DOI: 10.36347/sjebm.2017.v04i03.002

Scholars Journal of Economics, Business and Management e-ISSN 2348-5302

Sch J Econ Bus Manag, 2017; 4(3):140-150 p-ISSN 2348-8875

© SAS Publishers (Scholars Academic and Scientific Publishers)

(An International Publisher for Academic and Scientific Resources)

Replacement of Conventional Energy Source with Solar Powered Electrification Systems: An Empirical Study in Educational Institutions

Hrishikesh Sharma[1], Dr. Arobindo Debnath[2]

[1]Department of Management, Assam Downtown University, Assam, India

[2]Department of Economics, Kokrajhar College, Assam, India

*Corresponding Author

Hrishikesh Sharma

Email: hrishikeshsharma2@gmail.com

Abstract: This study in conducted in selected educational institutions in the state of Assam, considering the large amount of energy consumption in public establishments exceeding 20KW. With an addition of few high capacity of solar installation to an extent of even 5 MW, the load on the state supplied electricity will have a big relaxation. Replacement of conventional energy source by solar will also have the bigger social impact, with such pilot projects increasing the visibility of solar installations and knowledge of the importance of renewable energy among masses. A systematic cost benefit analysis with data from selected 12 institutions in Kamrup district of Assam is carried out to show the economic feasibility of such a project in replacing the existing source of state supplied electricity with a payback period of 5 years. Also a study to understand the challenges faced on ground are studied to come up with practical implementation strategies. The recommendations would be submitted to Assam Energy Development Authority to handle the problem of power deficit and action points to be adopted. A renewable source of energy like solar installation also ensures reduction in emission of pollutants and a sustainable source of power adding to infrastructure development.

Keywords: Solar energy; Meeting power demand by solar; Sustainable Energy Project

INTRODUCTION

Considering the current world we live in, it is almost impossible to think of a single day without the use of an electrical appliance or electronic gadget with the demand curve rising exponentially. A simple pattern of economic development highlights the fact that countries with more energy consumption per capita are more developed than the once with less consumption of energy [1]. For India, the GDP growth rate has been roughly around 7.3% YoY , with growth of installed electricity generating capacity standing at around 6.21% CAGR, which shows a crystal clear co-relation of the economic growth linked to increasing generating power capacity in the country [2]. A fast developing country like India faces this huge challenge to cope up with the ever increasing energy demands. Out of the total power capacity of the country (2.8 GW), only 0.50% power is available in the state of Assam, whereas the share of population is 2.85%. Current power availability of the state is approximately 1200MW with a deficit of around 200MW, with demand rising approximately twice in last 5 years [3]. To cater the rising energy demands of ever increasing population, pressure on the existing source of energy majorly fossil fuel and hydro is constantly building up due to limited availability. The current available power comprises of 60% sourced from hydro projects, and most of the remaining from thermal projects, which is falling far below the expected levels indicating the limited scope of further expansion in both these arenas. In such a scenario, an alternative source of power has become essential.

Current utilization

Solar power has been acknowledged as one of the most viable (commercially and technically) source of clean energy. The SECI (Solar Energy Corporation of India under the Ministry of New and Renewable Energy) publication on 9th Dec 16 declared a 1000 MW of grid connected roof top solar PV system scheme is to be implemented in different states in India. This would majorly be concentrated for Govt. buildings and Educational institutions considering the huge amount of energy consumed in such establishments and the social impacts. The total funds allocated for solar energy development in terms of subsidiary sanctioned by the MNRE has been scaled up from previous Rs.500 Crores to Rs.6000 Cores in April 2016 which is to be implemented in phase wise manner and completed till 2022 [4]. Total installed renewable energy capacity in India is around 45 GW till Sept 16, with solar contributing approx. 8.5 GW. MNRE has set high targets of scaling up this total capacity to 175 GW by the year 2022 with 100 GW being contributed from solar power. Solar has on a very fast growth trend in India with high sentiments that India would very soon become one of the world leaders for developing renewable energy resources.

The source of energy generation is a key factor to be considered while having a holistic and long term planning of energy utilization. The major sources of energy used today are derived from coal and petroleum. There are two aspects to be considered while discussing about the source of energy which are*: current reserve of the limited supply and effect of usage*. Firstly both coal and petroleum are fossil fuels which mean that these fuels have been formed from the course of thousands of years of decomposition of carbons in the surface of earth. This gives us a direct indication that there is a limited supply of such fuel deposited in the surface of earth and these supplies will deplete or finish after a certain duration of time. At the same time, consumption of energy has increased drastically majorly due to modernization, industrialization and increase in population burst. Looking at the rate at which demand is increasing and supply sources has not increased with the same pace, a huge gap is likely to be formed in the demand and supply of fossil fuel. Crude oil reserves are vanishing at the rate of 4 billion tonnes a year. If we continue to carry on at this rate without any increase for our growing population or aspirations, our known oil deposits will be gone by 2052 [5]. According to the Association for the Study of Oil and Gas (ASO), the rate of discovery has been falling steadily since. This leads to a general conclusion that oil will be depleted soon. In 2009 proved reserves were estimated as follows with that year's fuel consumption in mind: Oil: 46 years (depleted in 2055); Natural gas: 63 years (depleted in 2072); Coal: 119 years (depleted in 2128).

Secondly the usage of such fossil fuels releases greenhouse gases in the atmosphere. Last few decades has seen a significant growth in the population levels of humans. Industrial and economic activities have also increased drastically to cater to such high population which resulted major changes in the climatic conditions of earth. This change has been distinctly visible post the industrial revolution era of our civilization due to increase in level of greenhouse gases in atmosphere. Increased level of greenhouse gases traps more heat in the atmosphere and makes the earth warmer resulting in. Higher temperature has severe impacts to our ecosystem resulting in increased sea levels due to melting of the ice and at the same time harming various species and ecosystems existing in the earth ultimately threating the existence of human civilization on earth. With 1 degree increase in temperature levels crop yield decreases by about 5 percentages [6]. Due to this increase in temperature levels, global average sea levels rose by 19 cm from 1901 to 2010. If this rate of increase of greenhouse gas emission persists, global temperature is likely to increase by 1.5*C. This would lead to increase in sea levels by 24-30 cm by 2065 and 40-63 cm by 2100.

Solar energy concept

The average annual solar radiation arriving at the top of the Earth's atmosphere is roughly 1361 W/m2 with radiation distributed across the electromagnetic spectrum from radio waves through the infrared, visible and ultraviolet to X-rays and gamma rays. However, around 98 per cent of the energy of solar radiation is contained in the wave length band from 250 nm to 3000 nm, comprising the near ultraviolet, visible and near infrared regions of the solar spectrum. About 40 per cent of the solar radiation received at the earth's surface on clear days is visible radiation within the spectral range 400 nm to 700 nm, while 51 per cent is infrared radiation in the spectral region 700 to 3000nm, with a very small amount of ultraviolet radiations in less than 400 nm range. Solar energy based applications like Solar Photovoltaic systems are limited to utilizing solar radiation wave lengths between 290 nm and 550 nm since a major part of the spectrum gets attenuated in other wave- lengths due to either absorption or scattering in the atmosphere en route the earth's surface [7]. The Sun's rays are attenuated as they pass through the atmosphere, leaving maximum normal surface irradiance at approximately 1000 W /m2 at sea level on a clear day. When 1361 W/m2 is arriving above the atmosphere, direct sun is about 1050 W/m2, and global radiation on a horizontal surface at ground level is about 1120 W/m2 [8]. The latter figure includes radiation scattered or reemitted by atmosphere and surroundings. The actual figure varies with the Sun's angle and atmospheric circumstances. Ignoring clouds, the daily average insolation for the Earth is approximately 6 kWh/m2.

The solar radiations received in earth are like packets of energy known as photons. These energy packets are the primary source of energy to drive everything in earth which required power. Be it fossil fuels or hydroelectricity, every energy source has its origination from solar energy. Other sources of energy like hydro power or wind power are also derivatives of solar energy. Solar energy heats the water which evaporates and raise in the atmosphere and later falls down from higher potential heights, which ultimately can be a source of electricity generation by using turbines in form of hydroelectricity. Heat of the sun warms up the air, which leads to displacement of hot air upwards in the atmosphere which ultimately leads to flow of air, potential to generate energy from wind flow. Photovoltaic was a major discovery which set up an arrangement where the energy from sunlight can be directly converted into electricity, which could be used as a primary source of energy to cater to our energy needs.

Solar Photovoltaic technology has made a huge advancement in terms of its efficiency from the time of its initial inception which has given opportunity to utilize the sun rays directly for electricity generation and avoid the conversion losses and intermediary resources required to extract energy from. During the time of inception of solar energy to be utilized by humans, simply sun rays were used as heat source and was used as passive heating for homes. After the industrial revolution, solar heat was used to heat water and in turn utilize the steam generated to run steam engines. Photovoltaic is the property of processed semiconductor materials to generate electricity when exposed to light. Silicon as on today is the most preferred semiconductor material used as PV solar cells due to its availability and its conversion ratio of solar rays to electricity. Various configurations of silicon array of solar cell are used like thin film solar cell, Wafer solar, polycrystalline, Amorphous Silicon, Concentrated PV, Crystalline silicon, etc., being the most commonly used. Data analysis reveals that nearly 58% of the geographical area in India potentially represents the solar hotspots in the country with more than 5kWh/m2/day of annual average global insolation [9]. A techno-economic analysis of the solar power technologies and a prospective minimal utilization of the land available within these solar hotspots demonstrate their immense power generation as well as emission reduction potential.

METHODOLOGY

Selection of sample

This study is a descriptive research study conducted to find the viability of solar electrification project as an infrastructure growth and replacement of the main grid electricity supply. Since the quantum of electricity consumption is much higher in public institutions, Gov. Office, schools & colleges, it makes more sense to conduct the study in such institutions first. Kamrup is a district which experiences the highest rate of urbanization among all districts in the state of Assam and it also houses the capital of the state [10]. The samples selected are educational institutions in Guwahati city. The research is basically an exploratory one which is based on both primary and secondary data. The primary data will be collected by the technique of field survey, Personal Interview and questionnaire. Secondary data collected from different books, journals, Journals, websites etc. A detailed source of secondary data is mentioned in the appendix section.

It is estimated that there are around total of 38 Educational institutions of higher studies (Graduation Colleges) in Kamrup district. We have selected a few institutions on the basis of maximum usage of power. Geographical segmentation is done and one institution is selected in each area of East, West, North, South and Central of metro Guwahati.

This study is conducted in some of the educational institutions of Guwahati to understand the feasibility of replacement of the power source from conventional energy source to solar. Educational institutions are selected for the case study since it will be less challenging to attract funds for these non-profitable organizations since solar installation will have a high initial cost. Another important factor for carrying out this study in educational institutions is to raise the interests and awareness of the students towards renewable energy domain. Renewable energy still remains as a very small contributor to our energy requirements. A huge amount of research needs to be carried out if we envision making the nation self-sufficient for our ever increasing energy requirements and shifting to renewable energy sources as the major source of our energy requirements. Solar installations and successive works and research by students of those institutions is expected to increase the visibility of solar systems to many folds and will increase the overall awareness of the solar energy generating systems to the common people. A combined effect will ultimately increase the share of electricity generation with solar energy as a major source, reducing consumption and dependency on fossil fuel.

Another major reason to choose this segment is considering the economic behavior of consumers in case of renewable energy products. Renewable energy installations are more beneficial in terms of long term views. So in case of Individual customer, it is very difficult to propagate this value proposition since majority of individuals do not think of long term benefit more than 2 3 years. However institutions are more beneficial to long term investments which will be a good return to their investments within a span of time. Also the amount of power consumption for individual customer is very less as compared to that of an Institution. So the amount of power savings in terms of usage will increase with increasing amount of power usage.

Following parameters mentioned below are an integral part of our study

a. Total population: Total universities in Ghy.
b. Sample size to be selected
c. Geographical segmentation is to be done.
d. The type of management, i.e. Gov. and Private management is to be considered.
e. List of selected respondents;
    i. Decisions makers in universities (DEAN, VC, Director, Registrar, HOD technical and 3 professors with technical background) - No’s 10 each university.
    ii. Technical persons related to academics- No’s 10.

iii. ASTEC and other regulatory authority- No's 10.
iv. Existing manufacturers and vendors- No's 10.
v. Selected individual consumers-No's 10.

Questionnaire and survey with a good mix of open end and close ended questions are administered. Focused interview is to be conducted with decision makers and key individuals having a strong understanding of the subject matter. Once data collection is done, correlation study is done to understand the perception of the people in regards to solar energy considering the preference of renewable energy against the demographic and socio economic characteristics of the respondents. Following is the list of higher educational institutions in Guwahati where the study will be conducted.

Table 1: list of higher educational institutions in Guwahati where the study will be conducted

Sr. No.	University	Location	Type state	Established
1	Gauhati University	Guwahati	State	1948
2	Assam Don Bosco University	Guwahati	Private	2008
3	Assam Engineering College	Guwahati	State	1955
4	Girijananda Chowdhury Institute of Management and technology	Guwahati	Private	2006
5	Krishna Kanta Handique State Open University	Guwahati	State	2007
6	Assam Down Town University	Guwahati	Private	2010
7	Cotton College State University	Guwahati	State	2011
8	Guwahati Medical College	Guwahati	State	1960
9	North Eastern Regional Institute of Management	Guwahati	Private	1992
10	Guwahati Commerce College	Guwahati	State	1962
11	Guwahati College of Architecture	Guwahati	Private	2006
12	IIT Guwahati	Guwahati	State	1994

Location and Limitation

This study is concentrated in Kamrup district for the fact that Kamrup district is the central place of North East India where consumption of power is the highest. Further it is observed that a majority portion of power is used by the educational institutions in Kamrup district. We have considered the high energy consumption entities of these educational institutions where the sample size is restricted to 12 highest power consuming institutions among the total count of higher educational institutions in Kamrup district. Regarding the limitation of the study it is to be mentioned that the study mainly concentrates on selected number of educational institutions which used the highest amount of power. In a further course of study and future research scope, more numbers of institutions and different establishments can be considered under the study to get a further insight about the subject.

Calculations

The demand and supply side of an electrification system is studies in details. We have considered a sample and based on the inputs from the total load in the facility, the power requirement and the possible replacement by solar to cater the demand is studies.

The cost benefit analysis of replacement of electricity source by solar energy is calculated. A mathematical model is created which will provide the results from the input data required.

Information required from the existing consumption in the samples under study;

1. Total consumption cost per month.
2. Capital expense of state electricity board (Transformers, Cables and connections)
3. Tariff cost per month.
4. Maintenance expense accounted.

Information for solar powered project;

1. Capital expense of equipment.
2. Space cost.
3. Generation cost
4. Maintenance cost.
5. Existing schemes by regulatory authorities for solar.

Capacity requirement

Power is calculated in terms of the SI units "Watt" can be defined in electricity consumption terms as the rate of energy transfer. Electric utilities consume power supplied from power stations or distributed generations which is calculated using an electric meter [11]. The theory of calculation of power consumed can be viewed in simple terms as defined below;

For example: if a 100 W light bulb is on for 10 hours a day then:

100/1000 (kilowatt) x 10 (hours) = 1 kWh per day.

In one month, that same 100 W light bulb, turned on for 10 hours a day will consume:

100/1000 (kilowatt) x 10 (hours) x 30 days = 30 kWh hours per month.

So based on the electrical utilities which are to be used in a particular facility, total load quantity is decided. A rough estimate of how theoretical calculation of load is done is shows below; Numbers are shown for illustrative purposes only;

- 16 W bulb (on for 10 hours) - 4.8 kWh/month x Quantity
- 100 W bulb (on for 12 hours) - 36 kWh/month x Quantity
- 290 W Computer (on for 8 hours) - 70 kWh/month x Quantity
- 75 W Fans (on for 10 hours) – 22.5 kWh/month x Quantity
- Other laboratory electric equipment - 75 kWh/month

Total power consumed per month is addition of all the above loads which in totality comes to 208 kWh for the above example. So this is the units consumed for a month which is charged according to the tariff applicable from the service provider. In our sample of study the tariff charges from APDCL (Assam Power Distribution Company Ltd.) is considered at 6.85 per unit. So the total consumption charges in this particular case is 208 x 6.85 = Rs.1425. Apart from this there would a fixed component of charge depending on the total load capacity for the facility.

A sample of load test report is attached in appendix as to how calculations are carried out in these facilities during the time of initial allotment of power requirements. Based on those estimates, load capacity is assigned to the customers by the energy service provider (in our case the facilities).

Starting with smaller capacity study, a typical home requires approximately 3.85 kWh per day, then we require the following capacity from the solar panels: 3.85 kWh (per day) divided by 7 hours of sunlight (per day) = 0.55 kW from the solar array.

If we have a 120 W panel, then we require:

0.55 (kW) divided by 120/1000 (kW) = 4.6 panels

This is a rough calculation but it shows that under ideal conditions, we need more than one solar panel to meet a typical lifestyle. This is assuming the following:

- The roof is large enough to accommodate 5 panels (since you can't really have "4.6" panels).
- The panels receive direct sunlight for at least 7 hours a day.
- There are no obstacles in front of the arrays.
- The panels are kept clean.

The below table gives a clear calculation of how the monthly power consumption is calculated per units, per month and the charges are derived.

Table 2: Monthly power consumption

Application	***100W Bulb***	***16W bulb***	***Fan***	***Computer***	***Special Lab equipment***
Power rated per unit	100	16	75	290	400
Duration of operation in Hrs.	12	10	8	8	6
Quantity	15	200	120	80	10
Total power consumed per day	18000	32000	72000	185600	24000
Total power consumed per month	540000	960000	2160000	5568000	720000
Power in kWh	540	960	2160	5568	720
Total monthly Power consumption units (kWh)	**9948 kWh**				
Monthly Power consumption bill considering tariff rates 6.85	**Rs.68144**				
Total monthly bills (Consumption + Fixed charges approx. Rs.3000/month)	**Rs.71144**				

Supply side calculations

Based on the power consumption pattern studied above, the system design is carefully done taking into account all variable factors. During the operations of a solar electrification system, there are losses in converting the energy from the sun into DC power, and turning the DC power into AC power. The losses are incurred due to wiring, power, and inverter efficiency etc. This ratio of AC to DC is called the 'de-rate factor', and is typically about .8. This means we can convert about 80% of the DC power into AC power [12]. Since majority of the utilities and appliances run on AC power, the design of the system is to be done keeping this factor of power loss in mind.

To figure out how many kilowatt-hours (kWh) solar panel system puts out per year, we need to multiply the size of system in kW DC times the .8 de-rate factor times the number of hours of sun. So if we have a 7.5 kW DC system working an average of 5 hours per day, 30 days a month, it'll result in 900 kWh in a month. So considering the AC amount we need: 6kW and divide by .8 (6kW/.8 = 7.5kW DC). This means that we need 30 numbers of panels with 250W solar panels or 27-28 numbers of 270W panels.

Hence the system can be designed by 30 panels of 250W which gives 7.5kW DC power output. This system operating for 5 hours x 30 days a month gives a total of 1125kWh of power output monthly, which after considering 80% efficiency will be able to run AC power requirements of 900kWh. In our above calculation table cited, to cater monthly requirement of 9984 kWh of AC load, the total capacity requirement of solar installation would be around 84kW DC solar electrification system considering 5 hours daily working at peak power.

Space requirement

Continuing our working of the considered facility where we derived the capacity requirement of 84kW. The required number of panels with capacity considered of 250kW each panel can be calculated as follows;

Total Output power = Number of panels x Capacity of each panel

84kW = 340 No's x 250 kW

Now the "area required" for installing 340 numbers of solar panels can be calculated as;

Total Power Output=Total Area x Solar Irradiance x Conversion Efficiency

Assuming the required Total Output Power is 1000 Watts (10 panels x 100 Watts), the Solar Irradiance for a surface perpendicular to the Sun's rays at sea level on a clear day is about 1000 Watt/m2 and the Conversion Efficiency is 18%. Plugging these numbers in the above equation we get:

1000 Watts = Total Area x 1000 Watts/m2 x 0.18

Total Area = 5.56 m2

If we have to install all the panels in one line, we would need a space of approximately 1 m x 5.56 m (each panel having a size of 1 m x 0.556 m) on rooftop.

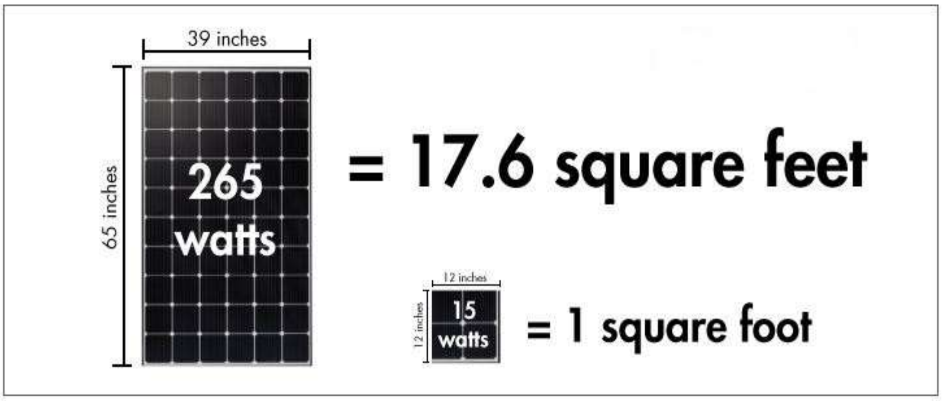

Fig-1: Area requirement for Solar PV installation

In a typical panel shown in the figure above, considering the length as 65 inches (5.42 ft.) and width 39 inches (3.25 ft.) the space covered per panel is 17.615 Sq.ft with an individual panel capacity of 265~250 kW. So a total of 340 numbers of such panels would require 5892~6000 square foot of area [13]. So arranging the panels in a linear array with 2 panels in vertical manner (10.84 ft.) and 30 panels in horizontal manner (97.5 ft.) with total sq.ft area coverage of 1057 sq.ft will give an output of around 8kW. So in total 6 such arrangement with coverage of 1057 sq.ft per arrangement unit is to be carried out to get the total required capacity of 84kW as required by the system design.

Feasibility

Based on the calculations conducted above, it is estimated that total 84kW capacity of solar would be necessary to cater to the current demand of the sample studied above. Space requirement for accommodating 340 numbers of panels is approx. 6000 Sq.ft, is no bar in this case since all the 12 sample institutions considered in our discussion has ample amount of space in their rooftop or other disposable open space. The cost of solar electric system is estimated to be nearly 4500000 for the entire installation [14]. This is considering the various MNRE subsidiary and accelerated depreciations schemes. The usage cost of grid supplied electricity is considered as per our earlier calculation of Rs.71144 monthly. The operational expense for solar are estimated as 10,000 for cleaning and regular maintenance purpose for the solar PV panels.

Table 3: Cost Benefit Analysis of Solar Installation

No. of years		**1**	**2**	**3**	**4**	**5**	
Main Grid Supply							
Capital Expense	Transformer	200000					**4558640**
	Cabling	80000					
Operational expense	Usage cost	853728	853728	853728	853728	853728	
	Maintenance				10000		
Total		1133728	853728	853728	863728	853728	
Solar Energy							
Capital Expense	PV Modules	3500000					**4550000**
	Inverter	200000					
	Battery bank	500000					
	Balance of system	300000					
Operational expense	Usage cost						
	Maintenance	10000	10000	10000	10000	10000	
Total		4510000	10000	10000	10000	10000	

From the calculation it is observed out that the total cost of electricity calculated over a span of 5 years is almost same for the state board supplied electricity and the electricity generated from a solar energy project. In other words, the solar project reaches to a breakeven point in a span of 5 years, where the cost of electricity from a state supplied and solar generated are equal. After this period, the incremental cost in solar installation is very small and savings would be very high comparing with electricity usage cost of main grid electricity [15]. *This cost benefit analysis gives us a crystal clear picture of the feasibility of replacing a main grid supply with a solar powered project*. Another aspect that needs to be considered is that solar installation will reduce the problems faced due to power shortage and frequent power cut offs faced in power from main grid especially in rural or areas with shortage of power supply. Here such an installation gives much more independence and flexibility to the users. Also usage of renewable energy project will mean lower usage of coal or other fossil fuel for generation of the same energy used which will contribute to reduction in greenhouse gas emission curbing the harmful effects of climatic changes in the form of global warming.

BUYING BEHAVIOR TOWARDS RENEWABLE ENERGY

Perception of people towards solar energy

A lot of advancement has been achieved in the sector of harnessing and using solar energy from the time of its initial inception where people realized that energy from sun can be trapped and utilized for energy requirement. Even though such a system promises a lot of benefits, consumers are not yet confident of the projected benefits and whether such a system will really yield such results [16]. The adoption levels of solar electric systems by common mass people have not reached an exponential growth rates till date. Few of the important reasons are highlighted as;

Awareness levels

Solar electrification is still a new concept for the masses. One of the major reasons for this low confidence is the lack of visibility of such systems in and around us. People are aware of solar and renewable and its benefits only superficially, when it comes to actual purchase decision, people are very less informed. Stated preference and actual adoption has a huge gap.

Commercial gaps

Consumers calculate the value of a product based on the benefits gained against the cost born to buy the product. The benefits of such a system is ultimately electricity generation to run the daily utility like TV, lights, air conditioner etc. , electricity generation do not directly give a value to consumers, hence involvement levels of people to evaluate source of electricity is low. Since initial cost of such systems is very high, people avoid getting further detailed commercial calculations of cost of system in a lifespan of the installation.

Technological reliability

Existing suppliers or service providers have not been able to build up the confidence of masses on reliability of solar energy systems. People perceive a lot of risk in adopting the technology which is relatively new in the market and not time tested. Consumers look at this as technically complicated product which they are not familiar to using and feel helpless in case of any break down or faults.

Space constrains

Space constrains and aesthetic appeal of solar electric systems have turned out to be a critical factor which hampers the decision making of consumers to adopt this source of power. Solar powered systems are more probable to be adopted by people who have a basis technical understanding of the benefits of such a system. Challenge is majority of such population is settled in urban settlements, where houses are mostly apartments buildings which face a major challenge to install such systems requiring additional space.

Support from regulatory authority

The role of regulatory authorities is very critical in the case of solar electric systems. Since energy is a strongly regulated sector, people face risk in moving away from the existing systems without the support of local regulatory authorities. Concept of independent source of energy to drive the day to day power requirements in a household is not accepted easily since people are used to regulatory bodies being involved in providing the power.

Solar PV system as infrastructure

The definition of infrastructure is “Components and installations that form the basics of any operation or system”. Installation of solar electric system has the potentiality to replace the main grid supply of power and also adding to the infrastructure development of the establishment. Big electronics majors like Toshiba and Hitachi have extensive numbers of solar projects installations in various establishments. Just like buildings, classrooms, furniture, library, laboratories, grounds etc. solar PV energy system can contribute to the infrastructure of an educational establishment. Decision of any infrastructure establishment will have a long term implications to the institution since a lot of money and time is invested in deciding for an infrastructure to be developed. Solar as a part of infrastructure will add value to overall development of the establishment and provide a huge support in terms of fulfilling the overall energy requirements of the particular establishment. The highlights of why solar is a good choice for addition to infra of an institution are discussed;

Demand of power is increasing at a very high rate, whereas the supply side has not seen much of increase resulting in shortage of supply in many places. This has caused a major gap of demand and supply chain which results in shortage in supply and irregularities of power supply in terms of power cut offs and black outs [17]. An in-house source of power supply in this case acts a boon to ensure continuous power supply without hampering the day to day activities. The most important factors which shows value to such a system is the level of independence of having a self-sufficient source of power for an establishment. So the problems of power shortage and frequent power cut offs will drastically reduce.

Considering the cost of energy utilization, the recurring cost of energy as per existing tariff from existing main grid is high. Solar installation has negligible maintenance cost involved, which makes this system all the more commercially viable to be used as an infrastructure addition to a facility. Since public establishments and institutions have a huge quantum of energy that is being used, thus making payback period calculations of solar installation much shorter. This makes the real sense of installation of solar PV system as an infrastructure. Solar equipment comes with a long life span warranty for e.g. most of solar panels have warranty of 15-20 years. So once the initial set up is done, there is a long time return on investment which results in a very good addition to the infrastructure of the establishment.

Another important consideration is that solar PV energy installation in educational institutions will also raise the interest of the students and other people involved with the institution in solar energy technology. Since a lot of academic and research field work is yet to be done in our country in terms of solar energy, such a physical setup would raise the interest of the academic people involved and also provide a physical real time setup for better understanding of the working of a solar PV system. Students and stake holders can observe the various parameters of daily operations of such a set up to identify the challenges and limitations and further research in this field can be carried out.

On and above all these points discussed, one of the most critical considerations to be taken is the increase in global warming due to greenhouse gas emission. The rate of increase of greenhouse gas emission has reached an alarming situation and throughout the world steps are being taken to reduce the emission of such harmful gases due to economic activities. Govt. provides a lot of helping hand in term of tax holidays, CDM mechanism and providing subsidiary to such installations in public establishments carried out with the help of state nodal agencies which results in promising of long term return of investments through such infrastructure setup.

SYSTEM DESIGN

Configurations

The factors of cost, ease of installation, geographical constrains, load requirements will ultimately decide the configuration which would be best suitable for the particular application.. For e.g. an unregulated stand-alone system can be configured to provide enough electricity to run applications of a house hold in the lowest costly manner and a remote location devoid of maid grid electricity supply, however such a system will not be of any use during nights or time of low sun rays intensity. Also the quality of electricity generated from such system might consist of spikes which may result in malfunctioning of certain electric appliances. On the other hand, regulated hybrid system will ensure best utilization of the solar grid and un-interrupted supply of electricity to the load with a backup provision and power conditioning arrangements. However this will substantially increase the project cost and complexity with requirement of regular battery replacements and other maintenance cost [18]. Also post installation, the monitoring of the system performance is also necessary to ensure maximum output of the system. There are majorly three types of arrangement of solar electric systems discussed below. Each of the configurations has its own advantages and limitations, so a trade-off needs to be maintained to design the system which should be able to solve the final goal of gaining clean and efficient energy.

Grid Inter-Tied Residential Solar Power Systems

A grid inter-tied solar power system is directly connected to the home and to the traditional electric utility grid. Grid inter-tied systems allow the homeowners to get power from either the home electric system or the utility grid. Switching between the residential system and the grid is seamless. The prime advantage of this type of system is the ability to balance the system production and home power requirements. When a grid inter-tied system is producing more power than the home is consuming, the excess can be sold back to the utility in a practice known as net metering. When the system is not producing sufficient power, the home can draw power from the utility grid.

Grid Inter-tied Residential Solar Power System with Battery Backup

A grid inter-tied solar power system is also connected to the traditional utility power grid and adds battery-backup to the system. The addition of a battery backup enables the system to balance production and demand and protects against power outages. When sunlight is abundant, production can exceed demand. When production exceeds demand, the excess power can charge the batteries, which store the electricity. When the system is producing less electricity than demanded by the home, the batteries can make up the shortfall. Grid Inter-tied systems are also connected to the utility power grid. This enables the homeowners to draw from the grid during periods of excess demand and to sell power to the grid when there is excess production. Even though this system is more flexible, the disadvantage is that charging and discharging batteries reduces the overall efficiency of the system and these systems are more complex to design and install and therefore more expensive.

Off Grid Solar Power Systems

An off-grid residential system is completely disconnected from the traditional electric power grid. Without a connection to the utility grid, batteries are essential to balance periods of excess production and excess demand. To protect against shortfalls of power when the solar system is under-producing and the batteries are discharged, an electric generator is usually added to the system. The generator is used as a power source during periods of prolonged excess production or unusual demand.

Challenges faced during and after installation of solar energy project at a site.

Installation details

Space is a major factor that needs to be taken care of while designing a solar power project. Since in this case we are dealing in educational institutions, there are ample amount of space in these campus which can be allotted for solar power project installation. The other option available is rooftop installation in case of cases where there is a space constrains. Balance of system consists of all components of a photovoltaic system other than the photovoltaic panels which includes the wirings, switches, solar panel frames and mounting system, battery charger and battery bank. The output electrical power from a Solar PV array is in DC form. Hence for utility of solar energy in our home appliance which runs on AC supply, an inverter is required to be introduced into the system. Also with this a battery to store charge during the no supply of power from the PV array is put into the system to provide backup power supply.

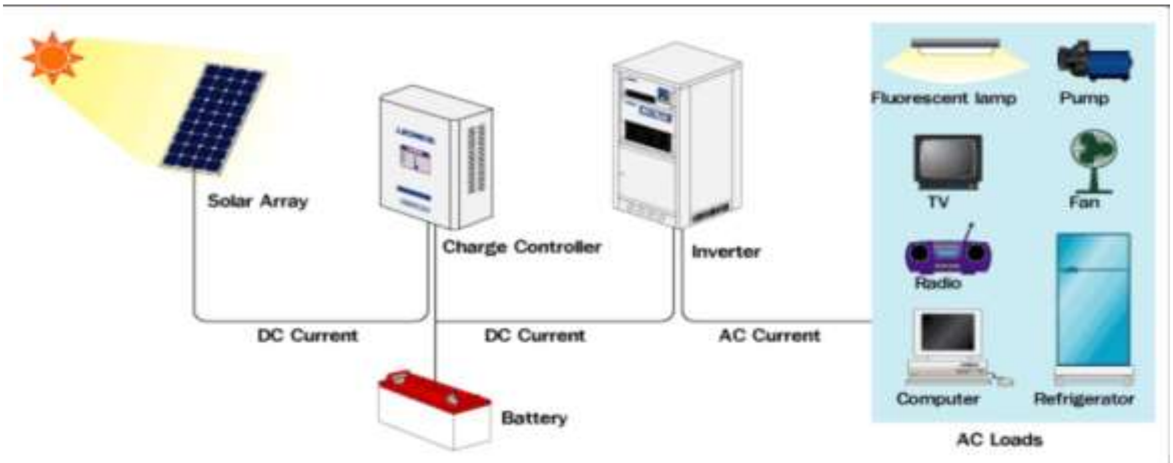

Fig-2: Solar electric power system layout

Maintenance issues

Solar electric systems have one of the best advantages of low maintenance cost. The overall system requires negligible maintenance and care during its operations. The major concern that occurs is the inverter and the battery backup system. The battery charging cycles are very rigorous in a solar electric system and the inverter system is constantly converting the DC generated power to AC power to run our appliances. Even though warranty is provided with the system, it is very important to take a note of the warranty of various components of the entire system. The solar panels are generally covered under a warranty scheme of 20-25 years. Out of this, output of min 80-85% of peak power is guaranteed for 15 years which makes the solar panel maintenance negligible apart from regular cleaning to remove dusts over the panels. In terms of the battery and inverter system, manufacturers provide a warranty of approximately 15 years for the inverter and 10 years for the battery. Even then, the preventive maintenance of these two parts becomes extremely sensitive to ensure no breakdown in power generation capacities of the overall system.

CONCLUSIONS

The above discussion gives a very clear picture that it is commercially viable to replace the current state supplied electricity in an educational institution with a solar electric powered solar energy project. This has been closely studied in the consumption patterns of the selected set of educational institutions. Even though the initial equipment cost of solar projects are on a higher side, when apportioned over a period of 5 years, the total *cost of ownership is lower* compared to state supplied electricity, and beyond 5 years, the saving are immense considering high power cost of state supplier electricity. One reason is because solar powered projects have negligible recurring cost of usage when compared against high tariff of state supplier electricity. On top of this there is a factor of *energy independency* in case of solar powered projects which are makes the institute self-sufficient for their energy requirements. Such an installation adds to the infrastructure of an establishment since solar installation will prove to be an asset which will make the establishment self- sufficient in terms of its energy requirements and will bring down the energy usage cost drastically. This will also *cut down the emission* of greenhouse gases released during generation of electricity and at the same time cut down the cost of energy usage and dependency on main grid supply. Another major factor to be considered is that a solar electric system requires a good amount of *space to set up* the entire system including the solar panels, frames, batteries and other balance of system. In our study of samples of educational institutions, there were ample amount of open space provision in those establishments which did not raise any issue of space constrains.

RECOMMENDATIONS

Based on the observation of various feedbacks from stake holders and existing countries where solar power has been a success, actions by the regulatory authority is a critical step to be taken in order to increase the presence level of solar energy. Government incentives and tax holidays are one of the most lucrative schemes which motivate the public to adopt solar as an alternative source of energy. Funding schemes from financers is another such scheme which can go a long way to support in the initial introductory time of solar installation among masses. In case of solar projects, initial investment in solar setup is the major cost involved which prevents a lot of prospective buyers to hesitate in their decision to go ahead with solar. A good finance scheme would prove to reduce the perceived risk of common masses to go for solar power. NGO and awareness spread by activities are very critical to spread the awareness level of people about the advantages of solar energy. The critical aspect of the effects of global warming and its major negative impacts on our planet needs to be communicated to common masses. The combined effect of awareness of the benefits of solar energy and its role in reducing global warming would increase the morale of people towards solar power. Technical expertise and reliability is another important reason why people take a step back. Since there is a low visibility of this technology, people are not yet confident of this technology and the existing suppliers have not been able to build up the confidence levels. Hence few of such pilot projects funded by govt. would give a strong boost to scale up the visibility.

REFERENCES

1. Heller, Thomas, Shukla PR. Development and Climate: Engaging Developing Countries.” In: Beyond Kyoto: Advancing the International Effort against Climate Change, Pew Center on Global climate Change, Arlington, VA, 2003.
2. Sharma NK, Tiwari PK, Sood YR. Solar energy in India: Strategies, policies, perspectives and future potential. Renewable and Sustainable Energy Reviews. 2012 Jan 31;16(1):933-41.
3. Executive summary on Power sector” In; Central electricity authority by Government of India, February 2014.
4. Upadhyay A, Chowdhury A. Solar Energy Fundamentals and Challenges in Indian restructured power sector. International Journal of Scientific and Research Publications. 2014 Oct;4(10):1-3.
5. Roa GB. Environmental impacts of renewable energy”, In; International Journal of Emerging trends in Engineering and development. 2012;4(2).
6. Garg A, Bhattacharya S, Shukla PR, Dadhwal VK. Regional and sectoral assessment of greenhouse gas emissions in India. Atmospheric Environment. 2001 May 31;35(15):2679-95.
7. Ramachandra TV, Jain R, Krishnadas G. Hotspots of solar potential in India. Renewable and Sustainable Energy Reviews. 2011 Aug 31;15(6):3178-86.
8. Mani M, Pillai R. Impact of dust on solar photovoltaic (PV) performance: Research status, challenges and recommendations. Renewable and Sustainable Energy Reviews. 2010 Dec 31;14(9):3124-31.
9. Ray S. Calculation of sun position and tracking the path of sun for a particular geographical location. International Journal of Emerging Technology and Advanced Engineering. 2012;2(9):81-4.
10. Sarma D, Gogoi R, Nath B, Konwar S, Meitei CL. Design, Fabrication and the Experimental Performance Evaluation of Flat Plate Solar Water Heater specifically for Jorhat, Assam (26.75 N, 94.22 ºE). International Journal of Engineering Trends and Technology (IJETT). 2014 Jun;12(7):341-52.
11. Solanki CS. Solar Photovoltaic: fundamentals, technologies and applications”. PHI Learning Pvt Ltd, 2015.
12. Sinha B, Joshi K. Analysis of India’s solar photovoltaics research output. Annals of Library and Information Studies (ALIS). 2012 Jul 13;59(2):106-21.
13. Upadhyay A, Chowdhury A. Solar Energy Fundamentals and Challenges in Indian restructured power sector. International Journal of Scientific and Research Publications. 2014 Oct;4(10):1-3.
14. Gyanpuri Y, Kumar A. Solar Power and Its Development in India: Overview. In; Progress In Science and Engineering Research Journal. PISER 12, Vol.02, Issue: 02/06 March.
15. Sharma NK, Tiwari PK, Sood YR. Solar energy in India: Strategies, policies, perspectives and future potential. Renewable and Sustainable Energy Reviews. 2012 Jan 31;16(1):933-41.
16. Devine-Wright P. “Reconsidering public attitudes and public acceptance of renewable energy technologies: a critical review”, published by the School of Environment and Development, University of Manchester, Oxford Road, Manchester M13 9PL, UK, 2007.
17. Ian V. Rooftop Revolution?: Comparative Effectiveness of State Policy Incentives for Encouraging Residential Solar Adoption in the United States”; Paper for presentation at the Association for Public Policy and Management Annual Conference, Washington, DC, Nov. 7 2013.
18. Sultan F, Winer RS. Time preferences for products and attributes and the adoption of technologydriven consumer durable innovations. Journal of Economic Psychology. 1993 Dec 1;14(4):587-613.