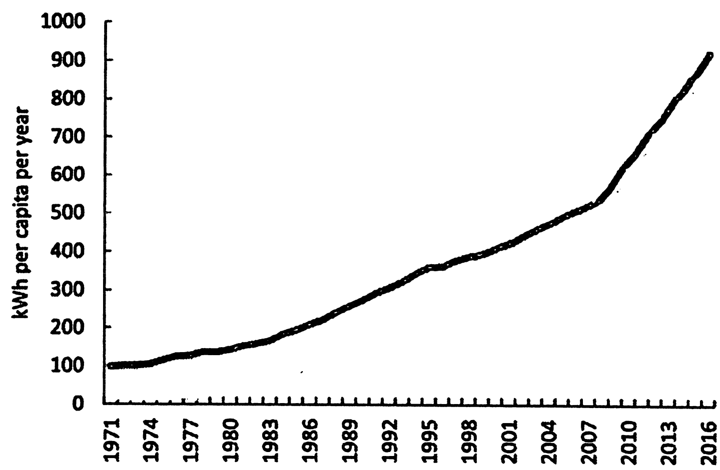

Figure 2.1: Per capita electricity consumption of India from 1971 to 2016

2.1.3 Interconnectivity

Being a vast country, India still has to improve on its electricity interconnectivity and infrastructure [42]. Serious improvement in the interconnectivity is achieved under the 'one nation - one grid' initiative of the power grid corporation of India and the green energy corridor scheme. Inter connection of different power grids of the country help in accessing the power from renewable based generation system which may be located in remote locations due to the land and resource availability.

2.1.4 Electricity mix

Electricity mix refers to the fuel used for the electricity generation. In India, coal is the primary fuel used for the electricity generation. Coal contributed to 78% of the total electricity generation in 2017. Natural gas and oil account for 5% and 1% of electricity generation in 2017. Hydel plants accounts for 9% of electricity generation which is the highest among the non-conventional sources [43]. Solar plus wind share in the electricity mix has reached 5% in 2017. The installed capacity of wind and solar in 2017 was 33 GW and 18 GW respectively. Figure 2.2 shows the share of coal and solar plus wind in the electricity mix from 2000 to 2017.

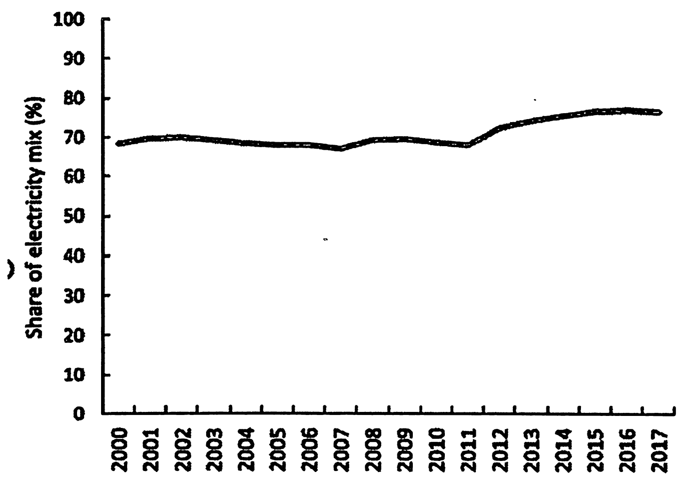

Figure 2.2: Share of coal in electricity generation from 2000 to 2017

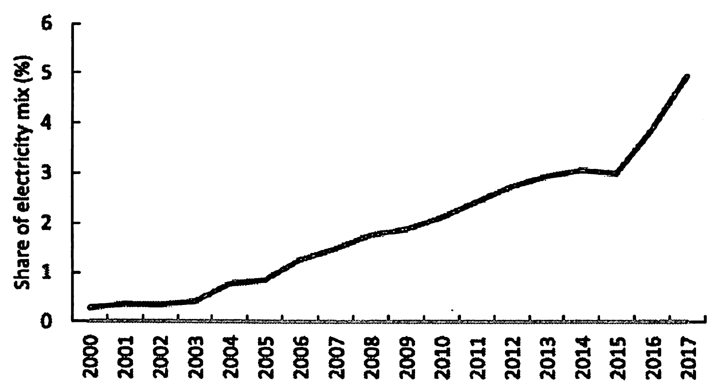

Figure 2.3: Share of solar and wind energy in electricity generation from 2000 to 2017

2.1.5 Operational aspects

Energy is included in the concurrent list of the Indian constitution. This implies the centre and the states have dual jurisdiction in the matter of energy. The distribution and sale of electricity in the states are achieved through the state electricity boards. States can have separate tariff structure and different states have different policies with regard to the renewables.

2.2 Overview of solar PV systems in India

India's location near tropic of cancer has a greater potential to harness the solar energy. As per the data the installed capacity of solar power (15.82%) comes in second place after the wind-power (62.6%). The bio-power (11.3%) and other sources including small hydropower (10%), and waste to power (0.27%) comes subsequently. Series steps has taken to increase the total cumulative renewable power installed capacity in India to 175 GW by the end of 2022 by Ministry of New and Renewable Energy. As a result, the total installed capacity has reached to 42.72 GW by the beginning of 2016. The total average value of global horizontal insolation ranges between 3.2 kWh/m^2 per year to maximum value of 6.1 $kW h/m^2/day$. This is a huge potential for a country like India. The total potential of solar power estimated by National Institute of Solar Energy (NISE) to be 748.98. While installed capacity of solar power ranking for India is among top ten solar powered countries. The solar policies and its impact place a major role in the continuous growth of solar power. The strategic policies, plan and framework adopted by the government and its agencies to solve the challenges can accelerate the solar power generation capabilities. The framework and policies considering the cost of PV, labour cost and infrastructure cost etc. are essential for future developments.

2.2.1 Status of solar PV system

India is blessed with high availability of solar irradiance throughout the year. India becomes an ideal place for the deployment and utilization of solar based energy generation technology like solar PV system as it has an equivalent energy potential of about 6 billion GWh per year from the sun. Being a vast country, India has significant difference in the irradiation received by its different parts. Even after having such difference, on an average India receives 5.1 $kWh/m^2/day$ irradiance [44, 45]. The installed capacity of solar PV systems increase rapidly in India. The policies adopted by the governments both at the centre and state have major role in such rapid increase. Being the sixth largest consumer of energy in the world, India accounts for 3.4% of the total energy consumption in the world.

According to the JNN solar mission, India targeted for having solar PV capacity of 22 GW by 2022. Figure 2.3 offers an overview of annual solar capacity additions as target in the JNN solar mission. Two years back, the government of India announced the increase of its solar target to 100 GW. This is to be achieved through the installations of utility scale solar PV plants of minimum 1 GW capacity. To be aligned with the central government's solar policy and target, the state governments also developed numerous policies to enhance the solar PV utilization.

Two Indian states, Gujarat and Rajasthan stand out regarding commissioned solar PV capacity by November 2014 [46]. These two North-western states of India are the leading solar photovoltaic states in India, sharing a combined installed solar PV capacity of 1657 MW (Gujarat 919 MW & Rajasthan 738 MW). The total cumulative commissioned capacity by November 2014 for India stood at 2908 MW [47]. Figure 2.4 indicates the total grid-tied solar PV capacity commissioned by the state, and the list of total grid-tied capacity by the source of commissioning.

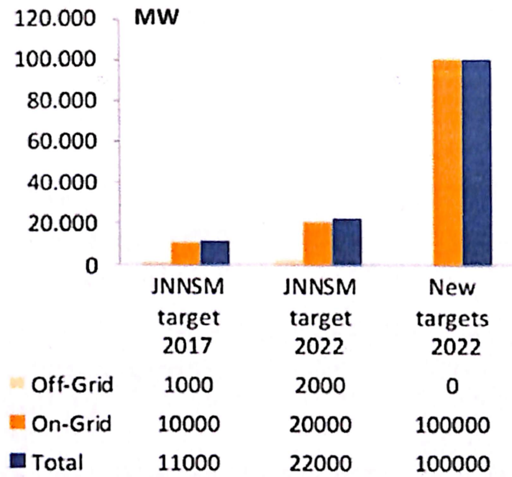

Figure 2.4: Solar targets as per JNN solar mission

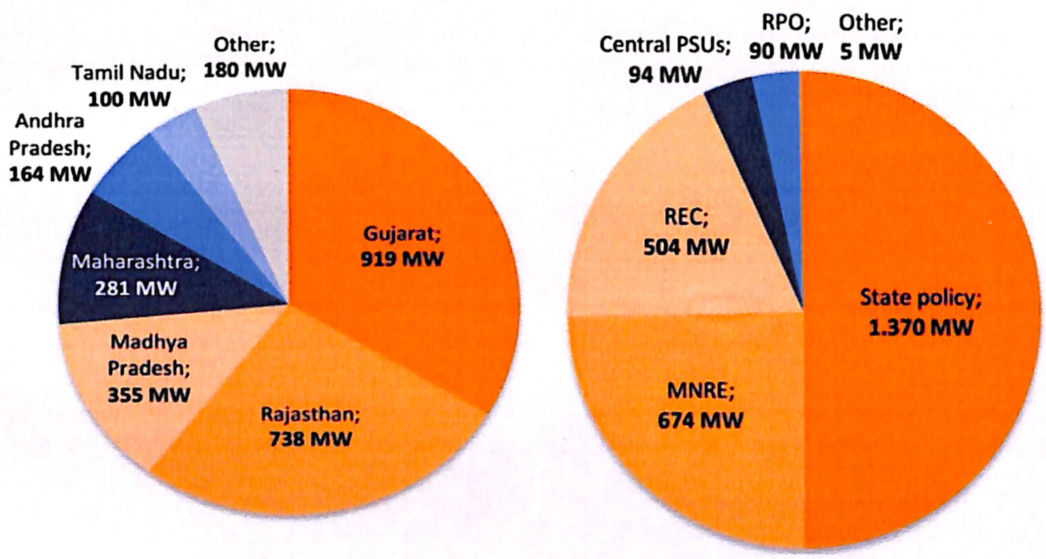

Figure 2.5: Total grid connected solar PV capacities in Indian states till 2014 and the sources commissioned them

2.2.2 Status of rooftop solar PV systems

Solar PV is one of the most promising and emerging technologies and is a viable alternative to the fuel based power generating stations like the diesel generators. It is promising to look into the growth of solar rooftop market in Germany because, out of the total 40 GW of solar PV installation about 74% are installed on the rooftop and 70% of the total rooftop systems are less than 10 kW of capacity [48, 49]. In India, with the aid of various Government initiatives, the cumulative solar PV installation adds to more than 9012 MW by the end of 2016. The rooftop segment in India has also gained popularity in the past 2 - 3 years.

In the past 2 years, the total annual growth of the rooftop solar PV system was about 90%. Around 73% of the rooftop market is captured by commercial and industrial (C&I) segment and remaining 27% is covered by the residential segment. Figure 2.5 shows the state wise distribution of solar PV installed capacity up to September 2016. The cumulative installed capacity of solar rooftop segment in India is 1020 MW as of September 2016. Out of this total installed capacity, around 80% of the solar rooftop PV systems were installed under CAPEX model and only 20% were installed under RESCO model. In the year 2016 world largest operating solar rooftop PV system has been installed in Punjab with a capacity of 11.5 MW on a single premise covering a roof area of 1.621 million ft^2 [50].

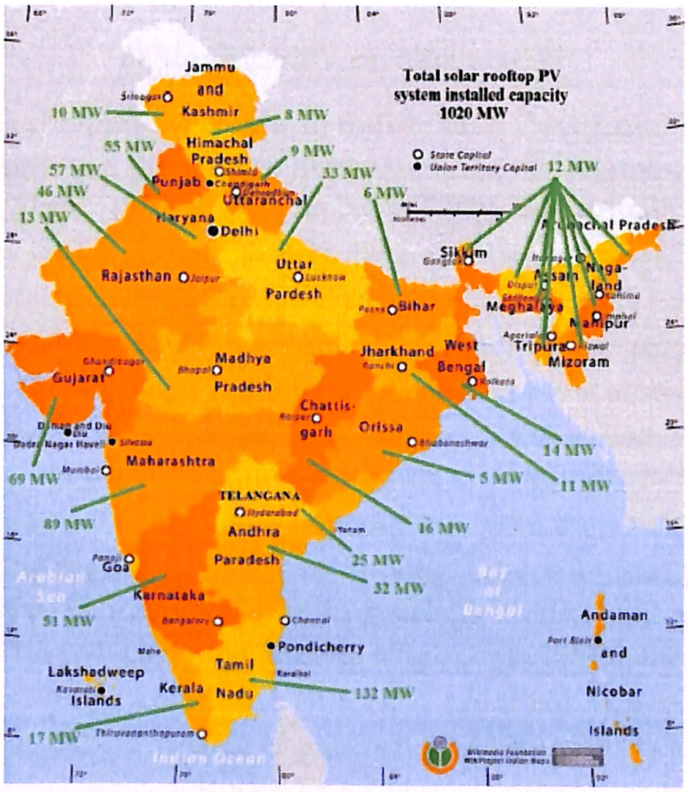

Figure 2.6: Installed capacity of rooftop solar PV in Indian states

2.2.3 Status of building integrated PV systems

Integration of solar PV system to the buildings offers a new method of power generation. Such system is called building integrated PV system or BIPV. There is a huge market potential for the BIPV systems across the world. Major solar thrust nations like Germany, France, Spain, etc. have already implemented BIPV system in largescale [51]. About 80% of the BIPV installation are roof mounted while the 20% are façade mounted. Figure 2.6 shows the available BIPV products in the market at present.

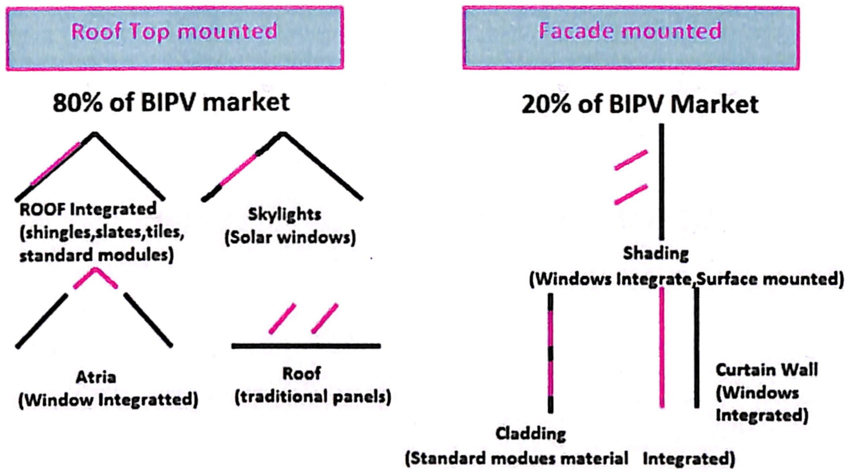

Figure 2.7: BIPV product market

BIPV technology is comparatively new to Indian land. Companies like Tata BP solar, Moser Baer Solar Ltd., etc. pioneers in implementing this technology in India. Use of BIPV helps in reducing the building materials [52]. In addition to generation of electricity, BIPV also enhances the aesthetic beauty of the buildings. BIPV modules are comparatively costlier than the glass based PV modules. Recently Moser Baer installed 1.8 kW BIPV in the façade of the Jubilee Hills shopping complex building in Hyderabad India. Tata BP Solar has also implemented BIPV system at the Samudra Institute of Maritime Studies in Pune. A unique BIPV system of 19.52 kW was commissioned in an industrial facility of FESTO, December 2011. Tata Power Solar undertook this work in view of powering the office with a renewable energy source as well as decreasing the energy usage for cooling, especially during summers. Here solar panels of 80Wp rating are placed in specially made stainless steel structures fitted to the wall. This will avoid the direct sun light from hitting the building, thereby reducing the room temperature. The structures are tilted to maximize the energy output. This BIPV system is capable of producing 17,106 units of electricity, reducing carbon emission of 13.6 tonnes. Since a battery based system was employed, separate UPS was not required for computer and other applications [46].

Chapter 3
Solar PV market in India

The increasing demand for electricity and the rising concerns of environment compel the shift from conventional methods of energy generation to the renewable energy based schemes. The Paris Agreement that insists the reduction of GHG emissions also paved the way for the wide spread deployment of renewable energy technologies like solar PV and wind turbine systems. During the initial phase of the development of the solar cells, its efficiency was very less and the cost was significantly higher than the electricity produced through coal fired power plant, which was available easily. According to [53], the price of solar modules have reduced 80% since 2009. The gradual and exponential decline of price of solar PV modules and the efforts of decarbonisation of the power sector have resulted in the wide spread deployment of solar PV systems. Increased production of PV modules have also resulted in the development of PV market in the country.

Figure 3.1 indicate the causes of the development of PV market in India. Increase in the PV module efficiency from 8 to 9% in 1980's to around 20% in 2020 made people to adopt the technology even with higher cost. In India, Department of Non-Conventional Energy Sources (DNES) and BHEL have included solar PV products in their portfolio. Initially DNES and BHEL had a monopoly over the solar PV market.

Establishment of Tata BP solar ltd., a joint venture of BP solar UK and House of Tata has marked the turning point in the solar PV industry of India as it ended the monopoly of BHEL and DNES. TATA BP Solar was the major manufacturer of solar panels in India. The 21st century saw an overwhelmingly large number of private corporations venturing into the solar PV sector. A report published by the Ministry of New and Renewable Energy, outlining the targets and achievement of the National Solar Mission shows the various corporations involved in PV installations and development throughout various states of the country. Table 3.1 highlights some of the corporations involved in respective states. Table 3.2 lists the top corporations involved in solar PV development in India.

Table 3.1: Corporations involved in the state wise PV installations

State	Names of Corporation
Rajasthan	Alex Spectrum Radiation Pvt Ltd., Maharashtra Seamless Ltd., Mahindra Solar One Pvt Ltd., SunEdison Energy India Pvt Ltd., Azure Power Pvt Ltd., DDE Renewable Energy Pvt Ltd.,
Tamil Nadu	CCCL Infrastructure Ltd.
Uttar Pradesh	EMC Ltd.
Orissa	Aftaab Solar Pvt Ltd
Andhra Pradesh	Saisudhir Energy Ltd., WELSPUN Solar AP Pvt Ltd.,

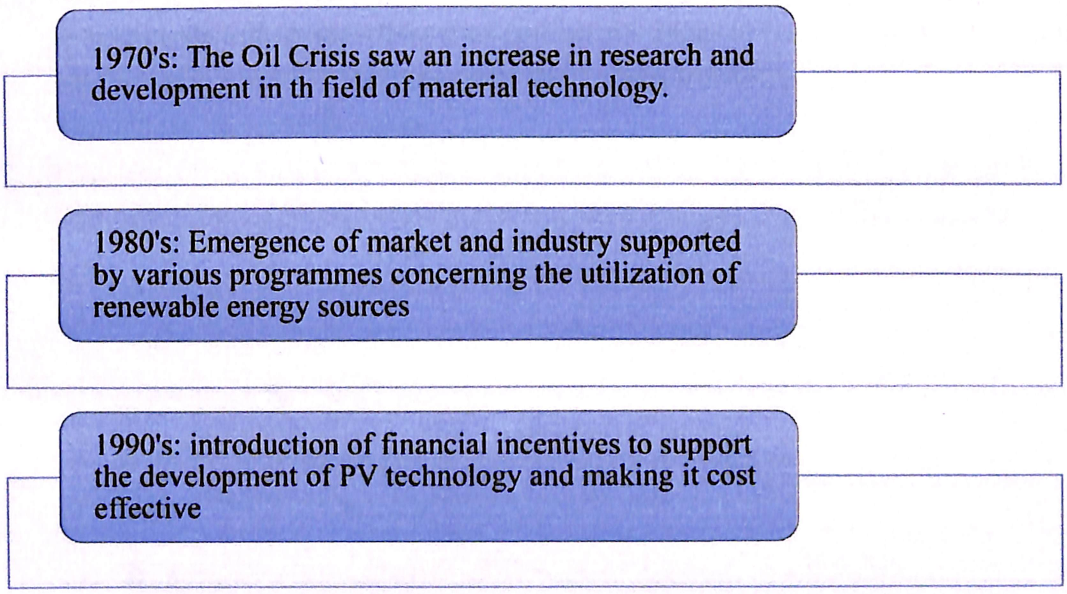

Figure 3.1 Development of PV market in late 20th century in India

Table 3.2: Major corporations involved in PV development in India

Tata Power Solar Systems Ltd	• Subsidiary of Tata Power • India's leading solar company. • Manufactures solar cells, modules and other solar products.
EMMVEE	• One of the most diverse solar companies in the country. • Founded in 1992 • Offers solar PV as well as solar thermal products.
Kotak Urja Pvt. Ltd.	• Founded in 1997 in Bangalore • A subsidiary of Kotak Group
Icomm Tele Ltd.	• Boasts of a presence in the international market • Offers solar solutions in the field of telecom, power and defence.
Mosar Baer Solar Ltd.	• Also has a global presence • Produces crystalline and thin film modules for different PV systems. • Assisted the ANERT program in Kerala to install solar panels on rooftops.
Indosolar Ltd.	• Founded in 2008 with the aim of developing world class manufacturing techniques.
Enertech Group	• Began in 1990. • Leading solar UPS manufacturers in India. • UPS is equipped with in-built multi power point tracker.
Delta India	• Delta India is the first to cross the milestone of over 1 GW rooftop installations.
Toshiba Mitsubishi-Electric Industrial Systems Corporation	• Formed in 2003. • Company supplies Solar Inverters in 1000 V and 1500 V capacities in industries across India.

During the period 2007-2015, India introduced slew of measures to grow the solar PV Manufacturing:

- SIPS capex incentive: Companies under this scheme were not benefitted as incentives under these schemes could not be disbursed.
- Introduced Domestic Content Requirement in JNNSM Phase-1: Little benefit to industry due to skewed pattern of allowing Thin Film imports. Subsequently, WTO objections led to the withdrawal of the scheme.
- Reserving capacities with higher VGF.

India introduced revised measures in 2018:

- Safeguard Duty on imports of PV cells and modules - the resultant increase in project costs led to slowdown of Indian PV market coupled with the crash of cell & panel prices - little benefit to the Indian industry.
- Mandatory BIS certification.
- Registration of cell & module companies with MNRE. India has been heavily dependent on Chinese imports for implementation of its solar program.

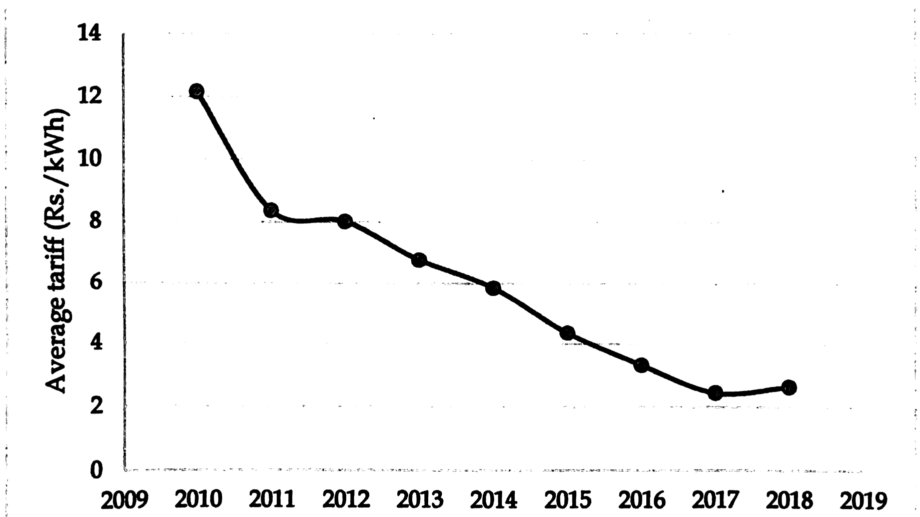

Figure 3.2: Trajectory of solar tariff in India

India needs energy security and sustainable energy solutions. Amongst the various energy sources solar energy has emerged as the preferred option since it is available across geographies, relatively unlimited vis-à-vis other green sources, freely available and in fact the country is endowed with possibly the highest band of average annual solar radiation and well suited for decentralized and distributed power requirements. India's solar market is on a roll with over 25 GW of largescale solar (PV) capacity installed in the country as of December 2018. Indian solar boom is set for a 40-50% growth rate over the next five years, as bottlenecks such as integrating solar farms with the grid are overcome. Grid parity was possible due to the quick drop in quoted tariffs by the Indian solar developers. Solar tariff decreases gradually in India. Figure 3.2 shows the gradual decrease in the solar tariff of the country. With the record low tariffs, the PV power installations have succeeded beyond expectations; but, the PV manufacturing is yet to attain critical mass. The country's installed manufacturing capacity of cells is about 3.1 GW (consisting of 18 companies) and that of the Modules is about 11 GW (consisting of nearly 175 companies). While there are only couple of GW scale companies, majority of the plants are of 50-200 MW capacity, having very high operating costs. Without credible manufacturing capacity, import dependence would move from oil to solar panels. Indian solar PV market is expected to grow 10 - 20 GW/year, which is a huge support base to develop and sustain domestic manufacturing.

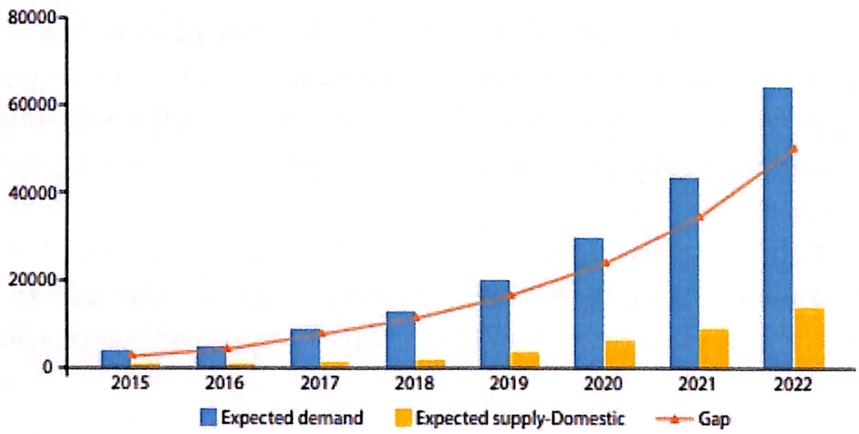

Figure 3.3: Expected scenario for solar PV manufacturing in India

India's domestic PV manufacturing industry could meet on 15% of the country's annual requirement. Figure 3.3 shows the expected scenario for solar PV manufacturing in India. The high level manufacturing costs for each segment of PV Value chain mainly consist of silicon cost, BOM costs, utilities, and labour and finance costs. The cost structure of the integrated PV Manufacturing for an Indian company are estimated based on the capital costs, operating costs information obtained from technology/turnkey solution/BOM suppliers, for a new project in India. Information related to SGA and other expenses are based on the industrial practices followed in India.

Chapter 4
Solar energy policy development in India

The research activities in the field of solar PV began in the 1980s aiming at the improvisation of the solar cell materials as well as the enhancement of the solar module manufacture [8]. In order to enhance the field of solar energy and other renewable energy sources, ministry of new and renewable energy, which was initially known as the ministry of non-conventional energy sources was formed in India. In 1995, India was the third largest consumer of the solar energy technologies and by 2002, most of the solar energy technology was employed in the street lighting, telecommunications, and water pumping sectors, having main focus on the off-grid applications.

4.1 Requirement of solar policy

The electricity generation capacity of India at the time of its independence was 1350 MW, which has increased to an enormous figure of 160 GW by the end of 2018. A projection of 90 GW of electrical energy is forecasted for the next 7 years to meet the basic electrical needs in India. According to IEA, India is expected to be the second largest contributor to the global electricity demand by 2035 [10]. The contribution of renewables in the electricity sector of the country was 0% during the time of independence. Enhanced implementation of new technologies in the power generation may gain opposition from the public even though it generates power efficiently [26]. Hence proper awareness, grid parity, cost effectiveness, and cost competitiveness are thus essential for the elaborate implementation of these technologies. This can be achieved only through well-structured energy policies. Subsidy for the renewable energy has been offered by the government even though the subsidised cost of renewable energy being still greater than that of the electricity generated through the conventional means [11]. Hence, well-structured and developed policies for the solar energy has turned out to be the need of the hour.

4.2 Major policies of India

In order to facilitate the research and development activities in the field of solar PV, a commission was set up in the department of science and technology by the Indian government. This was merged with the department of non-conventional energy sources in 1992. Lack of exploitation of the non-conventional energy sources resulted in the development of numerous policies that enhanced the solar PV industry in India. These policies were introduced as the part of tenth and eleventh five year plan of the central government. As a result of these policies, the installed capacity of the solar PV system have raised to 19% of the total installed renewables. The government has now set the target of having 100 GW of solar PV system in the country by 2022. Private investments also have significant role in enhancing the solar PV installation in the country. Few of the major policies of the government, set up for the enhancement of the electricity utilisation and renewables are discussed in brief below:

4.2.1 Electricity Act 2003

In 2003, the electricity Act was introduced to reduce the interference of the government and to boost the power sector by providing a framework [54]. The other main focus area includes the rationalization of electricity policies, establishing law and framework and restructuring of tariff. Guidelines and restructuring of electricity boards focusing on a centralized operating approach to maximize the policy benefits were added. As part of this section 61 and section 86 ensure the maximum utilization and enhancement of renewable energy sources. The act promotes the generation and cogeneration of electricity by interstate infrastructure and the transmission and wheeling cost structure optimized. The act includes appropriate measures for the selling of electricity at any power plant with grid connection. This act has led to the development of tariff policy. It has also aimed at the privatisation of the generation, transmission, and distribution sectors. Feed in tariff (FiT) and renewable purchase obligation (RPO) were introduced as a result of this act.

4.2.2 Electricity Policy 2005

Quality and reliable priced electric power at affordable price and higher efficiency for every household was the focus of the national electricity policy amendment in 2005. Privatisation and transmission challenges are minimised to boost interstate transmission. To improve efficiency various adoption of technologies like Supervisory Control and Data Acquisition (SCADA) and data management were encouraged. The cost and tariff also amended. Separate target for renewable energy was also set to the states [7].

4.2.3 Tariff Policy 2006

Financial feasibility on the power sector by attracting investors was another advancement in power sector introduced by the national tariff policy [55]. The pricing structure was main focus to make affordable unit cost. The efficiency and cost balance were considered by promoting competition. Multilayer tariff was introduced with the help of state electricity boards. The license distribution and resource usage were done by bidding. Regulatory committee State Electricity Regulatory Commissions (SERC) were empowered to monitor all the operation and deals among power sector. According to the committee minimum percentage of energy purchase from renewable sources of energy taking with account availability and impact were mandated.

4.2.4 Integrated Energy Policy

The Integrated Energy Policy was developed by an expert committee of the Planning Commission that was brought into effect in August of 2006 addressing all aspects of energy in the country including energy security, access and availability, affordability and effects on the environment [27]. Following are the main proposals of this policy.

- It mandates the power regulators to develop schemes or incentive structures to encourage utilities to integrate solar and other renewable systems to their grid.
- To mandate the feed in laws for the solar energy as prescribes in the Electricity act 2003.

4.2.5 National Action Plan on Climate Change

In 2008, the national action plan focused on climatic change and the sustainability especially in the energy sector was introduced. It emphasised the environmental responsibilities are important along with financial goals of power generation [56]. The mission like carbon footprint reduction, solar energy scheme named Jawaharlal Nehru National Solar Mission (JNNSM) implementation and its execution, green India mission and mission on energy efficiency were the highlights of the NAPCC [57].

4.2.6 Generation Based Incentives for Solar

In order to boost the energy generation using solar PV systems, a generation based incentive scheme was introduced in 2009. Main target of this scheme was the small scale solar projects that have capacity less than 33 Kw. It also aimed to lower the tariff gap between INR 5.5 and the rate set by the central electricity regulatory commission (CERC). It also helped in attracting private investments in the field of solar PV systems [8].

4.2.7 Jawaharlal Nehru National Solar Mission

This mission was the extension of NAPCC objective of JNNSM introduced in 2008. Goals of this mission were to meet the energy demand by encouraging solar power and it's potential. As part of this the target of 20 GW capacity of solar energy in 3 phases by 2020. The first phase had a target of 1 GW by 2013, while the third phase goal was to attain a 10 GW capacity by 2017 and final phase has a targeted capacity of 20 GW by 2020. This mission enable the wider objective of the country's capability to become leader in solar power. The RPO is the key approach to promote the solar energy usage with reduced tariff for alternative energies. The mission promotes technological advancement in-order to solve the huge infrastructure and initial investment cost for solar energy plants. Scaling-up and cost optimization approaches were adopted in the mission. JNN solar mission provides opportunities for decentralized and off grid solar photovoltaic applications in remote areas where grid penetration is neither feasible nor cost-efficient. The Mission promotes the development of stand-alone rural solar power plants in special-category states and remote areas by offering 90 per cent incentives for off-grid solar systems. Through the remote village electrification scheme, MNRE aims to provide solar lighting systems to span nearly 10,000 villages.

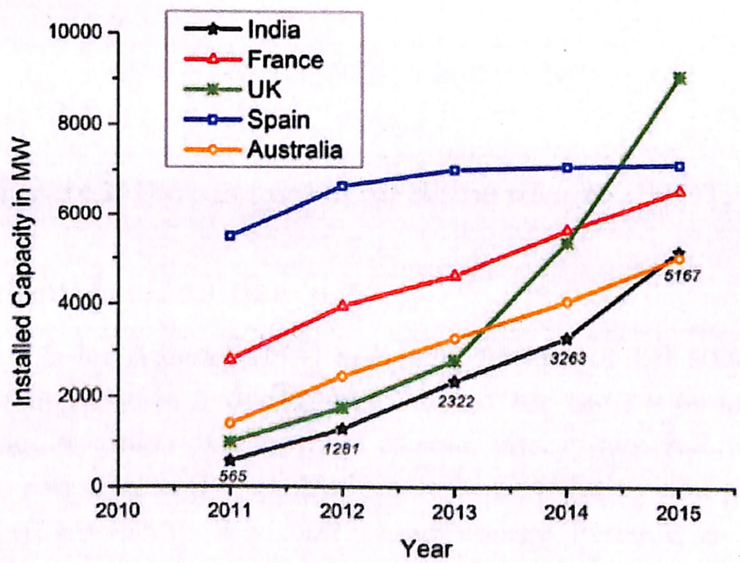

Figure 4.1: Installed capacity of grid connected solar PV in India and its competitive countries

4.2.8 National Institution for Transforming India (NITI) Ayog

On 1 January 2015, NITI Aayog was launched to succeed India's 65-year old Planning Commission. The commission's aim is to devise strategic plans for a long-term policy, system structures with interventions and monitor progress and effectiveness. Figure 4.1 shows the year wise installed capacity of India and its main competitors. A 60%

drop in the price of solar PV cells by 2014 from 2010 can be seen as shown in figure 4.2 [58]. This leads to the revision of target of other mission like JNNSM from 20 GW to 100 GW by 2022 [59]. By the end of March 2016, the solar power installed capacity reached to 6.76 GW. Though the goal was to achieve 1.4 GW, India was able to achieve more than twice of targeted value amount to 3.018 GW. MNRE aims to build solar parks and ultra-solar power plants, each with a production of 500 MW and above, within five years (2015-19). NITI Aayog focuses on improving the infrastructure and developing capacity to execute programs and initiatives across the country NITI Aayog also addresses the issue of grid maintenance and the stability of the system due to volatility and instability of solar photovoltaic power plants production.

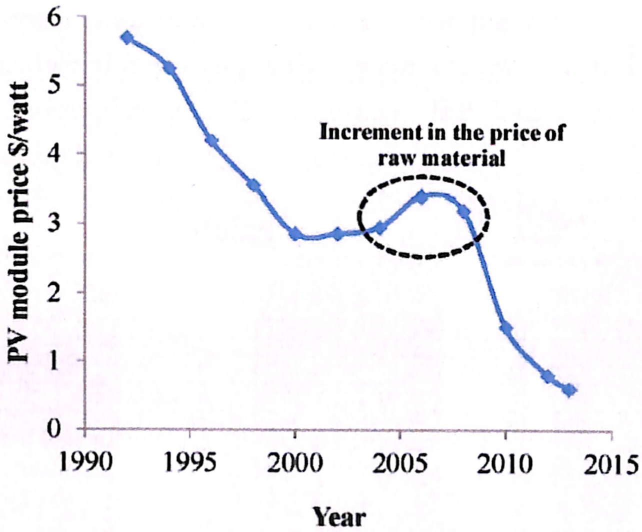

Figure 4.2: Drop in price of the silicon solar modules [60].

4.3 International solar alliance

The International Solar Alliance (ISA) is a joint venture of 121 solar rich countries with the vision to provide a dedicated platform for the cooperation among the countries to promote global development of solar energy generation. ISA provide a platform for the countries and organizations to come together and participate in the common goal of enhancing the solar based energy generation in the member countries. Headquarters of ISA is located at Gurgaon, Haryana, India. On the global scale, ISA aim to deploy the solar PV installations of 1000 GW capacity with an investment of 1000 trillion USD.

4.4 Policy instruments

Policy instruments are mainly those strategies developed for the enhancement of solar PV utilisation. There are two categories of policy instruments. They are generation based and finance based policy instruments. Generation based policy instruments include the feed in tariff, renewable energy credits, and renewable purchase obligation. Finance based policy instruments include the tax benefits, power purchase agreement, and concessional custom and excise duty [61, 62].

4.5 Organizations involved in solar energy development

In order to propagate the solar energy utilization, various organizations are set up by the governments both at the centre and the states. These include the public sector institutions like SECI, IREDA, etc. and educational institutions that take part in the promotion and development of solar energy based electricity generation. Figure 4.3 shows the publics sector organization dedicated for the research in solar energy in India. Different educational institutions that focus on the research and development of solar energy technologies are IIT Bombay, IIT Delhi, IISc Bangalore, TERI University, BITS Pilani, etc.

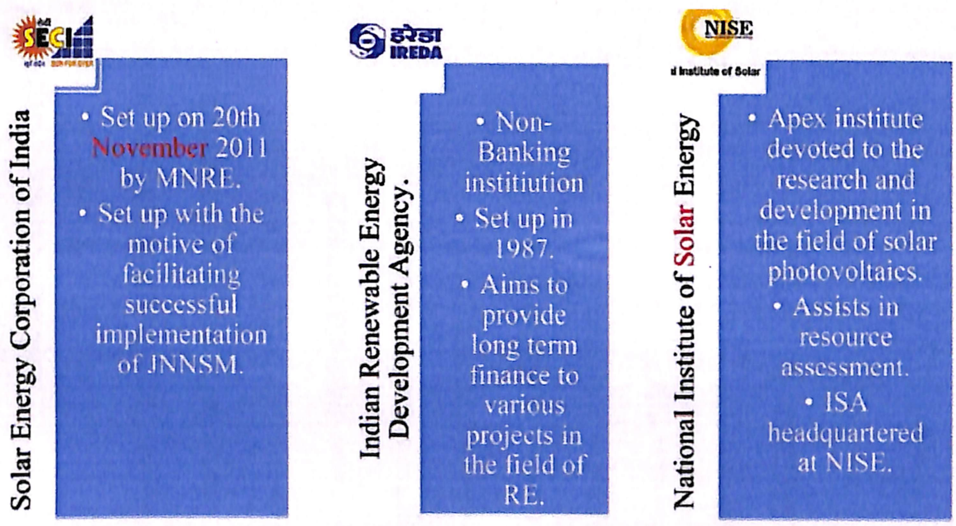

Figure 4.3: Public sector organization in India for the R&D in solar energy

4.6 Solar policies of different states

Following the implementation of the JNNSM in 2010, other states followed Gujarat to develop their first solar policy. After 2013, few states restructured as a result of their advantage in bringing forward the second version of the solar policy, Uttar Pradesh is the first state to do so. In place of solar policy, Maharashtra developed a consolidated policy on renewable energy in 2014, along with solar energy plans. Nearly every state has installed solar power plants, irrespective of the nature of the scheme. In 2015, the state updated its solar policy structure anticipating substantial growth in the electricity sector in the coming years. The state wise installed capacity of commissioned solar power plants as of 31 March 2016 is shown in Figure xx.

Rajasthan has cumulative installed capacity 1.27 GW, followed by Gujrat holds the top position in the state-wide installed solar power capacity with a cumulative installation of 1.12 GW. And Rajasthan with a potential of 142.31 GW, the highest among all states.

The government of India declared various solar incentives by the end of July 2015. The depreciation rate were reduced from 80% to 40%, The capital subsidies change from 30% to 15% attracted the developers to install their solar plant more than before. Few measures like renewable energy certificates that enable intrastate energy transaction, agreement assure the purchase of generated solar power and net metering offers that guarantee financial benefits to the plant owner etc. caused the installed capacity to rise in 2015-2016 alone by 45% with respect to previous year. The benchmark cost of capital for the solar modules has declined from 1700 lakhs/MW to 612 lakhs/MW by 2009 to 2014 [60].

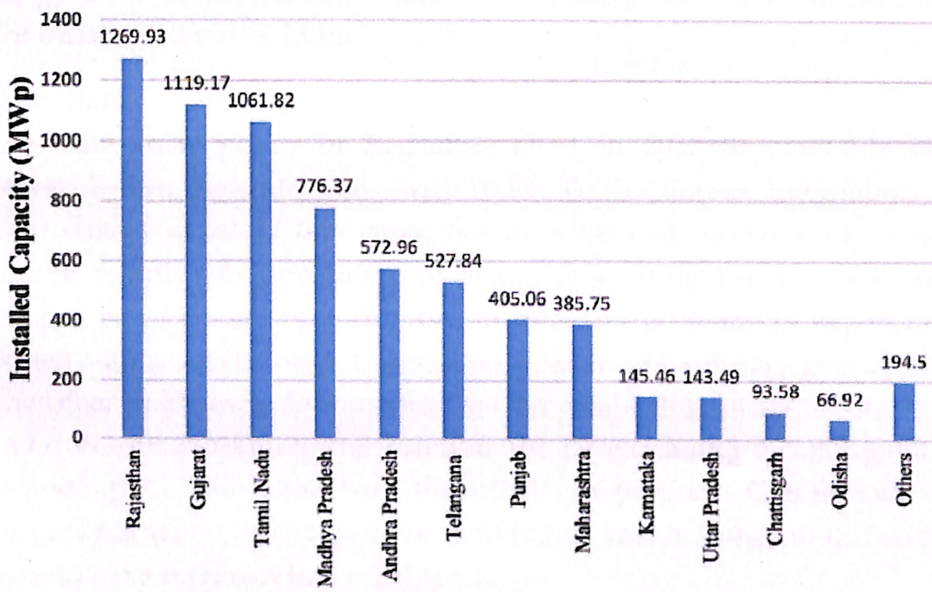

Figure 4.4: State wise installed capacity of installed solar power plants

4.6.1 Common traits of solar infrastructure among states

The land topography and infrastructure differ for each state, however there are common characteristic objective between the state solar policies frameworks. The overall goals are to encourage and grow solar power, reduce reliance on conventional energy, exploit unproductive land, fund research and development, and create jobs. It also aims to reduce cost of energy while adding capacity for generation. Table 4.1 describes the grid-connected solar photovoltaic infrastructure and system of the Indian states that adopted solar policy plans. The charges like wheeling charges for every state are set as per the SERC and it is reviewed frequently. The subsidies on the installation provided by MNRE varies among NE states and other states. For NE states 70% is the installation subsidy while other states enjoy only 30%.

The installed capacity ranking has Gujrat, Rajasthan and Tamil Nadu are in the top position. Gujrat and Rajasthan receive same range of global insolation but the availability of land (usable wastelands Gujrat 19,563.5 square km, Rajasthan 42,093.5 square kilometres) and difference in net capital cost make Gujrat (Rajasthan is approximately 40% lower than Gujarat) to secure first position. Tamil Nadu receives highest solar radiation among all the states and secure third position. It set the 2022 target of 8.88 GW installation of solar power is a result of the relatively lower cost of capital of 5.86 Cr/MW for a solar plant.

4.6.2 Overview of the policy framework of major States

In this subsection, an overview of the solar policies of different states and union territories of India is elaborated. Table 4.1 compares the solar infrastructure and policies of different states of India.

A. ***Rajasthan***

The state solar policy of Rajasthan cited in 2011 to meet the electricity necessities for the state along with India. To develop an international hub of solar energy of 10–12 GW capacities by means of contributing to long-term energy security in upcoming 10 years, generating tremendous direct and indirect employment opportunities in solar, introduction of expert and semi-skilled staff assets through training services are the primary goal of the policy. The other goals include industrial set-up establishment by involving foreign and domestic workforce and promote the Research and development in solar technologies. The Rajasthan Electricity Regulatory Commission (RERC) decides norm and its competitive tariff biding rate is Rs6.45 unit. The details of norms cost are shown in the Table 4.2.

B. ***Karnataka***

The state developed its solar policy for the period of 2014 to 2021, 2 GW cumulative generation of solar power includes grid connectivity of 1.6 GW and Roof top of 0.4 GW by 2021 [31]. Investment attraction by public and private partnership is the sole goal of the policy. The Karnataka Electricity Regulatory Commission (KERC) decides norm and its competitive tariff biding rate is Rs. 8.40 per unit [63]. The details of norms cost are shown in the Table 4.3.

Table 4.1: Comparison of solar infrastructure and framework of different states

States	Year established	Range of GHI (kWh/m^2)	Solar potential (GW)	Net capital cost (Cr/MW)	Tariff rate (Rs./kWh)	Install capacity (MW)		Schemes of installed capacity (MW)			Target for 2022 (GW)
						Minimum	Maximum	MNRE projects	State policy	REC	
Andhra Pradesh	2012	5.12 - 6.08	8.65	NA	6.49	NA	NA	94.75	115.01	37.70	9.83
Chhattisgarh	2012	5.31 - 5.63	18.27	10.00	NA	NA	NA	4.00	1.68	4.60	0.15
Gujarat	2009	5.63 - 6.08	35.77	10.00	8.42	5.00	NA	20.00	974.05	6.00	8.02
Haryana	2014	5.12 - 5.63	4.56	12.96	NA	NA	NA	7.80	5.00	0.00	4.14
Himachal Pradesh	2014	4.01 - 5.31	33.84	NA	NA	NA	50.00	0.20	0.00	0.00	0.77
Jammu & Kashmir	2013	3.25 - 6.08	111.05	6.05	NA	1.00	NA	16.00	0.00	0.00	1.15
Jharkhand	2015	5.31 - 5.63	18.18	8.42	NA	NA	NA	5.00	73.22	0.00	1.99
Karnataka	2011	4.84 - 6.08	24.7	6.05	8.40	1.00	NA	0.025	0.00	0.00	5.69
Kerala	2013	4.84 - 6.08	6.11	10.00	NA	NA	NA	185.25	297.55	80.78	1.87
Madhya Pradesh	2012	5.47 - 5.78	61.66	10.25	10.44	0.025	100.00	57.00	185.38	121.32	5.67
Maharashtra	2015	5.31 - 6.08	64.32	13.50	6.03	1.00	NA	12.00	15.42	4.50	11.92
Odisha	2013	5.12 - 5.63	25.78	9.00	NA	NA	NA	789.10	65.00	193.00	2.37
Rajasthan	2011	5.31 - 6.08	142.31	5.97	6.45	5.00	10.00	16.00	33.82	98.16	5.76
Tamil Nadu	2012	5.78 - 6.08	17.67	5.86	7.01	NA	NA	0.00	39.35	23.40	8.88
Telangana	2015	5.47 - 5.78	20.41	NA	NA	NA	NA	0.00	0.00	5.00	-
Uttar Pradesh	2012	5.12 - 5.47	22.83	NA	NA	5.00	NA	12.00	59.26	0.00	10.69
Uttarakhand	2013	4.01 - 5.31	16.80	10.00	NA	1.00	50.00	5.00	0.00	0.00	0.90

Table 4.2: Capital cost projections for PV projects in Rajasthan

Particulars	Capital Cost Norm for Rajasthan (lakh/MW)	Capital Cost Norm as per CERC (lakhs/MW)
c-Si PV modules	326.76	328.39
Land cost	7.3	25
Civil and general works	50	35
Mounting structure	50	35
Power conditioning unit	45	35
Cables, transformers and evacuation cost	55	44
Preliminary and pre-operative expenses, IDC, etc	47.74	27.63
Others (connectivity, evaluative, and transmission)	15	NA
Total	596.8	530.02

C. *Gujarat*

The first solar policy for the state is introduced by Gujrat in the year of 2009. It was well before the implementation of JNNSM mission introduced by the centre. The State promotes the solar power efficiency by identifying and incorporating various features, such as relaxation from forecasting and scheduling , grid connectivity and evacuation accommodations ,exemption from payment of electricity duty, wheeling charges as per GERC (Gujarat Electricity Regulation Commission), high feed-in tariff scheme as detailed in table 4.4 , release of demand cut, open-access for third-party sale ,authorizing renewable purchase obligation, and conveying of state nodal agencies for ease of operation. In 2010 GERC was the country's first State Electricity Regulatory Commission (SERC) to issue a general tariff order.

Table 4.3: Capital cost projections for PV projects in Karnataka

Particulars	Capital Cost Norm for Karnataka (lakh/MW)	Capital Cost Norm as per CERC (lakhs/MW)
c-Si PV modules	332.35	328.39
Land cost	25	25
Civil and general works	50	35
Mounting structure	50	35
Power conditioning unit	45	35
Cables, transformers and evacuation cost	55	44
Preliminary and pre-operative expenses, IDC, etc	48.5	27.63
Others (connectivity, evaluative, and transmission)	NA	NA
Total	605.85	530.02

D. *Madhya Pradesh*

The state developed its solar policy in the year of 2012. The primary objective is to develop a favourable environment for the private sector by providing incentives and benefits to set up Solar Power projects. The tariff is fixed for different capacities. For more than 2 MW the tariff amount is Rs.10.44 and for less than 2 MW the tariff amount is fixed at Rs. 10.70. These rates are fixed for the next 25 years in 2012. The rate of tariff for the state is highest when compared to other rates of states hence needs an updating and revivals.

Table 4.4: Levelized tariff of solar projects in Gujarat

Levelized tariff for MW and kW scale power projects from time to time decided as per GERC		
Plan		**Levelized Tariff (Rs/kWh)**
		July 1, 2015, to March 31, 2016
Large Rooftop and MW-scale PV Power Plants	Without AD (Accelerated Depreciation) Benefit	6.77
	With AD Benefit	6.17
kW-scale PV Power Plants	Without AD Benefit	8.42
	With AD Benefit	7.64
		April 1, 2016, to March 31, 2017
Large Rooftop and MW-scale PV Power Plants	Without AD (Accelerated Depreciation) Benefit	6.30
	With AD Benefit	5.74
kW-scale PV Power Plants	Without AD Benefit	7.83
	With AD Benefit	7.11
		April 1, 2017, to March 31, 2018
Large Rooftop and MW-scale PV Power Plants	Without AD (Accelerated Depreciation) Benefit	5.86
	With AD Benefit	5.34
kW-scale PV Power Plants	Without AD Benefit	7.28
	With AD Benefit	6.61

E. ***Andhra Pradesh***

The state developed its solar policy in the year of in 2015. This policy is five-year policy. The project's goal is to build solar parks, to set up solar-powered agricultural pump sets, and to encourage developers to implement solar power projects, increase jobs, and promote distributed generation of power in the state. The target focus for the next five year is 5 GWp including 2.5 GW of solar parks. The tariff details of the state are shown in Table 4. The AP Electricity Regulatory Commission decides norm and its competitive tariff biding rate is Rs. 6.49 per unit [64].

F. ***Haryana***

The state developed its solar policy in the year of in 2014. Promotion of environmental consciousness among all citizens, Up-gradation of the skills of the youth in the field of solar, diversification of the energy range, and decentralization are the core objective of the Haryana solar power policy. By 2017, the policy aims installation of 0.1 GW capacity of MW Scale Grid connected solar power project. The State shall promote and facilitate the construction of solar power plants for the sale of solar power by third parties at average power purchase cost to the DISCOM under REC (Renewable Energy certificate).

G. ***Tamil Nadu***

The state implemented the solar power policy on 2013. The goal is to project the state as an energy hub by working against the target of 3000 MW of solar energy generation and to achieve grid parity by 2015. TANGEDCO (Tamil Nadu Generation and Distribution Corporation) decided the rate of solar power tariff rate and norms. The tariff rate is Rs. 7.01 per unit of solar PV projects excluding AD benefits.

H. ***Uttar Pradesh***

The state implemented the solar power policy on 2013. The goal is to provide favourable investment options for private sectors to increase capacity, efficiency, modernisation and sustainability. The target installation id 0.5 GW of grid-connected solar plant in next four years.

I. ***Odisha and Chhattisgarh***

The state implemented its first solar policy in 2013. The policy aims to create performance testing facility in OREDA (Orissa Renewable Energy Development Agency) for different types of thermal systems and solar PV with their components. Chhattisgarh introduced its solar policy in 2012, which is valid up to next five years. The objective is to encourage innovation in solar power systems, creating a favourable environment for the development and investments in manufacturing, and universalization of access to clean energy falls within the objective of the state. The state targets to achieve 0.5 GW generation capacity by end of five year from its initiation.

J. ***Punjab***

The state policy was drafted in early 2014, the goal was to create improved rooftop solar infrastructure, implementation of net metering grid-interactive rooftop. As a result, the capacity increased to 405 MW (as of march 2016) and even targeting to achieve 1GW by 2022. The state has a record of incorporates World's Largest Rooftop Solar PV Plant of 11.5 MW on a single roof. That facility is located in BEAS Amritsar. Ministry of New and Renewable Energy, Government of India provides 30% subsidy and Benchmark cost is Rs. 75,000 per kW. The subsidies on the installation of Roof Top Solar power plants are subject to a maximum of Rs. 22,500 per kW for residential and not profit-making institutions only. Table 4.5 shows the cost and subsidy on rooftop installations in Punjab.

Table 4.5: Cost and subsidy on rooftop solar PV in Punjab

Cost and subsidy on roof top solar power plant installation of Punjab		
Capacity of rooftop solar	**Installation cost (Rs.)**	**Subsidy (Rs.)**
1 kW	85,000–95,000	22,500
2 kW	170,000–185,000	45,000
3 kW	250,000–270,000	67,500
5 kW	400,000–425,000	112,500

K. ***Other states***

Similarly, the state of Himachal Pradesh (2014), Telangana, Jharkhand, Jammu and Kashmir (2015), Kerala and Uttarakhand (2013), have recently introduced their policy of solar power. The main objectives are similar to the various schemes like JNNSM and MNRE and includes to promote these schemes, clean development mechanism (CDM), and create clean energy by increasing solar power. Each state has got its own solar power generation target as below. The state of Jharkhand targets to 2.65 GW by the year 2020, While Telangana target is 0.5 GW by 2017 with an extension of 2.5 GW by 2030. Telangana also adopted zero charge for wheeling of power open access. The state Uttarakhand aims is to reach 0.5 GW by 2017.

4.7 Solar policy for rooftop systems

The Jawaharlal Nehru solar mission that was launched by the Government of India under the National Action plan on climatic change targeted the following [65]:

- Installing 20,000 MW of grid connected solar power by 2022.
- Off-grid solar applications of 2000 MW including 20 million solar lights by 2022.
- Twenty million square meter area for solar thermal collector.
- Creating healthy and positive measures for developing solar manufacturing capability in the country.
- Promote R&D so as to develop an alternative energy source that can generate power at LCOE.

The year wise target that was set by the government during 2011 was revised in 2015. The revised target set by the government is shown in figure 4.5. The Government of India with the aid of JNNSM launched a program known as the 'grid connected rooftop and small solar power plants program' forecasting a power output of 40 GW out of the 100 GW target. The main goal of this program is to enhance and increase the grid connected solar rooftop and small power generating plants among residential and commercial establishments. All parts of India were targeted for the installation of solar rooftop program with a minimum installation of 1 kW to 500 kW. Various agencies like solar energy corporation of India (SECI), state nodal agencies (SNA), channel partners, financial institutions are also expected to help the government in this program.

A. ***State nodal agencies (SNA)***

These are government agencies set up in every state, monitored by the respective state governments. They document all the records and files submitted by the beneficiaries for the installation of the project. There are two modes devised for the solar power installations: one is called the program mode where the capacity will be less than 50 kW while the second is the project mode where the capacity is more than 50 kW. The SNA has the responsibility of deciding the target for their respective state.

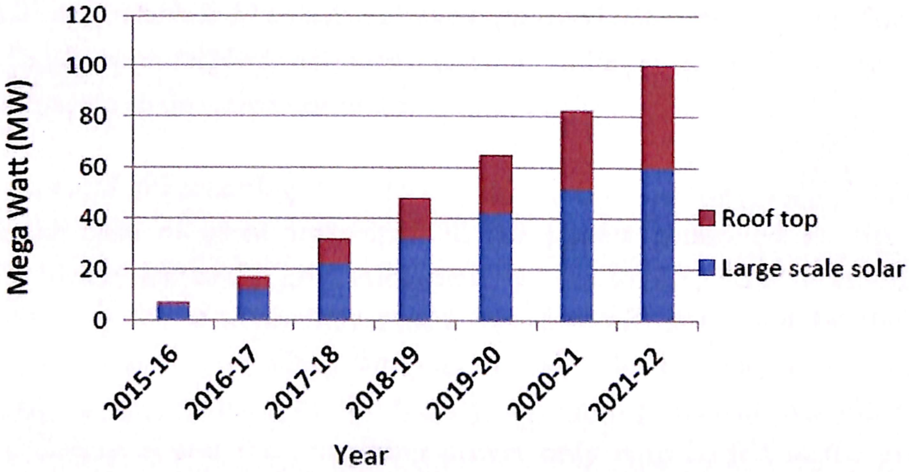

Figure 4.5: Revised target of JNN solar mission

B. ***Solar Energy Corporation of India (SECI)***

It is a public sector undertaking establishment under the direct administrative control of the Ministry of New and Renewable Energy (MNRE). The SECI prepares and submits the documents related to planning, design, renovation, maintenance, construction, and operation of the solar PV to the MNRE for approval. It also implement the same after gaining the approval from the ministry.

C. ***Channel partners***

These are organisations enrolled by the MNRE for helping people to get the benefits from the solar PV scheme. These agencies review the technical and financial strength, market sales and provide a detailed report to the MNRE according to which the MNRE allocates funds for the project.

D. *Financial institutions*

The institutions like NABARD, housing banks, IREDA can design and develop the solar rooftop scheme by getting necessary funds directly from the MNRE or any other source. A 30% subsidy will be provided by the MNRE in the form of central finance assistance to the respective beneficiaries account through these central agencies. Subsidy is measured in terms of the total project cost or the benchmark cost whichever is lower in case of general category states and a subsidy of 70% for special category states. A government incentive of INR 7500 to 45000 per kW is applicable for solar projects built on government or public sector. Apart from providing the incentives/subsidies, the regulatory bodies around the world use two main tools known as gross metering and the net metering. Around 108 places across the globe have employed the gross metering whereas 48 countries have employed net metering [66]. The JNN solar mission also employs the same tools in India, as to be in the same level as compared to the other countries.

E. *Gross and net metering*

In the case of gross metering, all the power generated by the facility is completely fed to the grid. All the energy fed to the grid is monitored using a feed-in meter at a predetermined feed-in-tariff, approved by the regulator through a power purchase agreement (PPA). In the case of net metering, the power is first utilised by the facility owner to power all the internal power requirements and the remaining power only is to be fed to the grid. In this facility, a single meter is used which shows net power consumed by the consumer from the grid after exporting excess solar power to the grid.

As of now, 18 states and union territories have their own policies for the solar PV scheme and the remaining states and union territories will be monitored by the state electricity regulatory commission for the implementation of the solar PV policies. By the end of June 2015, all the states of India have implemented the policies to support the solar rooftop PV systems either through SNAs or state energy regulatory commissions (SERCs).

4.8 Recommendations to improve solar PV policies

The target planned by government of India is capacity of solar totalling 100 GW, out of it 60 GW of utility scale projects and 40 GWP of rooftop by 2022 [59]. The year wise upcoming targets to achieve this milestone are detailed in figure 4.6.

4.8.1 Periodic revision of state and central policies

Despite the fact that the cost constraints, technological challenges and infrastructure limitation in the period 2015-2016 alone, India has able to reach 3 GW of the solar capacity. The states boards also played a major role by following MNRE and JNNSM scheme there by providing technical, financial and strategic solution to the challenges. There is still area for improvement, some of the pain area including the states which are yet to come up with the policy, 13 states are there in this list. Another area is the 12 states which are yet to revises the policy. In order to constantly grow in the solar power and achieve the target periodic revision is an essential activity.

4.8.2 Inclusion of geographical factors to determine key parameters

The PV potential of the state varies from region to region. The determining factor for the PV potential includes many like PV energy generation, capital cost, type of tracking/mounting, land requirement, ambient light and temperature, incident radiation, etc. hence it is not reasonable to generalize the PV potential. Therefore, the implementation of an appropriate method or recommendations in the strategy must be enforced to define certain patterns of land. The methods like PV yields, correlation plotting and the rasterized maps for radiation, and land pattern analysis could enhance estimation of the solar potential.

4.8.3 Encouragement for rooftop installation

India has enormous potential that is yet to be tapped to increase the rooftop capacity. The industrial zone, growing cities, business establishment etc. have a huge potential for transforming towards cleaner energy by capturing and utilization of solar energy. The market, economic potential and technical potential are 124 GW, 210 GW and 352 GW respectively for roof-top Solar PV. Thirteen states have already devised the solar rooftop policy which will help to reduce the huge initial cost of infrastructure. This will ultimately increase the ROI of the land which otherwise are found to be barren. To improve the structure of rooftop and improve the capacity of generation each state should come up with customized rooftop construction methods, policies that suit to their available resources. Separate legislation and guidelines are also required for classification and improving the operation by giving subsidies and benefits.

4.8.4 Specific tariff and technical standards

As the difference in policy planning and offers the tariff structure across the state varies largely. A uniform tariff structure enables easy transmission and grid parity. The targeted date for this objective identified is before 2022. Punjab is the first state to implement net metering which allows the rooftop owner to save on power consumed. This also help them to exempts from charges like wheeling and banking. This is a role model for future policy. Beside the tariff structure technical distribution standards like harmonic standard, wherein harmonics level and total harmonic distortion is taken into account, and inverted standard, wherein continuous supervision of grid connection is enabled so as to disconnect the circuit in case of failure, should be adopted.

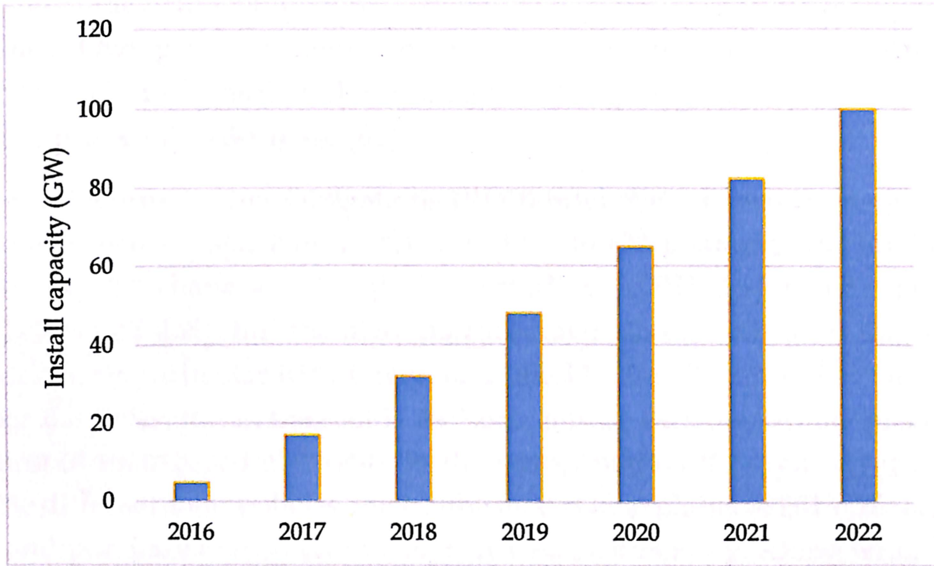

Figure 4.6: Future targets solar PV installations in India

4.8.5 Data acquisition and use of predictive models

The data driven approach should be adopted to predict the energy yield forecasting. This will help to accurately plan and draft the policy and structure of solar schemes. The studies have shown that ambient temperature, global radiation and PV energy yield for minimum required parameter for prediction. The predicted model should be validated on a real time environment to arrive the accuracy levels. The data collection will help to derive detailed future policy by real time analytics. Hence data acquisition plays a vital role, varies climatic conditions, whether forecasts and power parameters like temperature, hourly energy generation, grid failure time and radiation sunshine hour should be recorded for analysis. Making this data publicly available helps in R&D and thus aids for technological innovations.

4.9 Review of solar power tariff, installation cost, RPO, and exchange price

The solar power tariff is depending on various internal costs. The cost distribution is given in the figure 6. According to the figure the PV module cost is the major cost amount to about 62%. The various developments that leads to decrease in the cost of PV module manufacture has resulted in overall cost reduction of solar power tariff. India's Central Electricity Regulatory Commission (CERC) has announced the module's average cost of c-Si technology to be 0.48 US$/watt. According to the solar tariff order, FY 2016-17 by CERC is Rs. 5.3 Cr/MW for solar PV projects for the year [67]. The cost reduction was resulted with various developments and advancement in technology. Thus, the cost decline was evident as the commission agreed that the uniform tariff for 2015 would be Rs.7.04 and Rs.6.35 per kWh of solar PV generation. And further, Owing to central government's declared incentives for producing solar photovoltaic photovoltaics under semiconductor policy 2007, the cost of solar modules is projected to decrease [68].

The Renewable Purchasing Obligations (RPO) offer the renewable energy market a continuous impetus. Rajasthan (2.5%), Tamil Nadu (2%), Jammu and Kashmir (2%), and Gujarat (1.75%) have achieved the highest RPOs in 2015–16 [7]. The expected RPO rise by 2022 is 3% [68]. But the state policies have adverse effect on the renewable energy due to its particular RPO target, identified by the SERCs. Other factors which added for the reduction in the cost is the solar power exchange in the process of the transaction of solar-based electricity in the power market through buyer and seller. Due to the different solar policies and established power plants in 2013–2016, the value of sales and purchase bids in GWh has increased significantly, Along with, the effect of the cost reduction of the PV module is the reduction of the clearing price, which is equal to the cost of the solar energy generated by the sale of energy bids.

Chapter 5
Policies and solar PV market growth

5.1 Barriers for solar energy market

Solar energy deployment in a country initially depends on the governmental policies that enhances the same. Even then, there might be many factors that hinders the development of solar PV systems in India. This section reviews barriers to the large-scale adoption of solar energy technologies and thereby to the growth of PV market in India.

5.1.1 Market position of fossil fuels

A major barrier to upscale solar and wind projects in India is the deep-rooted market positions of coal, oil & gas and other fossil fuels. There happens to be powerful political-economical forces seeking to maintain and growth of the markets for fossil-fuels, which also include state-owned enterprises. In India, more than half a million of its population work in the coal industry, and the railways and banks have business models which are closely entangled with the fossil-fuel industry [69]. The fossil fuel industry is also a very important source of revenue for the government and the industry enjoys political support in the country [70]. In the context of fossil fuel, the existence of long-term Power Purchase Agreements (PPAs) for coal-fired power stations present a challenge for the speedy rise of renewables in the country [71]. A large number of PPAs for coal-fired power stations have already been signed in India. These typically compensate power generators via both fixed (i.e. capacity) and variable (linked to electricity generation quantities) payments over a period of around 25 - 30 years [72]. Coal-fired power generators have a strong interest, however, in ensuring offtake of their electricity to receive the variable payments. They may also believe that off-take will consolidate their ability to continue to collect the fixed payments.

5.1.2 Significance of prices

A. Electricity and fossil fuel subsidies

A key challenge in India is that, solar projects must compete against subsidized fossil fuels industry, and subsidized on-grid electricity. The subsidies - adding up to US$ 13 billion in 2016 - are the result of consumers being able to purchase energy products such as electricity, petrol, diesel, and natural gas at low prices. Access to low on-grid electricity reduces the attractiveness of direct investments particularly in rooftop solar. In other case, the fossil fuel industries in India are beneficiaries of production assistance in the form of tax cuts and subsidies. In India, subsidies on electricity particularly for the domestic sector is very much entangled with socio-political gains.

B. Under-priced or under-taxed externalities

Fossil fuels are a major source of negative externalities in the form of air pollution and greenhouse gas emissions. They also causing major health hazards and affect economic progress [73]. Indian cities are among the world's most polluted. According to the work presented in [74], estimates that outdoor particulate matter pollution from fossil fuels and other sources led to around 670,000 deaths in India in 2017. Pricing or taxing such negative externalities, however, is very limited in India.10 Instead, subsidies are provided to fossil fuel use. According to [75], countries which do not have a price or tax on carbon are less successful in the adoption of solar for electricity generation. An exclusion in terms of externality pricing has been India's clean energy cess: a tax on production and imports of coal, lignite, and peat which was introduced in 2010. The cess aimed to penalize coal and promote the use of clean energy. Revenue went into a National Clean Energy Fund (NCEF) to finance clean energy initiatives, although in practice most of the funds have not been used in this way (Comptroller and Auditor General of India, 2016). The cess was initially ₹50 (US $0.76) per tonne of coal. It was increased to ₹400 (around US $6) by 2016. The cess was then merged into India's new goods and services tax (GST) in 2017. Remaining funds in the NCEF were diverted to a GST compensation fund.

C. Lack of dynamic pricing

Another issue preventing the competitiveness of solar projects in India is a lack of dynamic pricing. Real-time electricity markets are thin, thus making it challenging to manage grids with increasing portions of sporadic renewable energy as there are often insufficient real-time signals to incentivize ramp-able power generation from renewables. Retail prices are also typically set in a rigid way that does not reflect temporal variation in the scarcity of electricity. This leads to, for example, consumers facing an inhibited incentive to install rooftop solar, which is able to generate electricity during relatively high electricity demand.

5.1.3 Resistance from utilities

Electricity utilities in India are cautious about supporting solar and wind projects, for several reasons:

- Solar and wind power generation projects directly compete with existing generation assets.
- Generation for self-consumption presents direct competition for grid connected electricity sales, thus limiting revenue collections.
- Grid management challenges due to intermittent power supplies.
- Renewable projects are often located far away from existing transmission lines, thus requiring substantial investment in infrastructure which the utilities often do not have the suitable incentives to invest in this transmission infrastructure. Utility-scale solar and wind projects have received exemptions from paying inter-state transmission charges in India known as wheeling charges [76].
- Utilities very often have large debts and operate at a financial loss [77, 78] limiting their ability to chase renewable energy investments. This issue also contributes to off-take risks.

Resistance from utilities has contributed to difficulties in obtaining net meters for rooftop solar in India which has a target of 40 GW by 2022 [79]. Transmission issues has also stalled utility scale solar and wind projects in India [80].

5.1.4 Grid management challenges

Managing sporadic energy supplies presents several technical challenges which exceed the capabilities of grid management practices currently available. As a result, solar power generation has often been shortened. Limits on the share of intermittent renewable power supply on the local grid, and on rooftop solar PV connection sizes, are also imposed. India has developed comprehensive real-time markets, including ancillary services such as frequency control. Major improvements in grid management are required for a large-scale transition to intermittent power resources.

5.1.5 Protectionism

The solar market in India is dominated by imports, largely from China. Domestic solar module production capacities are relatively low, and domestic panels are usually more expensive and of lower quality than panels available in the international market. Protectionism in the form of safeguard tax is pushing up project costs, thus severely affecting vendors, utilities, and consumers. Cent percent foreign investment in solar and wind projects is possible in India [34]. However, under Phase I of the Solar Mission, the MNRE required projects to use minimum quantities of domestic components. In Phase II, tenders were split into "open" and "domestic content requirement" (DCR) categories. In order to qualify under the DCR category, solar cells and modules are required to be made in India. In 2014, the US requested the establishment of a World Trade Organization (WTO) dispute resolution panel to hear the complaints regarding India's domestic requirements. The panel considered whether the requirements breached the Agreement on Trade- Related Investment Measures (1994) (TRIMs). It found that India's domestic mandates fell within article 1(a) of the TRIMS Illustrative List, which lays out trade related investment measures that are inconsistent with a country's obligations under the General Agreement on Tariffs and Trade 1947 (GATT). An important question was whether the DCR measure was "mandatory" and "enforceable". Several considerations influenced affirmative findings. First, failure to comply with domestic content requirements within 180 days of signing a PPA attracted the forfeiture of any monetary deposit. Second, PPAs issued under the first two phases of the Solar Mission contained "conditions subsequent", which included the fulfilment of domestic content requirements. Non-fulfillment could trigger sanctions and penalties. The panel also found that India had breached GATT article III - the "national treatment" obligation - which prohibits discrimination between imported products and "like" domestic products. Further, it found the measure was not government procurement, and therefore did not fall within a GATT exemption from the national treatment obligation.

5.1.6 Land access and availability

Access to land has always been a key challenge to the success of solar and wind projects. The development of transmission and distribution infrastructure in India have brought complications arising from fragmented ownership, unregistered land, and overlapping permits [81]. Land procurement often reflect a lack of agreement between community members, land owners, and the government over issues such as rightful ownership and the fairness about the price of the land. Some delays represent genuine concerns, while others reflect bureaucratic delays or opportunistic behaviour. Land related issues and complications have led to the cancellation of many projects.

5.1.7 Regulatory settings

India ranks 29th in the 'ease of doing business' category related to the solar industries among 190 countries [82]. It is a remark for the better performance of the country in the case of business friendliness for investors in the renewable energy sector.

5.2 Impetus to solar rooftop in India

For any kind of business or a technology to gain the confidence of market and to flourish there are some motivational factors that promote the growth of the technology. These include commercial, industrial, geographical etc. and it varies from places to places. In case of Indian market the percentage of the factors that affect the market is high because of its traditional nature. Few of the factors that impacts the solar rooftop system are described below:

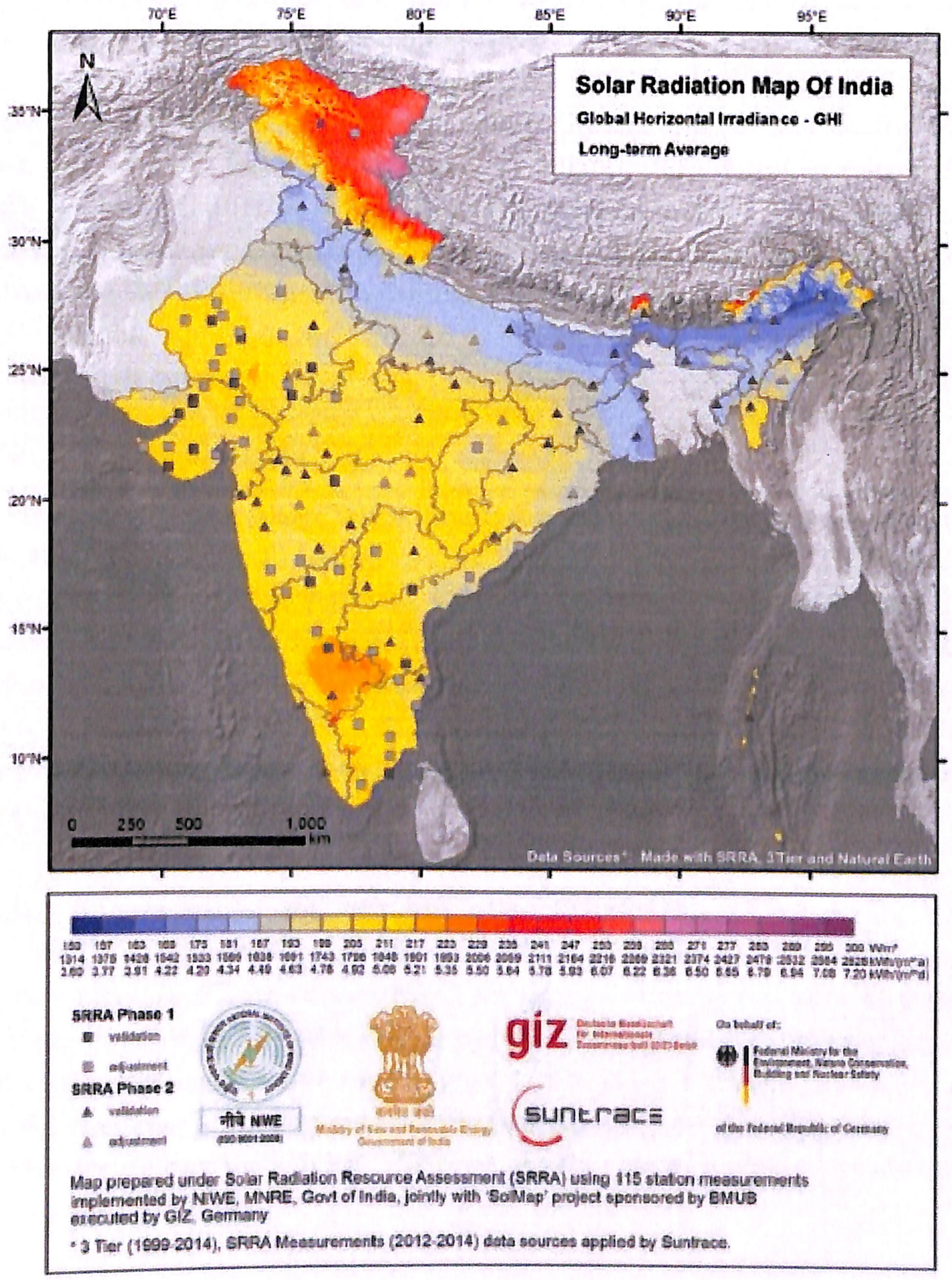

Figure 5.1: Global horizontal irradiance map of India

5.2.1 Solar radiation availability

The economics of solar PV depends on the availability of solar radiation. The availability of solar radiation in-turn depends on the geographical location of India. The geographical location is favourable for the growth and development of solar PV because it lies between the Tropics, which receive maximum solar radiation throughout the year. The geographical extent of India lies between 8°4′ to 37°6′ north latitude and 68°7′ to 97°25′ east longitude and it is the 7th largest country in the world, having landmass of 2.9 million km^2. the annual average direct normal irradiance in most of the Indian states is around 4.5 to 5.0 $KWh/m^2/day$ as per the stats shared by the NREL which is enough to produce 6,081,709 TWh/year putting India among the top solar PV generator countries like Brazil, China, and United States. A solar radiation map of India has been generated in collaboration with German consulting company Suntrace GmbH as shown in the figure 5.1. Increase in temperature will decrease the performance ratio of the solar PV system and therefore to get maximum power from the solar PV system, the ambient temperature must be normal [83]. Figure 5.2 indicate the temperature profile of India, as developed by the Indian meteorological department.

5.2.2 Government Initiatives

Despite the fact that the solar PV's are more economical and environmental friendly the growth of solar PV in Indian market is comparatively less [84]. The government plans to improve the existing 10-12% solar PV share to approx. 40% by 2022. The government had taken various measurements to improve the cumulative installed capacity of the solar rooftop PV segment up to 2020. Under JNNSM the government has approved the scaling up of funds associated with solar rooftop PV from Rs. 6000 million to Rs. 50,000 million up to 2020 [49]. This method will improve the solar PV installed capacity to achieve the target of 40 GW by 2022.

The initial investment of the off grid solar PV is high as compared to other decentralized ways of power generation like diesel generator etc. The investment cost will further increase if batteries are used for energy storage. In-order to tackle this situation the government has decided to provide a direct subsidy into the account of the end customers irrespective of the type of the solar PV been constructed. The subsidy for the solar PV's depends on the benchmark cost of the respective project and will be decided by the MNRE. The benchmark costs of various types of solar PV projects has been revised in 2017-18 is given in the table 5.1.

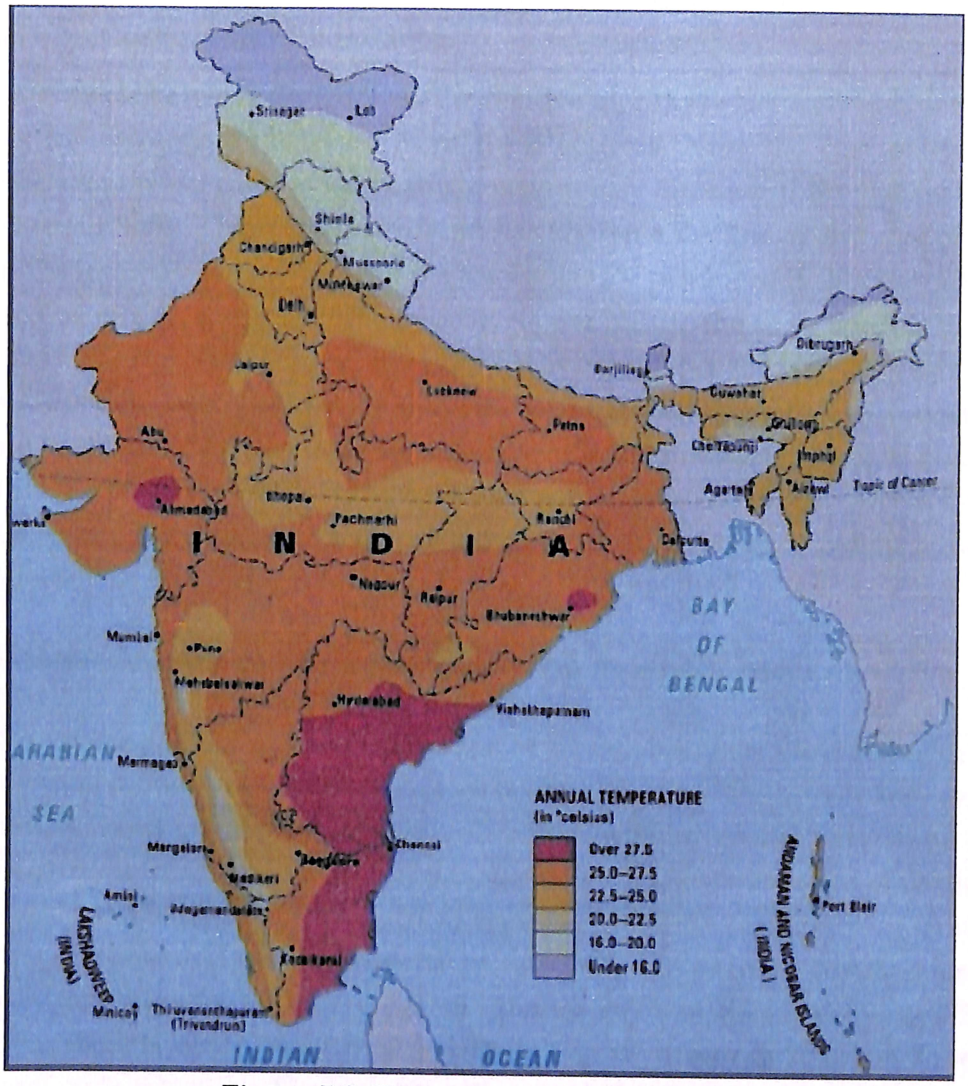

Figure 5.2: Temperature map of India

Table 5.1: Benchmark cost for subsidy disbursement of off-grid solar projects

S.No.	Off-grid solar power plant type	Category	Benchmark cost (in US $)
1	Lighting systems ($/$W_p$)	LED (Home light system + Solar lantern)	5.33 $
		Streetlights (Lead-acid battery)	
		Streetlights (Lithium-ion battery)	7.44 $
2	Power packs (With battery bank @ 7.2 Vah/W_p) ($/$W_p$)	Up to 300 W_p	3.13 $
3	Solar power plant with battery back up ($/$W_p$)	1 KW_p to 10 KW_p (With battery bank @ 7.2 VAh/W_p)	2.11 $
		1 KW_p to 10 KW_p (With battery bank @ 3.6 VAh/W_p)	1.69 $
		1 KW_p to 10 KW_p (With battery bank @ 1.2 VAh/W_p)	1.41 $
		10 KW_p to 100 KW_p (With battery bank @ 7.2 VAh/W_p)	1.88 $
		10 KW_p to 100 KW_p (With battery bank @ 3.6 VAh/W_p)	1.50 $
		10 KW_p to 100 KW_p (With battery bank @ 1.2 VAh/W_p)	1.25 $
4	Solar power plant without battery backup ($/$W_p$)	Up to 100 KW_p	1.57 $[a]
		100 KW_p to 500 KW_p	1.41 $[a]
5	Solar street lighting system	Up to 100 KW_p	3.13 $
6	Solar photovoltaic water pumps ($/hp)	Up to 3 HP (With DC Motor)	1879.20 $
		3 HP-5 HP (With DC motor)	1487.70 $
		5 HP-10 HP (With DC motor)	1487.70 $
		Up to 3 HP (With DC Motor)	1566.0 $
		3 HP-5 HP (With DC motor)	1331.10 $
		5 HP-10 HP (With DC motor)	1331.10 $

5.2.3 Cost of solar PV module

The Indian market always depends on the relative merits of electricity generation and the costs for extracting electricity from these sources. Now the cost of electricity generation from fossil fuels is increasing continuously because of limited reserves of coal and fossil fuels. The solar investment has shown a decline as the cost of silicon wafer in the international market. Of the total solar PV produced in 2015, around 93% was based on silicon wafer technology [85]. As per NREL, the solar module accounts for around 50% of the total cost of the solar PV system. Since for last few years cost of solar module decreased and so the overall cost of the solar module also decreased. The main cost barrier for the solar PV generation is the installation cost as compared to the other forms of energy generation. Government provides all support in the form of capital subsidies, easier loans, low rate of return, etc. in order to enhance the solar PV installation in the country.

5.3 Discussion on policy implication on solar PV market

Present years see a boom in the contribution of renewable energy technologies to the electricity generation worldwide. This has been made possible by advancements in the technology and the growing public concern over rising global temperatures and pollution attributed to the industrial scale production and consumption of fossil fuels. Being located in the tropical region, India receives ample amount of solar irradiance throughout the year that enables solar PV generation possible in the country. Since the technology necessary for the conversion of solar energy into electrical energy through solar PV system is complicated and expensive, government support is a must to initiate any such activities. The country has an ambitious renewable energy target of 227 GW by 2022, with 100 GW through solar energy, following the historic Paris Agreement in 2015. Between 2014 and 2018, India increased its solar-generation capacity eight times from 2,650 MW over 20 GW

Even after having numerous successful implementation of solar projects in the country, still few policy related issues needs to be assessed. Introduction of goods and services tax (GST) in the country has resulted in the sprouting of few uncertainty. There is still confusion persisting related to the rate to be applied for the EPC services. There are conflicting advance rulings in different states varying from anywhere between 5% and 18% GST. To alleviate the shadow of angst looming over the industry, the central government must intervene and put to rest this confusion. Failure in this case would result in the adverse affecting of the investors. This would harm the sector in a long run.

Given the growing commercial demand for solar panels, India is widely viewed as a dumping ground for foreign companies who are able to produce and export the Solar cells and Modules cheaper than Indian manufacturers. The introduction of the Safeguard Duty, which is essentially a 25% tariff on foreign solar panels, will go a long way in ensuring that domestic manufacturers remain competitive and commercially viable. The safeguard duty will also help create energy security in India and encourage manufacturers to become active participants in the country's shift towards sustainable energy. Safeguard duty may propel foreign manufacturers to set up production facilities within India leading to help the country move towards tapping its vast reserves of solar power, while simultaneously creating thousands of jobs in largely rural areas. Arguably one of the most negative impacts on the solar industry has been due to currency devaluations. During the course of 2018, the rupee has seen a fall of 15% compared to the dollar, creating an enormous, possibly insurmountable challenge for the solar industry. The devaluation of the rupee has also resulted in considerably inflated costs of cells, modules and inverters, along with auxiliary components such as structures and cables, owing to the fact that the prices of imported metals have also increased substantially. Even though the policies of the government are in favour of the solar PV industry and expect to further develop the PV market, the issues of GST and drop of value of Indian currency pose serious issue to the market. Solar power has more potential than just the energy generation. Continuous use of fossil fuels for more than 100 years have resulted in serious issues like climate change and pollution, which can be reduced by the adoption and wide use of clean energy technologies like solar PV systems.

Chapter 6
Conclusion

Solar PV installation are gaining popularity and acceptance because of the ever increasing power demand and rising concerns for a clean environment. Apart from the techno-economic evaluation of the solar PV system and the enhancement achieved in the number of installations of PV systems because of different policies of the government, a proper analysis regarding the market growth of PV system accessories mainly the solar PV modules is necessary. In this report, the present status of different solar PV systems are assessed along with the policies and acts developed by the central government and state governments for the enhancement of the solar PV installations there by increasing the PV market in India. Also few recommendation for improving the policies are also put forwarded in this dissertation. Even though the policies of the government are in favour of the solar PV industry and expect to further develop the PV market, the issues of GST and drop of value of Indian currency pose serious issue to the PV market.

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