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Suitability of Solar Homelighting Systems in Households Near Forest Areas - A Case Analysis from India

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Abstract: ***In India, the Corporate Social Responsibility Act (CSR) encourages companies to spend at least 2% of their average net profit on philanthropic activities. Solar Domestic Systems (SDS) comprising of 4 light points with a mobile charging point, a portable light, mobile charging provision and a Direct Current (DC) fan were distributed to the un-electrified households near forest areas using the corporate funds. A comparative analysis indicated that the households with only SDS as electricity option spend much lesser for the timely and quality illumination than the electrified households. In addition, the systems sustained for about four years in the institutional model involving the corporate and the community. The intervention resulted in drastic reduction in market Kerosene where the price of the kerosene fluctuates following the rules of demand and supply. A feel of improved quality of life is reported by the users due to better and clean illumination. Increased levels of comforts were reported for students in their studies, women in kitchens and with weaving, and men while moving out during rainy season along with reduced fear of elephant attacks and snake bites/attacks. This paper is based on the primary information and suggests that the CSR funds may be utilized in India to attain 100% rural electrification, particularly in the households in vicinity of forest areas.***

Keywords: Solar Domestic Systems, Clean energy, Kerosene, India

1. Introduction

Rural household electrification in India still stands at 55 % (Census of India, 2011). The rate of rural household electrification is further low in the northeastern part of India. The households in vicinity of forest areas in general are the last one to receive electricity through conventional mode. To achieve the Sustainable Development Goal (SDG) no. 7 (i.e. to provide clean and affordable energy to all) for such households, the options like decentralized systems are to be explored.

In India, the concept of Corporate Social Responsibility (CSR) is governed by clause 135 of the Companies Act, 2013, which was passed by both Houses of the Parliament, and had received the assent of the President of India on 29 August 2013 (Confederation of Indian Industries, As on February 2019). This CSR Act is applicable to companies with a net profit of 700000 USD [I INR = 0.014 USD] and more, and encourages companies to spend at least 2% of their average net profit in the previous three years on CSR activities.

The present paper assesses the suitability of CSR fund and implementation model in electrification of rural households using Solar Domestic Systems (SDS) in vicinity of forest area. The case undertakes the CSR initiative of Numaligarh Refinery Limited (NRL), the Public Sector Unit operating in in the state of Assam, which is situated in the Northeastern part of India with 35.26% of forest cover (Government of Assam, 2018). Household electrification rate in rural Assam is merely 54% (Ministry of Power, As on May 2018). In the year 2015, NRL understanding the importance of clean and quality lighting, decided to move towards illuminating households using clean energy. A basic scoping study was conducted by The Energy and Resources Institute (TERI) with support from NRL in the year 2013. The need for basic and clean lighting at household level emerged very strongly. NRL together with TERI proceeded to address the community need. Assessments of impacts were conducted in the year 2017 and 2018

Project area

The project was executed as part of the Corporate Social Responsibility (CSR) of NRL with TERI as implementation and knowledge partner in the district of Golaghat (One among the 33 districts of the state Assam). Out of 354,070 hectares areas of the Golaghat district, about 152,294 hectares is under forests, which come to about 43.0% of the total areas. About 46% of the rural households (Ministry of Power, Government of India, accessed as on 25th May 2018) have been electrified through grid and renewable energy. Street lights are rarely observed in the rural localities of the district. The economy of the district thrives on agriculture. The households in the rural areas, particularly near the forest, depend on agriculture and tea gardens for livelihood (Districts of India, As on June 2018). The income level of the households is in general of subsistence level in these villages. Among the other challenges, elephant attacks are common in the villages near forest area. About 22 numbers of villages were covered over the period of 3 consecutive years (2015-2019) in the working area of NRL. Figure 1 presents the geographical location of the implementation sites.

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Figure 1: Implementation Area

1) **Implementation phases: The project was implemented in three phases (Figure 2):**

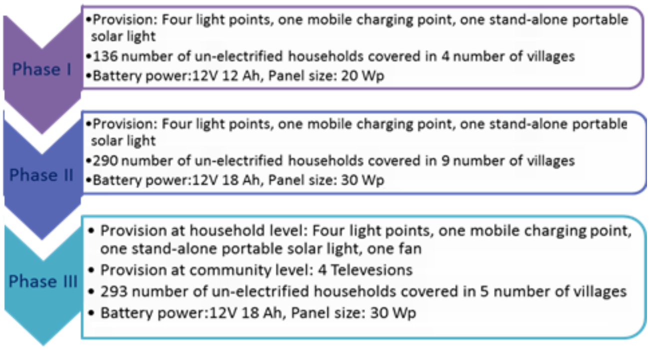

Figure 2: Implementation phases

Institutional Model: The institutional model of the project is presented at figure 3. NRL supported the communities by taking up activities such as skill development, livelihood support and infrastructure building.The village coordinators are the link between users and NRL coordinators. Users register faults to the village coordinators, who in turn inform NRL coordinators, and the NRL coordinators further register faults to the suppliers.

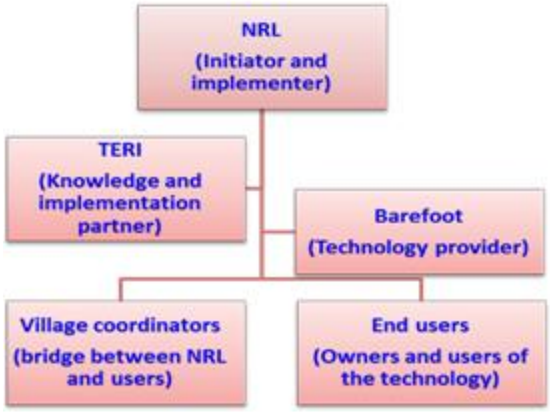

Figure 3: Institutional Model

2) **Technology: Two types of systems were used:**

1) Solar Domestic System with Light
2) Solar Domestic System with light and fan

Solar Domestic System with Lights: The SDS is a technology to provide home lighting solutions and mobile charging facility for cellular handset to rural households. The system has 4 light points which includes two LED bright tube lights of 3.3 W each & two LED pendant lights of 1.5 W each along with a mobile charging point fixed to it (Figure 4). The system is designed to sustain a daily load of basic household lighting energy needs for 5 hours and mobile charging for 2 hours. Additionally, for mobility purpose a high quality mobile lantern is also provided. SDS are cost-effective, yet reliable lighting systems for home use in rural areas. It performs for a longer period of time and requires low maintenance cost. The households are direct beneficiaries of this technology, where ownership is placed upon them. For the purpose of mobility, the SDS also includes a pendent light.

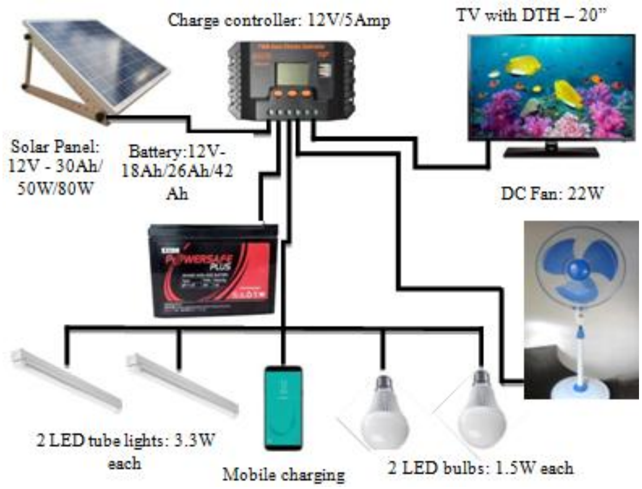

Figure 4: Solar Domestic System with Lights

Solar Domestic Lights with DC Fan: The model consists of solar lights with pedestal DC fan and mobile charging facility for cellular handset. This system contains 2 light points, which includes 2 numbers of LED Bright Tube Lights of 3.3 W each, panel capacity 50Wp and battery 42 Ah (Figure 5). The system is designed to sustain a daily load of basic household lighting energy needs for 6 hours, mobile charging for 2 hours. In addition to this, a pedestal DC fan with capacity of 22 Watt can be used for 10 hours daily.

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Figure 5: Solar Domestic Systems with Lights and DC Fans

2. Impact Assessment Methodology

Inductive method of assessment is followed wherein the impact is considered based on study of sample households in the sample villages. The village selection was based on the number of distributed systems. Three dimensions of assessments were considered:

1) Performance of the technology: The performance of the technology is assessed through the indicators such as hour of usage, faults reported in the systems and repair mechanisms.
2) Impact of technology on the community: Indicators used were perceived benefits and drawbacks, case studies, reduction in usage of kerosene, change in expenditure on fuel for lighting, quality of illumination.
3) Functionality of the institutional model: The functionality of the institutional model was gauged through interviews with the users, NRL coordinators and village coordinators.

Three tools were used to assess the abovementioned impacts:

1) Household questionnaires: Household questionnaires were administered in about 60 households. Respondents were mainly users and small proportion of non-users. Users from phase 1 were included in the sample to gauge long term impacts of the systems.
2) Focused Group Discussions (FGD): FGDs were conducted in five villages with minimum of eight respondents representing different economic and social strata of the village society. The FGDs comprised of elderly people, men, women and children.
3) Unstructured interviews with NRL coordinators and village coordinators: Interviews were conducted with village coordinators and NRL coordinators on the performance of the systems, institutional models and impacts of the systems.
4) Observation: The interviewers also observed the systems and the placing of the light points & fans.

Removal of bias: For perception mapping, the respondents were requested to mention the first benefit and drawback that comes to their mind instantly. The other respondents were requested not to influence the thought process of the respondents. The impact was assessed in the year 2018. The results discussed in the paper are of the assessment year 2019. The results of assessment for both the years were almost

Sample profile: The assessment in the year 2018 had 80% of the respondents were users of phase II & III, and 12% were non-users. Phase II users are referred as old users. Overall, all the users and non-users were found to be leading a poor life quality considering ownership of assets, unavailability of electricity, quality of house, and usage of poor quality fuel.

3. Results and Discussions

1) Cost of electricity and kerosene for lighting by different category of households

This section analyses maximum and minimum expenditure incurred by different category of households for electricity as well as for kerosene (only for lighting purpose). Households are categorized into six; (1) BPL with electricity, (2) APL with electricity, (3) BPL without electricity and SDS, (4) APL without electricity and SDS, (5) BPL with SDS and without electricity, and (6) APL with SDS and without electricity. The maximum expenditure scenario is perceived on the basis of primary data (mode) and FGD.

The electrified households suffers power cuts for about 6-7 hours a day and primarily during evening time. These electrified households on an average spend about 3-5 litres of kerosene for lighting in a month. The average electricity bill per month ranges between USD 3.78 and USD 7.00. The households without electricity and SDS on an average consumes about 5 Litres of kerosene in a month and the BPL households in best possible scenario are able to avail about 3 Litres of kerosene from PDS. Households with SDS and without electricity consume minimum kerosene for lighting (Figure 6).

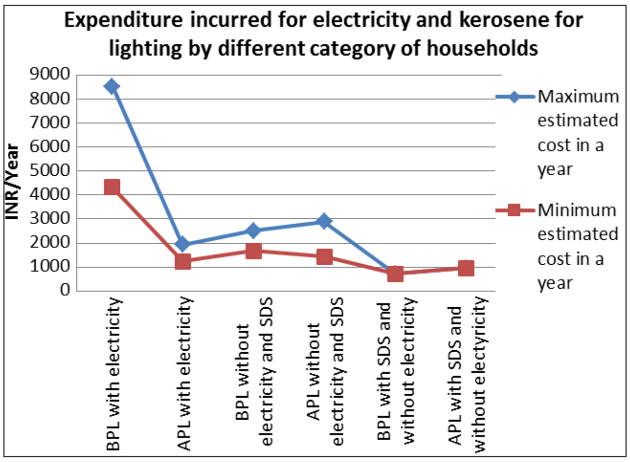

Figure 6: Maximum and Minimun Expenditure Incurred for Lighting by Different Category of Households

The table 1 presents the maximum and minimum estimated expenditure incurred by different category of households in detail.

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Table 1: Maximum and minimum estimated expenditure incurred by different category of households

Particulars	Maximum estimated cost in a year		Minimum estimated cost in a year	
	Rates	USD/Year	Rates	USD /Year
BPL with electricity				
Electricity bill	USD 7/month	84.00	USD 3.78/month	45.36
PDS kerosene expenditure	3 L / month @ USD 0.42/L	15.12	3 L / month @ USD 0.42/L	15.12
Market kerosene expenditure	3 L / month @ USD 0.56/ L	20.16		0
Total expenditure		119.28		60.48
APL with electricity				
Electricity bill	USD 7/month	84.00	USD 3.78/month	45.36
PDS kerosene expenditure		0		0
Market kerosene expenditure	3 L / month @ USD 0.56/ L	20.16	2 L / month @ USD 0.56/L	13.44
Total expenditure		104.16		58.70
BPL without electricity and SDS				
Electricity bill		0		0
PDS kerosene expenditure	3 L / month @ USD 0.42/ L	15.12	2 L / month @ USD 0.56/L	10.08
Market kerosene expenditure	3 L / month @ USD 0.56/ L	20.16	2 L / month @ USD 0.56/L	13.14
Total expenditure		35.28		23.22
APL without electricity and SDS				
Electricity bill		0		0
PDS kerosene expenditure		0		0
Market kerosene expenditure	6 L / month @ USD 0.56/L	40.32	3 L / month @ USD 0.56/L	20.16
Total expenditure		40.32		20.16
BPL with SDS and without electricity				
Electricity bill		0		0
PDS kerosene expenditure	2 L / month @ USD 0.42/ L	10.08	2 L / month @ USD 0.42/ L	10.08
Market kerosene expenditure		0		0
Total expenditure		10.08		10.08
APL with SDS and without electricity				
Electricity bill		0		0
PDS kerosene expenditure		0		0
Market kerosene expenditure	2 L / month @ USD 0.56/ L	13.44	2 L / month @ USD 0.56/ L	13.44
Total expenditure		13.44		13.44

The result indicates that the expenditure per year incurred for lighting is lowest among the un-electrified households with SDS. The SDS is economic especially for the economically poor un-electrified households.

2) Reduction in consumption of kerosene post installation of SDS:

A drastic reduction in consumption of market kerosene is observed. About 97% of the users stopped procuring market kerosene after installation of SDS. The corresponding figure prior to SDS installation was mere 25%. Only APL households still procure market kerosene because they don't have access to PDS (Public Distribution System) kerosene. Percentage of households not using PDS kerosene increased to 63% from 22% after installation of SDS. 70% of the users were using 2-3 Litres of PDS kerosene prior to installation of SDS. Percentage of such users reduced to 33% post installation of SDS. The households with SDS mostly use PDS kerosene now to ignite traditional stoves and for lighting the traditional lamps over the night.

Considering the sample households for users, the per month consumption of PDS kerosene reduced by 57 Litres and the corresponding figure for market kerosene is 114 Litres (figure 7). There is drastic reduction in consumption of market as well as PDS kerosene. Extrapolating the figures (by multiplying with 4.8) for the 290 households, the per month consumption of PDS kerosene is reduced by 276 Litres while the corresponding figures for market kerosene is 551 Litres. In a year, the total savings of PDS kerosene for lighting for approximately 290 households is about 3300 Litres while of market kerosene is about 6600 Litres.

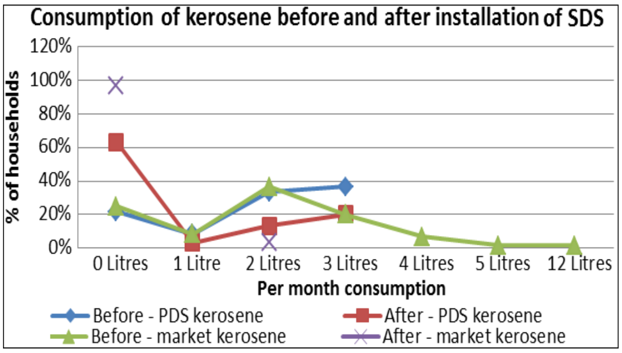

Figure 7: Consumption of Kerosene for Lighting before and after Installation of SDS

3) Reduced expenditure on kerosene

Figure 8 clearly indicates that the average per month expenditure on market kerosene reduced drastically after installation of SDS. The average per month expenditure on market kerosene among non-users is about USD 0.84 while the amount is almost negligible in case of users.

The average expenditure on per month PDS kerosene was about USD 0.73before installation of SDS. The amount reduced to USD 0.35 after installation of PDS. The present expenditure on per month PDS kerosene among non-users is USD 0.98 while among old users is USD 0.42. The figure for old users and new users (SDS light) is same, i.e. USD 0.42 per month. The kerosene rates at PDS in the year 2017

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were USD 0.35/Litre and the rate as on July 2018 reported by the respondents is USD 0.42/Litre. The increasing rates of kerosene are providing the sense of worth for SDS among the users.

Installation of SDS has almost stopped expenditure on market kerosene and has considerably reduced expenditure on PDS kerosene. The reduction in expenditure on market kerosene is more distinct in case of the users of SDS with light. In addition, the increasing cost of PDS kerosene and fluctuating cost of market kerosene has induced the worth of SDS among the users.

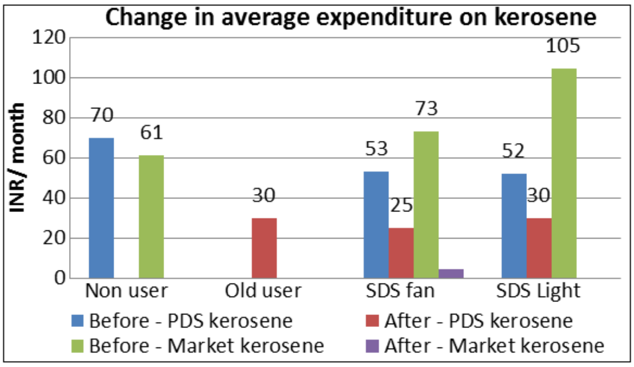

Figure 8: Change in Average Expenditure on Kerosene

4) Reduction in CO_2 equivalent

On an average, one SDS reduces CO2 emissions by 95 kgs per household in a year. The intervention, carried out in 293 households is able to reduce CO2 emissions by 27836 kgs in a year.

Table 1: Reduction in CO_2 equivalent

Indicators	After	Before
Average consumption of Kerosene (Litre) in a month*	1	3.9
Default Emission Factor (EF) for Kerosene, Kg CO_2/ Litre**	2.73	2.73
Kg CO_2 (one month)	2.73	10.65
Kg CO_2 (for one year)	32.76	127.76

*Based on the calculations from the section "SAVINGS ON KEROSENE FOR LIGHTING"

**EF in kg CO_2/TJ terms: 71,900 kg CO2/TJ, Source: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf

5) Perceived Benefits of SDS

The elderly people, men, women and children were requested to list the benefits or drawbacks of SDS perceived by them. To avoid bias, the respondents were asked to speak out whatever comes to their mind as a first thought. The count of responses is presented in figure 9. The SDS has impacted students in their studies. About 29 children mention that they are able to study comfortably using SDS. About 25 men and women say that they are able to get better quality light. Many are able to sleep comfortably using fan.

The perceived benefits were also asked in the FGD. The responses were similar to the household survey except one additional mentioned benefit, "we get light when required."

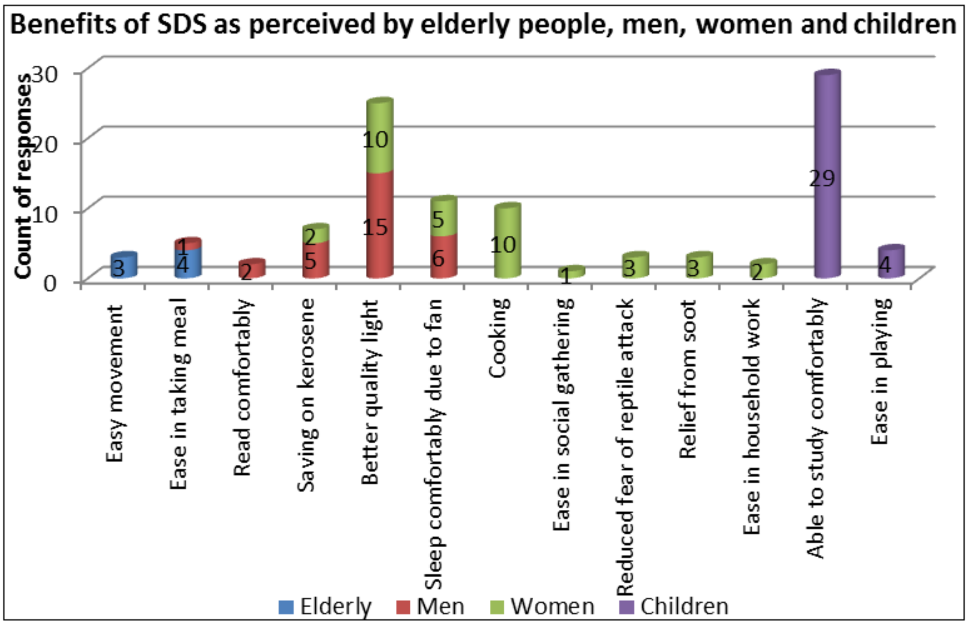

Figure 9: Benefits of SDS as Perceived by Elderly People, Men, Women and Children

6) Value for money

Cost of each system with taxes is USD 174.47and the systems are provided at highly subsidized cost to the users. Majority of the users (73%) mentions that they paid USD 14.60 one time for the systems. NRL, paid about 90-94% of the system cost. The cost of distribution and maintenance to NRL per system, definitely, goes beyond USD175.20 (The Energy and Resources Institute, 2018). The users feel that the amount paid by them is worth for the system they are using. However, none of the users were aware of the actual cost of the system. It is important that the users are aware of the actual system cost to understand the actual value for money associated with the distribution and maintenance of the system.

The non-users were willing to pay the cost offered to the existing users for the SDS. None of the non-users expressed

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his/her willingness to pay more than the cost offered to the existing users.

A local bank financing household level RE devises operates in the rural areas of the district. The bank provides loan of USD 102.20 to buy solar lantern or solar home light system with one light point. Repayment is through weekly installments of USD 1.61 for a year. Poor households were unable to avail the scheme offered by the local Bank (The Energy and Resources Institute, 2018).

7) Reliability of power

Those receiving conventional power supplies in village Lakhipur mentioned of power cuts during peak hours of the day (i.e. 6.00 to 10.00 PM) with a total of 12-13 hours of power supply. During the evening hours the requirement of quality illumination is highly desired and needed. Thus, many of the electrified households also insisted for SDS. However, it is more important to provide SDS to the un-electrified households first. The concept of reliable power may be explored once 100% household electrification is achieved.

8) Performance and usage of SDS in field scenario

Repair: About 71% of the households reported no fault till date. Incidences of faults are only 21%. These faults were reported only in the luminaries, and were replaced by the supplier within 15 days as the systems are under warranty period.

Coordination: Majority of the problems were reported immediately after the installations. The repair/replacement time in most of the cases is about 15 days. Village coordinators, presently work on voluntary basis. A more organized structure for repair and coordination is to be developed for sustained use of the technology.

Level of awareness: All the users are aware about system capacities and how to adjust in terms of number of luminaries based on the desired duration of usage. The users are also aware that the system capacity reduces during cloudy weather. The level of awareness creation on usage, dos and don’ts are extremely satisfactory.

4. Conclusion and Policy Implications

1) Electrification of un-electrified and poor households: The project has reached the socially backward and economically poor un-electrified households. The initiative is contributing strongly towards 100% electrification of households.
2) SDS is the most economical solution for lighting: The expenditure incurred for lighting (including on kerosene) for the un-electrified households with SDS is about USD 14 per year which is much lower than the expenditure incurred for lighting by electrified households and un-electrified households without SDS. The SDS is economical especially for the economically poor un-electrified households. The model provides affordable and reliable power to the unelectrified poor households.
3) Drastic reduction in consumption of kerosene: The yearly consumption of PDS kerosene reduced by 3300 Litres and the corresponding figure for market kerosene is 6600 Litres. There is drastic reduction in consumption of market as well as PDS kerosene.
4) Respite from increasing cost of PDS kerosene and fluctuating cost of market kerosene: Installation of SDS has almost stopped expenditure on market kerosene among the user households. This drastic reduction is prominent among the users of SDS with light. The increasing cost of PDS kerosene and fluctuating cost of market kerosene has induced the worth of SDS among the users.
5) Reduced CO_2 emission: The intervention is able to reduce CO_2 emission by 27836 kg in a year.
6) The other benefits perceived by the users are easy movement, ease in taking meal, better quality light, sleep comfortably due to fan, ease in cooking, ease in social gathering, reduced fear of reptile attack, relief from soot, ease in household work and sale to study comfortably.

The results clearly indicate that the Solar Domestic Systems using CSR funds is able to provide reliable and affordable electricity to the poor households at last mile. SDS may be considered as one of the interventions by the companies to use their CSR funds.

5. Acknowledgment

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