*Available online www.jsaer.com*

***Journal of Scientific and Engineering Research*, 2021, 8(3):30-39**

**Research Article**

**ISSN: 2394-2630**
**CODEN(USA): JSERBR**

# Economic and environmental impact of Solar Domestic Systems on users in rural areas of Northeastern part of India

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**Abstract** About 280 Solar Domestic Systems were installed across six villages of three districts of Assam using Corporate Social Responsibility funds of Numaligarh Refinery Limited (NRL). Impact assessment was conducted a year after installations. The systems have positively influenced the lives of the users by making it more convenient in terms of household work, quality illumination, reduced expenditure on kerosene and reduced fear of snakebites. On an average, a household reduced its monthly consumption of kerosene from 5 L to 2 L due to installation of Solar Domestic System. The intervention is able to reduce $CO_2$ emissions by about 27.5×103 kg in a year. Eventually the households were electrified due to fast pace of electrification in India. The systems hold its importance in the electrified households in terms of carbon footprints, providing reliable lighting during power cuts and reduced electricity bills. The primary benefit of the SDS is that the users get quality illumination when required and at no regular usage cost.

**Keywords** Solar, India, Electricity, Kerosene, Impact

## 1. Introduction

In India, about 94% of the rural households in India possess electricity connection [1]. The success of electrification and electricity services are achieved through multipronged approach [2]. In India, electricity was made available to the last mile through grid and off-grid routes to achieve universal electrification. Government and private sector both played important roles in electrification. Initially, Off-grid solutions were provided to the remote un-electrified villages through various initiatives. The electrification rates picked a high pace in the last 5-6 years. Thus, gradually, the households with off-grid electrification also started receiving grid connections. This paper discusses the case in the state of Assam, where Solar Domestic Systems (SDS) were provided to un-electrified rural households in the state of Assam and eventually the households received electricity connections. Assam is a state located in the North-eastern part of India. As per the recent Economic Survey of Assam, the status of power is not satisfactory in the state as there is a gap between generation and demand [3]. To address this challenge, the Numaligarh Refinery Limited (NRL) along with The Energy and Resources Institute (TERI) installed Solar Domestic Systems (SDS) in about 280 households across six villages in three districts of Assam in the year 2019. NRL provided the financial resources using its Corporate Social Responsibility (CSR) funds. The SDS were installed in the year 2019. A year later, an assessment of impacts was conducted. The present paper presents the findings of the study with a focus towards economic and environmental impacts in the scenario where the users were gradually receiving grid electrification.

Off grid, solutions do provide benefits even in the situation when grid electricity is available but is unreliable. Impact study mentioned that electricity in the rural market places significantly increases the income level of the users [4] in both electrified and un-electrified locations.

### 1.1 Technology

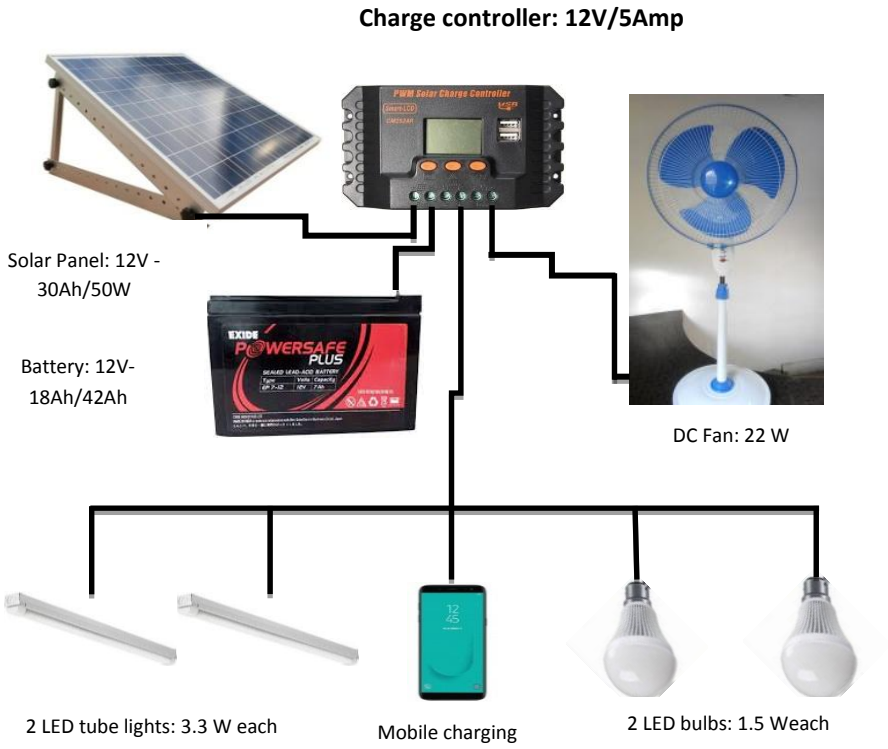


*Figure 1: Schematic diagram of SDS [5]*

SDS comprises of four light points which includes 2 number of LED bright tube lights of 3.3 W each, panel capacity 30Wp , battery 12V 18Ah and 2 number of LED pendant lights of 1.5 W each along with a mobile charging point fixed. The system is designed to sustain a daily load of basic household lighting energy needs for 5 hours, mobile charging for 2 hours. Additionally, for mobility purposes the SDS also includes a high quality portable mobile lamp with a provision of mobile charging. Few systems comprises of two light points, one fan, one potable light and one mobile charging point.

SDS includes a portable solar lamp that the community can use it to do chores outside their homes multiple brightness settings allow the user to conserve power until it's needed. This bright LED solar light comes with an integrated solar panel and three different settings "Low" setting, "Medium" setting, and "High" setting.

## 2. Materials and Methods

The methodology included group discussions, observations and user's interviews. The entire field study was segregated into four steps, depicted in the figure 2.

## 3. Results & Discussion

About 77% of the surveyed rural households possessed Below Poverty Line (BPL) card. Agriculture is the primary occupation for 83% of the surveyed households. The SDS were installed in about 280 un-electrified rural households in the year 2019. However, due to the accelerated pace of rural electrification in India, most of the un-electrified households got electrified. About 66% of the surveyed households received electricity connection after two months of receiving SDS. Ideally, the SDS is able to provide light for 5 hours a day depending on the charge received. 77% of the users keep their 2-4 lights switched on for more than 5 hours a day. Among these 77% of the users, 44% of the users did not received electricity connection. As per system capacity, the SDS is able to provide power for 5 hours a day. Users indicated that they are aware of the system capacities. Only 20% of the surveyed households had fan attached to their SDS.

### 3.1. Consumption and expenditure on Kerosene

Kerosene lamps are the most prominent source of lighting in the study villages in absence of SDS and electricity. There are two sources of kerosene in the study villages. One is through Public Distribution System (PDS) and another source is the open market. The price range in PDS is regulated by the government.

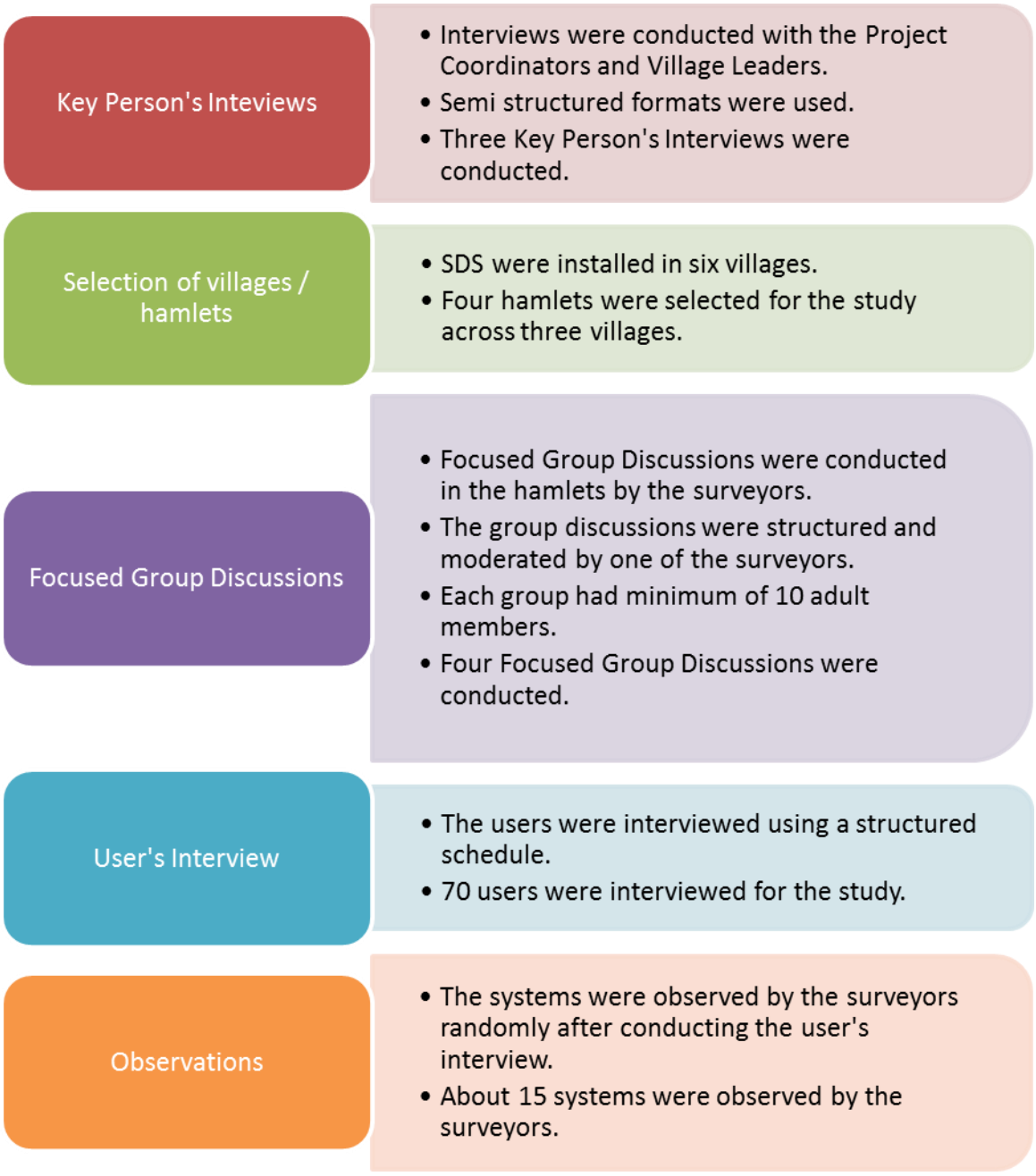


*Figure 2: Methodology*

#### 3.1.1. Consumption and expenditure on PDS Kerosene

Scenario before installation of SDS: On an average, the users used kerosene lamps for about 3 hours in day for illumination. The average cost of PDS kerosene reported by the users was INR 30/Litre. The average consumption of kerosene reported was 3 Litres. The monthly expenditure on PDS kerosene ranged between

INR 30 and INR 120. 69% of the users reported that they spent about INR 90 per month on PDS kerosene. On an average, a household receives 3Litres kerosene from PDS.

Scenario after installation of SDS: Only 7% households reported consumption of PDS kerosene for lighting purpose. The 7% users reported consumption of 2-3 Litres of PDS kerosene per month for lighting purpose. These were the un-electrified households. The average cost of kerosene is reported as INR 40-45 per Litre. For calculation purpose, the cost of kerosene per Litreis considered as INR 40. On an average, the households who still use PDS kerosene for lighting purpose spend in the range of INR 80 to INR 120 in month.

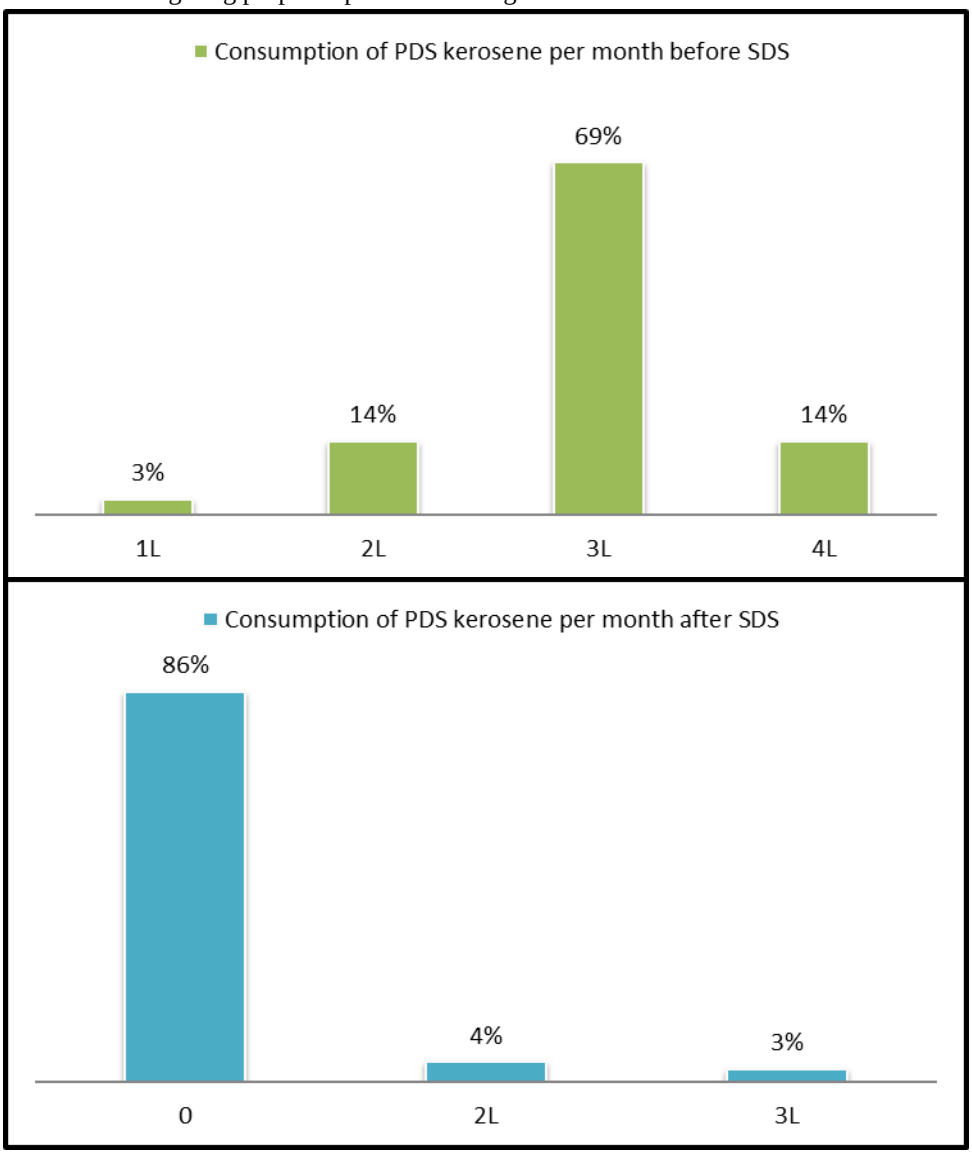


*Figure 3: Monthly consumption of PDS kerosene before and after SDS (by % of households)*

Figure 3 and 4 above indicate the drastic reduction in consumption of PDS kerosene by the user households. Decreased consumption of PDS kerosene leads to savings in monetary terms as well.

### 3.1.2 Consumption and expenditure on market kerosene

The average consumption of market kerosene before SDS was about 2 Litres per month per household prior to installation of SDS. Different households reported the cost of market kerosene in the range of INR 40 to INR 60 per Litre. However, the average (mean, median and mode) for cost of market kerosene per litre during January

2019 is estimated as INR 40. None of the households reported consumption of market kerosene after SDS. Consumption and expenditure on market kerosene is reported at figure 6.

### 3.1.3 Comparative analysis

The average monthly consumption of PDS kerosene per household reduced from 3 Litres to 2 Litres. The average monthly consumption of market Kerosene has reduced by 2 Litres. On an average, a household reduced its consumption of kerosene by 3 Litres per month due to installation of SDS. Thus, in year, a household saves 36 Litres of kerosene.

Similarly, on an average, a household is able to save INR 30 per month on PDS kerosene and INR 80 on market kerosene. In a year, a household now saves about INR 1320 on kerosene due to SDS. The change in consumption and expenditure on kerosene is presented at figure 6.

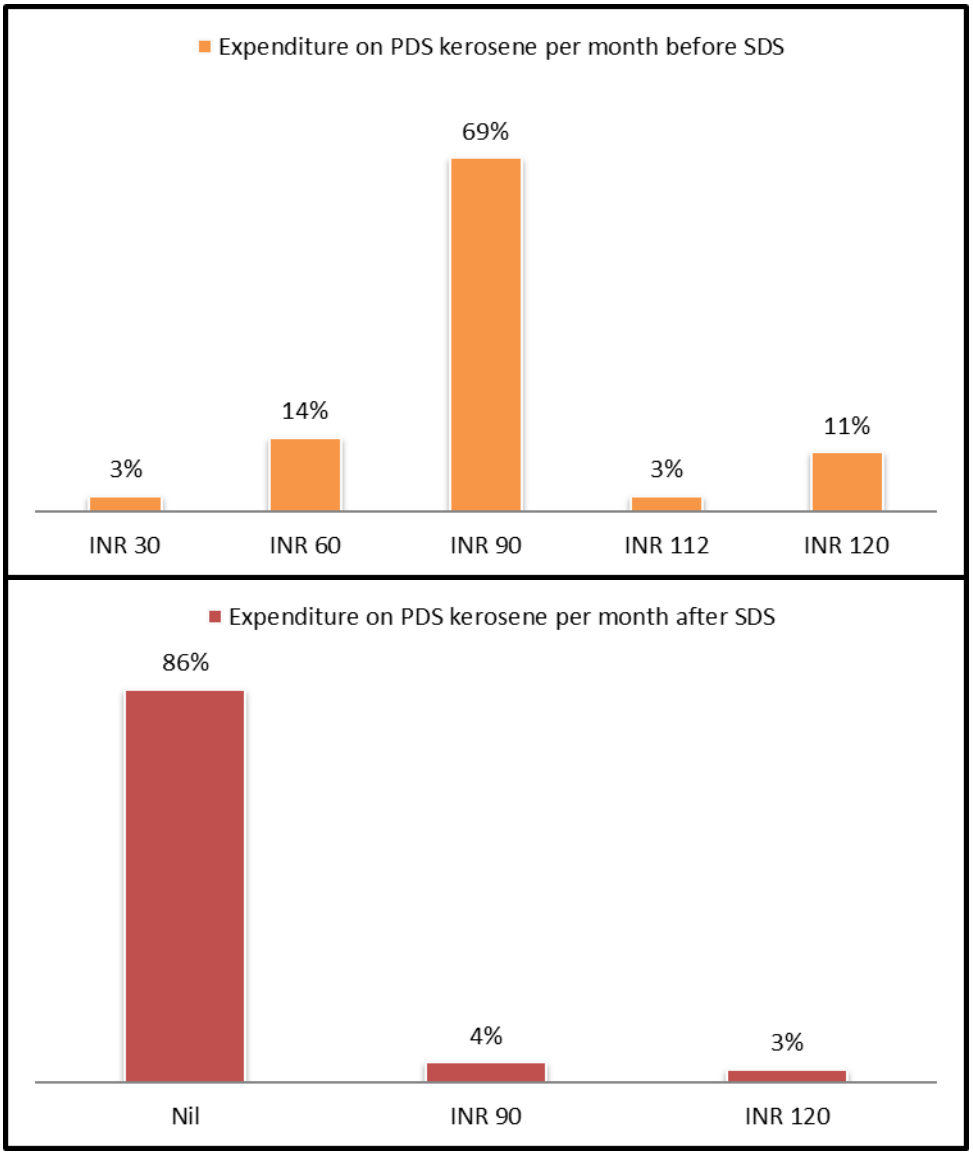


*Figure 4: Expenditure on PDS kerosene per month before and after SDS (by % of households)*

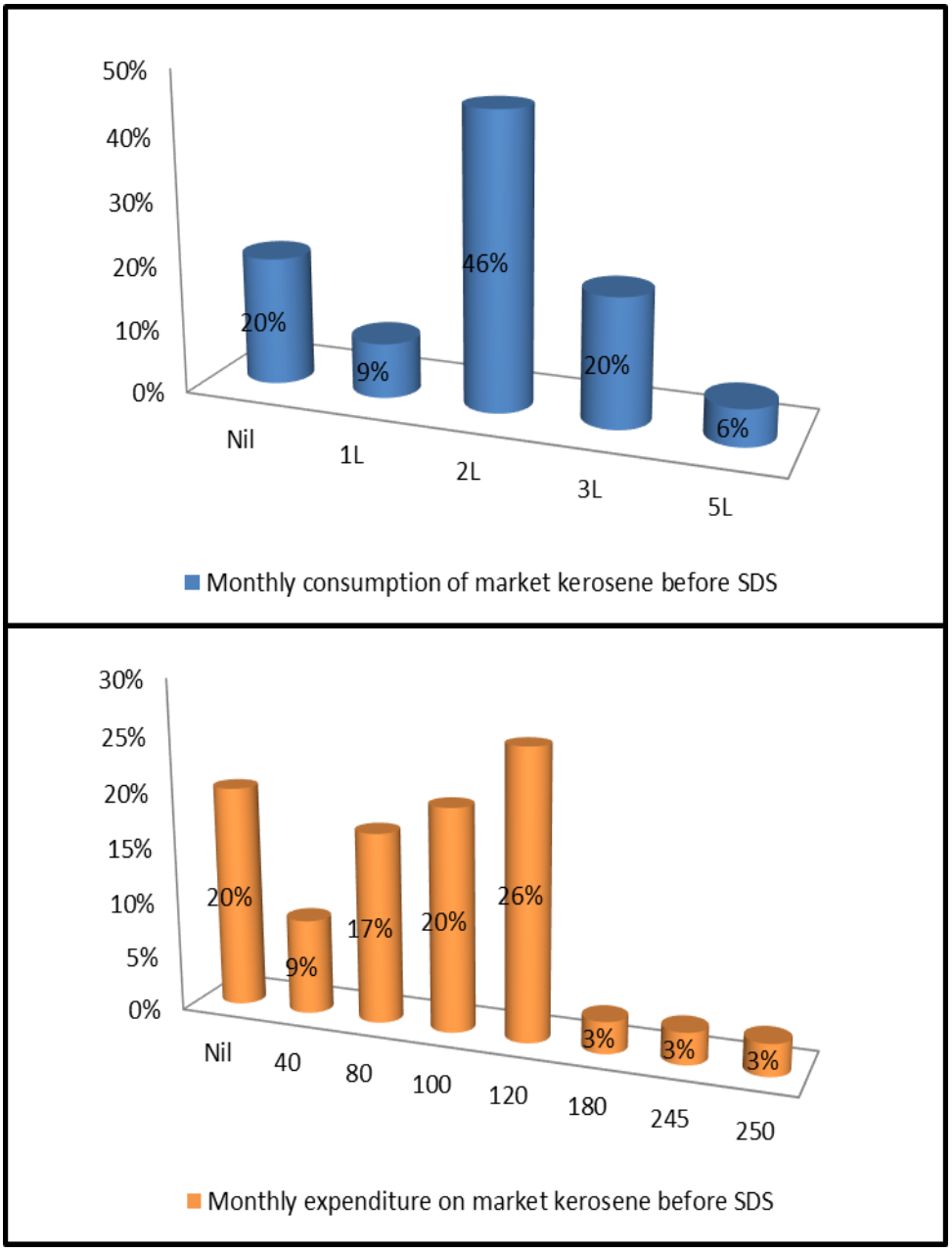


*Figure 5: Consumption and expenditure on market kerosene before SDS*

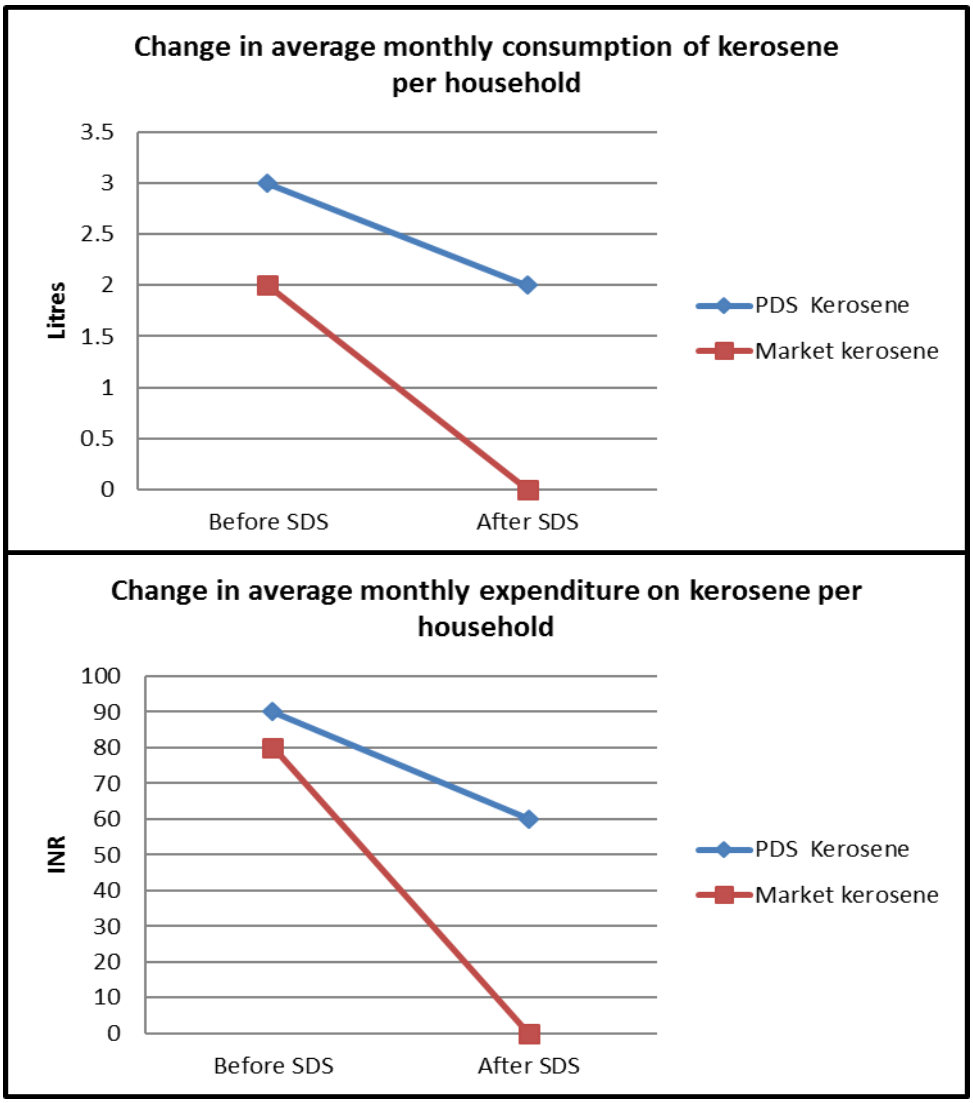


*Figure 6: Change in average monthly consumption and expenditure on kerosene per household*

### 3.2. Reduction in $CO_2$ equivalent

On an average, one SDS reduces $CO_2$ emissions by 98 kgs per household in a year. The intervention, carried out in 280 households is able to reduce $CO_2$ emissions by 27519 kgs in a year.

**Table 1 Reduction in CO2 equivalent**

| Indicators | After | Before |
|---|---|---|
| Average consumption of Kerosene (Litre) in a month[1] | 2 | 5 |
| Default Emission Factor (EF) for Kerosene, Kg $CO_2$/ Litre[2] | 2.73 | 2.73 |
| Kg $CO_2$ (one month) per household | 5.46 | 13.65 |
| Kg $CO_2$ (for one year) per household | 65.52 | 163.8 |
| Kg $CO_2$ (for one year) for 280 households | 18345 | 45864 |

[1] Based on the calculations from the section "SAVINGS ON KEROSENE AT PROJECT LEVEL"

[2] EF in kg CO2/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

### 3.3. Expenditure on electricity

66% of the surveyed households received electricity connections after installation of SDS. The fixed monthly charges under 'jeevandhara3' are INR 20 while for others the fixed monthly charges are INR 40. The unit cost under 'jeevandhara' is INR 4.60/kWh.

Differential tariff is followed. The unit cost for Above Poverty Line (APL) is INR 5.45/kWh for the first 120 units. The tariff increases to INR 6.70/kWh for the next 120 units. Majority of the households, about 39%, mentioned that their monthly electricity bill on an average is about INR 80 while 35% households on an average pay INR 100 as their monthly electricity bill. Around 18% of the households pay INR 200 monthly on electricity while only 4% reported to pay INR 400-500 as their monthly electricity bill.

### 3.4. Other benefits of SDS mentioned by users

Ten benefits of the SDS were identified based on the impact assessments of previous similar reports, author's 30 years of experience in energy access and interaction with the subject experts. The users were requested to scale the benefits into three:

1. No difference
2. Better than before (or better compared to the days before installation of SDS)
3. Very much better than before (or very much better compared to the days before installation of SDS)

The scaling of perceptions is presented at figure 8.

**Ease in kitchen work:** 94% of the users mentioned that the kitchen work is now very much easier compared to the days without SDS. Earlier, some part of the dinner was cooked in the illumination received from kerosene lamp and the household members used to have their dinner in low illumination.

**Ease in household work:** 74% of the users find that the convenience in household work during evening hours has increased very much than before while 23% of the households find the improvement in moderate terms.

**Ease in study:** 91% of the users scale 'ease in study' as 'very much better than before. SDS has helped in the students as studying in better illumination is much more convenient than studying in the poor illumination of the kerosene lamps.

**Ease in livelihood:** 74% of the users mentioned that they benefited from the SDS for their livelihood by responding 'very much better than before' for the option 'ease in livelihood'. 20% of the users selected the scale 'better than before' for the same option.

**Movement at evening/ night within the house:** 89% of the users mentioned that their movement inside house during evening/night hours has become much easier than before due to SDS.

Movement at evening/night outside the house: Only 40% of the users mentioned that the movement outside their house premises is much better now.

**Social gathering inside house premises:** 31% of the users reported that the social gatherings inside house premises are very much livelier and much more frequent during evening hours after installation of SDS. Majority of the users, about 63%, scale this option as 'better than before'.

Illumination inside house: 66% of the users scale 'very much better than before' for the option on 'illumination inside home'. The quality of illumination has improved inside the house premises.

**Reduced fear of snakebites:** 89% of the respondents mentioned that their fear of snake bites has reduced very much compared to the scenario when SDS was not with them. The users mention that they can now see any movement of reptile within their house.

**Reduced fear of animal attack:** The users mentioned that dogs and foxes attack their domestic chickens. After installation of SDS such attacks has reduced. 80% of the users mention that their fear of animal attacks has reduced very much compared to the times without SDS.

[3] Electricity tariff bracket for BPL households

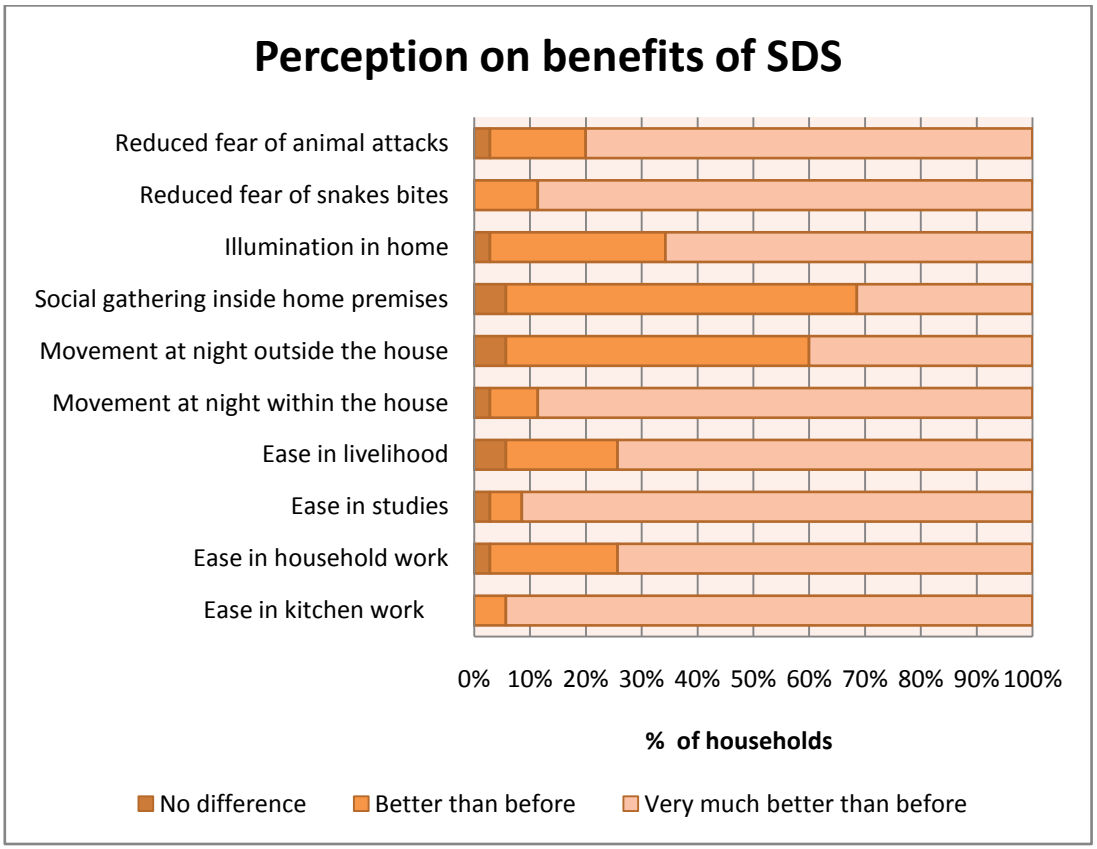


*Figure 7: Perception of users on benefits of SDS*

*Photo 1: Lighting through SDS*

**Conclusion**

The Numaligarh Refinery Limited (NRL) with The Energy and Resources Institute (TERI) has electrified about 280 un-electrified households in three districts of Assam using Solar Domestic Systems (SDS) in the year 2019. These households were dependent on kerosene lamps for lighting purpose. Two types of systems were designed. The SDS is able to operate up to 4-6 hours in a day in its full capacity. Households received quality illumination. Reduced usage of kerosene for lighting purpose was an obvious benefit of the SDS. In absence of electricity, the households were consuming about 5 litres of kerosene for lighting purpose. From Public Distribution System (PDS) a household is able to receive 3 Litres of kerosene. The rest of the kerosene was procured from open market at high cost. Presently market kerosene is not used at all by the SDS users.

Some of the benefits mentioned by users are ease in kitchen & household work, ease in studies, convenience in movement during night within the house, reduced fear of snakebites, convenience in secondary livelihood and quality illumination inside home.

Eventually many of the households with SDS received electricity. SDS was very useful during rainy season and floods as the conventional electricity supply was disrupted for about 15-20 days. The SDS users with electricity connection reported lesser electricity bills compared to the households without SDS. The primary benefit of the SDS is that the users get quality illumination when required and at no regular usage cost.

**Acknowledgment**

We would like to express our sincere gratitude to NRL for providing financial assistance for carrying out the project in the un-electrified households of villages of Assam. We are grateful to Mr. Prabir Talukdar, Senior General Manager (HR) and Mr Rajkamal Saikia, Deputy General Manager, CSR (NRL), for providing indispensable support and guidance. We are also grateful to Mr. Amit Kumar, Senior Director, Social Transformation Division, TERI for valuable guidance.

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