Is Solar Electrification a Sustainable Solution for RuralElectrification? Learning from Field Experience

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Abstract

Addressing the needs of sustainable development also needs to address the issue of rural electrification. The government of India has taken different policies for rural electrification for remote villages in India by distributing Solar Home System (SHS). Such programs have been executed in the state of Assam also, which is situated in the North Eastern part of India. But the thing to be noted is that such installations are highly subsidized. Under such circumstance people may not be eager to buy from market and there is problem of non-payment of monthly sustenance charge which beneficiaries are supposed to pay for replacement of batteries. There is difficulty in repairing SHS which is coupled with non availability of spare parts. Therefore, sustainability of such program is a very relevant issue to address. The main objective of this research is to see whether the installation process is sustainable or not and to discuss the impact of solar electrification on the community. It will also study the factors that affect purchasing decision of SHS. The study will help policy makers to promote sustainable rural development by providing reliable source of energy for rural electrification.

Keywords: solar home system, village electrification committee, subsidy

1. Introduction

One major concern for sustainable development is accessibility of clean and affordable energy by the poor. Therefore, in order to address the needs of sustainable development, it is necessary to examine the constraints related to rural energy and to find appropriate solutions that have a bearing across all sectors of rural development [1,2]. Rural electrification is an indispensible part of any strategy to address the issue of rural energy needs. Rural electrification improves the society in different ways. With rural electrification there is an improvement in health facilities, there is relief from indoor pollution which might arise due to use of kerosene for lighting, enhances knowledge through access to television and better nutrition from improved knowledge and storage facilities from refrigerator [3].

The International Energy Agency Statistics indicate that around 1.44 billion people globally have to live without access to electricity [4, 5]. Of these, approximately one out of four people is from India. In absolute terms, 25 percent households in the country still do not have access to electricity [4]. As a result, grid electrification is neither feasible nor recommended. The Ministry of New and Renewable Energy has been implementing different schemes from time to time to electrify these villages by installing solar photovoltaic home lighting system and solar mini grids. However, such programs are not based on the need of the ultimate users but they are judged in terms of administrative criteria and the needs of the implementing organization [6]. It finds that such photovoltaic technologies play an important role in sustainable development of a region [7]. Contrary to this, [8] have found that renewable energy also offers the scope to sustain livelihoods in remote villages. [9, 10] have found that SHS improves not only socio economic condition but also reduces adverse environmental condition contrary to the belief that the financial burden of such systems imposed on the families outweighs the benefits from the system. But unfortunately, a study [11] have confirmed from field observation that most of SHS have been found to be out of order due to component failures for which there is no monitoring or maintenance. Such programs may be very effective in rural areas where there is no possibility of grid electricity [12]. Rather electricity is not always the most appropriate form of energy, nor is it the quickest or most cost-effective way of providing energy services to the poor. For example, extending an electricity grid to households in rural areas can cost seven times more than for grid electricity in urban areas. In most of sub-Saharan Africa, less than 10% of the population has access to electricity. It is estimated that it would take over 250 years to supply all households in Uganda with electricity at current rates of electrification [13]. Therefore, under such circumstances, solar energy may be a suitable alternative.

Understanding the diffusion of solar appliances is a complicated process. It has been found [14] that people's choices for solar appliances are many times determined by economic as well as cognitive factors. Sometimes subsidy may be a major driver behind

rapid increase in solar photovoltaic energy generation [15, 16, 17, 18]. To date, there are relatively few empirical studies that can inform this debate, and the available evidence is mixed. It has been found in Bangladesh that subsidies in rural areas are progressive when programs are appropriately targeted even using the private sector delivery model contrary to the commonly held views that subsidies for promoting SHS dissemination in rural areas benefit mainly better-off households [19]. One study in China has found that adoption of renewable technology in rural areas is significantly influenced by initial investment followed by subsidy and financial support, technical service, and the technology exchange visit. Therefore, it needs empirical evidence to prove whether subsidy is really an important factor or not.

2. The problem

The government of India has taken different policies for rural electrification in India in the last couple of decades. The need of solar electrification arose because the supply of grid electricity was not sufficient. Rural electrification has remained a priority in India's five year plan and there are different flagship programs for rural electrification. In spite of such ambitious programs, there are 579.10 million people in India without access to electricity which is 35.44 percent of the world population [2]. About 67.6 million rural households in India rely on kerosene as fuel for lighting in absence of grid electricity. The total number of villages in Assam is 25,590 and the percentage of villages electrified to total villages is only 77 in the state. There are 2,145 remote villages that cannot be electrified through grid because they are situated far away from the mainland where extension of grid electricity will be highly expensive [20]. Therefore, these villages have been brought under different programs of the Ministry of New and Renewable Energy (MNRE) of Government of India, for electrification through solar photovoltaic systems. They are sponsored by Ministry of Non Conventional Energy Source (MNES), state government, Member of Parliament fund, North Eastern Council and many more. The Assam Energy Development Agency (AEDA), the Assam State Electricity Board (ASEB) and the Forest Department of Assam government are implementing these programs in the state. Such solar electrification program started in 1991-92 for the first time in Assam. There are NGOs to identify the beneficiaries and assist the beneficiaries to form Village Electrification Committee (VEC) with only the beneficiaries as members. The VEC collects the payment to be made by beneficiaries for obtaining the SHS on behalf of the state-implementing agency. The VEC is also responsible for collection of maintainability fee. In this way almost 57,499 families in 1042 villages have been electrified in Assam till 2011-12.

But the thing to be noted is that such installations are highly subsidized where the beneficiary has to pay a small share regardless of their level of income. Such highly subsidized scheme may create financial burden on donors. Moreover, SHS program has limited reach due to paucity of funds. There are demand for SHS under such schemes but supply is often limited [17]. Under such circumstance people may not be eager to buy from market. Instead, they may wait for the lowest SHS price to be announced by government under different subsidy schemes or they may wait for another scheme to be announced which may never actually happen.

There are some other problems associated with such schemes. One such problem is the non payment of monthly sustenance charge or maintainability expenses [21]. This deposit is meant for procurement of fresh battery replacing the earlier one once defunct [22]. Without this deposit, the poor may not be expected to replace the battery after its life time is over. Another problem is the difficulty in repairing of SHS. The technology is itself unsustainable unless accompanied by effective follow-up servicing and maintenance support [17]. There is hardly any technician in the villages to repair the system. This problem is coupled with non availability of spare parts in the area. Therefore, sustainability of such program is a very relevant issue to address [21]. Therefore, the main research question to be addressed in the study is as follows-

Are the programs for solar electrification sustainable?

3. Objectives

The main objective of this research is to see whether the installation process is sustainable or not. Subsequently the other objectives are-

- To discuss the impact of solar electrification on the community.
- It will also study the factors that affect purchasing decision of SHS.

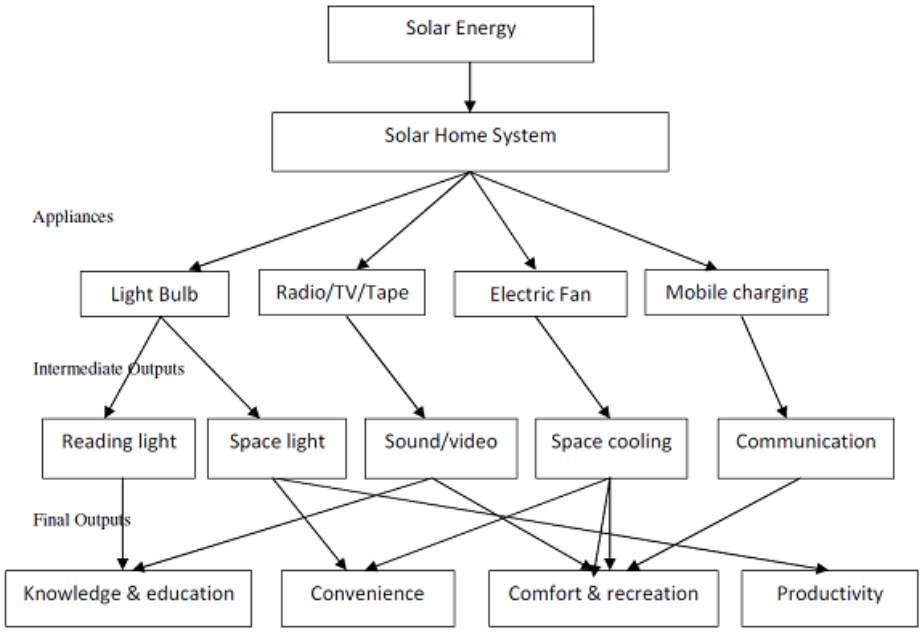
The study will help policy makers to promote sustainable rural development by providing reliable source of energy for lighting.

4. Conceptual framework

Access to modern energy services, whether from renewable or non-renewable sources, is closely correlated with measures of development, particularly for those countries at earlier development stages. Access to energy may improve health condition, promote gender equality and women empowerment and also improves literacy rate. Use of cleaner energy like solar energy can help to achieve sustainable use of natural resources and enhances environmental sustainability by reducing emissions which protects the lo-

cal and global environment [13]. Energy services reduce the time spent by women and children (especially girls) on basic survival activities, freeing up time for education or income-generating activities. A number of statistics show the very strong association between increasing commercial energy consumption and human welfare, as measured by indicators like the Human Development Index [13]. In fact the theoretical approach of the proposed study is mainly based on previous World Bank efforts to evaluate the benefits of rural electrification, Millennium Project and Department for International Development (DFID) approach. The theoretical idea is based on the view that demand for electricity is derived demand and it may contribute towards improvement of human well-being [23].

Fig.1 *Conceptual framework of the study*



The conceptual framework shown in figure 1explains the usefulness of solar energy harnessed through SHS in remote rural households. The basic flow chart had been adopted from ESMAP [24] but adopted to the rural environment of Assam in accordance with the capacity of SHS supplied in the study area by MNRE. There is no doubt that larger systems can power a water pump, wireless phone, refrigerator, electric tools like sewing machines and a VCR or VCD. But SHS sold under government schemes can be used to watch black and white television, radio, cassette player, and fan or for charging mobile phones.

5. Methodology

To understand the effectiveness of such solar electrification scheme a case study was conducted in the char areas (River Island) of Brahmaputra in Kamrup district of in the state of Assam situated in the North Eastern part of India. Kamrup is a district which experiences the highest rate of urbanization among all districts in the state and it also houses the capital of Assam. These villages are 6/7 kilometers away from the mainland amidst river Brahmaputra. The survey was carried out in different villages of the char areas of Brahmaputra under Goroimari Development Block of Chhaygaon in Kamrup. These villages are frequently affected by flood and erosion. People are landless and homeless. These villages are supplying vegetables, paddy, wheat etc to the mainland but flood destroys their crops every year causing poverty. These villages are geographically disadvantaged and it will not be feasible to connect these villages through grid electricity. Therefore, there is no electricity connection. When the authors and the data enumerator arrived in the villages' people were thinking that the team was there to distribute forms for allotment of SHS. Everyone insisted to be interviewed and some of them were ready to give passport size photograph also. Consequently there was problem in conducting the survey.

The study was conducted in Batahidiya Gaon Panchayat under Goroimari Development Block of Assam, India. It is 42 km away from Dispur, which is the capital of the state of Assam. There are approximately 3349 households in the Batahidiya Gaon Panchayat and AEDA has distributed SHS to 382 families in the year 2010. The study will include 230 families, which is 60 percent of the total families who have been allotted SHS. Primary data has been collected from these 230 families during November 2012 with the help of structured questionnaire at household level. These households have been selected from 14 villages which were purposively selected because they were beneficiaries of solar electrification scheme. Samples were drawn by using convenience sampling because households were selected without any underlying probability-based selection method. The villages were selected purposively which belonged to solar electrification schemes. Besides simple statistical tools such as percentage, frequency, logistic regression model

has also been used in the study to see the factors which affects willingness to purchase SHS from market. Logistic regression analysis examines the influence of various factors on a dichotomous outcome by estimating the probability of the event's occurrence. This model gives the log odds ratio which provides a more simplistic description of the probabilistic relationship of the variables and the outcome [24].

6. Demographic and socio-economic characteristics of the respondents

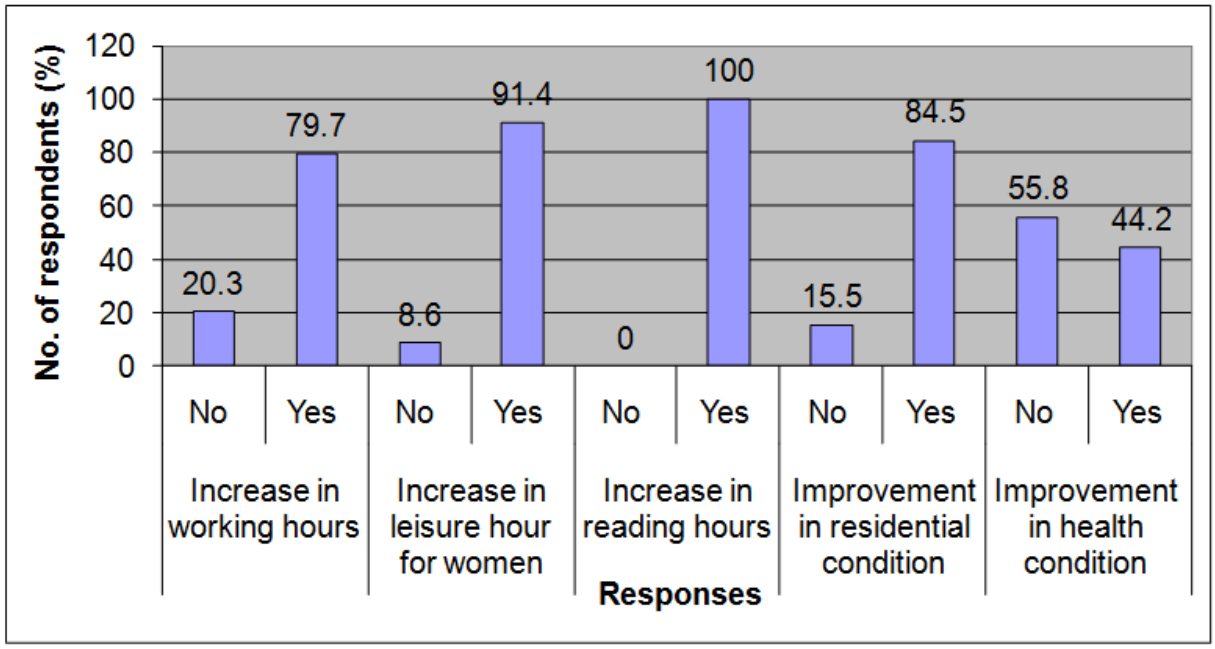
The villagers are mostly poor who practice subsistence farming. Except few most of them are engaged in agriculture and there are some families who are dependent on remittance sent by their family members who are working in other places. The average monthly income of the respondents is Rs. 3533.70 and monthly average expenditure on food, clothing, cooking and lighting, health and other items was Rs. 2145.57. The respondents have not been found to be so well educated. Almost 38 percent of them are illiterate; another 30 percent were educated up to primary level, 20 percent were educated up to middle school and 12 percent are under metric. None of the respondents have pucca (cemented) house. Almost 47 percent of them have thatch roof and remaining have tin roof but with katcha (earthen) plinth. Out of the total 230 households who have been distributed the solar home system, 68 percent households still use wick lamp along with and remaining 32 percent households use kerosene lamp for lighting along with SHS. It clearly shows that the 37 watt SHS which is capable to power two bulbs is not sufficient for the family.

There is a close relationship between power consumption and ownership of electronic goods. When they were asked about the ownership of electronic goods 39 percent of the respondents have been found to have no electronic goods at their houses and the remaining sample household had some or the other electronic goods like radio, mobile phone or tape recorder. None of the families were found to have television. Their knowledge about the SHS was also assessed in the survey. It has been found that almost 44 percent of the respondents do not have any knowledge prior to government distribution, 56 percent heard about it. It is clear that level of awareness about solar photovoltaic is low in the study area.

7. Impact of solar electrification on the community

Literature review has shown that use of SHS in the remote areas have improved quality of life. As a result of the use of SHS there is increase in working hours, extended and comfortable reading hour, people can enjoy more leisure and there is overall improvement in the housing condition due to better lighting condition. It has been found from the field survey that almost 80 percent of the respondents have reported that there is increase in working hour at least by 1 hour due to use of SHS. Some of them can work for more than 2 hours also in the evening. Their extended work hours increase their income as well. There is improvement in women's living condition also. Before the use of SHS, women had to complete every household chore previous to getting dark. But now almost 91 percent of them enjoy leisure hour. Such duration of leisure vary between one to two hours. This is a significant contribution in rural backward society towards improving women's living condition.

Fig.2 *Benefits from SHS*



It has been reported that there is extended reading hour in the family and children and the adult can ready comfortably without

the harmful exposure caused by kerosene lamps. There is also improvement in residential condition with the introductio-n of SHS. Almost 85 percent of the respondents have reported that they enjoy living in houses equipped with a SHS. But 16 percent of the respondents have reported not to enjoy any such improvement in residential condition. When respondents were asked whether their health condition had improved or not, majority of them reported that they did not notice any improvement in their health. The response is not so surprising because a period of 2-3 years may not be sufficient to understand or realize any change in health condition. But overall, improvement has been reported by majority of the respondents in different dimensions as a result of the use of SHS. The situation is shown by figure 2. It has been observed from the diagram that significant benefit has been enjoyed while reading at night.

8. Assessment of sustainability

The issue of sustainability is important for any policy measure so that there is no waste of resources because the subsidy that has been given for distributing SHS could have been used for more productive purpose also. Without sustainability the very objective of any policy measure is invalidated in the long run. In the case of solar electrification programs also, the assessment of sustainability is crucial as it involves huge subsidy from the government's side. SHS in the villages of char areas were distributed between May and June of 2010. So these systems are hardly 2.5 years old. The lifetime of the solar panels varies between 15-20 years whereas the guaranteed battery lifetime is 5 years. These batteries, when defunct, needs to be replaced by a new one. Therefore, there is provision in the schemes that each beneficiary should pay Rs. 70 per month to the VEC out of which Rs. 20 is maintenance fee and Rs 50 is deposited in their respective account so that the deposits may be used after five years for replacement of battery. But it has been found that all 230 households do not pay the maintenance fee to the VEC. They gave different explanation for the issue of non-payment as shown in table 1.

Table. 1 *Reason for nonpayment to VEC*

Reason	Responses (in percentage)
Do not have faith on VEC people	9.6
Do not have money whenever VEC come to collect money	37.5
VEC representatives do not come regularly	21.9
Govt. should pay	22.5
Respondents is Incapable to pay money	8.5

The issue of non-payment of maintenance fee may make these programs unsustainable after certain period of time. Almost 37.5 percent of the respondents have reported that they did not have enough money to pay the fee to VEC people whenever they arrived and 8.5 percent were incapable to pay the fee. Surprisingly, 22.5 percent of the respondents nourished the view that it was the duty of the government to deposit the fee on their behalf. One important thing to be noted is that their average income is very low. So they cannot be expected to accumulate enough money to buy a battery after the guarantee period is over.

At the same time 100 percent respondents reported that there is no one in the village to repair the system if any technical problem arises. Whenever any such technical problem arises, they talk to the people in their locality and find some solution. Some of them consult the educated youth and solve the problem by trial and error method. If that cannot solve the problem, they have to call someone from town area which is an expensive and time-consuming process. But once they do not find anyone in town also, that SHS remains completely out of order. It is a serious setback for the beneficiaries. The nonpayment of monthly fee and non availability of technician may make solar electrification programs unsustainable in the long run. Therefore, it cannot be expected that such schemes will generate any leverage effect to foster the process of rural electrification.

9. Factors affecting purchasing decision of SHS

During the visit to the study area, it was found that many people who did not get the SHS under government scheme were willing to buy it from the market. But they did not know how to procure it. One NGO named 'Human Welfare Society' used to supply them SHS. But that was not a sustainable solution too because supply was very limited and people could not avail any financing schemes. Therefore, the survey wanted to find what possible factors contributed towards taking a decision to purchase from market and respondents were asked if they would have purchased from the market had the government not supplied it at subsidized price. Almost 51 percent of the beneficiaries replied that they would have purchased it from the market also. Therefore, it was tried to find the factors what affected their purchasing decision. Since the dependent value may take only two possible values: '0' for not purchasing and '1' for purchasing, logistic regression has been used to determine the variables, which affect purchasing decision. The description of the independent has been given below.

The first independent variable is educational qualification. An increase in educational qualification may increase awareness and

income that in turn may influence their decision to procure SHS from market. The second independent variable is presence of school children in the family. Parents may be interested to provide them with good lighting system to study at night, which may influence purchasing decision. The third independent variable is development of residential condition due to the use of SHS. The realization that SHS improve living condition may inspire respondents to purchase the system. The fourth independent variable is the impact of use of kerosene lamp on health. In absence of electricity the use of kerosene is the most common phenomenon and any negative influence caused by the use of kerosene lamp may also motivate people to purchase SHS. The fifth independent variable is improvement in health due to use of SHS. Use of SHS may give relief from the use of kerosene. In brighter light people may not have eye problem also. Therefore, an improvement in health condition may inspire people to adopt SHS. The sixth independent variable is knowledge about SHS. Usually people in remote areas are not so much aware about the recent development in science and technology. Therefore, once people have knowledge about the SHS, they may try to procure one. The seventh and the last independent variable is availability of electronic goods. Electronic goods need power and in may indirectly influence the purchasing decision of SHS. The significant variables out of these seven variables will come out from the results of logistic regression analysis as shown in table 2.

Table. 2 *Results of logistic regression analysis to show the factor that affect purchasing decision*

Variable	Coefficient value	Significance level	Exp (B)
Educational qualification (edu)	.090	.559	1.094
Presence of school children in the family (sch_child)	.175	.017*	1.191
Perceived development of residential condition (dev_res)	-21.735	-.998	.000
Perceived impact of use of kerosene lamp on health (impact_kerosene)	.743	.143	2.101
Perceived improvement in health (impact_health)	.853	.019*	2.347
Knowledge about SHS (knowledge_SHS)	1.002	.003*	2.722
Availability of electronic goods (availability_electronics)	1.093	.001*	.335
Constant	20.790	.998	1.069E9
LR $chi^2(7)$ =28.44	Prob > chi^2 = 0.0002		
Log likelihood = -132.49313	Pseudo R^2 = 0.0969		

Dependent variable: decision to purchase SHS from the market.

* Represents variable significant at 5 percent.

The coefficient values of logistic regression cannot be explained in the same as one explains the coefficient values of ordinary least square method. From table 2 it is clear that the variable 'edu' is not a significant variable to determine the adoption of SHS. But the variable 'sch_child' is a significant variable to affect the purchasing decision and those families with school going children is 1.191 times more likely to buy the SHS in comparison to those who do not have school going children. The reason is obvious: people's decision to purchase from the market is influenced by the fact that it gives quality time for reading at night. The variable 'dev_res' has not been found to be statistically significant. It might happen because the SHS supplied under government subsidy schemes are not so powerful to light up the whole house. Similarly, it is clear from table 2 that 'impact_kerosene' is not a significant variable to affect purchasing decision of SHS. The probable reason might be because people are unable to realize the adverse impact of the use of kerosene. But contrary to this the variable 'impact_health' has been found to be significant. It shows that although people are unable to realize the adverse impact of kerosene use on health, they are able to realize positive effect of use of SHS on health. Respondents who perceive the positive effect of SHS on health have been found to be 2.347 times more willing to buy SHS even in the absence of subsidy in comparison to those who do not perceive to be so. Another significant variable is 'knowledge_SHS' and those who have knowledge of SHS are 2.722 times more willing to buy SHS in comparison to those who do not have any knowledge of SHS. The odds ratio 2.722 is the highest among all odds ratio. The last significant variable in table 2 is 'availability_electronics' has been found to be statistically significant to influence purchasing decision.

10. Conclusion and recommendation

The study clearly shows that people are benefited from the scheme implemented for distribution of SHS. Some of them enjoy extended reading hour as well as leisure, extended working hour and there is also improvement in living condition. Most of the respondents are satisfied with the service rendered by SHS. In a char where there is no possibility, people are benefited to such an extent that they have shown willingness to buy from market without subsidy too. The decision to buy from open market is attributed to significant factors like presence of school going children, improvement in health condition, knowledge about SHS and availability of electronic goods. The benefit and satisfaction from SHS are really important which induce them to buy the system. Seeing these benefits there will be many non-adopters willing to procure from market. Therefore, government should contact private companies to

hold information and training camp. There should be awareness programs in remote areas with the help of companies who manufacture SHS so that the systems are easily available in such areas. In this respect the role of micro credit facility may be very important.

But at the same time the study also poses some gloomy picture about the effectiveness of solar electrification scheme. There is dearth of competent person to fix a problem with the SHS whenever arises. Neither people are willing to pay the maintenance fee. To ensure sustainability, the role of VEC should be made more active and stronger. In this respect AEDA also has to play a role. It should select some youth and they should be trained to solve the technical problem as the 'Barefoot College' in Rajasthan has been doing. This will not only prove employment but also solve a major bottleneck that arises in execution of solar electrification scheme. It has been found from the survey that 35 percent people have shown preference for solar lantern and 29 percent want both SHS and solar lantern and the remaining respondents want SHS alone. The reason for such preference for solar lantern is its portability and easy affordability. Therefore, these rural people may be brought under 'Lighting a Billion Life Scheme" so that they have access to light at night.

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