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Domestication of photovoltaic solar system from economic feasibility perspective: A case study of Punjab

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Abstract
The sustainability of natural resources and human development is the buzz word of modern era. However for last few decades, we had been developing at the tremendous pace at the cost of natural resources jeopardising the whole megum of ecological balance resulting into global warming, environmental pollution, depletion of ozone, Extinction of species, traffic hazards and many more. The warning signs have been ringing at global level with the call to save 'mother earth'. This prospective study was carried out on users of domestic photovoltaic system residing in various cities of Punjab, India. A total of 300 adults (both male and females) constitute the sample of the study. The study is descriptive in nature and primary data is used for this purpose. A self-constructed interview schedule was used to collect the data from the users of the solar PV system. A sample of 300 families from different cities of Punjab consisting 27 families from Jalandhar, 47 families from Patiala, 13 families from Mohali, 200 families from Ludhiana and 13 families from Amritsar who had installed photovoltaic systems in their residence in 2014-17 were selected for the study. The present paper illustrates the economic feasibility of solar photovoltaic system at domestic level indicating the payback period of solar photovoltaic system varying from 5-8 years with almost zero maintainance cost for 25 service years. It will help in correcting myopic perspective of Punjabis pertaining to solar photovoltaic system and contribute towards ecological sustainability without compromising the development.

Keywords: Renewable energy system, solar photovoltaic system, roof mounted and ground mounted

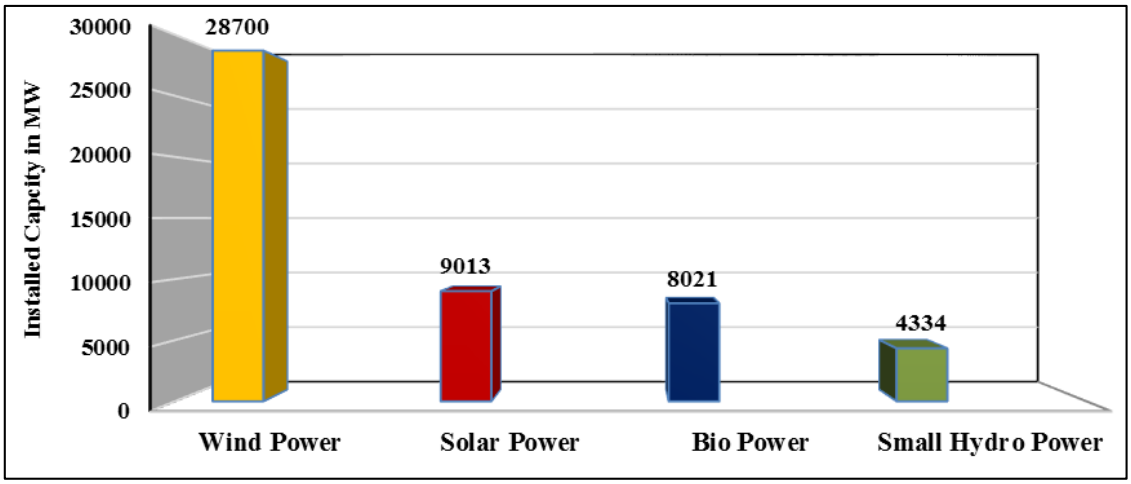
1. Introduction
The energy has enslaved each aspect of our life – domestic as well industrial and commercial to the extent that our progress as a country and our success as an individual has become directly and strongly proportionate to the availability and consumption of energy. This has become more pertinent for the country like India which is passing through a developing phase as a country and striving hard to compete and come at par with developed countries. Our need for energy is humongous not only for industrial progress but also to meet the domestic need of the surmounting population. International Energy Agency in 2017 has ranked India at 3rd from top on energy consumption in transportation, industry, residential area and other sectors. Till now India is depending on coal but it is believed that country's coal reserves won't last further than 2040-50. FICCI report on Power Transmission, 2013 says that India loses 68 billion USD (4,14,800 crore approximately) i.e. 0.4 per cent of its Gross Domestic Product due to electricity shortage. More than 72% of population residing in rural areas and half of the villages or the rural areas remain without electricity (William 2005). At this moment, India is relying heavily on coal, crude oil and natural gas as prime sources of energy. However these are non-renewable sources and would come to end sooner than later with the present pace of increase in demand and use of energy. Hence it is high time that India should go for renewable sources of energy and for the country like India due to its geographical location which enable it to have the abundant access of sunlight and that also for 7-8 months of a year, solar energy is the excellent form of energy and it can bridge the demand-supply gap in the energy.
The government of India has target to achieve a renewable power capacity of 175GW by the year 2022 including 100 GW from solar energy, 60 GW from wind energy, 10 GW from bio energy and 5 GW from hydro power (MNRE 2016-17). In the United Nations Framework Convention on Climate Change on Intended Nationally Determined Contribution (INDC), India has proposed to achieve 40% Electric Power Capacity through non-fossil energy resources by 2030 (MNRE 2016-17). Currently, India is moving fast in achieving a power capacity higher than the target for the year 2015-16 with 3423MW capacity increase of wind

energy which is 43% more than target and solar energy of 3019 MW which is 116% more than targets. (MNRE 2016-17) In a progressive country like India, renewable energy has a significant role in security of the energy. The following table gives an overview of the gross capacity of grid interactive renewable power in India as on December 2016. It witnesses a growth of 20 per cent in the last five years.

Table 1: Cumulative deployment of various renewable energy systems and devices as on 31st December 2016)

Sector	Achievement during 2016-17 (up to December 2016)	Cumulative Achievements (31.12.2016)
I. Grid-Interactive Power (Capacities In Mw)		
Wind Power	1922.99	28700.44
Solar Power	2249.81	9012.66
Small Hydro Power	59.92	4333.85
Bio Power (Biomass & Gasification & Bagasse Cogeneration)	151.40	7907.34
Waste to Power	7.50	114.08
Total	4391.62	50068.37
II. Off-Grid/ Captive Power - Capacities In Mweq (Megawatt Equivalent)		
Waste to Energy	4.47	163.35
Biomass(non-bagasse) Cogeneration	0.00	651.91
Biomass Gasifiers		
-Rural	0.00	18.34
-Industrial	4.30	168.54
Aero-Generators/Hybrid systems	0.38	2.97
SPV Systems	98.50	405.54
Water mills/micro hydel	0.10 MW + 100 Water Mills	18.81
Total	81.99	1403.70
III. Other Renewable Energy Systems		
Family Biogas Plants (in Lakhs)	0.35	49.40

Source: MNRE 2017



Source: MNRE 2017

Graph 1: Sector-wise Installed Capacity of Renewable Energy in India as on 31.06.2016

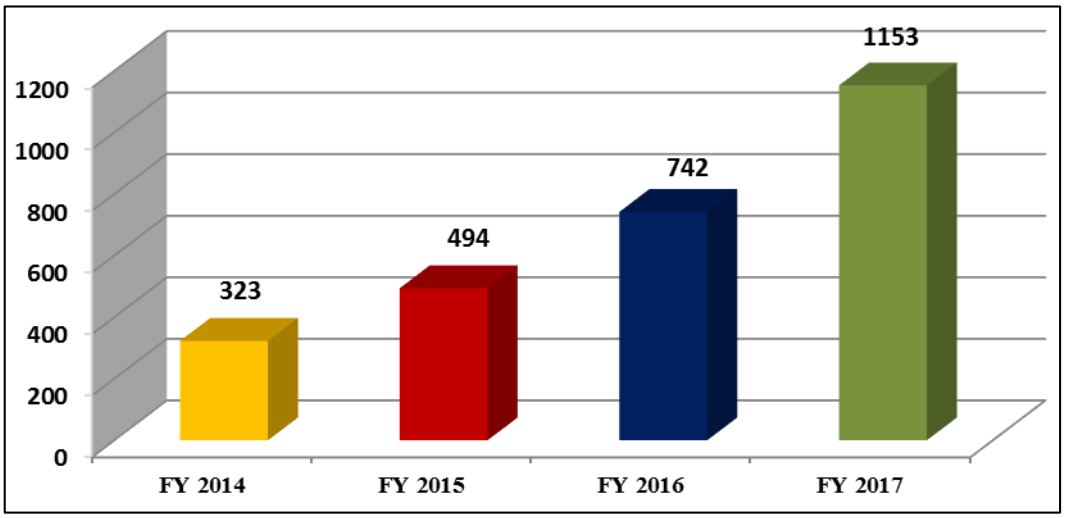
Punjab being one of the affluent states of India has shown a great potential and inclination towards generation of renewable energy. Moreover the state gets a high solar radiation for around 300 days in a year due to its geographical location. Thus the state can successfully install solar-based power projects with solar radiation of 4.6 KWH/Sq.m./day. Presently, the state is only realizing 21% of total capacity while 79% of renewable energy resources are yet to be harnessed (State Renewable Energy Action Plan for Punjab, 2017).

Table 2: Renewable Energy Realization Statistics in Punjab as on December 2017

RE (Renewable Energy) Technology	Potential (MW)	Achievement (MW)	Realization (%)
Solar	2810	795	28.3%
Small hydro power (SHP)	441	145.5	33%
Biomass+ Cogeneration	3472	473.5	13.6%
Overall RE	6723	1413.15	21%

Source: MNRE and Ministry of statistics and programme implementation (MOSPI) Energy Statistics 2017

The graph 2 given below clearly shows that solar energy is growing at a fast rate. Large scale solar projects are being installed in Punjab reaping benefits of solar energy and protecting the environment.



Source: MNRE and MOSPI Energy Statistics 2017

Graph 2: Growth of RE Capacity (MW)

Various institutions have been established by the government of India for promotion and execution of renewable energy projects in Punjab. These authorities include Punjab Energy Development Agency (PEDA) as state nodal agency, Punjab State Electricity Regulatory Commission (PSERC) for Regulation, Punjab State Transmission Corporation Limited (PSTCL) for generation and Punjab State Power Corporation Limited (PSPCL) for distribution (State Renewable Energy Action Plan for Punjab, 2017).

In order to elevate renewable energy, Punjab government has formulated two policies i.e.

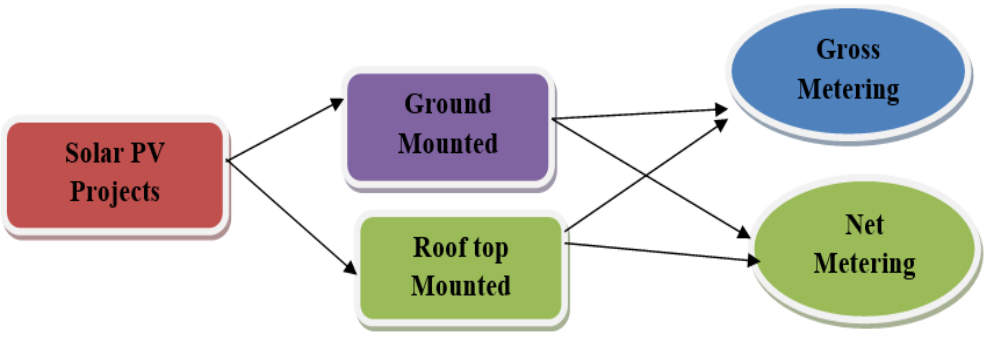
1. NRSE (New and Renewable Sources of Energy) Policy, 2012 NRSE Policy 2012 was formulated by the Punjab Government in order to increase the installed capacity of our E by 10% by 2022. The major highlights of this policy include increasing biomass energy to 600 MW capacity, cogeneration to 500 MW, solar to 1000 MW and SHP to 250 MW. PEDA is appointed as the nodal agency for successful implementer for the policy (State Renewable Energy Action Plan for Punjab, 2017).
2. Solar Rooftop Net Metering Policy, 2014 Net Metering means a system where solar energy systems ae installed on the rooftops of the customers. The policy was formulated with the objective of providing surplus electricity off-setting the electricity supplied by the distributor. A form is required to be downloaded from PSPCL site and submitted for approval from PSPCL sent within 30 days of application. The plant is installed within 180 days and inspected by PSPCL. After installation, a bi-directional meter is installed and solar PV project is commissioned as net metering project (Narula, 2015).

Punjab has acclaimed the Best State Award for Solar Energy Capacity Addition for generating three MW solar energy in 2013 to 1000 MW in 2017. The further targets in line for the Punjab Government for escalating the growth and development of renewable energy.

Table 3: Renewable energy capacity & target statistics in Punjab as on December 2017

RE (Renewable Energy) Technology	Installed Capacity (MW)	Mission 2030 (MW)
Solar power	797	4900
Small hydro power (SHP)	145	350
Biomass power	63	950
Waste to energy	1	20
Co-generation power	410	775
Total	1.4 GW	6.9 GW

Solar energy is an endless, non-renewable and an eco-friendly source of energy. It does not discharge carbon dioxide and various gases which contaminate the atmosphere. As India being one of the most polluted countries in the world with 178 rank out of 180 countries in environment health index, it is quite appropriate for India as the alternative for power generation. The various solar projects undertaken by Punjab government are:



Ground-mounted solar panels can be installed anywhere - the front, side, or backyard of the house whereas rooftop-mounted panels have to be installed to the roof of the building. Ground-mounted panels require a lot of space, additional material, time, and labour to install them and hence cost more but at the same time, they are easy to clean and repair. On the other hand, rooftop-mounted panels are more common, and they're easier and economical to install. Both provide the options of gross metering and net metering. Net metering is the process in which the generated power of solar power plant is first used in the building as per the requirement and the surplus power is fed to the grid of PSPCL. During winter, the energy will be banked with PSPCL which will be settled in summer in the settlement period of October to September every year and the consumer will get net bill after the adjustment of import and export of power. In gross metering system, the power generated by solar power plant is fed into the grid of PSPCL by the generator at a tariff fixed by PSERC (Punjab State Energy Regulation Commission).

As Punjab is endowed with vast potential of solar energy with over 300 days of sunshine in a year, PEDA is trying to exploit the solar energy potential to its full brim @ 4-7 KWH/Sq.mtr of solar insulation levels. To achieve this target, Government is strengthening power infrastructure in the State by setting up Solar Energy based power projects so as to save the depleting resources for our future generation and to combat global warming, fast depleting conventional sources of energy and resultant increased environmental pollution.

In spite of massive steps taken by the Union government and Punjab Government to make solar energy popular and profitable, initiation at the part of the public to install solar PV systems at domestic level is not very encouraging. A study has been conducted to assess the its economic feasibility at the domestic front.

2. Material and Methods

This prospective study was carried out on users of domestic photovoltaic system residing in various cities of Punjab, India. A total of 300 adults (both male and females) constitute the sample of the study. The study is descriptive in nature and primary data is used for this purpose.

A self-constructed questionnaire was used to collect the data from the users of the solar PV system. A sample of 300 families from different cities of Punjab consisting 27 families from Jalandhar, 47 families from Patiala, 13 families from Mohali, 200 families from Ludhiana and 13 families from Amritsar who had installed photovoltaic systems in their residence in 2014-17 were selected for the study. The economic feasibility of the solar PV systems were calculated using Internal Rate of Return (IRR), Benefit Cost Ratio (BCR), Payback period and Annual saving from systems.

Internal rate of return (IRR)

Internal rate of return (IRR) is a metric used in capital budgeting to estimate the profitability of potential investments. The interest taken for this purpose as proposed by the model, current bank interest rate was taken which in present condition is 7% at fixed deposit as it is assumed that the consumer would prefer to keep his/her money in lacs in fixed deposit account to assume it the least.

$$\text{irr} = \left(\frac{\text{FV}}{\text{PV}}\right)^{\frac{1}{\text{N}}} - 1$$

Where, PV stands for Present Value
FV is Net Cash flow

Benefit cost ratio (BCR): Benefit cost ratio (BCR) is used in capital budgeting to analyze the overall value for money of undertaking a new project. If a project has a Benefit cost ratio (BCR) greater than 1, the project will deliver a positive NPV and will have an internal rate of return (IRR) above the discount rate which in turn suggests that the project should be considered. If the Benefit cost ratio (BCR) is equal to 1, it indicates that the NPV of expected profits equal the costs and if a project's Benefit cost ratio (BCR) is less than 1, the project's costs outweigh the benefits and hence the project should not be undertaken.

$$\text{BCR} = \frac{\text{PV}_{\text{benefits}}}{\text{PV}_{\text{costs}}}$$

Where,
$\text{PV}_{\text{benefits}}$ = present value of benefits
PV_{cost} = present value of costs

Payback Period (PP): The payback period is the length of time required to recover the cost of an investment. The payback period of a given investment or project is an important determinant of whether to undertake the position or project, as longer payback periods are typically not desirable for investment positions.

The payback period is calculated as:

$$\text{Payback Period (PP)} = \text{years full recovery} + \frac{\text{Unrecovered cost at beginning of last year}}{\text{cash flow in following year}}$$

3. Results and Discussions

The prime objective of the present study was to assess the economic viability of solar photovoltaic system for the users of solar photovoltaic system for domestic purpose. The economic viability analysis was done to mathematically assimilate the basic assumptions made by the solar photovoltaic system parameters and the predictions in terms of cost benefit model so as to corroborate the outcomes of the decisions made in favour of the buying of the system. The viability of the solar photovoltaic system in the present study was estimated by its cost and benefit components which predict the feasibility to pursue solar power systems over conventional power systems for domestic purpose. The investigator has made certain assumptions in terms of bank interest rate in the research model and monetized cost and benefit components in order to predict the futuristic rate of return annually and its present value.

The economic parameters such as internal rate of return, net present value, payback periods and annual saving had been calculated to determine the viability of solar photovoltaic system in economic terms through critical examination of real time data and sources.

Table 4: Initial investment, benefit inflow, internal rate of return, payback period, benefit cost ratio and annual saving on domestic solar photovoltaic system (2014-2017)

Year	No.	System Capacity (Kw)	Initial Investment	Benefit Inflow/Year	IRR	Payback Period	BCR	Annual Saving
2014	6	2	170000	21836.93	16%	7.78	1.93	21836.93
	4	3	240000	32755.39	17%	7.33	2.59	32755.39
	3	4	305000	43673.86	18%	6.98	3.15	43673.86
	3	5	365000	54592.32	19%	6.69	3.25	54592.32
	2	6	427350	65510.78	20%	6.52	3.30	65510.78
	1	7	491000	76429.25	20%	6.42	3.34	76429.25
	1	8	556800	87347.71	20%	6.37	3.35	87347.71
	1	10	685000	109184.64	20%	6.27	3.39	109184.64
2015	17	2	165000	21836.93	17%	7.56	2.99	21836.93
	15	3	235000	32755.39	18%	7.17	3.09	32755.39
	10	4	300000	43673.86	18%	6.87	3.19	43673.86
	9	5	360000	54592.32	19%	6.59	3.28	54592.32
	8	6	422350	65510.78	20%	6.45	3.33	65510.78
	5	7	486000	76429.25	20%	6.36	3.36	76429.25
	3	8	551800	87347.71	20%	6.32	3.38	87347.71
	3	10	680000	109184.64	20%	6.23	3.41	109184.64
2016	12	2	160000	25099.15	15%	6.37	2.83	25099.15
	17	3	230000	37648.73	16%	6.11	2.91	37648.73
	12	4	295000	50198.30	17%	5.88	2.98	50198.30
	15	5	355000	62747.88	17%	5.66	3.06	62747.88
	15	6	417350	75297.46	18%	5.54	3.10	75297.46
	9	7	481000	87847.03	18%	5.48	3.13	87847.03
	7	8	546800	100396.61	18%	5.45	3.14	100396.61
	10	10	675000	125495.76	18%	5.38	3.17	125495.76
2017	15	2	155000	28128.36	18%	5.51	3.11	28128.36
	19	3	225000	42192.54	18%	5.33	3.19	42192.54
	15	4	290000	56256.72	19%	5.15	3.26	56256.72
	19	5	350000	70320.90	20%	4.98	3.34	70320.90
	15	6	412350	84385.08	20%	4.89	3.39	84385.08
	9	7	476000	98449.26	20%	4.83	3.41	98449.26
	7	8	541800	112513.44	21%	4.82	3.42	112513.44
	13	10	670000	140641.80	21%	4.76	3.45	140641.80

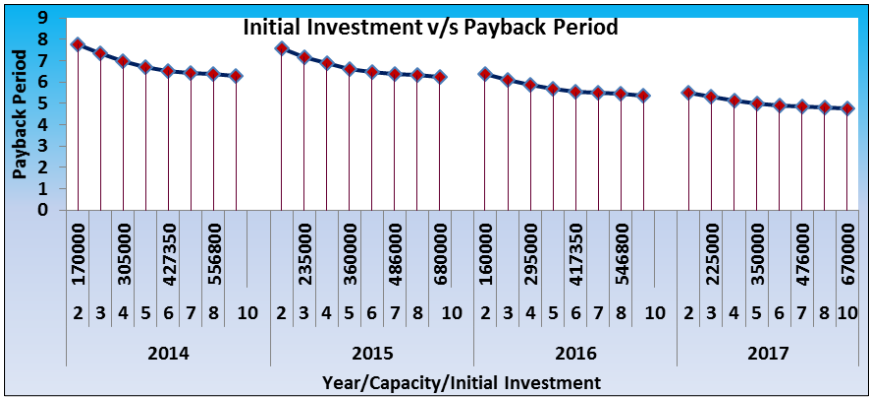


Fig 1: Initial Investment v/s Payback Period of domestic solar photovoltaic system (2014-2017)

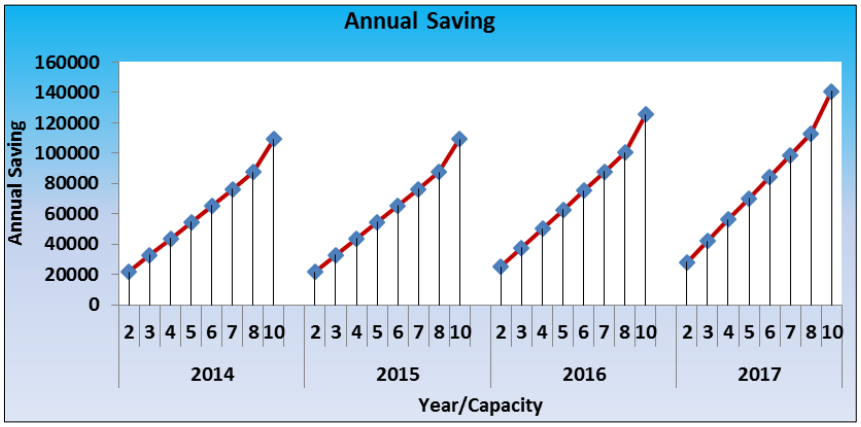


Fig 2: Per kilowatt annual saving on domestic solar photovoltaic system (2014-2017)

Table 4 indicates that initial investment done on solar photovoltaic system in terms of the average cost of solar photovoltaic system inclusive of all cost. It was obvious from the table that the initial cost of solar photovoltaic system varied from Rs. 85000/kw to Rs. 68500/kw in 2014 which went down to Rs. 77500/kw to Rs. 67000/kw in 2017. It indicate a steady decrease during the period of 2014-17. Also the total initial cost of solar photovoltaic system is directly proportion to its capacity i.e. higher the capacity of the solar photovoltaic system, higher its cost. However per kilo watt cost of solar photovoltaic system reduced with the increase in the capacity of the system. As per the illustration of the Table 4.26, the total initial cost of solar photovoltaic system of two kilo watt capacity was Rs. 170000/- which was increased to Rs. 685000/- for ten kilo watt capacity system in 2014 and in 2017, the variation was from Rs. 155000/- to Rs. 670000/-. However the per kilo watt cost of two kilo watt system was Rs. 85000/- and Rs. 68500/- for ten kilo watt system in 2014 which was reduced to Rs. 77500/- per kilo watt for two kilo watt system and Rs. 67000/- per kilo watt for ten unit system in 2017.

The feasibility and profitability of any project is directly proportional to the project's internal rate of return. In other words, higher the internal rate of return, more profitable it is. The internal rate of return (IRR) is primarily based on four major components in the solar system analysis, (i) initial investment; (ii) benefit cash inflows; (iii) interest rate; and (iv) the duration of the project. The benefit cash inflows are a resultant of solar power produced and its subsequent system size. Larger the system size, higher is the benefit cash inflow in terms of rupees annually.

The initial investment of Rs.170000/- in the year 2014 in a 2 kilo watt capacity solar system results in 16% internal rate of return which increased steadily to 17%, 18% and 19% for investment of Rs. 240000, Rs. 305000 and Rs. 365000 on 3 kilo watt, kilo watt 4 kilo watt and 5 kilo watt capacity system respectively. The internal rate of return rose to 20% for the investment of Rs. 427350/- on 6 kilo watt capacity solar photovoltaic system which remained the same for the investment of Rs. 685000/- on 10 kilo watt solar system. Similarly the initial investment of Rs.165000/- in the year 2015 in a 2 kilo watt capacity solar system results in 17% internal rate of return which increased to 20% for the investment of Rs. 422350/- on 6 kilo watt capacity solar photovoltaic system which remained the same for the investment of Rs. 680000/- on 10 kilo watt solar system. The initial investment of Rs.160000/- in the year 2016 in a 2 kilo watt capacity solar system results in 15% internal rate of return which increased to 18% for the investment of Rs. 417350/- on 5 kilo watt capacity solar system which remained the same for the investment of Rs. 675000/- on 10 kilo watt solar system. The initial investment of Rs.155000/- in the year 2017 in a 2 kilo watt capacity solar system results in 18% internal rate of return which increased to 21% for the investment of Rs. 350000/- on 5 kilo watt capacity solar system which remained the same for the investment of Rs. 670000/- on 10 kilo watt solar system.

Table 4 reveals that the payback period of domestic solar photovoltaic system came out to be 7.78 for 2 kilo watt capacity solar system in 2014 which was reduced to 6.27 for 10 kilo watt capacity solar system. In 2015, the payback period of solar system came out to be constant 7.56 for 2 kilo watt capacity solar system which was reduced to 6.23 for 10 kilo watt capacity solar system. Similarly the payback period of solar photovoltaic system came out to be constant 6.37 and 5.51 for 2 kilo watt capacity solar system and 5.38 and 4.76 for 10 kilo watt capacity solar system purchased in 2016 and 2017 respectively.

The benefit cost ratio (BCR) of domestic solar photovoltaic system in the period of 2014-2017 increased from 1.93 to 3.11 for 2 kilo watt capacity system whereas for 10 kilo watt capacity solar photovoltaic system, the benefit cost ratio was increased from 3.39 to 3.45. The benefit cost ratio (BCR) of domestic solar photovoltaic system greater than one confirms the usefulness of the investment on domestic solar photovoltaic system.

The installation of 2 kilo watt capacity PV system decreased gradually from 29% in 2014 to 13% in 2017 whereas the installation of 10 kilo watt capacity PV system increased gradually from five per cent in 2014 to twelve per cent in 2017.

The annual saving on solar photovoltaic system is equal to the annual cash flow or saving on electricity bill because in case of domestic solar photovoltaic system, the consumer start getting electricity directly from solar system and hence need not to pay any amount to electricity board. Moreover the solar photovoltaic system had zero maintenance cost with battery life of 25 years, hence whatever cash flow comes in terms of saving of electricity, it may be taken as annual saving.

4. Conclusion

The overview of the results illustrated in Table 4 very clearly and vividly represented that the per kilo watt cost of solar photovoltaic system reduced with the increase in the capacity of the system i.e. higher the capacity of solar photovoltaic system, lower the per kilo watt cost. It also showed that the cost of solar photovoltaic system reduced over the period and still reducing. The findings confirmed the report of National Renewable Energy Laboratory report entitled U.S. solar photovoltaic system cost benchmark by Feldman *et al* (2017) which reported that the modeled PV installed costs declined, year over year. The benefit inflow/year and annual saving from domestic solar photovoltaic system increased with the increase in capacity of the system.

The initial return of solar photovoltaic system is very impressive which motivates the consumer to buy solar photovoltaic system for domestic purpose. The findings are supported by Parmar (2016) who worked on domestic solar photovoltaic system and found the cash flow in case of domestic solar photovoltaic system increased progressively in terms of year of installation. Same was the case of internal rate of return and benefit cost ratio of solar photovoltaic system. However the payback period of solar photovoltaic system decreased with the increase of the capacity of system and over the period of time. The payback period of solar photovoltaic system varied between 5-8 years which indicated that the users of domestic solar photovoltaic system recovered their initial investment within the time period of four to six years of the installation of the system in terms of its saving on electricity bill and after that the saving on electricity bill till twenty five years of its life, might be taken as saving from the system.

Hence proves the viability of solar photovoltaic system not only from ecological angle but from economic angle as well discarding the common perception of residents of Punjab that it is a costly affair and only affluent class can afford it.

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