International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-4, April 2019

Quantification of Potential Benefits to Punjab's DS Consumers from On-Grid Type Solar Systems

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Abstract*: *In recent years, use of Solar Energy for Electricity production has been promoted by various companies, research institutes and governments as a clean and free source of Energy. As an outcome of the promotions by such entities, idea of solar energy production has reached from Industries and commercial consumers to Domestic consumers also. Government has schemes in terms of subsidies, low interest loans and tax rebates to promote installation of Solar Power plants. This paper shows a detailed analysis of the performance of a domestically installed Solar Power Plant that pertains to the state of Punjab (INDIA), keeping in view unit KWH energy rates as decided by Punjab state power corporation ltd. (PSPCL) which vary a little depending upon the agreements and policies of different state governments. In this paper quantification of the potential benefits to the end consumer has been done to analyze whether the consumer gains by installation of solar power plants in terms of monetary benefits, regularity of supply, independence from faults etc. or not.. Data for 2 years has been collected for a Domestic consumer, 1 year before installation of solar power plant and 1 year after installation, thus covering all seasons. Comparison has been done to analyze benefits in totality including initial cost, total production of Solar units, Space constraint, Independence from faults etc.

Index Terms: PSPCL, PEDA, MNRE, KWH, KW, Production, Units, Consumption.

I. INTRODUCTION

Various developments in the efficiency of Solar cells have been reported in the last few decades. Technological advancements reported have been brought into use by many countries. For the fulfillment of energy demand in developing countries it becomes a challenge to satisfy the demand solely on the basis of non renewable sources of energy. So developing countries like India, china, Pakistan etc. have shifted greatly to renewable sources of energy and now Solar, Wind, Geothermal, Hydropower, Biomass etc. share a large proportion of total energy production of these countries[1]. Wind, Geothermal, Hydro energy and biomass are some sources which are not feasible for installation for every individual at their own end but solar energy production is something which can be done even at end user owing to the small setup required for its production as well as to recent advancements which has led to its successful installation even at domestic consumer's premises [2].

Manuscript published on 30 April 2019.
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Indian government has been promoting use of Solar Energy from past many years and for the purpose it has been providing various subsidies to the consumers whether it is an Industrial Consumer, Commercial consumer or Domestic consumer. Subsidies include Loans at lesser rate of Interest, tax refunds on solar installations etc. Ministry of New and Renewable Energy (MNRE) persuades state governments to promote such installations and provides funds to respective states for bringing renewable energy into use. A complete record of renewable energy generated is done at production end by using check meters and billing is done at the consumer end by using NET (Bidirectional) meters [3]. For the purpose of checking i.e. record keeping to quantify renewable energy generated, a simple unidirectional three phase or single phase meter is used and for billing purpose a bidirectional meter is used which is also three phase or single phase depending on the load of the consumer. Upto 5 kw load a single phase meter is used by PSPCL and above 5kw a three phase meter is preferred.In this paper, quantification of benefits has been done for domestic consumer and an analysis has been done to investigate how much a consumer is gaining in monetary terms. And an opinion has been given whether to go for such sources of energy or not, which may vary depending on priority of every individual.

II. TYPES OF SOLAR POWER PLANTS

Solar systems for energy production are classified into three broad [4, 5] categories, namely

A. On-Grid Type Solar Power Plant

In these systems, Solar system is directly connected to traditional grid. Energy produced by Solar system is directly shared with the Grid through a meter called 'Net Meter'. For installation of such system it is necessary that traditional grid is available and is providing energy to premises under consideration. Excess power generated by solar system is sent to the Grid and in case sufficient power is not being produced it is taken from Grid [6]. At the end of the month Consumer is charged for the net energy consumed. Some utilities also consider time of power exchange. If during peak loads energy is given by consumer, more credit is given to the consumer but during Off-peak load lesser credit is given. The main advantage of this system is that its cost is minimum as least number of components are required and also its life is more as batteries are not involved. But at the same time disadvantage comes along that it works only till the time supply from grid is there i.e. in case of outage or bad weather it stops supplying power unlike Hybrid or Off-Grid solar power plant.

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Main role in this solar system is played by inverter. Switching between Grid and Solar system is uninterrupted and seamless. A system depicting the setup can be seen in the picture ahead:

Figure 1: ON-GRID Solar Power Plant

B. Off-Grid Type Solar Power Plant

Off- Grid type solar power plant as the name suggests is connected where traditional grid is not supplying energy or consumer doesn't want to connect to Grid or else Utilities don't provide facility of Power exchange [7, 8]. Hence it is not connected to grid and only supplies power to the household it is connected to. Since energy generated by Solar panels needs to be stored, hence a battery backup is connected for storage of DC supply generated which is further converted to AC for use with the help of an Inverter. To protect against shortfall of energy produced some kind of Electric generator is needed to fulfill the need at time of Peak load.

This method requires a huge setup of batteries for storage of energy which makes it quite expensive. Batteries need periodic maintenance and have certain life span so they need to be replaced after sometime which is very inconvenient for consumers as it is an expensive task. A general layout of Off-grid solar power plant is shown in the figure below:

Figure 2: Layout of OFF-GRID Solar Power Plant

C. On-Grid Solar Power Plant with Battery Backup/ Hybrid Type

This power plant is also called Hybrid type Solar Power plant as it involves both On-Grid and Off-Grid functionality. It consists of a Net meter for providing credit to consumer and also has batteries to save excess amount of energy. This backup of batteries helps the consumers to protect against Power outages which occur during bad weather conditions or Peak loads. This system has more flexibility but has disadvantages that it is a complex system and hence more expensive to install. Also continuous charging and discharging of batteries reduce the overall efficiency of system, although the amount of batteries required are less as compared to Off-Grid type plant because Off-Grid solely depend on batteries for maintaining continuity of supply [9, 10]. Also periodic maintenance and replacement of batteries stays a challenge both in monetary terms, time consumption and botheration to consumer. The diagram ahead depicts equipments required for making a Hybrid Solar plant:

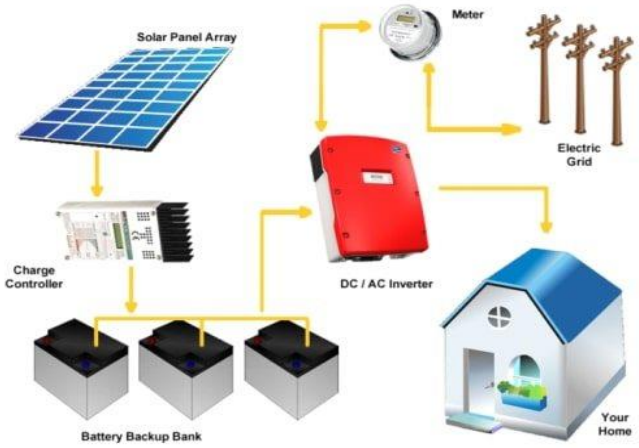

Figure 3: Hybrid Solar Power Plant

All the three types of Solar Power plants have their own advantages and disadvantages. Depending on the Energy required, type of premises, Cost etc. a suitable kind of Solar system is installed. Domestic consumers in the area of our consideration i.e. State of Punjab as usually opting for On-Grid type of Solar systems depending on the Energy requirement, Climate and Punjab state power corporation ltd.(PSPCL) and Punjab Energy Development Authority (PEDA) policies [11,12] both under the guidance of Punjab government and MNRE.

III. NET METERING AND CONNECTIONS

Recently Utilities in India have started allowing consumers to install On-Grid Solar power plants based on the insistence and incentives of Ministry of New and Renewable Energy (MNRE). Earlier when Off-Grid solar power plants were used there was no need for net metering as there was no exchange of power between the Utility and the consumer but in On-Grid solar power plant since consumer gives power to Utility as well hence a meter needs to record these values [13].

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So for the purpose, a net meter is used which records KVAH, KWH and MDI (Maximum demand indicator) for both Import and Export of energy. Also it records the net value of KWH and KVAH on which final billing is done. A typical diagram of a three phase Net meter also called as three phase bidirectional meter along with connections is shown ahead:

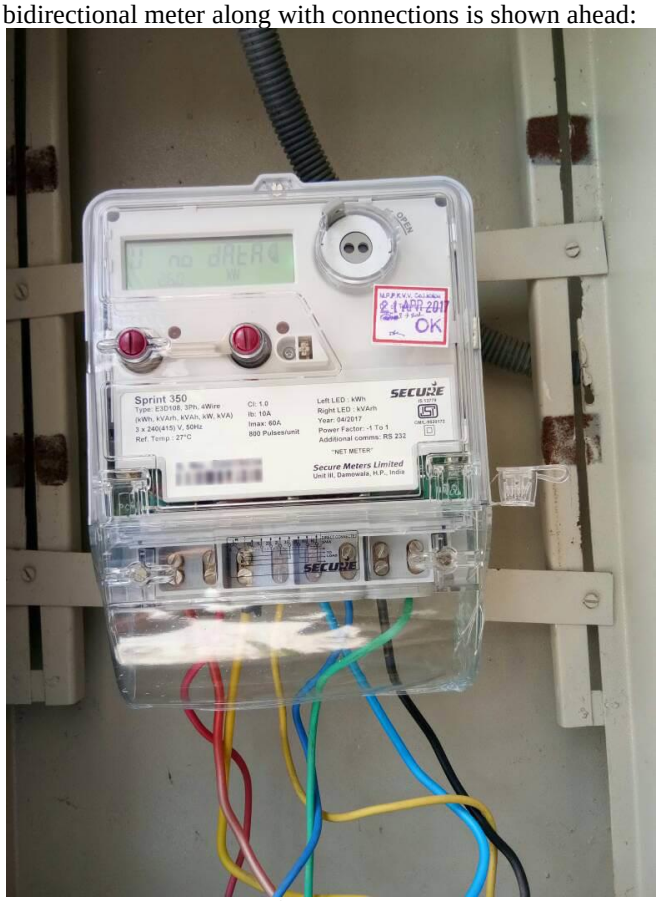

Figure 4: Picture of a Net meter with connections

Since installation of Net meters is a recent trend, Power corporation in Punjab i.e. PSPCL has not yet made a PO (purchase order) for these meters, so they allow purchasing meters from some private companies like Secure and L&T only, and then get them tested from ME (Metering Equipment) lab which undergo rigorous testing for continuous 16 to 24 hrs depending upon the type of meter i.e. single phase or 3 phase or HT meter (11KV meter).

IV. ANALYSIS OF A TYPICAL ON-GRID SOLAR POWER PLANT

Various parameters are involved while analyzing any On-Grid solar power plant, which involves its cost analysis, life expectancy, efficiency etc. Firstly some details are given about the options given by Indian government to choose from under 'Make in India initiative' and then parameters to be focused upon are discussed.

A. Indian government 'Make in India' Initiative

Indian government for the purpose of promoting generation of Solar energy and setting up of more and more solar power plants provides a subsidy (Refund) of 30%through Ministry of New and Renewable Energy (MNRE) on the total cost involved and as a part of Make in India initiative it promotes installation of Solar plants from the material manufactured by certain manufacturers only who have their production houses in India. A consumer is allowed to purchase required material from any company but MNRE doesn't provide the above mentioned subsidy on it. Consumers purchasing panels from Solar panel manufacturer companies/groups like Adani Solar, Vikram Solar and Waaree solar etc. are eligible for the subsidy of 30%. Inverters can be purchased from manufacturers like KSTAR, Delta and Solax Power etc. to be eligible for the subsidy. Wires to be installed should be from KEI Industries, Polycab India ltd. and others to fulfill the eligibility criteria to avail subsidy. There is a complete list of all different empanelled companies which is available at [14] Punjab Energy Development Agency (PEDA).

B. Cost Analysis

Cost of the Solar panel varies depending upon the Solar Installation capacity. For On-Grid type of Solar power plant, maximum capacity of a plant allowed for a domestic consumer vary from 80 to 90% of the total sanctioned load depending upon policies of different state governments.

Normally for installation of a 1KW solar plant MNRE has decided maximum cost equal to 60,000 INR also known as 'Tender Price'. And as per subsidy policy which is 30% of the total cost involved a refund of 30% of 60000 i.e. 18000 INR is refunded in the bank account of consumer. Also to promote installation of Solar plant government [15] considers the solar setup as an asset and one can claim benefit on taxation over it. Consumer is also eligible for Loan facility against this asset upto double the value of the asset as its life is for a long term and Cost can be recovered after few years of installation.

C. Space Analysis

Space is a factor that plays an important role while installing solar power plant. Setup of this plant needs a space free from shadows, open to sky, proper south facing for successful and efficient operation of the plant. For a 1 KW plant 3 panels are needed [16, 17] and each panel needs a space of 1 meter*2 meter. Thus for setting up a 1KW solar plant 6m^2 area is needed probably on the rooftop of a building/house. An illustrative picture for a 1KW solar power plant can be seen in Figure 5.

Figure 5: Picture of a 1KW solar power plant

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D. Output Analysis

A solar plant is subject to many kinds of losses as every other power plant is. Since solar plant involves many components so losses occur at every stage. Initially when the light falls onto the panel Conversion losses occur. Solar panel is only able to convert around 25% of the solar energy falling over its surface and rest energy is either reflected back or dissipated as heat to surroundings, then prominent loss occurs in the batteries. Since in our case On-Grid type of solar power plant is considered hence this loss can be avoided. After Solar panel energy goes to Inverter that converts DC to AC supply which is of importance to us. And lastly it is transferred through Wires into our supply system. Here loss known as 'Transfer loss' [18] occurs which is very small but yet considerable. This is the reason that only pure copper wires are installed in solar power plant.

Apart from all these losses, efficiency is greatly affected by temperature rise of the solar panel. It appears counter-intuitive but efficiency of Solar panel decreases in summer when Sun availability is at its peak. This is because hot summer leads to a temperature rise of the panel which affects efficiency drastically. High temperature leads to an exponential increase in output current but at the same time linear decrease in voltage. Solar cells are tested at a temperature of about 25 ^{0}C, anything higher leads to a drop of 10-25% of efficiency depending upon the location.

For the area under consideration i.e. State of Punjab, depending upon climatic conditions output of solar plant varies. In different seasons it is different depending on the availability of Sun. Usually it is Hot summer in the month of June-July, so it produces around 6 to 6.5 units of energy per day and in the month of September production is about 4 to 5 units of energy per day. In Cold winters like in December and January production of energy by solar power plant of 1 KW is about 1.5 to 2 units of KWH. For a year a steady value for the purpose of calculation is difficult to deduce from generation data [19, 20].

Normally in a house, solar plant upto a capacity of maximum 5KW is recommended because of the space constraint. It can be more or less depending on the space available and keeping in mind the limit of 80-90% of the sanctioned load.

E. Life Analysis

Anything anywhere is world has its life which is counted in terms of years, reactions or charging discharging cycles etc. Similarly Solar panels also have a limited life as it is open to sky. Climate changes [21-23], Rains, Fog, pollution etc. affect its life which is determined in form of number of years. Typical life of the solar panels as claimed by the manufacturers is 25 years. It is a guarantee directly from the manufacturer that for first 10 years it will work at an efficiency of 90% and for the rest 15 years efficiency will be atleast 80%. If any consumer doubts the efficiency of panels in this span of 25 years he/she will get free checkup of the setup and free replacement from the manufacturer in case of any malfunction.

V. PERFORMANCE OF A 4KW SOLAR POWER PLANT BASED ON TWO YEAR DATA

A complete analysis has been done for a 4KW solar power plant installed on a domestic consumer premises with sanctioned load of 8 KW. As per Punjab government's policy maximum solar power plant capacity allowed for installation is 80% of the sanctioned load, which gives a value of 6.4KW. So 4KW solar plant is well within the limits as per norms. Here analysis is done for the total energy saving as well as monetary savings using the data minutely collected over period of 2 years with the help of PSPCL for an account under the name of Darshana devi [24]. Data includes all seasonal variations (which are bound to effect performance of solar) as it is collected for an year prior to the installation of 4KW solar power plant and 1 year after the successful commencement of plant in May 2018. Table 1 depicts KWH consumption and associated billing for that particular time. It is clear from the data that Production of energy units is more in the summer season rather than winter.

Table I: Consumption and Billing data after Installation of Solar Power Plant

Starting Date	Ending Date	Total Number of Days	Bill Amount	Import (KWH-From PSPCL)	Export (KWH-To PSPCL)	Net (KWH)
07-01-19	25-04-19	108	770	453	592	-139
22-12-18	07-01-19	16	420	129	102	27
05-11-18	22-12-18	47	990	387	313	74
14-08-18	05-11-18	83	3585	1115	718	397
25-04-18	14-08-18	112	6694	1619	850	769
		366	**12459**			

As per PSPCL policy, billing is done after a period of 2 months in case sanctioned load is 10KW or lesser and consumer under consideration has a sanctioned load of 8KW so billing is after approximately 2 months. Sometimes billing has been missed out of some technical reason then a cumulative billing is shown for total time. Net meter records values like KWH, KVAH, KVA,MDI (Maximum demand indicator) but since for a domestic consumer billing is done on KWH, so data only for KHW values which is relevant to us is shown in Table I. Import values shows the amount of energy units consumed by the consumer and Export values depict the energy units generated by solar power plant and given to PSPCL.

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A final net value of consumption of Units of KWH which is actually the difference between KWH (Import) and KWH (Export) is the amount a consumer is charged for. Per unit rate is approximately Rs 7.5 per kwh, but after including all kinds of taxes and octroi etc. it goes upto Rs8 per unit kwh. It is worth mentioning here that PSPCL settles the credit of kwh produced [25, 26] with kwh imported only and rest of the taxes, octroi, rentals are charged. This is the reason that even if KWH generated by solar is more than KWH Imported from PSPCL, there is an amount charged by PSPCL from period of 07-01-19 to 25-04-19 as well. Negative 139 units of energy will be credited for the next billing cycle and will be subtracted from imported units [27-30] of Energy. For a total of 366 days from April 2018 to April 2019 an amount of Rs 12,459 is charged from the consumer.

Now data collected for the year prior to the installation is shown in Table 2 underneath.

Initially an amount of Total Tender Price is paid by the consumer and subsidy is provided only after 1month of the commencement of the project. Banks work as per govt. policy which sanctions a loan upto 80% of the total tender cost of plant. Thus for this 4KW plant bank provides a loan upto

$$= 80\% \; of \; 240000 = 1{,}92{,}000 \qquad (3)$$

The amount paid by consumer himself on his part is calculated as:

$$20\% \; of \; 240000 = 48{,}000 \; INR \qquad (4)$$

The current rate of interest taken by bank on this 4 KW solar power plant is 10.50% for a tenure of 5 years, which leads to a monthly installment of 4127 INR.

So total amount paid by the consumer can be calculated as sum of amount paid to bank in 5 years and amount paid by consumer himself other than bank loan (i.e. 20% of total cost of plant) minus the subsidy received by consumer after a month of successful commencement of plant [36, 37]. In mathematical terms it can be written as:

NET Cost of Solar Power Plant

$$= (4127 * 12 * 5) + 48000 - 72000 = 223{,}620 \; INR$$

In a span of 5 years solar power plant payment is complete thus incurring a cost of Rs 223,620 INR but one year saving from solar power plant as seen from 2 year analysis of Billing is 36,381 INR, thus practically recovery of total cost of plant also known as Return on investment is complete in

$$Saving = \frac{223{,}620}{36{,}381} = 6.15 \; years \qquad (4)$$

So to conclude it can be said that solar power plant of 4KW installed capacity recovers its cost in almost a span of 6 years. Only after 6 years the cost is recovered and practically the solar plant becomes free thereafter.

Table II: Consumption and Billing data before Installation of Solar Power Plant

Starting Date	Ending Date	Total Number of Days	KWH Consumed	Bill Amount
28-02-18	25-04-18	57	864	7030
30-12-17	28-02-18	61	1015	8340
29-10-17	30-12-17	63	816	6250
29-08-17	29-10-17	62	1449	10600
28-06-17	29-08-17	63	670	5430
30-04-17	28-06-17	61	1530	11190
		367		**48840**

Since the data above is before the installation of solar power plant so there is no concept of Net metering and hence no values for import of Energy and Export of energy given. Simply a 3 phase unidirectional meter [31-34] was installed which gives the values of KWH consumed by the consumer over a period of time staring from April 2017 to April 2018. Clearly for a period of almost a year i.e. 367 days, the electricity consumed amounted to Rs 48,840. Now looking at the picture of 2 years it can be said that a saving of Rs 36,381 has been done.

VI. RETURN ON INVESTMENT (ROI) ON THE BASIS OF DATA COLLECTED

It can be clearly seen that a solar power plant of 4KW installed capacity incurs an initial cost, calculated as under:

Installation rate of solar setup per KW	60000 INR
Subsidy provided by MNRE per KW	30%
Total installed capacity of Solar Plant	4KW

It is the policy of MNRE that it provides refund of 30% of the total project cost after PEDA officials visit the actual site of installation of solar power plant for verification [35]. Almost in a month the subsidy is credited to the Bank account of the consumer on behalf of the report submitted by PEDA to MNRE.

Total Tender Cost for 4kw solar power plant

$$= 60000 * 4 = 240{,}000 \; INR \qquad (1)$$

Total subsidy received from MNRE

$$30\% \; of \; 240{,}000 = 72000 \; INR \qquad (2)$$

VII. BENEFITS AND DISADVANTAGES OF SOLAR INSTALLATION

Depending upon the whole analysis there are certain advantages as well disadvantages that come along with solar plant. Firstly here disadvantages are written which are not limited to monetary terms only and then a light is thrown on the advantages ones gets after installing solar power plant:

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A. Disadvantages

1) Solar power plant really consumes a lot of space of the rooftop. So it devoid a person from what he/she can have otherwise, an open rooftop which can be used for many other purposes. Although there is an option to lift Solar panels to a proper ceiling height but it adds to additional cost. But even then Sunlight is not available for human use.
2) Climatic change affects the wiring. In a span of few years the insulation which is in open punctures which further results in efficiency loss and also shock probability increases.
3) Climatic changes, Pollution, rains, etc. are expected to throw a bad impact on the efficiency and working of Solar Panels. It causes gradual degradation which is difficult for a layman to count and notice. Thus it gives additional botheration of noticing the electricity billing everytime because in case there is some increase in the billing or reduction in units of energy produced by solar plant it is very difficult to quantify whether this decrease is because of bad weather or some fault or efficiency drop of the system.
4) There is always a danger of physical damage to the solar plant setup in such a long span of time because of human negligence or storms etc. which are inevitable. In any case a householder is bothered with a huge cost of calling officials as physical damage is not covered for any kind of warranty.
5) Government policies change time to time. Electricity corporations or Boards change the policies time to time depending on the Loss of Revenue to them and other factors like availability of Power. It is often observed that many Utilities credit more for the KWH units produced during Peak hours and lesser credit for the units produced during Off-Peak hours. It has been observed that governments sometime discontinue this service based on the internal disagreements, and this all leads to inconvenience to customers. In this case monetary loss is evident.
6) As the technology is changing very fast. There are many efforts going on in many parts of the world which lead to enhancement in the efficiency of solar panels. There is much chance that by the time a person is not even able to recover the cost or recovers cost only which takes 5 to 6 years the technology might change demanding complete revamping of the Solar power plant.
7) One more disadvantage for a person opting solar power plant is that the money is plugged in the plant as capital investment which could have been used in the time of emergency.

B. Advantages

1) From a broader perspective i.e. society point of view, Pollution, Sustainable development definitely Solar plant installation should be opted.
2) Solar power plant especially helps in developing countries like India where meeting energy demand is a challenge and this will lead to the sharing of surplus power with the needy.
3) Technically, points where solar power is injected in to feeders it leads to voltage boost up. Hence voltage drop which is a problem in long feeders will be addressed as a repercussion of this power injection method.
4) As per current Indian government policies, Solar plant setup is considered as a Asset, which means it can be used as an asset over which depreciation can be claimed further leading to tax benefits.
5) Government has allowed Loan facility upto almost double the value of the plant as government supports the idea that this asset can recover money for moneylenders (Like banks) also within some period of time by producing electricity and also this setup has its own value as an asset which doesn't depreciate steeply because it is under warranty for 25 years.
6) One of the perspective regarding installation of Solar plant on rooftop gives added advantage that roof doesn't get heated up in summer because of direct sunlight. Hence rooms don't get hot leading to lesser use to electricity in form of air conditioners to normalize room temperatures.

VIII. CONCLUSION

As it is clear many advantages and disadvantages come along with installing a solar power plant. But opting for installation of such a plant is something that cannot be generalized and this decision varies from person to person needs. The two year long research done to analyze the benefits suggests that a person having enough space or open area and having a permanent resident who is looking for using the place for minimum 6 to 7 years can benefit from it. But if one is on a temporary residence, then going for Solar plant might not be a good idea as it takes some minimum years for paying back the investment and only after this time any return on investment can be expected. So blindly opting for Solar Power plant installation is not a good idea and it is a careful and a conscious decision. I leave it upto the need and wisdom of consumers for opting it, keeping in mind the advantages and disadvantages as mentioned.

ACKNOWLEDGMENT

I whole heartily acknowledge the confidence and direction given by Dr. H.R Pota, Associate Professor UNSW Canberra, Australia. His Persuasion, support and encouragement was unprecedented. Also I acknowledge the help that I received from my Colleagues and subordinates of PSPCL in collecting the data and carrying out the research in this popular topic. I am indebted to the cooperation that I received from PSPCL and consumers whom I approached for the collection and verification of data.

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