SAMVAD: SIBM Pune Research Journal, *Vol XVI, 1-12, December 2018.*
ISSN (Print) : 2249-1880
ISSN (Online) : 2348-5329

Solar Rooftop Systems: A Promising Option for Renewable Energy in India

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Abstract

The advantage of solar energy when compared to other renewable along with long-term reliability and almost immune to climate change has motivated countries around the world to frame pro-solar energy policies. However, consumers' willingness and acceptance of solar rooftops in India is relatively low as compared to consumers in other countries. High initial investment and uncertainty of returns are significant barriers to installation of a solar rooftop. The paper presents, a cost-benefit analysis using break-even point, discounted payback period and internal-rate-of-return of the solar rooftop systems of varying capacities both with and without subsidies. The results show that there is a direct relationship between the size of the solar rooftop systems and individual financial return, which means that as the size of the solar systems increases from 1kW to 10kW the return on investment also increases gradually. The paper concludes that solar rooftop systems provide huge potential to tap the natural source of energy at lower cost as well as reducing emission intensity of growth, particularly for energy hungry countries like India in their pursuit to high growth trajectory.

Keywords: Entrepreneurial Opportunity, Financial Viability, Renewable Energy, Solar Rooftop System

1. Introduction

Solar is one of the most promising renewable energy with long-term consistency and almost immune to climate change and thus motivating many countries around the world to formulate solar energy policies to reduce dependence on fossil fuel (Solangi et al., 2011). In comparison to other renewable energy, the Solar Photo-Voltaic (SPV) has far more scope on account of both its primary raw material (silica) and source of energy (sun) being freely available in abundance (Arora et al., 2010; Magana, 2015). The generation of electricity through solar rooftops has multiple direct and indirect benefits such as –cost-effective mitigation option to reduce Green-House Gas (GHG) emissions as well as avoidance of associated pollution arising out of coal-based electricity generation (Ahmad & Alam, 2018); avoid forest degradation from coal-mining (Kishore, Shah, & Tewari, 2014); help meet peak power deficits; ideal renewable source of energy; considerable reduction in Transmission and Distribution (T&D) losses (Narula & Reddy, 2015 and transmission lines from electricity grids; and enhanced regional/national energy independence (Sidiras & Koukios, 2004; Tsoutsos, Frantzeskaki, & Gekas, 2005).

The positive aspect is that there has been a dramatic fall in the prices of solar panels (contributing 55-70% of total solar system cost) in recent years (Razdan, 2016). Staggering $77 per watt in 1977 less than $1 per watt in 2012 (Carr, 2012) almost at par with coal in 2016 and potentially even cheaper than coal in near future (Aggarwal & Bhaskar, 2017; Bloomberg New Energy Finance, 2016; Kishore, Shah, & Tewari, 2014). The sharp reduction in the price of SPV panels coupled with the growing scarcity of fossil fuels leading to price fluctuations (Hasnain, Alawaji & Elani, 1998) are the key motivating factors for energy-deficit countries, including

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India, in formulating pro-solar energy policies (Thakur & Chakraborty, 2015). As a result, the cumulative global solar energy installation which was just 0.3 Giga Watt (GW) in 2000 has surpassed 300 GW at the end of 2016 (Bridge to India, 2017) and is projected to reach 613 GW by 2020 (Renewable Energy Policy Network for the 21st Century, 2014).

2. Motivation for Research

2.1 Solar Potential and Targets Set by India

India has enormous potential to harness solar energy to meet its growing energy needs. As per the Central Statistical Organization (Central Statistics Office, 2017) report, the potential of renewable in India include – solar energy (62.48%) followed by the wind (33.78%), small-hydro power (1.65%) and biomass, waste to energy and bagasse based power (2.09%). A shift from coal-based electricity source to solar rooftop system has the greatest potential in reducing emissions intensity of fast economic growth for countries like India and to play a vital role in achieving India's social, political and environmental objectives and help the country ensure its energy security at an affordable price and to take out millions of is people out of poverty (Yenneti, 2016).

Among the leading states, in terms of solar energy potential include – Rajasthan with a share of about 19%, followed by Jammu and Kashmir with 15%, Maharashtra 8.6% and Madhya Pradesh 8.2% as on March 31, 2017 (Calculated from data available in Central Statistics Office, 2017 report).

To reduce its dependence on import of fossil fuel and meet its energy requirement in a sustainable manner, India has set a tall target of 100 GW solar energy installations by the year 2022 under Jawaharlal Nehru National Solar Mission (JNNSM) 2015 a five fold increase from the earlier 20GW targets. Once realised, this would help the country reduce 170.483 million tons of carbon dioxide (CO_2) emissions over the full life cycle of these projects and generate one million jobs (Tripathi, 2016). This will also help India meet its Paris Agreement (COP21) 2015 targets. At present India sources 76.5% of its electricity requirement from highly polluting thermal power plants (Central Electricity Authority, 2016; Ministry of Power, 2018).

2.2 Global Status of Solar Rooftop Systems

The rooftop solar systems have gained significant share in overall solar energy installations in many countries. For example, 16.5% of the all households in Australia have solar system on their rooftops with 85% of these having less than 10 Kilo Watt (KW) of capacity (The Conversation, 2016). In Germany, about 74% of total solar energy (total 42.5 GW) is mounted on 1.5 million household rooftops with less than 10kW capacity (German Cooperation, 2016; Fraunhofer Institute for Solar Energy Systems, 2017). Similarly, 46% of total solar energy production in the USA (total 42 Giga Watts) is from solar rooftop systems, 60% in Spain (total 4.7 GW), 18% in China (total 112 GW) (Bridge to India, 2017), 20% in UK (total 12.5 GW) (Bloomberg New Energy finance (BNEF), 2016; Clover, 2017) and only 5% in India (total 21.6 GW) (MNRE website) as on March 2018. Substantial initial investment and uncertainty of return has been the primary barriers towards the acceptance of solar system installation in developing countries like India.

2.3 Status of Solar Rooftop Systems in India

The Government of India has set a target of 40 GW of photo-voltaic rooftop solar systems to be installed by the year 2022. According to Census 2011, there are 148 million households in India with appropriate brick, stone, asbestos and concrete roof (NITI Aayog, 2017) withpotential for solar rooftop installation of various capacities ranging from 1kW to 10kW. As on January 6, 2017, the State Electricity Regulatory Commission of all 34 States/UTs have notified regulations for net-metering/gross-metering with capital subsidy up to 30% of project cost for general category States and up to 70% of project cost for special category States/Islands for the vacant rooftop areas of buildings in residential/social/institutional sectors (EU – India Technical Cooperation Project: Energy, 2017). To provide the required subsidy for solar rooftop for residential and institutional consumer segment, the MNRE in 2015 sanctioned ₹50 billion ($781.25 million) (Bridge to India, 2017; Singh, 2015). Against an annual average target of more than 5000 MW of solar rooftop installations, only 823 MW installations was achieved as on 31st October 2017. Hence achievement of 40GW rooftop based solar systems by 2022 seems to be non-feasible given the past experience. Also, none of the states in India is likely to reach its objective by 2022 (Sekhar, 2016).

2.4 Status of Solar Rooftop Systems in Madhya Pradesh

Madhya Pradesh (M.P.) is located in Central India and it receives more than 300 rich sunny days (Ramachandra, Jain, & Krishnadas, 2011) in a year with NDI of 5.5kWh/m^2/day. As per the recent Central Statistics Office (2017), the renewable energy potential of the state has been estimated at 77,337MW, which accounts for 6.45% of the total national potential. About 80% renewable energy potential of the state is in the form of solar energy. As per Census 2011, there are six million households in M.P. with proper brick, stone, asbestos and concrete roof (NITI Aayog, 2017) having potential for solar rooftop system installation.

Government of India has indicated 5636 MW as Solar RPO target for M.P. by 2022. Out of the objective of 40 GW of solar rooftop development by 2022 by the MNRE, the state of M.P. has been allotted a target of 2.2 GW (NITI Aayog, 2017). The typical sanctioned load for a domestic household in M.P. ranges from 1kW to 5kW for a single household and 6kW to 10 kW in case of joint family household.

The present study tries to analyses the financial feasibility of rooftop solar power systems for household consumers in three cities namely Bhopal, Indore and Gwalior in the central Indian provenance of Madhya Pradesh. These cities are among the 48 cities identified for developing as 'Solar Cities' in the country (Energy Saver, 2017). The twin objectives of the current study are: 1. to identify optimum size of solar rooftop systems that could be viable and beneficial for the sample households, and 2. to explore entrepreneurial opportunity for solar rooftop solutions in the study area.

3. Research Methodology

We analysed the economics of rooftop solar PV system of 1kW, 2kW, 3kW, 5kW, 6kW, and 10kW capacity over the period of 25 years, the assumed life of SPV systems. Three capital budgeting techniques that is Break-Even Point (BEP) analysis, Discounted Pay-Back Period (DPBP), and Internal Rate of Return (IRR) were employed to estimate financial viability of the solar rooftop system of different sizes (1kW, 2kW, 3kW, 5kW, 6kW and 10kW). BEP analysis provide a quick glimpse for the investors and used as an initial assessment for a majority of the projects in India and abroad. BEP analysis used here for solar system analysis is similar to payback period method widely used for quick project estimation by the investors (Khan & Jain, 2015).

The key variables that are used for the study include - efficiency of solar panels, per kW cost, yearly operation and maintenance cost, Capacity Utilisation Factors (CUF), Normal Direct Irradiance (NDI) and electricity tariff prevailing in urban area of three cities of Madhya Pradesh namely – Bhopal, Indore and Gwalior. CUF is defined as the fraction of the actual productivity from a solar plant over the year to the maximum potential production from it for a year under the ideal situation. Thus CUF is a function of solar radiation measured in kWh/m^2/day on a bright sunny day. NDI is the quantity of solar energy received per unit area by a surface that is always held vertical (or normal) to the rays that come in a straight line from the way of the sun at its existing position in the sky.

The summary of the metrics used in the study for the calculation of cost and revenue streams of each size of solar rooftop system are summarized in (Table 1).

3.1 Categorization of Solar Rooftop Systems in Madhya Pradesh

Model 1: Domestic consumer installed solar system without subsidy – The first business model is for household consumers who installed solar system on their rooftop without receiving any amount of subsidy from the government. A few advantages of solar rooftop system include – absence of additional investment in creating basic structure to mount solar system and hassles in acquisition of land. Land acquisition is one of the biggest hurdles in big projects in India (Chaudhary, 2015; Times News Network, 2017).

Model 2: Domestic consumer installed solar system with subsidy provided by Government of India (GoI) – The second business model is for household consumers who are willing to install solar panels only with a subsidy of (currently 30% of project cost) from GoI for solar plant system installation.

Table 1. Summary of the computational elements used in the study

Solar rooftop of different capacity analysed in kW	**1kW**	**2kW**	**3kW**	**5kW**	**6kW**	**10kW**
Capital cost of Installation at ₹70 per watt (without subsidy)	70,000 ($1,094)	140,000 ($2,188)	210,000 ($3,281)	350,000 ($5,469)	420,000 ($6,563)	700,000 ($10938)
Capital cost of Installation at ₹70 per watt (with 30% subsidy)	49,000 ($766)	98,000 ($1531)	147,000 ($2,297)	245,000 ($3828)	294,000 ($4,594)	490,000 ($7,656)
Grid Tariff for domestic consumers in M.P. in ₹/kWh (Further detail in Table 3)	5.41 (8.45 cents)	5.80 (9.06 cents)	6.09 (9.52 cents)	7.06 (11.03 cents)	7.33 (11.45 cents)	7.51 (11.73 cents)
Annual O&M expenses for the first year at ₹1.2 million/ MW	1200 ($19)	2400 ($38)	3600 ($56)	6000 ($94)	7200 ($113)	12000 ($188)
Annual increase in O&M expenses	5.72% per annum until 25th year of the plant					
Opportunity cost of capital for household consumers	7.5% (highest interest rate on fixed deposit by a public sector bank in India)					
CUF	19% for Madhya Pradesh as per CERC					
NDI (Further detail is provided in Table 2)	The average for three cities Bhopal, Indore and Gwalior is 5.40KWh/m2/day					
Derating factor assumed	1% compound annual decline rate after third year (or 22 periods)					
Average increase in Tariff	5% annually in Madhya Pradesh for domestic consumers					
Solar rooftop system lifespan	25 years					
Opportunity cost of Capital for Entrepreneur	@ 10% and 11% (taking average return on mutual fund in India)					

Model 3: The Entrepreneurial business model without subsidy – The third business model analyses solar panel system installed by an independent entrepreneur on the rooftop of a household consumer with lease rental paid for solar power generation to the household owner. It is assumed by the authors that a rate of ₹1 per unit of electricity produced from the solar system with five percent annual increase over the life of the solar panels can incentivise household owners to agree for solar panel installations on their rooftops.

The entrepreneur sells the electricity generated at the prevailing market rate to the same household or to nearby small retail outlets with the sole objective of generating revenue and profits from this enterprise.

Model 4: The Entrepreneurial business model with subsidy – The fourth business model is same as model 3 discussed above with an additional incentive of a 30% subsidy component provided by the Government agencies to promote solar rooftop system. This subsidy amount is deducted from the total cost of the solar system installed.

While calculating IRR for a solar system additional parameter of the opportunity cost of capital is assumed for both consumers and entrepreneur. The opportunity cost lost due to investing in a fixed deposit of bank as 7.50% is used for calculation. Two discount rates for corporate taken into consideration at the rate of 10% and 11%. It is used since it the average rate of return on mutual fund investment in India.

In order to calculate the BEP, DPBP and IRR the procedure followed is discussed in detail explaining each parameter and rationale for using it.

The fundamental element of a solar rooftop system is the solar panels used, and the efficiency of SPV panels' decreases over its commercial use every year. The solar panel once installed continues to work after 25 years of their warranted life and even beyond 40 years without replacement but with a considerable reduction in its original efficiency (Jordan & Kurtz, 2012; Markham, 2015; Shahan, 2011; Sharma, 2011). The declining rate of SPV efficiency is taken into account while computing annual power production for each size of the SPV system. As reported in the literature the SPV efficiency during the first three years of operation remain constant (Narula & Reddy, 2015), while for remaining 22 years the efficiency declines by 1% annually. Thus, during the 25th year of operation, the efficiency declines to 80% of the original efficiency for solar panels (Dinçer & Meral, 2010; Maghami et al., 2016).

The MNRE has defined three different slabs of benchmark cost per watt according to the capacity of on-grid rooftop SPV system without battery backup. It is ₹70 ($1.09) per watt up to ten KW capacity; ₹65 ($1.01) per Watt for 11-100 kW capacity; and ₹60 ($0.94) per Watt for 101-500 kW capacity (Ministry of New and Renewable Energy, 2015-2017). Since the study used 1-10 kW solar system thus ₹70 ($1.09) per watt cost is used for the calculation purposes. The cost of a solar photovoltaic system includes all hardware and civil works cost along with a warranty of 25 years of commercial life for the solar panels.

With regard to operating and maintenance (O&M) expenses, CERC document on solar plant cost provides a range from 0.7-1.2 million per MW ($10,938- 18,750) of capacity during the first year of operation which will escalate at a rate of 5.72% per annum over the 25 years solar plant life (Central Electricity Regulatory Commission, 2016, 2017; M.P. Electricity Regulatory Commission, 2016).

The O&M expense increases proportionally with the reduction in the size of a solar plant and vice-versa. For the present study, the O&M expenses of ₹1200/kW ($18.75, maximum in range) have been considered (Note: 1000kW=1MW).

For the purpose of calculation of annual solar output two estimates are taken into account i.e. CUF and NDI. For the state of MP the CUF value of 19% is used in the study (M.P. Electricity Regulatory Commission, 2016).

NDI for MP is calculated by taking the average of three cities namely Bhopal, Indore and Gwalior. The daily average global solar radiant in these three districts of M.P. is calculated from NREL, 2017 radiation map as 5.40kWh/m^2/day (Table 2).

For estimating return on the solar rooftop system, the current electricity tariff prevailing in the state is used.

Table 2. Monthly average NDI for three cities Bhopal, Indore and Gwalior in kWh/m^2/day

Month	Bhopal NDI	Indore NDI	Gwalior NDI
January	6.09	6.27	4.58
February	6.95	6.96	5.98
March	7.21	7.07	6.90
April	6.69	6.82	6.41
May	6.88	6.87	6.04
June	4.56	4.6	4.62
July	2.52	2.18	2.89
August	2.31	1.88	3.43
September	4.9	4.26	5.08
October	6.8	6.84	5.49
November	6.44	6.29	4.91
December	6.09	6.21	4.54
Yearly Average	5.62	5.52	5.07

(Source: National Renewable Energy Laboratory, 2017)

The grid tariff in Madhya Pradesh is revised every year with a hike of 5-10% in different consumer categories. The average tariff rise considered for urban residential consumers is about 5% per annum. The historical trend suggests that the related tariff has assumed to rise at the rate of 5% annually (Asian News International, 2017; Press Trust of India, 2015; The Hindustan Times, 2016; Times News Network, 2017). As reported earlier, the electricity tariff charged for domestic consumption depends on the monthly consumption slab (actual number of units consumed during the month) and the authorised load (peak electricity consumption authorised every hour during the given month). The residential consumers' tariff is calculated from Madhya Pradesh *Paschim Kshetra Vidyut Vitaran* Company online bill calculator at different month units (M.P. Electricity Regulatory Commission, 2017; M.P. Paschim Kshetra Vidyut Vitaran Company Ltd., 2017) (Table 3). The final unit tariff for urban domestic consumers is calculated as: *Total charges (Energy Charge + Fixed Charge)/Number of units consumed.*

While calculating the per unit tariff, the maximum units in a particular slab are considered. For example, if monthly consumption slab is 101-150 units, then 150 units are considered in the formula. Based on the average annual units of electricity consumed by domestic household the solar plant system size is distributed in six parts

Financial viability for solar plant size 1 kW to 10 kW was computed using capital budgeting techniques. However, the results for 4kW was found to be same with 5kW and 6 kW to 10 kW were found to be same and hence only 6 kW and 10 kW results are reported (4kW, 7 kW, 8 kW and 9 kW not included).

The maximum yearly consumption of 16,200 units is considered since it is the maximum output expected from a 10kW solar power plant in a year in Madhya Pradesh.

The electricity generated from a solar plant during the year can be calculated in two ways:

First method: Electricity generated (kWh) = Installed capacity (kW) × CUF (%) × 8760(h)

Where CUF for Madhya Pradesh is 19% (Sharma, 2011) and 8760 is the number of hours in a year that is 365×24. Electricity produced by this method is computed as1664.4 units per kWh of solar plant per year.

Second method: Electricity generated (kWh) = Installed capacity (kW) × NDI × number of sunny days in a year

Thus, Electricity generated by second method is 1620 units per kWh of solar plant per year (considering 300 sunny days in a year in MP). A conservative value of 1620 units of solar power generated per kWh of solar plant per year is used in this study. Total expenses are equal to onetime installation charges plus operating and maintenance charges on a yearly basis.

The discounted payback period for the solar system of different capacity is discounted at the rate of 7.50% per annum (a rate offered by public sector banks in India on the fixed deposit investment) (Indiastat, 2017; Vishwanathan,

Table 3. Calculation of per unit electricity tariff at monthly consumption slabs (December 02, 2017)

Monthly Consumption Slab (Units)	Yearly consumption (Units)	Per Unit tariff (in ₹)
Up to 50 units	0-600	4.85 (7.58 cents)
51-100 units	601-1200	5.20 (8.12 cents)
101-150 units	1201-1800	6.18 (9.66 cents)
151-225 units	1801-2700	6.53 (10.20 cents)
226-300 units	2701-3600	6.83 (10.67 cents)
301-375 units	3601-4500	6.97 (10.89 cents)
376-450 units	4501-5400	7.17 (11.20 cents)
451-525 units	5401-6300	7.27 (11.36 cents)
526-600 units	6301-7200	7.32 (11.44 cents)
601-675 units	7201-8100	7.32 (11.44 cents)
676-750 units	8101-9000	7.42 (11.59 cents)
751-825 units	9001-9900	7.47 (11.67 cents)
826-900 units	9901-10800	7.47 (11.67 cents)
901-975 units	10801-11700	7.47 (11.67 cents)
976-1050 units	11701-12600	7.47 (11.67 cents)
1051-1125 units	12601-13500	7.57 (11.83 cents)
1126-1200 units	13501-14400	7.57 (11.83 cents)
1201-1275 units	14401-15300	7.57 (11.83 cents)
1276-1350 units	15301-16200	7.57 (11.83 cents)

(Source: M.P. Paschim Kshetra Vidyut Vitaran Company Ltd., 2017 online bill calculator)

2017). Similarly, the yearly O&M charges used in the calculation of solar energy system cost is compounded at annual rate of 5.72%, being the official rate provided by government agencies for renewable energy projects (Central Electricity Regulatory Commission, 2016, 2017).

The annual revenue obtainable from a solar plant is calculated in the following manner:

Annual Revenue (₹) = Electricity generated in a year (kWh) × related electricity tariff (₹/kWh)

Yearly cash operation flow is calculated for 25 years, the accepted life of the solar panel. After third-year onwards, electricity generation is depreciated by compound annual decline rate of one percent till the life of the plant while the corresponding electricity tariff is computed by using 5% increase.

4. Results and Discussions

Summary of BEP analysis for four types of solar systems (Table 4) shows that the large size solar rooftop system of capacity above 5kW have better financial viability as against less than 5 kW capacity.

For example, the BEP for a 1kW solar system is 8 years whereas for 6kW it is 5-6 years. Further, it is evident that the government incentives in the form of subsidy (30%) reduce the BEP for a 1kW solar system to 5-6 years from 8 years and 4 years from 5-6 years for a 6kW solar system for business model 2-household customers.

Similarly, for entrepreneurial business models 3&4, it is evident that larger size solar system has lower BEP which means that larger size solar panel system (above 5 kW and up to 10 kW) provides more and faster return on investment that the smaller size (less than 5 kW).

In order to analyse the opportunity cost of investment made in the solar system at the household level or as an entrepreneurial business opportunity, DPBP and IRR tools are used. In case of household consumer model, the return on fixed deposit investment (7.50%) is considered for calculating DPBP while for the entrepreneurial model an average return on the mutual fund in India (two rates 10 and 11%) is used for computing DPBP. The results for DPBP and IRR for all four solar business models are provided in (Table 5).

The difference in results of BEP and DPBP is due to the inclusion of time value of money in DPBP method. Time value of money impacts the return of solar system.

As evident from the data in Table 5, DPBP changes from 12 years to 7-8 years as the solar plant size increases from 1kW to 10kW with the corresponding IRR of 13.54% to 19.20% respectively. It is also evident from Table 5 that the IRR on the investment on solar system is better for larger size solar panel system (13.54% for a 1kW and 18.73% for 6kW respectively).

Further, the subsidy component improves the IRR for 1kW solar system from 13.54% to 18.86% and 6kW from 18.73% to 25.71%. Thus, it can be inferred that as the size of the rooftop solar system increases, it becomes economically more feasible and viable to the consumers.

On account of high DPBP (16-22 years) and lower IRR (10-12%) in case of small size solar system (1-3 KW) makes it financially unviable proposition for the entrepreneurs. The subsidy of 30% does improve IRR to 15percent, which may be financially viable, but a payback period of 10-14 years is still prohibitive for any entrepreneurial venture in small size solar system (Table 5).

Table 4. BEP results summary for all four solar systems business model with the respective solar sizes

BEP in years/kW of solar plant	1kW	2kW	3kW	5kW	6kW	10kW
BEP for residential (without subsidy)	8 years	7-8 years	7 years	6 years	5-6 years	5-6 years
BEP for residential (with subsidy)	5-6 years	5-6 years	5 years	4-5 years	4 years	4 years
BEP for entre-preneur (without subsidy)	10 years	9 years	8 years	7 years	6-7 years	6-7 years
BEP for entre-preneur (with subsidy)	7 years	6-7 years	6 years	5 years	4-5 years	4-5 years

Table 5. DPBP and IRR of solar system for all four cases

Solar Plant Size	Model 1 (Without Subsidy)					
	1 kW	2 kW	3 kW	5 kW	6 kW	10 kW
DPBP	12 yrs.	11 yrs.	10 yrs.	8-9 yrs.	7-8 yrs.	7-8 yrs.
IRR	13.54%	14.64%	15.44%	18.03%	18.73%	19.20%
Model 2 (With Subsidy)						
DPBP	8 yrs.	7 yrs.	6-7 yrs.	5-6 yrs.	5-6 yrs.	5 yrs.
IRR	18.86%	20.29%	21.34%	24.77%	25.71%	26.34%
Model 3 (Without Subsidy)						
DPBP (@10%)	22-23 yrs.	18-19 yrs.	16 yrs.	12 yrs.	11 yrs.	10-11 yrs.
DPBP (@11%)	Not feasible	21-22 yrs.	18-19 yrs.	12-13 yrs.	12 yrs.	11-12 yrs.
IRR	10.52%	11.74%	12.60%	15.36%	16.09%	16.58%
Model 4 (With Subsidy)						
DPBP (@10%)	12 yrs.	10-11yrs.	9-10 yrs.	7-8 yrs.	7 yrs.	6-7 yrs.
DPBP (@11%)	13-14 yrs.	11-12 yrs.	10-11 yrs.	7-8 yrs.	7-8 yrs.	7 yrs.
IRR	15.04%	16.57%	17.67%	21.23%	22.02%	22.84%

5. Conclusion

In this article, we have tried to estimate the financial viability of solar rooftop system for the urban area in the state of Madhya Pradesh as well as the potential for an entrepreneur in the sector. The financial analysis reveals that small size solar rooftop system (1-3 kW) are less attractive as evidenced by the long BEP and poor return on investment (IRR). However, substantial size solar panel systems (5kW and above) are attractive for both household consumers as well as independent entrepreneurs. Government subsidy of 30% improves the financial viability and hence attractiveness of solar rooftop systems.

We can conclude that installing solar rooftop systems is beneficially for consumers economically and can play a vital role in fulfilling the energy requirement of domestic consumers. The solar system, on the one hand, will improve the consumers financially and on the other hand support in a continuous supply of electricity. It also provides a business opportunity for those interested but with a solar system size of sizes above 5kW.

5.1 Limitations and Scope for Further Research

Similar studies can be replicated in other parts of the country taking into account the CUF and NDI values of these regions. The candidates for such studies could be those states which have high solar radiation potential (NDI) such as Rajasthan, Gujarat, Ladakh region of Jammu & Kashmir, Maharashtra etc.

Since the present study has focused only in urban areas, new research in rural areas can reveal diverse situations in terms of difference in electricity tariffs, electricity consumption rates and social-geographic-economic conditions, Transmission and Distribution losses of grid connectivity etc.

Use of invertors is a necessity in order to convert Direct Current (DC) power generated from solar panel systems to Alternate Current (AC) required for household appliance operations. Thus, the power loss during this conversion also needs to be taken into consideration, particularly in Indian context, where invertor efficiency varies from 83% to 91% (Bureau of Energy Efficiency, 2016).

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