Rooftop Solar Photovoltaic Energy - A case Study of India

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Abstract

Photovoltaic (PV) devices generate electricity directly from sunlight via an electronic process that occurs naturally in certain types of material, called semiconductors. Electrons in these materials are freed by solar energy and can be induced to travel through an electrical circuit, powering electrical devices or sending electricity to the grid. Rooftop solar photovoltaic (PV) systems that allow consumers to generate electricity at the point of consumption, and send any excess to the grid, have emerged as an attractive option. This article discusses the Government of India demonstration and commitments to rooftop solar PV by setting ambitious targets by 2022. India aims to hit a solar capacity of 100 gigawatts (GW), 40 GW of which is to come from rooftop systems. The state of Karnataka has set an ambitious goal of its own 400 MW of grid-connected rooftop solar PV by 2018. Indian rooftop solar PV system could be a model for other developing countries facing energy crises.

Key Words: Energy, Renewable energy, Energy conservation

1. Introduction

Energy is essential to economic and social development and improved quality of life in all countries. Problems with conventional energy are that it produces greenhouse gases which affect climate and can't sustain for long time. It is essential to tackle these problems by moving towards renewable and clean energy while at the same time it also important to improve the life of billions who don't have access modern energy service. In September 2015, the 193 United Nation member states adopted the new Sustainable Development Goals consisting of 17 goals, supported by 169 targets and underpinned by 230 global indicators. Access to affordable, reliable, sustainable and modern energy for all is one of the UN sustainable goals set for achievement by 2030 [1]. Energy is one of the main Increased use of clean energy will be essential to tackling the problem of climate change, not only to reduce greenhouse gas (GHG) emissions but also to improve energy security, sustain the growth of the global economy, and provide energy access to the billions of people still living without modern energy services [2]. With fossil fuels still meeting more than 80 percent of the world's primary energy demand, energy production and use accounting for roughly two thirds of the world's GHG emissions, energy sector trends will play a large role in defining the world's future emissions trajectory [3].

Renewable energy is energy generated from natural resources which includes solar, wind, tides and geothermal. Photovoltaic is the direct conversion of sun light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current results that can be used as electricity. The photoelectric effect was first noted by a French physicist, Edmund Bequerel, in 1839, who found that certain materials would produce small amounts of electric current when exposed to light. In 1905, Albert Einstein described the nature of light and the photoelectric effect on which photovoltaic technology is based, for which he later won a Nobel Prize in physics. The first photovoltaic module was built by Bell Laboratories in 1954. It was billed as a solar battery and was mostly just a curiosity as it was too expensive to gain widespread use. In the 1960s, the space industry began to make the first serious use of the technology to provide power aboard spacecraft. Through the space programs, the technology advanced, its reliability was established, and the cost began to decline. During the energy crisis in the 1970s, photovoltaic technology gained recognition as a source of power for non-space applications (http://science.nasa.gov/science-news/science-at-nasa/2002/solarcells/). The basic operation of photovoltaic cell is illustrated in figure 1.

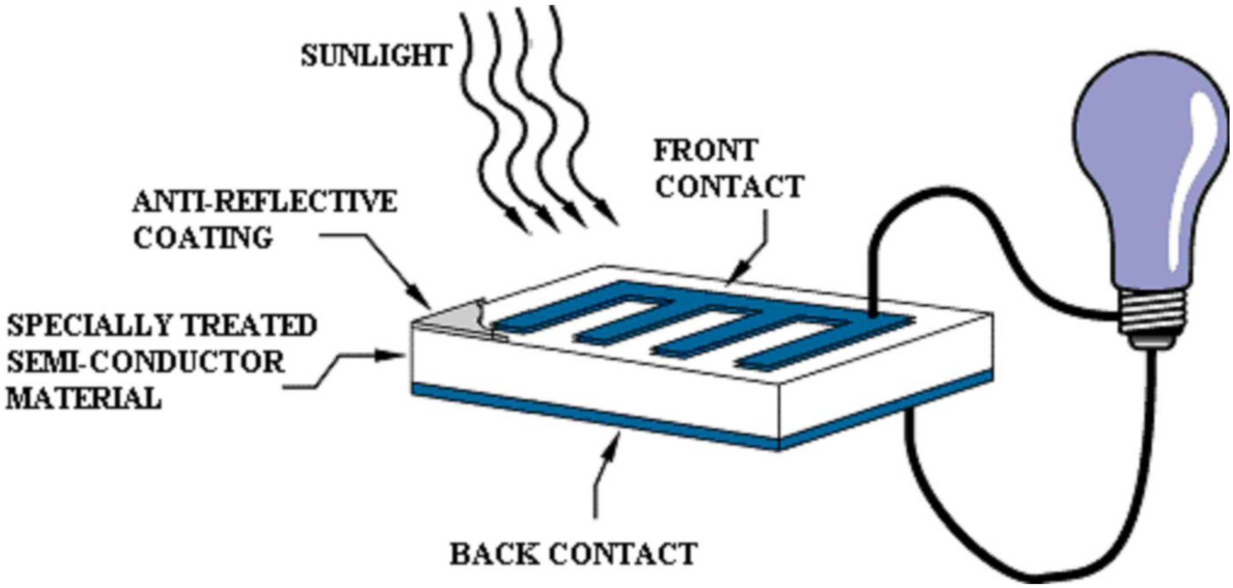

Figure 1. Basic Operation of Photovoltaic Cell (http://science.nasa.gov/science-news/science-at-nasa/2002/solarcells/)

The general formula which is commonly used to calculate the solar energy output is,

E = A x r x H x PR

Where;

E = Energy (kWh)

A = Total solar panel Area (m^2)

r = solar panel yield (%)

H = Annual average solar radiation on tilted panels (shadings not included)

PR = Performance ratio, coefficient for losses (range between 0.5 and 0.9, default value = 0.75).

Research conducted by Umar and Wamuziri looks at selected five different locations in Oman show a significant potential of solar for electricity generation [4]. The potential of energy contents in these locations is shown in figure 2.

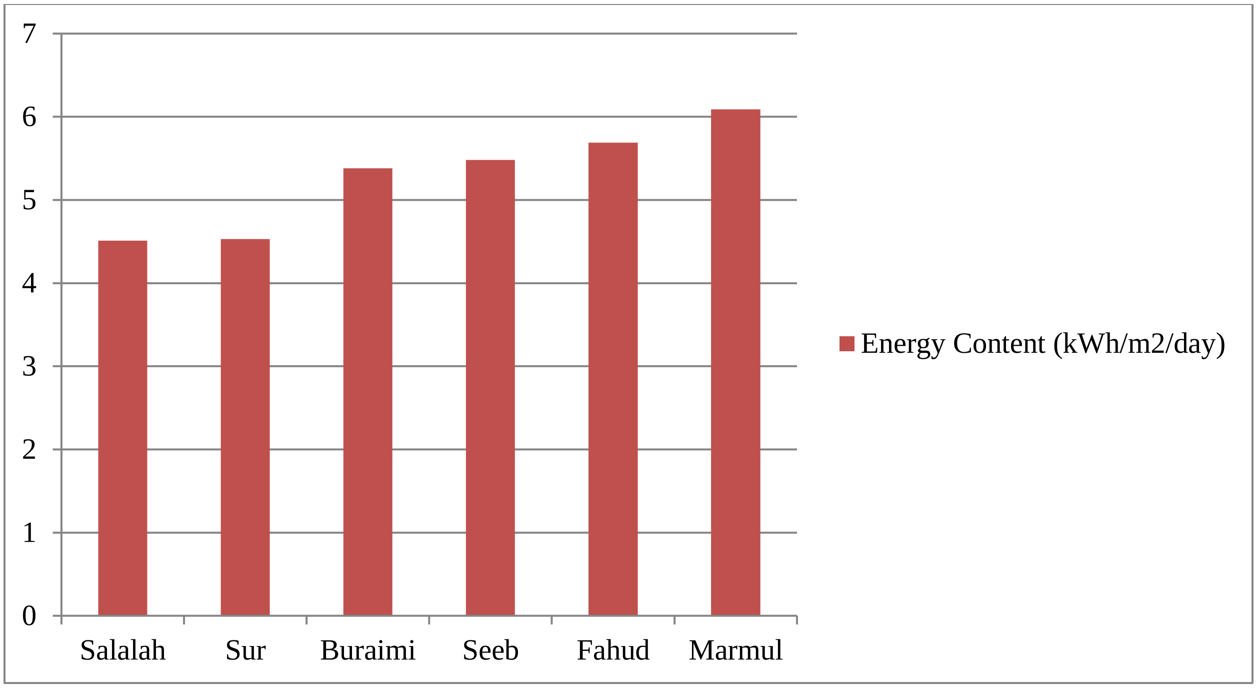

Figure 2. Solar Energy Content at Six different Locations in Oman [4].

Although there is a rich solar potential in different parts of the world for electricity generation, however dust and sandstorm are some of the factors that can reduce the efficiency and output of solar PV (photovoltaic) installation. Solar panels' efficiencies can decrease during sandstorms, and some of these decreases are permanent when the protective glass sheets are damaged by erosion [5]. Research conducted by Mani and Pillai [6] described different conditions influencing PV performance and dust deposition and recommended cleaning cycle to mitigate impact of dust. Further research need to be conducted to fully understand the issues of solar energy storage and distribution considering the local electricity demand and location. Research conducted in UK by Alexander and James [7] considered the impact of distributed energy storage in the form of heat pumps and electric vehicles which can help to balance a 100% renewable UK electricity grid. Chia Ai Ooi et al. [8] considered the use of in grid-scale battery energy storage systems (BESSs) by integration of a full-bridge modular multi-level converter and a large number of lithium-ion cells interfacing with an AC electrical grid.

This article discussed how the India is using the solar energy with a specific reference to solar rooftop photovoltaic panels and further described the policies which will support to increase the use of such panel for electricity generation. Firstly the global status of solar PV is discussed followed by the progress made by India taking a specific example of a major city. The support mechanism for adopting solar PV is briefly highlighted.

2. Global Status of Solar PV

In many countries, the number of prosumers installing rooftop solar PV systems is rising [9]. Supportive policies are emerging, such as net-metering for rooftop solar PV systems, to promote prosumer involvement with the electricity system (the grid). As of 2015, 48 countries, both developed and developing, had implemented net-metering policies [10]. In the United States, net-metering helped 1.2 Gigawatts (GW) of residential solar to come online in 2014 [11] and is projected to bring another 5 GW per year online by 2020 [12]. In several other countries, rooftop solar PV is emerging as a popular choice for electricity customers. Over 70 percent of solar PV capacity in Germany is classified as residential, commercial, or industrial. In the Belgium, Czech Republic, Denmark, and the Netherlands, over half of solar PV capacity is classified as residential [13]. The Chinese National Energy Administration set a goal of 7 GW in distributed solar PV capacity7 for 2015, with at least 3.15 GW coming from rooftop solar PV [14]. Globally, distributed solar PV8 is growing rapidly, with projected installation of 346 GW between 2015 and 2024 [15]. This represents an increase from a total installed capacity of roughly 12 GW in 2008 and just over 100 GW in 2014 [16]. Much of this growth is expected to come from the residential sector, where solar PV capacity is likely to almost double from approximately 45 GW in 2014 to roughly 80 GW by the end of 2017 [16].

3. Solar PV in India

The Government of India has set an ambitious national target of 100 GW of grid-connected solar power capacity by 2022. This national target has direct and significant implications for the residential sector because 40 GW is expected to come from rooftop solar PV systems [17]. India has enough rooftop space and market potential to meet its targets. The estimated technical potential of rooftop solar PV in urban settlements is around 352 GW and the estimated market potential is roughly 124 GW. This is enough to meet India's current target three times over, meaning that the goals are technically and economically viable [18]. However, for India to meet its rooftop solar PV goals, a significant increase in the adoption rate of rooftop solar PV among residential and other customers will be required. The economics of rooftop solar PV systems are becoming more attractive to customers across India as system costs come down and electricity tariffs continue to rise. Solar energy prices have dropped significantly in the last five years, from 17.90 INR per unit in 2010 [16] to bids as low as 5.05 INR per unit as of July 2015 [19]. Rooftop solar PV has already reached "grid parity"12 in 12 states for industrial and commercial electricity customers under certain policy conditions [20]. Electricity tariffs vary widely from state to state but, on average, between financial year 2009–10 and financial year 2013–14, residential tariffs increased by 15 percent and commercial tariffs rose by 16 percent (Table 1). This represents an annual increase of roughly 5 percent [21].

Customer	**2011-2012**	**2013-2014**
Residential	3.14	4.08
Commercial	6.9	7.64

Agricultural	1.44	1.83
Industry	5.14	6.26
Railway	5.54	6.64

Table 1. Average Indian Customer Tariff by Customer Type, 2011–2012 and 2013–2014 (Indian Rupee /kilo-Watt-hour) [21].

3.1. India Recent Progress on Solar PV

As of October 31, 2015, total installed rooftop solar PV capacity in India was 525 MW with 143 MW in residential installations [22], up from 285 MW in October 2014 [23] and 350 MW in June 2015 [20]. Figure 3 shows India rooftop solar capacity and expected growth (MW) by 2019. Rooftop solar PV capacity is projected to continue growing rapidly at a compound annual growth rate around 60 percent, reaching 4 GW by 2019 [20]. For comparison, from 2007 through 2014, renewable energy generation capacity in India grew at a compound annual growth rate of 18.4 percent [24] and total solar PV capacity grew at a compound annual growth rate of over 90 percent [16].

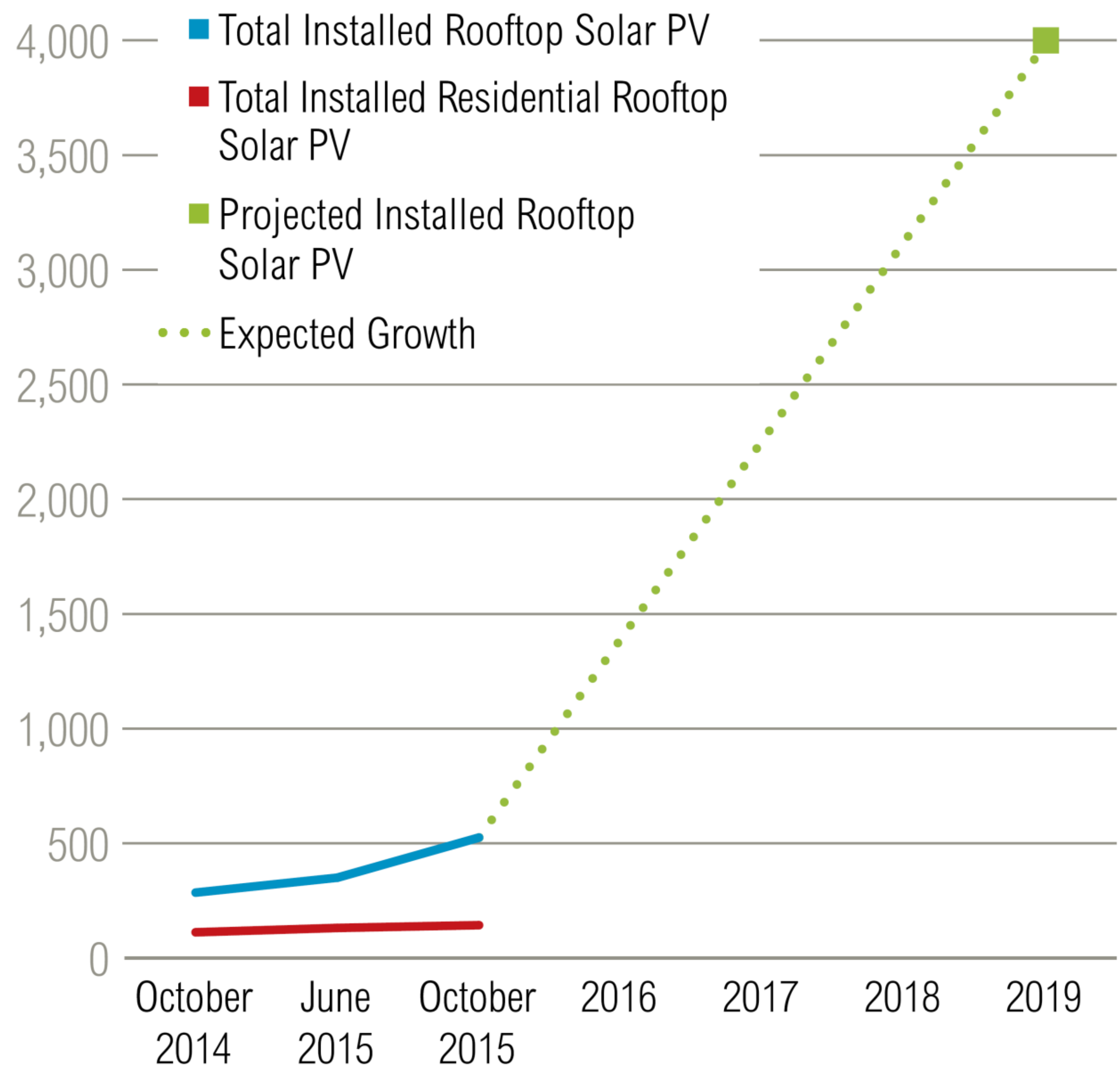

Figure 3. India's Rooftop Solar PV Capacity and Expected Growth (MW) [20].

3.2 Example of Karnataka State:

With over 9.6 million inhabitants, Bengaluru, in the state of Karnataka, is India's fourth largest city [25]. BESCOM, Bengaluru's electricity utility, serves 8.9 million customers, 76 percent of whom are residential [26]. Like many utilities serving rapidly growing urban centers in developing countries, Bangalore Electricity Supply Company Limited (BESCOM) is struggling to supply sufficient power to meet demand. Bengaluru depends largely on hydro to meet its energy needs. However, because of technical challenges and dropping hydro reserves, BESCOM has recently fallen short of meeting peak demand roughly 3,400 Megawatts (MW) by as much as 900 MW [27]. To meet demand and minimize the risks associated with droughts and erratic monsoons, BESCOM will need to diversify its electricity supply.

Rooftop solar photovoltaic (PV) systems can help reduce the pressure to meet demand by providing electricity supply at the point of demand. Like other large developing cities, Bengaluru is promoting rooftop solar PV largely because of this benefit. A growing number of "prosumers" (energy consumers who produce their own energy at the point of consumption and export their excess to the grid) are installing rooftop solar PV systems in the city. In November 2014, BESCOM introduced a net-metering program that allows consumers who generate electricity from solar power to transfer their surplus to the grid. As of March 2016, the program had resulted in over 5.6 MW of grid-connected rooftop solar PV systems on 262 rooftops. However, the rate of new connections will need to accelerate if Karnataka is to meet its solar goal of 400 MW of grid-connected rooftop solar PV by 2018 [28]. Karnataka rooftop solar PV targets and capacity are shown in figure 4.

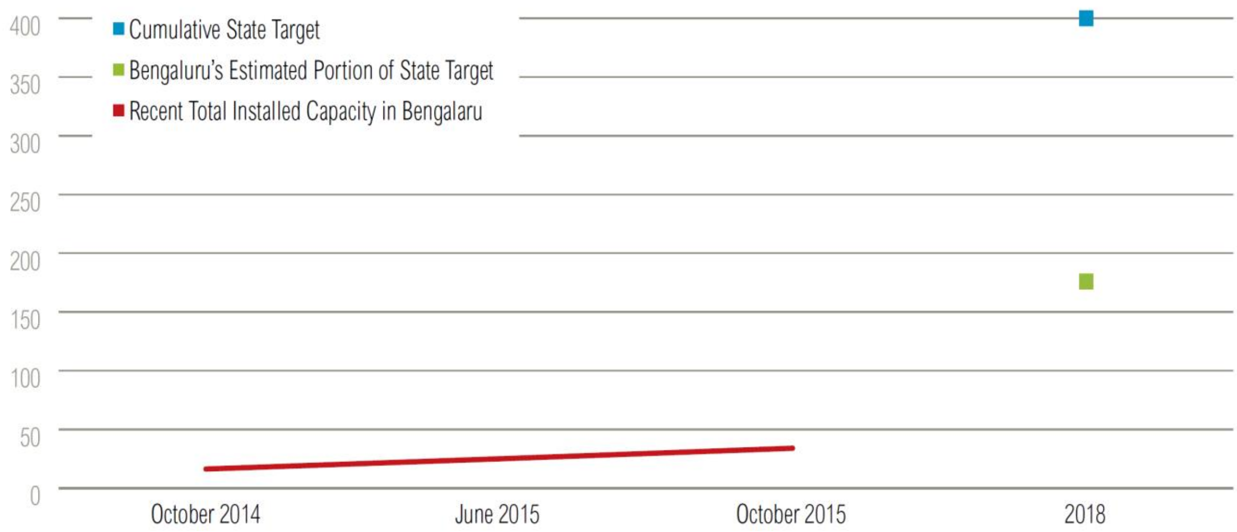

Figure 4. Karnataka Rooftop Solar PV Targets and Capacity [28]

Other states with net-metering policies show similar trends in capacity addition. In 2012, the Government of Tamil Nadu set a target of 3,000 MW of solar power by 2015 [29]. Total installed rooftop solar PV reached 76 MW in October 2015, 19 MW of which came from the residential sector. In 2013, the Government of Uttar Pradesh set a 500 MW target by 2017 [30], and by October 2015 reached a total installed rooftop solar PV capacity of 36 MW, 16 of which came from the residential sector [22].

Many Indian states are introducing their own solar policies, including capacity targets and net-metering schemes. As of May 2015, 19 states had either introduced or drafted a solar policy. The cumulative target for solar power capacity in these 19 state policies is 50 GW. While this falls significantly short of 100 GW, 10 of the 19 targets are to be reached by 2019; three years before the date of India's national target [20]. The number of states with net-metering schemes has increased dramatically over the last year. By October 31, 2014, nine states and union-territories had developed at least a draft net-metering scheme [23]. By April 2015, the number had grown to 12 [31] and, by the end of May 2015, 25 states reportedly had proposed policies [20].

4. Support Mechanism for Polar PV in India:

Policymakers use a number of support mechanisms to encourage the spread of renewable electricity technologies. Most commonly, these policies include renewable purchase obligations, feed-in tariffs, reverse auctions, public benefit funds, and net metering programs. These mechanisms have been well documented and their merits and drawbacks have been evaluated and compared at length. For governments choosing among policy mechanisms, their particular needs and objectives will determine the most effective policy combination [32]. In India, governments have implemented several support mechanisms in addition to net-metering policies, some of them are briefly discussed here.

4.1 Renewable Energy Certificates

Regulated by the Central Electricity Regulatory Commission, renewable energy certificates seek to create a national market for renewable energy-based generation, where renewable energy generators can sell renewable energy generation at a preferential tariff [33].

4.2 National Capital Subsidy Scheme

A subsidy for rooftop solar systems between 1 kilowatt (kW) and 500 kW is available from the Ministry of New and Renewable Energy's Grid-Connected Rooftop and Small Solar Power Plants Programme. The subsidy provides "15 percent of the benchmark cost" to qualifying residential, institutional, government, and social sector buildings [34].

4.3 Accelerated Depreciation Benefit

Commercial and industrial buildings that are not eligible for the national subsidy are eligible for an accelerated depreciation benefit of 80 percent of the capital cost of the rooftop solar PV system applied in the first year of operation [35]. This provides a value of approximately 26 percent of the system's capital cost when fully realized.

4.4 Gross Metering

An arrangement where the entirety of electricity generated from a renewable energy system (in most cases rooftop solar PV) is directly fed into the grid and the customer receives electricity supply from the utility grid. Separate meters read energy generated and energy consumed, and customers are billed separately for what they consume from the grid and what they export to the grid [36].

5. Conclusion

Energy is essential to economic and social development and improved quality of life in all countries. Access to affordable, reliable, sustainable and modern energy for all is one of the United Nations sustainable goals set for achievement by 2030. This paper recognizes that rooftop solar PV systems can help reduce the pressure to meet demand by providing electricity supply at the point of demand. The India's commitment and capacity of rooftop solar PV system and expected growth by 2019 are particularly discussed in this article. The expected growth of solar PV system in India is supported by Government policies, which could be a model to be followed by other developing countries having energy crises. It is necessary that further research need to be conducted to fully understand the issues of solar energy storage and distribution considering the local electricity demand and location. An appropriate cleaning cycle will help to reduce the effect of dust and sandstorm on the efficiencies of solar PV. Experimental research conducted by Vasisht et al. [37] in India focused on seasonal variation recommended that it is very essential to maintain the surface of the modules at low temperatures, especially during summers and similar weather conditions of the year to reap the maximum benefit from rooftop solar PV installations.

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