MILLION SOLAR URJA LAMP (SoUL) PROGRAM

Right to Clean Light

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An Initiative of
Indian Institute of Technology Bombay

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Concurrent Evaluation Report of Million SoUL Program in Orissa

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Million SoUL Programme

Million SoUL Programme (MSP) is an initiative of Indian Institute of Technology - Bombay (IIT-B). MSP headquarter is located in Mumbai within the campus of IIT-B. Its principle funders include Ministry of New and Renewable Energy (MNRE), Madhya Pradesh Govt., Sir Dorabji Tata Trust (SDTT), Larsen and Turbo (L&T) and Tata Motors.

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List of Acronyms

BP	British Petroleum
CEA	Central Electricity Authority
CRISIL	Credit Rating Information Services of India Limited
MDG	Millennium Development Goal
MNRE	Ministry of New and Renewable Energy
MSP	Million SoUL Programme
NGO	Non Governmental Organization
IEA	International Energy Agency
IIT-B	Indian Institution of Technology, Bombay
PDS	Public Distribution System
RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
RVEP	Remote Village Electrification Programme
SDG	Sustainable Development Goal
SE4ALL	Sustainable Energy for All
SELCO	Solar Electric Lighting Company
SKO	Superior Kerosene Oil
SoUL	Solar Urja Lamps
SRC	SoUL Repair Centre
SRCM	SoUL Repair Centre Manager
TERI	The Energy and Resource Institute

Executive Summary

The Million SoUL Program (MSP) an initiative by Indian Institute of Technology (IIT) Bombay aims to bring 'Right to Clean Light' to every child in India. With this vision, two year program is being implemented in 2014-15 across 4 states (Madhya Pradesh, Maharashtra, Rajasthan, and Odisha) with the help of NGO partners who act as implementers at the ground level. During two year program, one million solar study lamps called as Solar Urja Lamps (SoUL) are to be distributed in two phases (I & II). This report presents the results of the concurrent evaluation (Round I) of the MSP in the state of Odisha (OD) in India. The objective of concurrent evaluation is to bring transparency in the MSP, make mid-course corrections and assess impact of the SoUL. The concurrent evaluation, which is made by conducting the household survey in sample blocks, is planned in two rounds: (a) after SoULs are distributed (so that mid-course corrections can be made) (b) 4-5 month prior to the end of Phase I in December 2015. In order to understand the impacts, a comparison between treatment sample (households of students who purchased SoUL) and control sample (households of students who didn't purchase SoUL) as well as electrified and non-electrified households in both the samples was made. The MSP team of IIT-B study conducted this study.

The main findings for Odisha indicate a shift towards use of SoUL for different tasks like studying, household chores, etc. Though, there are no major difference in terms of studying hours between the treatment and the control groups, however results from the survey show less dependence on kerosene based devices for studying within treatment group. Studying under clean lighting source can also have health advantage like reduced exposure to soot coming from kerosene chimni. Differences observed between the treatment group and control group in terms of kerosene consumption and overall expenditure indicates the positive impact of SoUL on the rural households. Households also report of SoUL aiding in completing other household chores, which serves as an added benefit. One main concern with respect to performance of SoUL is the non-

functionality rate which above 20 percent in all the surveyed households. While the product quality is being observed as major issue, inappropriate user handling also serves as a major barrier in long term functioning of SoUL. Unavailability and unaffordability of current energy sources are driving the need for more renewable energy products. There is willingness to pay for lighting devices and cooking devices through renewable energy among surveyed households. Results from impacts of MSP show potential of targeted renewable energy programmes being alternative solutions to energy (in this case lighting) problems. Given the willingness to pay observed within the rural communities, suitable financial models needs to be worked out so as to convert this demand into actual sales realization for serving the energy needs of the rural communities.

Chapter 1. Introduction

Energy access is an important issue to be addressed at international, national and sub-national level to accelerate development of low income communities. As the development discussion has progressed from Millennium Development Goals (MDGs) to Sustainable Development Goals (SDGs), energy access became one of its central goals. UN General Assembly declared year 2012 as Sustainable Energy for All (SE4ALL) and 2014-2024 a decade for the same (UNDP 2011). In 2015, UN General Assembly adopted the agenda for Sustainable Development under which the goal 7 of SDGs aims to "*ensure access to affordable, reliable, sustainable and modern energy for all*"[1]. While the focus on improving the energy access has grown in last decade, there are still billion plus population across the developing and least developed nations across the world countries lack access to modern source of energy (IEA 2013). Lack of access to modern energy such as electricity undermines the key development indicators such education, health and livelihoods. It is clear through understanding of literature that without access to modern energy, achieving social and economic development of countries will remain distant dream. While the energy access is multidimensional which includes houhehold (cooking and lighting needs) and productive (livelihood) needs, this report is specially focused upon the lighting needs presenting arguments and results from evaluation of solar lighting project 'Million SoUL Programme' (MSP) introduced by Indian Institute of Technology – Bombay (IIT-B).

1.1. Energy Scenario in India

According to BP statistics review of world energy (2015), India is the fourth largest electricity producer in the world. However India is also home to the largest number of people without access to electricity (IEA 2013). On supply front, India faces multiple challenges in terms of making electricity available to its rural population. One of important challenge faced by the power utilities is form of under-recoveries from sale of

[1] Can be read further read about the goals Sustainable Development Knowledge Platform <https://sustainabledevelopment.un.org/topics>

electricity to the consumers. This results huge financial losses undermining the ability of the utilities to expand and improve services (CRISIL 2012)[2]. Apart from financial constraints that have burdened the state power utilities, the infrastructural challenges seem to more daunting towards making electricity available to the rural communities (IEA 2011). Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), the flagship programme for rural electrification had set objective to achieve complete rural electrification of rural area by 2012, which however the programme has missed and still large population live without electricity.

Most of the people without access to electricity depend upon kerosene as their primary source of lighting in the households. Census (2011) data shows around 43.2 percent of the rural households in India depend upon subsidized kerosene as the main source for lighting. Kerosene which pose substantial health risks at household level, also pose a burden on state and national financial budget by means of subsidy (Nouni et al. 2009). For example, TERI study shows the accumulated under-recoveries on the sale of kerosene over last decade amounts to INR 188,502 crore[3] (TERI 2014).

1.2. Emergence of Renewable Energy

Renewable energy has shown potential for being alternative to energy access problem, specifically for access to electricity for lighting needs. Off-grid applications of renewable energy have been growing over past decade in context of failure of grid electrification to reach the sparsely populated rural population. Various actors – governments, NGOs and social enterprise have experimented with business models for provisioning of off-grid based services. From government standpoint while range of off-grid renewable options (like biomass based generation, wind power, solar power etc.) is available, the most preferred option under renewable energy programmes like Remote Village Electrification Programme (RVEP)[4] is seen to be solar (Bhushan and Kumar 2012). As of August 2015, cumulative off-grid solar PV systems already accounts for 279.74

[2] More on the under recoveries of the state power and distribution utilities can be read in CRISIL (2012).
[3] Crore is Indian number system and equals to 10 Million.
[4] Remote Village Electrification Programme (RVEP) is government off-grid renewable technology electrification programme for remote villages and hamlets which could not electrified through grid electrification or covered under RGGVY.

Megawatt (MW)[5], of which 45.39 MW was added in the last one year (MNRE 2015). Off-grid systems are installed either through local mini/micro grids[6] or isolated solar home systems, solar lanterns. Similarly, a large range of social enterprises like SELCO, Mera Gaon Power, D.light are experimenting with solar technology as viable off-grid option through different service provisioning models. Off-grid interventions are fast becoming preferred option in rural areas over grid electrification due its reliability (Bhushan and Kumar 2012).

1.3. Literature Review

Literatures are available in context of impacts of off-grid solar interventions in India specifically in small system dissemination like solar lanterns. This impact assessment report adds to the growing literature on impact of small scale technologies like solar lamps and lanterns on improvement in lives and livelihoods of the rural communities. A study on impact of solar lantern programme named LaBL[7] conducted by TISS (2013), have outlined positive impact across education, health and livelihoods through increased studying hours, lesser exposure to sooth from the kerosene lamps and aiding livelihood activities. This substantiates the potential of off-grid solar intervention to offer benefits at household level. A research by Agoramoorthy and Hsu (2009) on 100 households in tribal areas of rural India also confirms increased study duration of children by hour and half as a result of provisioning solar lantern. Similarly, their study also reports of decreased expenditure on kerosene and electricity bill expenditure of these households post purchasing the solar lanterns. Their result were important as the rural areas where study was conducted were not receiving power between 3 to 6 am in the morning and 6 to 9 pm in the evening, which are actually dark hours. Similar insights are provided by Garg (2014) on the solar lantern programmes introduced by Government of India for school going girls in rural areas. Study of solar PV electrification programme in India by Chakrabarti and Chakrabarti (2002) reveal higher willingness to pay by the sample households who currently use solar energy. The study

[5] Megawatts are used to measure the output of a power plant

[6] Mini/micro grids are centralized generation at local village or Panchayat level

[7] Lighting a Billion Lives (LaBL) is solar lantern programme launched by TERI in 2008. More details about the programme can be found at the programme website http://labl.teriin.org/

also highlights the overall change in behavior as communities are willing to move towards adoption of cleaner technology. The authors state (pp. 41), ' … (communities) have expressed their willingness to continue the use of solar power, even if diesel power is available at low cost, to avoid the air and noise pollution caused by a diesel generator'. There are also literatures available on impact of other off-grid solar programmes, however systems disseminated in such cases are of larger capacity (like in case of Solar Home Systems under RVEP in India or IDCOL programme in Bangladesh) which can fulfill higher needs of the households and the impacts literature cannot be contextualized within the scope of MSP.

1.4. The Million SoUL Programme

IIT Bombay has developed the 'localisation of solar energy model' through its Million SoUL Programme (henceforth MSP). In this model the assembly, distribution and maintenance of the solar lamp are done by the local people. In order to achieve scale, the model is designed such that it can be replicated in parallel in multiple blocks, across districts and states. To achieve Speed, the assembly and distribution for any block is designed to be completed in 90 working days. In order to target skill development, rural people are trained in the assembling, distribution and repair of these lamps in their local areas.

The goal of the MSP is to fulfill 'right to clean light to every child' in rural areas for the study purpose during dark hours in the fastest possible way, thus reducing dependency on kerosene lamp and contribute to build a better future. The specific objectives are:

- Provide one SoUL to every student to increase their study hours
- Involve local people and develop their capabilities to assemble, sale, provide repair and maintenance service for solar products
- Generate sustainable employment in rural areas

The model is based on the solar PV technology with its inherent feature of providing off-grid decentralized energy at an individual or household level. It integrates three critical elements of speed and reach at wider scale (access) through saturation, cost

effectiveness (affordability), and sustainability. The model has three core concepts of 'partnership approach', 'capacity building' and 'financial viability'. These concepts in the model are interrelated and interdependent and they converge in to realization of localisation of solar energy.

During two year MSP, one million solar study lamps called as Solar Urja Lamps (SoUL) were targeted to be distributed in two phases (I & II). During phase I, 7,50,000 SoUL are distributed, while in phase II rest 2,50,000 will be distributed. Phase I is implemented across 72 blocks in four Indian states of Madhya Pradesh, Maharashtra, Rajasthan, and Odisha states covering more than 7900 villages. Funding from central and state governments as well as philanthropic partners contributed towards keeping the beneficiary contribution low. The actual cost per solar urja lamp (SoUL) is Rs. 500, however at the subsidised cost the beneficiary contribution is Rs. 120 per lamp. Any child enrolled in the school and studying between Class V to Class XII is eligible to purchase one SoUL and they can avail free servicing facility provided in their vicinity till end of the phase I, i.e. December 2015. For localisation and ground level implementation partnership is formed with the NGOs. The capacity building of the local people has resulted into development of 260 solar entrepreneurs (called as SoUL repair centres managers – SRCM). This report presents the results of the concurrent evaluation (Round I) of the MSP during phase I in the state of Odisha in India.

Chapter 2. Methodology

The phase I of the MSP has influenced the sizeable number stakeholders in rural areas of four Indian states in a short span which needs to be studied in depth to gain insights about the efficacy of the MSP. This can further contribute to up-scaling, replication, and the policy recommendations related to solar technology. Hence, the research component formed an integral part of the MSP and accordingly the concurrent evaluation of the MSP was conducted.

The objectives of the concurrent evaluation are to:

1. Assess performance of SoUL and SoUL Repair Centres (SRC)
2. Assess socio-economic impact of the Million SoUL Programme
3. Assess market potential for solar PV products in rural areas
4. Bring transparency in the project and make mid-course corrections
5. Assess localisation model for scalability and replicability

The objectives of the research guided to take the mixed methods approach. The research objectives consist of both qualitative as well as quantitative dimensions, so it was appropriate to employ quantitative and qualitative research methods. In the quantitative data the survey method was applied by collecting the data at the household level, whereas for qualitative data collection the focus group discussion and interview methods were used. The main focus of qualitative method is to assess the objective of localisation model and its scalability, whereas the household survey primarily focuses on the objective of assessing the impact of the MSP.

The concurrent evaluation covered both stakeholders as well as non-stakeholders of the MSP. The qualitative method covered NGO partners and the staff involved in the MSP, solar entrepreneurs (i.e. SRCM), parents of SoUL recipients' children, school teachers, knowledgeable person in the village, and IIT B's field officer posted with the NGO Partner. The quantitative method studied the households of the SoUL recipients (treatment sample) and SoUL non-recipients (control sample) who despite being eligible

had not purchased SoUL. The household survey is planned to be conducted in two rounds in 20 representative sample blocks. The round one is after SoULs are distributed and round two is 4-5 months prior to the end of Phase I in December 2015. In survey the same household will be surveyed twice at two intervals. This report presents the results of the household survey for the state of Maharashtra and the mid-course corrections that are required for improvement of the programme.

2.1. Sample for the household survey

The sampling method employed for selecting the sample was “stratified random sampling”. The sampling size and plan was as follows:

- Two samples were drawn, viz. Treatment Sample and Control Sample. Treatment sample was defined as the recipients of SoUL (who have purchased SoUL from the school) studying in class V-XII. While control sample defined as the children studying in classes V- XII who have not purchased SoUL from the school.
- 1.2% of the total population (i.e. one million students who have purchased the SoUL) was taken as the “treatment sample”.
- The control sample was considered as 10% of the treatment sample, with the 2% of the control sample as the error while surveying, making a total of 12% of the Treatment Sample.
- Stratified Random Sampling was used for the evaluation. The sampling involved dividing the population into two strata, viz. electrification status of house and caste category of the household. The castes were divided into three categories, namely, Scheduled Castes (SC), Scheduled Tribes (ST) and others comprising general and Other Backward Castes (OBC). Thus, the sample (number of households to be surveyed) was arrived at by referring to Census 2011 block level data which determined the proportionate percentage of electrified and non electrified households and caste composition.
- The blocks where the MSP has been implemented were clustered and then a representative block was chosen for the survey. This clustering was based on homogeneity of geographical and social characteristics of the population in each

block. Thus, sample of 20 blocks was selected of a total of 72 blocks where one Million SoULs were distributed.

- Using database on recipients of SoUL, villages having sufficient number of SoUL recipients of the required strata were selected. During selection it was ensured that remote and relatively small villages were not left out.

2.3. Profile of Odisha

The state of Odisha is the Indian state with an area of 155,707 sq.km and a 482 km stretch of coastline. It is bounded by Bay of Bengal on the east, Chhattisgarh on the west, and Andhra Pradesh on the south. As per Government of India's 2011 Census, 83.74 percent of Odisha's population resides in rural areas with 56.16% households having 1-5 members and 43.84 percent with more than 5 members. As per Ministry of Tribal Affairs, three districts entirely (Mayurbhanj, Sundergah, Koraput) and tehsils of six districts of Odisha come under Schedule Areas. Amongst these a district of Koraput is covered in the MSP. As per Census 2011, for 62.8 percent rural households in Odisha kerosene were the main source of light. The latest status of villages electrified as on 31-05-2015 in Odisha as per Central Electricity Authority informed that 91.9 percent villages are electrified with 3878 villages that are yet to be electrified. However, this percentage looks commendable due to the definition of an electrified village which does not require 100 percent households in the village to be electrified. Even if 10 percent of the total number of households in the village is electrified the village is considered as the electrified. The household survey conducted under the MSP revealed that 44.74 percent of the treatment households in Odisha were non-electrified highlighting that this is a significant percentage. The MSP was implemented in the blocks of two districts, namely Koraput and Nabarangpur. The river Indravati forms the border between these two districts.

Figure 1: Map of Odisha

The MSP is implemented in 8 blocks and two districts of Odisha, namely Koraput and Nabrangpur (spelt as Nowrangpur in the map) situated in south-western part of the state. There are two NGO partners and one vendor namely Sirius Solar Energy Systems Private Limited for supplying the material (disassembled kits) in Odisha. In the pilot phase of the MSP 56,551 SoULs were distributed in the state of Odisha. However, due to the fund constraints the implementation in the blocks where FES was the partner NGO had to be withheld. An overview of covered blocks in the district, the NGO partners, the vendor, and the number of distributed SoULs in the respective block are given in table 1 below.

Table 1: Overview of NGO partners, Vendors and SoUL Distribution in Odisha

NGO Partner	District	Block	Vendor	Distributed SoULs	Start Date	Saturation Date
HarshaTrust	Koraput	Kundra	Sirius	6702	21/07/2014	16/3/2015
HarshaTrust	Koraput	Jeypore	Sirius	5466	8/7/2014	26/3/2015
HarshaTrust	Koraput	Bariguma	Sirius	1101	10/9/2014	13/03/2015
HarshaTrust	Koraput	Kotapad	Sirius	4351	25/9/2014	16/3/2015
HarshaTrust	Koraput	Baipariguda	Sirius	7466	16/09/2014	24/3/2015
HarshaTrust	Nabarangpur	Nabarangpur	Sirius	6062	31/07/2014	22/3/2015
HarshaTrust	Nabarangpur	Papadahandi	Sirius	8309	30/07/2014	19/2/2015
HarshaTrust	Nabarangpur	Kosagumda	Sirius	10629	18/09/2014	23/3/2015
FES	Koraput	Bandhugaon	Sirius	393	17/09/2014	Implementation

FES	Koraput	Dasmantpur	Sirius	183	28/8/2014	was withheld in 11 blocks due to funds constraints
FES	Koraput	Koraput	Sirius	2691	9/9/2014	
FES	Koraput	Narayanpatna	Sirius	630	17/09/2014	
FES	Koraput	Potangi	Sirius	262	9/9/2014	
FES	Koraput	Semiliguda	Sirius	721	9/9/2014	
FES	Koraput	Koraput NAC	Sirius	0		
FES	Koraput	Lamtaput	Sirius	586	27/9/2014	
FES	Koraput	Laxmipur	Sirius	100	13/1/2015	
FES	Koraput	Nandapur	Sirius	361	24/10/2014	
FES	Koraput	Sunabeda NAC	Sirius	538	20/10/2014	

2.4. Cluster approach and representative block for the household survey

As aforementioned the distribution of SoUL in Odisha has taken place in 8 blocks. All these blocks have predominant tribal population, which resides in remote rural areas. Conducting household survey for the purpose of concurrent evaluation in all the implementation blocks was not feasible considering the geographic spread and resources required; hence 'cluster' approach was taken towards resolving this issue. The cluster of two or more blocks was formed on the basis of their geographic and demographic similarities, and one block is selected as a representative block from each cluster for conducting the concurrent evaluation. This allowed for generalization of impacts without compromising on the validity of the research sample. In case of Odisha there was change in the number of blocks to be considered for the household survey due to fund constraints. The fund constraints resulted into withholding of lamp distribution in five blocks and only 3 blocks could be saturated. A minimum of 35 percent distribution was considered as the benchmark for making the cluster for the household survey purpose. Apart from the basis of aforementioned criteria, this additional criterion was also included and accordingly three blocks were selected as a representative blocks for the concurrent evaluation. The following table 2 presents the clusters that were formed and the representative blocks in which the household survey was conducted.

Table 2: Representative Block and Block Cluster

Representative block for HH Survey	Names of Blocks in the Cluster	District	IP's Name

Paparahandi	Nabarangpur	Nabarangpur	Harsha Trust
	Paparahandi		
	Kosagumda		
Kundra	Kundra	Koraput	Harsha Trust
	Baipariguda	Koraput	Harsha Trust
Kotapad	Kotapad	Koraput	Harsha Trust

Chapter 3. Odisha – Concurrent Evaluation Result (First Round)

For the concurrent evaluation the household survey was conducted in three representative blocks of Odisha and the survey was conducted in the April 2015. The total sample household surveyed in Odisha were 877, amongst which 780 were treatment sample and 97 control sample. The sample households were distributed across 38 villages and 19 Gram Panchayats. Table 3 and 4 below give an overview of block wise sample households and villages covered.

Table 3: Distribution of Sample Households across the Sample Blocks in Odisha

Block	No. of Treatment Household	Percentage	No. of Control Household	Percentage
Kotapad	116	14.87	10	10.31
Kundra	280	35.9	30	30.93
Papadahandi	384	49.23	57	58.76
Total HH's covered in Odisha	780	100	97	100

Table 4: Number of villages and Gram Panchayats covered in Odisha

Block	Treatment		Control		Treatment		Control	
	No. of Villages	%	No. of Villages	%	No. of Panchayats	%	No. of Panchayats	%
Kotapad	11	28.95	3	15.79	7	36.84	3	21.43
Kundra	14	36.84	8	42.11	7	36.84	7	50.00
Paparahandi	13	34.21	8	42.11	6	31.58	4	28.57
Total	38	100.00	19	100.00	19	100.00	14	100.00

3.1. Socio-economic Background of the Sample Households in Odisha

As per Census 2011, in rural Odisha 17.78 % of the population was Scheduled Caste (SC), 25.72 % was Scheduled Tribe (ST), and 56.50 % Others. The table 5 given below presents the classification of sample as per social categories as well as the Census

2011 data for the same. In the sample the percentage of Scheduled Tribes (STs) was highest in both samples treatment (61.13 percent) as well as control (53.61 percent).

Table 5: Distribution of sample and rural population as per social categories

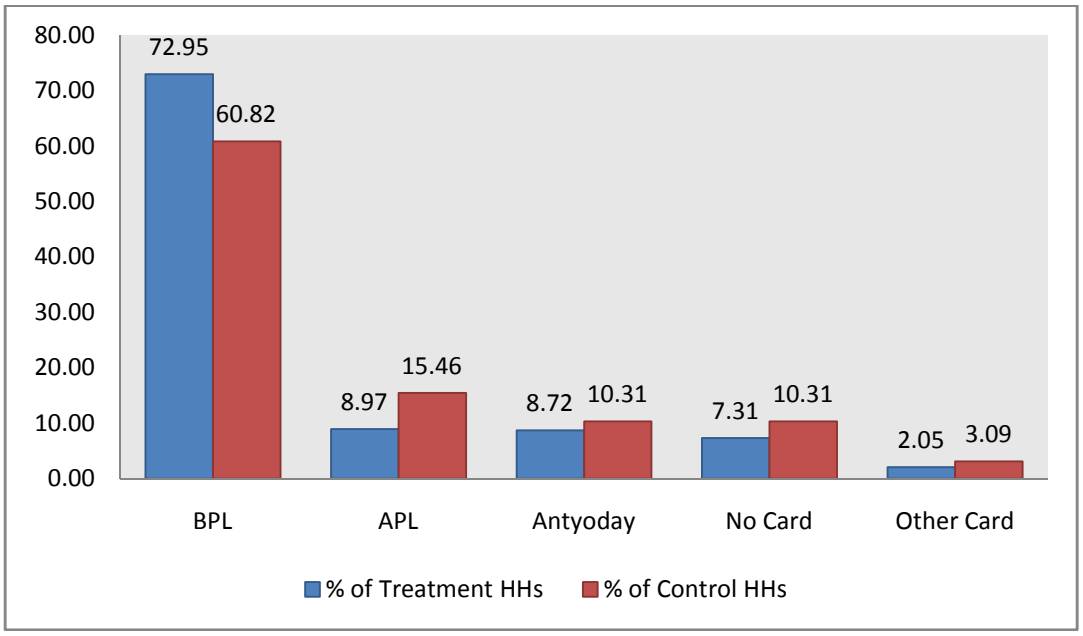
Social Category	No. of Treatment HHs	Percentage	No. of Control HHs	Percentage	Percentage of rural population as per Census 2011
ST	475	61.13	52	53.61	25.72
SC	126	16.22	16	16.49	17.78
OBC	125	16.09	20	20.62	56.5
General	48	6.18	9	9.28	
Others	3	0.39	0	0.00	
No response	3	0.39	0	0.00	
Total	780	100.00	97	100.00	100.00

Table 6: Occupation Profile of Sample Households in Odisha

Primary Occupation	No. of Treatment HH	%	No. of Control HH	%
Agriculture	207	26.54	31	31.96
Labor	180	23.08	27	27.84
Agriculture+ Labor	262	33.59	24	24.74
Service	31	3.97	1	1.03
Skill Based	18	2.31	1	1.03
Dairy	1	0.13	0	0.00
Remittance	0	0.00	0	0.00
Other	81	10.38	13	13.40
Total	780	100.00	97	100.00

The households possessing below poverty line (BPL) cards were defined as poor households. The figure 2 below presents the percentage of households and the type of cards possessed by them. It shows that 72.95 percent of treatment and 60.82 percent of control households belonged to the poor category. About the access to the grid electricity either through legal or non-legal (by putting hook) connection, it was seen that 44.74 percent of the treatment sample and 55.67 percent of control sample had no access, i.e. they were non-electrified. However, 52.69 percent treatment and 43.30 percent control households had legal connection, which means 2.57 percent treatment households and 1.03 percent control households had illegal connection.

Figure 2: Type of cards possessed by Sample Households



3.2. Children Details

In the sample households only the information of children that were either in the school going age group of 5-17 years or were studying between classes 1 to 12 was collected as they come under the age group that should attend the school. Moreover, children studying from class 1 onwards are expected to complete the home-work at home when given or are expected to study at home. Therefore, availability of light at home during dark hours enables them to study.

In 780 treatment households, 1371 children and in 97 control households 173 children were either in the school-going age (5 to 17 years) and or studied in classes from 1st to 12th. In treatment group of the total 1371 children, 96.43 percent and in control group out of 173 children 91.91 percent were enrolled in the school. The data on households with number of children falling in the school going age of 5 years to 17 years or studying between class I to class XII showed that in both the samples maximum percentage of households (49.36 percent in treatment and 50.52 percent in control) have one child followed by 32.18 percent in treatment and 27.84 percent in control having two children, and 13.33 percent in treatment and 15.46 percent in control with 3 children. The

remaining percent of households, which is approximately 6 percent, had more than three children.

The gender-wise classification of school-going children in the sample showed that in both treatment and control groups 55.45 percent each were male children. The classification of children as per the age group showed that maximum percentage (61.63 percent in treatment and 58.38 percent in control) of households have children in the age group of 10-15 years, followed by 5-10 years age group (30.56 percent in treatment and 28.32 percent in control) then the age group of 15-20 years (7.73 percent in treatment and 13.29 percent in control). The classification of school-going children as per the classes showed that in the treatment group 40.02 percent studied in upper primary (6^{th} to 8^{th}), while 27 percent studied in primary (between class I-IV), 14.75 percent in Class V, 14.60 percent in secondary (9^{th} & 10^{th}), and 3.48 percent in senior secondary (11^{th} & 12^{th}). There was one child each that studied in pre-primary and above 12^{th} class. In the control sample 29.56 percent studied in upper primary followed by 25.16 percent in primary, 20.13 percent in 5^{th} class, 19.50% in secondary, and 5.66 percent in senior secondary. Thus, the pattern emerged was observed to be similar in both the samples. The differentiation as per gender also showed the similar pattern for both the groups.

Of the total of 1322 school-going children in the treatment group 69.21 percent have purchased SoUL. As there was higher percentage of male children in the school-going age group in the sample the gender differentiation was not comparable, while the data within the gender category revealed 56.72 percent boys have purchased SoUL against 43.28 percent girls. Thus, a difference in gender was observed with regard to purchase of SoUL. In 780 treatment households there were 915 students who have purchased SoULs Amongst these households majority percentage, i.e. 85.64 percent, had one SoUL, while 12.56 percent households were with two SoULs, and 1.67 percent houses with three SoULs. There was only 1 household that had 4 SoULs.

As it could be observed from the table 7 below the reason for not purchasing SoUL revealed that 34.64 percent children in treatment and 16.98 percent children in control group were not eligible for purchasing SoUL as they studied in classes below class V. There were 25.79 percent in control group and 8.85 percent in treatment group did not purchase SoUL as they did not enough money at the time when SoUL was available for sale. There were no respondents in both the groups who stated expensiveness as the reason indicating that cost was not a barrier for accessing the SoUL.

Table 7: Reason for not purchasing SoUL in Odisha

Reason for not purchasing SoUL	No. of Children in Treatment	%	No. of Children in Control	%
Child not available when SoUL was given	14	3.44	31	19.50
Not Eligible	141	34.64	27	16.98
Not Enough Money	36	8.85	41	25.79
Not Given in School	31	7.62	24	15.09
Not Required	41	10.07	13	8.18
Purchased number of SoUL are enough	8	1.97	0	0.00
SoUL lamp not available	94	23.09	10	6.29
Studies from recipient sibling's lamp	40	9.83	0	0.00
Other	2	0.49	1	0.63
Total	407	100.00	122	100.00

3.3. Lighting: sources, devices and expenditure

3.3.1. Electricity bill: Interval of receiving it and amount paid by sample households

Maximum percentage of households in both the groups 76.37 percent in treatment and 93.75 percent in control received the monthly bill, followed by 12.09 percent in treatment and 6.25 percent in control receiving the bill after a gap of every three months. There were 10.99 percent treatment households that informed of receiving the bill every six months. In both the sample groups' majority of households informed of receiving the electricity bill of an amount of less than Rs. 300 (78.57 percent treatment and 87.50 percent control). 15.93% treatment households reported to receive the bill in the range of Rs. 300-600. There were very less percentage of households in the sample that informed that they receive electricity bill of Rs. 600 and above.

3.3.2. Kerosene: purchase, usage, and expenditure

The data related to kerosene purchase, expenditure and usage was calculated for only those households that purchased and consumed kerosene. The distribution of monthly kerosene purchase, usage, and expenditure was examined according to electrification status of the households to know if any differences exist. In both the groups all the households, except for four treatment households reported to purchase kerosene. For 76.54 percent treatment and 73.20 percent control households 'Public distribution system (PDS) was the 'only source of kerosene purchase' making it the predominant source of kerosene purchase. There were 3.85 percent treatment and 7.22 percent control households for whom open market was the only source, while 19.10 percent treatment and 19.59 percent control households purchased kerosene from both the sources.

The data on kerosene usage showed that lighting took precedence over cooking. There were only 1.16 percent treatment households that reported 'not using kerosene for lighting purpose', whereas there was not even a single such a household in the control group. There were 72.04 percent households in treatment and 67.01 percent in control reported 'not using kerosene for cooking'. There were 66.79 percent treatment households and 64.95 percent control households that consumed kerosene 'only for lighting' purpose, while remaining 33.21 percent treatment and 35.05 percent control households consumed it for other uses including lighting.

Of the total treatment group 95.64 percent and 92.78 percent of the control group every month purchased kerosene from the PDS. Amongst this majority of households fall under three categories: (a) for 40.35 percent treatment and 25.56 percent control per month kerosene purchase was between 1-2 litres; (b) 25.20 percent treatment and 28.89 percent control purchased kerosene between 2-3 litres per month; (c) 26.68 percent treatment and 36.67 percent control monthly kerosene purchase was between 3-4 litres. There was negligible percentage of households in both the sample groups that purchased more than 4 litres of kerosene per month. Similarly there were few percentages of households in both the groups that purchased less than one litre of

kerosene per month. Thus, the data on PDS kerosene purchase revealed that the per month purchase is more in control household than in treatment as higher percentage of control households were observed to purchase between 3-4 litres and 2-3 litres.

As aforementioned open market purchase of kerosene was not much. Amongst the households (176 treatment and 26 control) that purchase kerosene from the market, maximum percentages in both the sample groups fall in two categories: (a) per month purchase of less than 1 litre kerosene that has 52.27 percent treatment and 42.31 per cent control households; (b) per month purchase between 1-2 litres of kerosene that have 46.17 percent control and 36.23 percent treatment households. There were 8.52 percent treatment and 7.69 percent control households that reported to purchase per month kerosene in the range between 2-3 litres. There were just 4 treatment and 1 control household that reported to purchase more than 3 litres of kerosene per month.

As evident from table 8 in all categories, except for the category of 1-2 litres, control group has higher percentage of households indicating more kerosene consumption per month than in treatment. Per month kerosene consumption for the cooking purpose informed that in both the sample groups majority percentage consumed less than 1 litre of kerosene as the usage is limited to igniting the fire (refer table 9 below).

Table 8: Per Month Kerosene Usage for Lighting Purpose

Per month kerosene consumption for lighting (in litres)	No. of Treatment Households	%	No. of Control Households	%
0-1	52	6.7	10	10.31
1-2	312	40.21	25	25.77
2-3	245	31.57	33	34.02
3-4	144	18.56	24	24.74
4-5	12	1.55	3	3.09
5-6	1	0.13	2	2.06
Above 6 Litres	1	0.13	0	0.00
Kerosene not used for lighting	9	1.16	0	0.00
Total	776	100	97	100

Table 9: Per Month Kerosene Usage for Cooking Purpose

Per month kerosene consumption for cooking (in litres)	No. of treatment HHs	%	No. of control HHs	%
0-1	186	23.97	25	25.77
1-2	22	2.84	5	5.15
2-3	2	0.26	1	1.03
3-4	2	0.26	0	0.00
4-5	2	0.26	0	0.00
5-6	0	0.00	1	1.03
Above 6 Litres	3	0.39	0	0.00
Kerosene not used for cooking	559	72.04	65	67.01
Total	776	100	97	100

Since it was clear that kerosene is primarily used for lighting, it became imperative to understand the how much consumption occurs through kerosene based devices. To understand a difference in usage pattern of kerosene based devices, the number of kerosene based devices and daily usage of kerosene based devices like simple wick lamp (chimni) were asked from the household respondents. 94.62 percent of the treatment households possess simple wick lamp (chimni), similarly 94.85 percent of the control household own chimnis. Similarly, maximum number of the households (52.67 percent in treatment and 48.45 percent in control) own 2 chimnis showing no difference in terms of ownership of devices. From daily usage, it was clear that lesser percentage of treatment households use chimnis for higher number of hours. While 23.39 percent of treatment households' use chimnis 2-4 hours daily, 40.21 percent of control households use chimnis daily for same number of hours (Table 10).

Table 10: Usage of Kerosene Devices (in hours) for Lighting in Odisha

Number of Hours	Treatment Households						Control Households					
	Electrified		Non-Electrified		Total		Electrified		Non-Electrified		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0-2	312	74.46	208	59.77	520	74.46	29	67.44	22	40.74	51	52.58
2-4	98	23.39	99	28.45	197	**23.39**	12	27.91	27	50.00	39	**40.21**
4-6	8	1.91	39	11.21	47	1.91	2	4.65	5	9.26	7	7.22

6-8	1	0.24	2	0.57	3	0.24	0	0.00	0	0.00	0	0.00
8-10	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
10-12	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	**419**	**100.00**	**348**	**100.00**	**767**	**100.00**	**43**	**100.00**	**54**	**100.00**	**97**	**100.00**

Non-electrified households consume and spend higher on kerosene as compared to the electrified counter parts in control group. Expenditure on kerosene between electrified and non-electrified of treatment group is same; however non-electrified households consume more kerosene. However, the results indicate overall higher kerosene purchase and average monthly kerosene expenditure by the control households as against the treatment households. Comparison revealed differences between electrified households of the treatment group and electrified households of the control group, as well as non-electrified households of the treatment group and non-electrified households of the control group. Average monthly expenditure on kerosene of electrified treatment sample was only Rs. 60.07 as against Rs. 66.79 by the electrified group. Similarly, higher expenditure is seen in non-electrified control group with these households spending Rs. 75.06 as against Rs. 66.79 by the non-electrified treatment group (Table 11). These results present a general argument towards economic benefits attained by households using SoUL as against those not using SoUL.

Table 11: Source-wise per litre Kerosene Cost and Monthly Expenditure as per electrification status in Odisha

	Treatment Households				**Control Households**			
	Electrified		**Non - Electrified**		**Electrified**		**Non - Electrified**	
	Amount	**Numbers**	**Amount**	**Numbers**	**Amount**	**Numbers**	**Amount**	**Numbers**
Average Price from PDS Shops	18.94	407	18.92	339	19.31	38	19.01	52
Average Expenditure on PDS	55.40	407	50.30	339	63.47	38	57.13	52
Average Price from Market	30.67	52	32.25	127	31.11	9	32.35	17
Average Expenditure on Market	57.30	52	53.15	127	47.77	9	59.7	17
Total Kerosene Purchased *	3.01 L	427	3.17 L	349	3.23 L	43	3.46 L	54
Total Average Expenditure *	60.07	427	60.070	349	66.79	43	75.06	54

* these values have been calculated from the number of households that actually purchase kerosene

3.4. Electricity based devices used for lighting

In 431 electrified control households, 95.90 percent of households have incandescent bulbs, 43.16 percent have compact fluorescent lights (CFL) and 19.72 percent have rechargeable torch. Similarly, in 43 electrified control households, 90.70 percent of the households have incandescent bulbs, 41.86 percent have compact fluorescent lights (CFL) and 30.23 percent have rechargeable torch. Regarding the number of incandescent bulb in the households in treatment sample 60.39 percent households had two incandescent bulbs, followed by 18.83 percent with three bulbs. In the control sample 43.59 percent households had two incandescent bulb followed by 28.21 percent with two. Similarly about CFL in treatment 58.60percent households had one CFL followed by 24.19 percent with two CFL and 8.60 percent with three CFLs, while in control 50.00 percent had one and 27.78 percent had two, and 16.67 percent had three. Mean of per unit cost reported by respondent households was approximately Rs. 11 for incandescent bulb and Rs. 139 for CFL. The average bulb life was stated to be approximately three and half months, while for CFL it was eleven and half months. Amongst the households possessing tube light majority in both the samples had one tube light (72.73 percent in treatment and 100 percent in control). The average life of tube light reported by the respondents was one year one month with average cost of Rs. 90.45. Amongst those electrified households, majority of households in both the samples (95.29 percent in treatment and 92.31 percent in control) had one rechargeable torch.

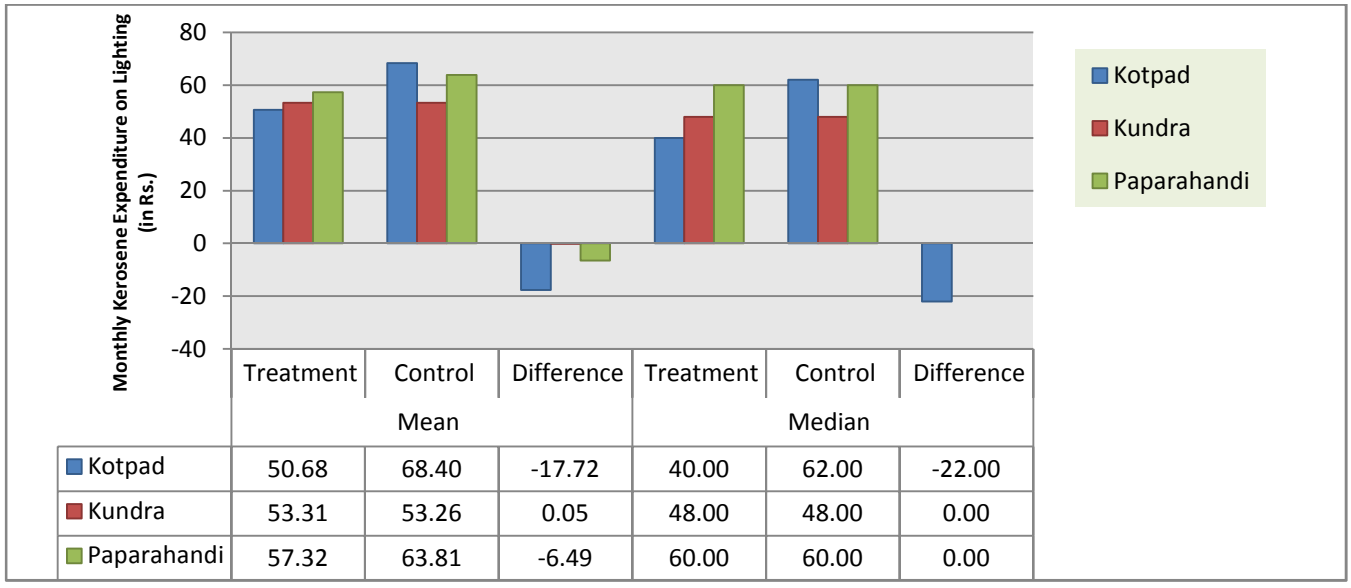
3.5. Expenditure on Lighting

In order to see the impact of SoUL on ‘lighting expenditure’ of the households the comparison was made between treatment and control households. However for this analysis, data was calculated for those households which had SoUL in working condition, while the households with non working SoULs were not considered. In order to arrive at monthly lighting expenditure monthly mean and median expenditure on various heads such as electrical lighting devices like CFL, incandescent bulb, electricity bill, and kerosene purchased for lighting purpose was calculated separately and then the total mean and median lighting expenditure was calculated.

3.5.1. Monthly expenditure on kerosene used for lighting

The figure 3 below presents the monthly mean expenditure on kerosene in treatment and control sample across the blocks in Odisha. Almost in all blocks, the expenditure on kerosene for lighting is higher in the control group than in treatment group. The difference in mean expenditure on lighting between control and treatment showed that it was highest in Kotapad block with control households spending almost 17.72 rupees more, followed by Paparahandi block where the difference was almost 6.49 rupees. In Kundra block, the expenditure is marginally higher by 0.05 rupees the treatment group as against the control group.

Figure 3: Mean & Median of Monthly Kerosene Expenditure on Lighting in Treatment & Control Groups in Odisha



	Mean			Median		
	Treatment	Control	Difference	Treatment	Control	Difference
Kotpad	50.68	68.40	-17.72	40.00	62.00	-22.00
Kundra	53.31	53.26	0.05	48.00	48.00	0.00
Paparahandi	57.32	63.81	-6.49	60.00	60.00	0.00

The table 12 given below makes two comparisons about kerosene expenditure on lighting: (a) electrified treatment and electrified control group (b) non-electrified treatment and non-electrified control group. It was found that non-electrified control households tend to spend more on kerosene than the treatment households in Kotapad and Paparahandi. Even in control electrified households the mean kerosene expenditure was more in all blocks except Kundra.

Table 12: Monthly Expenditure on Kerosene as per electrification status Blocks in Odisha

Odisha Blocks	Treatment				Control				Difference			
	Electrified		Non - Electrified		Electrified		Non - Electrified		Electrified		Non - Electrified	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Kotpad	38.70	36.00	59.67	57.75	45.00	40.00	91.80	36.00	6.30	4.00	32.13	-21.75
Kundra	44.56	40.00	60.49	53.00	41.50	40.00	57.54	52.50	-3.06	0.00	-2.95	-0.50
Paparahandi	54.51	54.00	62.64	60.00	56.16	57.00	72.31	70.00	1.65	3.00	9.67	10.00

3.5.2. Monthly expenditure on electric devices

Overall, it was seen that the treatment households were spending more on the electric devices as compared to the control households. The data on mean expenditure on electrical devices showed that in two blocks (Kotapad and Kundra) control households were spending more than treatment, whereas in Paparahandi treatment households were found to be spending more than the control households.

3.5.3. Monthly expenditure on electricity bill

The overall mean monthly expenditure is seen to more in households of control group compared to households from the treatment group. Block-wise analysis reveals the same pattern for all blocks except Kotapad where the treatment households are seen to have higher monthly electricity (Table 13).

Table 13: Monthly Expenditure on Electricity Bill across Sample Blocks in Odisha

	Treatment		Control		Difference	
	Mean	Median	Mean	Median	Mean	Median
Odisha	168.31	129	155	331.08	13.31	-202.08
Blocks						
Kotpad	168.87	150	152.5	155	16.37	-5
Kundra	190.91	166.66	206.66	200	-15.75	-33.34
Paparahandi	154.73	100	451.92	150	-297.19	-50

3.5.4. Monthly expenditure on lighting

The monthly expenditure on lighting show control households spending more on lighting as compared with the treatment households. As seen in table 14, the mean lighting expenditure was more in electrified control households in all blocks except Kotapad,

while mean lighting expenditure in non-electrified in treatment was more in just Kundra. The highest difference in mean expenditure on lighting between electrified treatment household and electrified control household was Rs. 254, while the same for non-electrified treatment household and non-electrified control household was Rs. 32.13.

Table 14: Monthly Expenditure on Lighting in Electrified & Non-Electrified Households across Odisha

Odisha Blocks	Treatment				Control				Difference			
	Electrified		Non - Electrified		Electrified		Non - Electrified		Electrified		Non - Electrified	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Kotpad	213	186.5	59.67	57.75	197.8	223.75	91.8	76.5	-15.25	37.25	32.13	18.75
Kundra	161	86.16	60.49	53	209.4	65.66	57.54	52.5	48.36	-20.5	-2.95	-0.5
Paparahandi	120	83.66	62.64	60	374.9	88	72.31	70	254.97	4.34	9.67	10

T-test for statistical significance

T-test was conducted for checking the statistical significance of the difference in the monthly expenditure on lighting between two samples i.e. treatment group and control group and the related heads. Furthermore t-test was also conducted in order to see any differences between electrified and non-electrified households across both groups. In the t-test mean treatment was subtracted from mean control to observe whether the differences are statistically significant or not. The expected outcome shall be that the expenditure on lighting in treatment should be less than those in control group.

Table 15 given below presents t-test results, which were run for two samples, i.e. treatment and control, by calculating 'the mean' for total expenditure lighting and for related heads separately. The T-test results show all variables for Odisha - 'expenditure on electricity bill', 'expenditure on electric devices', 'expenditure on kerosene used for lighting' and 'total expenditure' to be significant. Block wise break also indicate some variables to be significant at various levels. The results indicate the positive impact of SoUL on overall expenditure on lighting by the households.

Table 15: Two Sample (Treatment & Control) T-test results for Odisha

	Exp on Electricity Bill		Exp on Electric Devices		Exp on Kerosene used for lighting		Total Expenditure	
	t- test	P-Value	t- test	P-Value	t- test	P-Value	t- test	P-Value
Consolidated OD	3.4504	0.0007*	2.1745	0.0302#	2.3516	0.0190#	3.451	0.0006*
Block Wise								
	t- test	**P-Value**	**t- test**	**P-Value**	**t- test**	**P-Value**	**t- test**	**P-Value**
Kotpad	-0.3382	0.7368	-1.8438	0.0703@	2.0244	0.0452#	0.4919	0.6237
Kundra	0.2069	0.8371	-0.6581	0.5118	-0.0108	0.9914	-0.3759	0.7073
Paparahandi	3.1573	0.0023*	2.4184	0.0163#	2.045	0.0416#	3.4782	0.0006*

* The value is significant at 99 % confidence; # The value is significant at 95 % confidence; @ The value is significant at 90 % confidence

3.6. Studying during dark hours: lighting devices, electrification status, gender differentiation (studying during dark hours henceforth referred as studying in night)[8]

Regarding usage of lighting devices for study at night it was reported that 97.50 percent children in treatment and 92.45 percent in control study at night. The reason for not studying during the night were asked, which revealed that in treatment 75.76 percent and in control 33.33 percent children were not interested in studying, while 66.67 percent in control and 12.12 percent in treatment informed to be not studying during dark hours. As the remaining 4 children in treatment sleep early they do not study at night.

The 'lighting devices used for study at night' is a single and or multiple response question. Of 1,289 children from treatment sample who study at night, 79.21 percent used **SoUL as one of the study device** (either as the only lighting device or along with other devices), whereas 20.79 percent children did not use SoUL as one of the studying devices. Amongst those not studying in SoUL, for the maximum 96.27 percent students non-functioning of SoUL was the reason, while for remaining percentage their sibling do not share the lamp.

[8] Dark hours are defined as the time when there is no daylight and there is darkness and lighting devices are required for the illumination. The dark hours pertain to hours from dusk (darker stage of twilight) to dawn (the first appearance of light in the sky before sunrise). These hours will vary from season to season for example in winters it becomes dark early in the evening and the nights are longer as sun rises late and vice-versa during summer.

As seen in table 16 below the data on usage of **solely kerosene** based **lighting devices** like C*himni* (simple wick lamp) and hurricane revealed that in treatment group only 9.31 percent, whereas in control group **48.98 percent** children used it. There were 6.83 percent in treatment and 17.01 percent in control used **electricity as a single source** to study at night. It was observed in the treatment group that **59.27 percent** children used **'merely SoUL'** as a lighting device followed by 11.40 percent who used SoUL and electricity. Data points towards difference in pattern of lighting devices used for studying in night between treatment and control group. With regard to reliance on kerosene based devices, control group relied heavily on it, whereas in the treatment group this reliance is not much indicating SoUL's contribution towards reducing this dependence.

Table 16: Devices used for Studying in Night

Devices used for studying in night	No. of Children from treatment group	%	No. of Children from control group	%
Electricity, Kerosene Source	56	4.34	28	19.05
Kerosene Source, Other Solar Device	0	0.00	0	0.00
Only Electricity	88	6.83	25	17.01
Only Kerosene Source	120	9.31	72	**48.98**
Only SoUL	**764**	**59.27**	0	0.00
Other Device	0	0.00	2	1.36
Other Solar Device	0	0.00	5	3.40
SoUL, Electricity	**147**	**11.40**	0	0.00
SoUL, Electricity, Other Device	0	0.00	3	2.04
SoUL, Kerosene Source	98	7.60	0	0.00
SoUL, Other Device	9	0.70	0	0.00
SoUL, Electricity, Kerosene Source	3	0.23	0	0.00
SoUL, Kerosene Source, Other Device	0	0.00	0	0.00
Electricity, Other Device	3	0.23	1	0.68
Kerosene Source, Other Device	1	0.08	11	7.48
Total	**1,289**	**100.00**	**147**	**100.00**

The comparison across the blocks about the only SoUL used for studying revealed that Paparahandi had highest percentage (48.43 percent) of users followed by 29.45 percent

in Kundra, and 22.12 percent in Kotapad. Due to insufficient observations in the treatment group T-test for children studying during night using 'only kerosene based devices' and for children studying 'only in grid electricity' could not be run. Treatment group had only 2-3 households which despite having SoUL in working conditions used kerosene based devices. However, the users of only kerosene based devices test could not be run as in treatment group there was only one household that despite having SoUL in working conditions used 'only kerosene' based devices or used 'only electricity' based devices while studying during night. Thus, the data on lighting devices used for night study clearly indicated substantial decline in usage of kerosene and electricity based devices in treatment as compared control group.

3.6.1. Study hours during night

The data on studying hours in table 17 showed that the pattern is uniform across both the sample groups and even in the electrified and non-electrified households as the maximum percentage of children in each category studied between 1-2 hours. Maximum percentage of children (55.28 percent) in treatment studied for less than an hour at night followed by 37.66 percent studying for 1-2 hours, and 5.68 percent for 2-3 hours. In control group, 46.14 percent children studied for 1-2 hours, followed by 44.07 percent studying for less than an hour, and 8.16 percent studying for 2-3 hours. In both the groups less than 2 percent each are observed to study for more than 3 hours. Thus, not much of a difference could be observed between treatment and control group with regard to study hours and similarly no gender differentiation was observed in this regard.

Table 17: Studying Hours amongst Children in Odisha

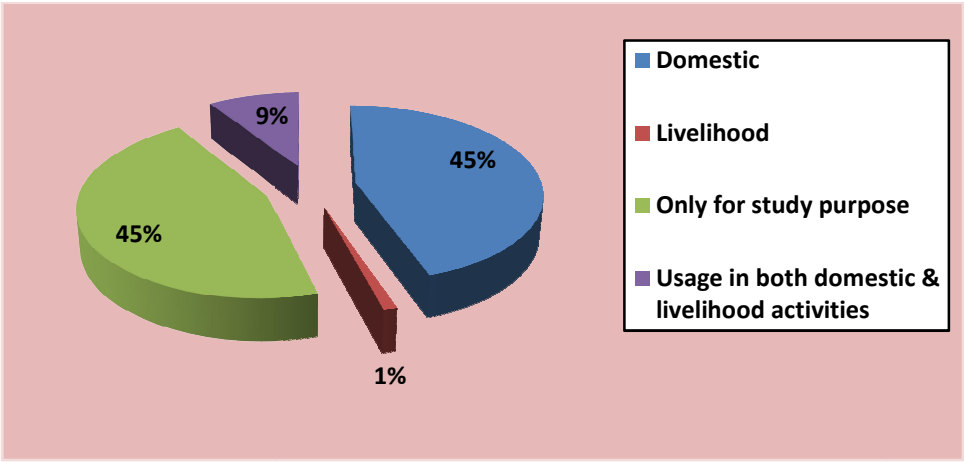
	Treatment Household						Control Households					
	Electrified		Non-electrified		Total		Electrified		Non-electrified		Total	
Hours Studies	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0-1	163	28.45	176	39.29	339	33.20	28	38.89	34	45.33	62	42.18
1-2	347	**60.56**	233	**52.01**	580	**56.81**	30	**41.67**	34	**45.33**	64	**43.54**
2-3	51	8.90	29	6.47	80	7.84	13	18.06	7	9.33	20	13.61
3-4	8	1.40	9	2.01	17	1.67	1	1.39	0	0.00	1	0.68

4-5	2	0.35	1	0.22	3	0.29	0	0.00	0	0.00	0	0.00
5-6	2	0.35	0	0.00	2	0.20	0	0.00	0	0.00	0	0.00
Total	573	100.00	448	100.00	1021	100.00	72	100.00	75	100.00	147	100.00

3.7. Other Uses of SoUL

"Other uses of SoUL" is a multiple answer question. The data showed that the beneficiary households besides using SoUL for studying during night also used it for multiple and diverse purposes. As presented in figure 4 below there were 45 percent household that reported using it only while studying during night, whereas 54.87 percent households reported using SoUL for other purposes. Amongst those using SoUL for other purposes, 45 percent households used it as an aid in domestic activities, while 9 percent in both domestic and livelihood activities, and merely 1 percent used it in livelihood activities. The main domestic activities include aid during cooking and having dinner.

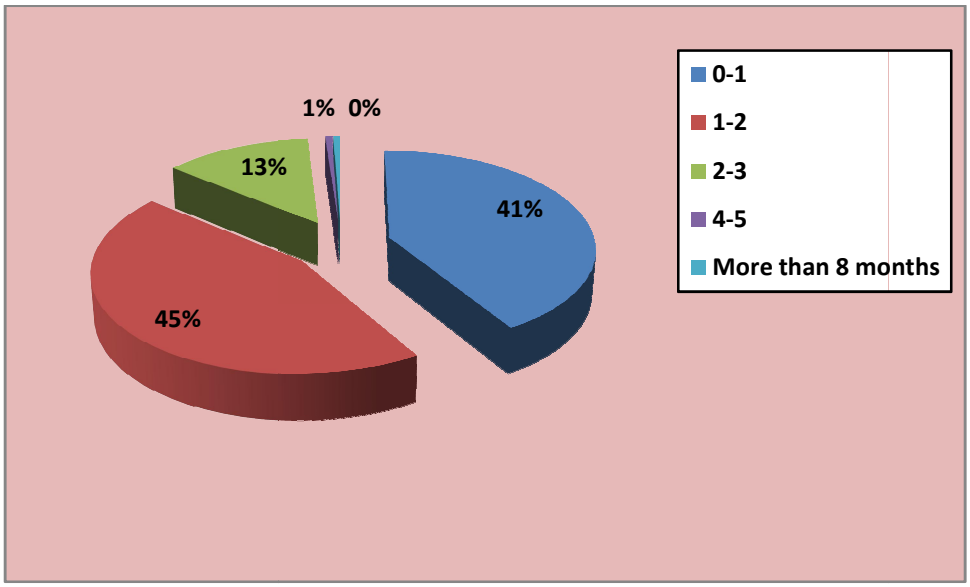
Figure 4: Percentage of households using SoUL in various activities in Odisha



3.8. Performance of SoUL

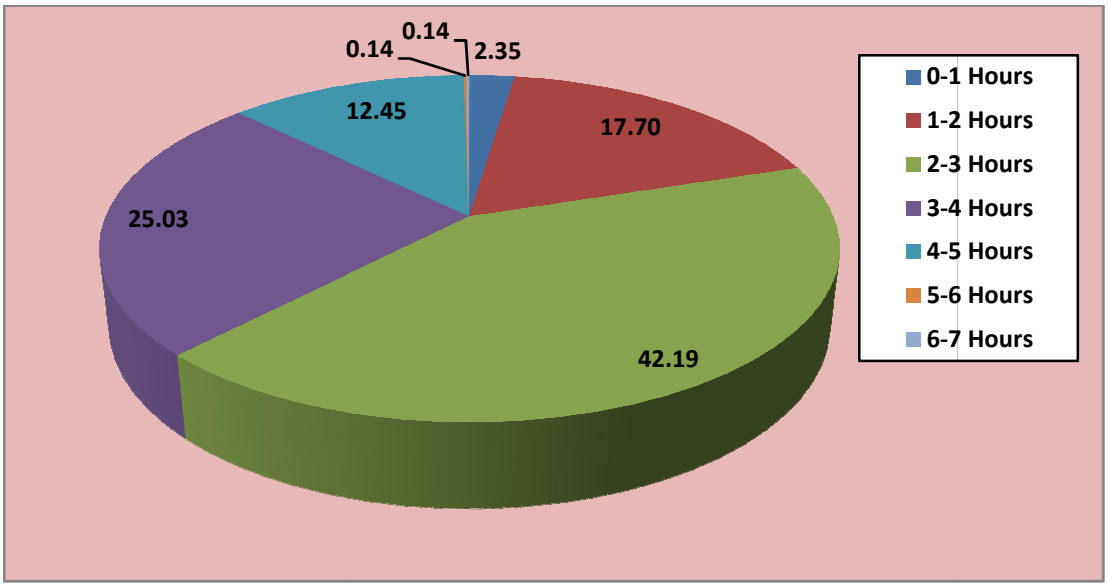
Out of 907 SoULs received by 780 treatment households, **20.29 percent** were found **non-functional.** The data on period for which non-working SoULs worked for before they stopped functioning is given in the pie chart below (refer figure 5). As evident from the figure 5, maximum percentage of lamps functioned between 1-2 month and up to 1 month.

Figure 5: Percentage of SoUL and No. of Months they functioned before stop functioning



The working SoULs were checked for functioning of its various parts. Amongst 723 functioning SoULs, 66.80 percent were without any problem or no part was defectives, whereas 33.20 percent lamps had some problem relating to one or the other part of the lamp. Amongst the SoULs with some problem, two main problems identified were loose connection in 15.91 percent lamps and non-working of green light in 15.21 percent lamps. 7.75 percent lamps had problems related to switch. Panel and red light indicator related problems were 3.46 percent each. The respondents were asked about the lighting back-up in hours that SoUL provided after one day of charging. There was a broad range of response ranging from less than an hour to up to 5 hours. As it can be seen from figure 6 below for majority of lamps, i.e. 42 percent, gave back-up between 2-3 hours. There are 38 percent households reporting back-up more than 3 hours.

Figure 6: Back-up provided by SoUL



In three sample blocks selected for the study, there was one NGO partner – Harsha Trust and one vendor, Sirius. The block wise performance of SoUL showed that Kotpad had merely 1.45 percent non-functionality rate, whereas Kundra had high non-functionality rate of 32.65 percent. The remaining sample block, Paparahandi, had 16.43% non-functional SoULs.

3.9. Need for solar energy based products and willingness to pay

The household survey tried to explore the household level solar energy related needs and in case of presence of such needs then willingness or capacity to pay assuming there is no subsidy available and they are to purchase it from the market. The exploration of needs was linked to assessing the market potential for the solar products in rural areas. However, households in the SoUL programme implementation areas being rural and tribal tend to have less exposure to solar technology and solar products. So the barrier about knowing or visualising the product and state some cost that they think they can afford to pay was anticipated. In order to overcome this barrier a placard illustrating pictures of solar products like solar light, solar torch, solar home lighting system, solar fan, solar pump for irrigation, solar drier for drying crops (food grains, vegetables) and their approximate costs in the market at present was prepared. While

administering the questionnaire it was shown to them and care was taken to inform and assure them that any kind of marketing of solar products was not intended and there is no commitment when they state they can afford certain amount. Need for solar energy based products mainly covered four types of needs: lighting, cooking, irrigation and additionally if they expressed any other specific need it was recorded. About stating the cost it was noticed that the respondent households were hesitant to state any amount as most of them belonged to poor households.

The total households surveyed were 780 for treatment and 97 for control group. The figure 7 below shows the percentage of households and the number of solar product needs that they were expressed by them. From the figure it could be observed that 87.83 percent treatment household and 89.69 percent control households has expressed the need for the solar product/s. Maximum percentage of households, 67.44 percent in treatment and 68.04 percent in control had one need. From the following figure 8, it is observed that maximum percentage of households in both the groups (85.13 percent in treatment and 88.66 in control) have expressed the need for solar home lighting.

Figure 7: Percentage of Households expressing Need for Solar Products

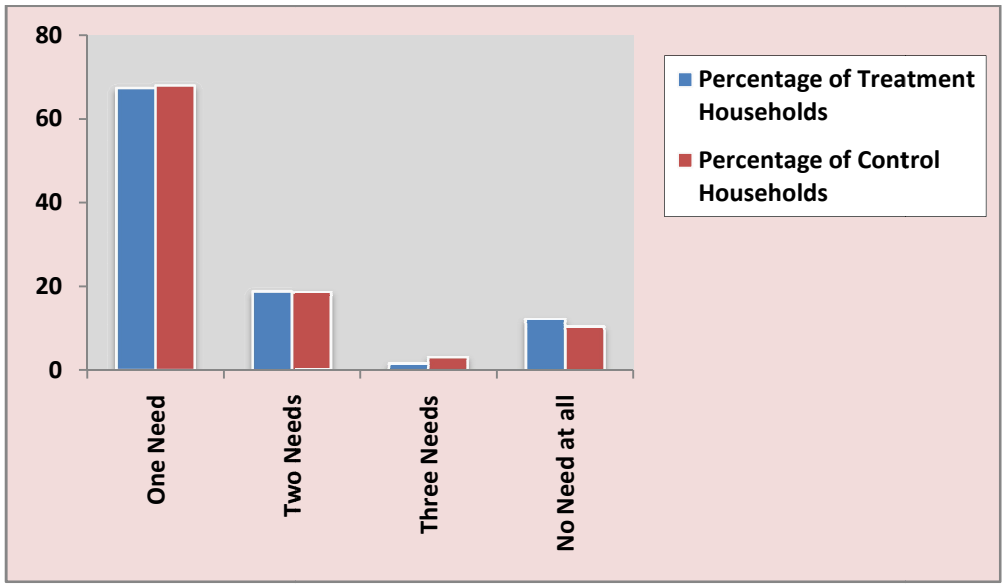
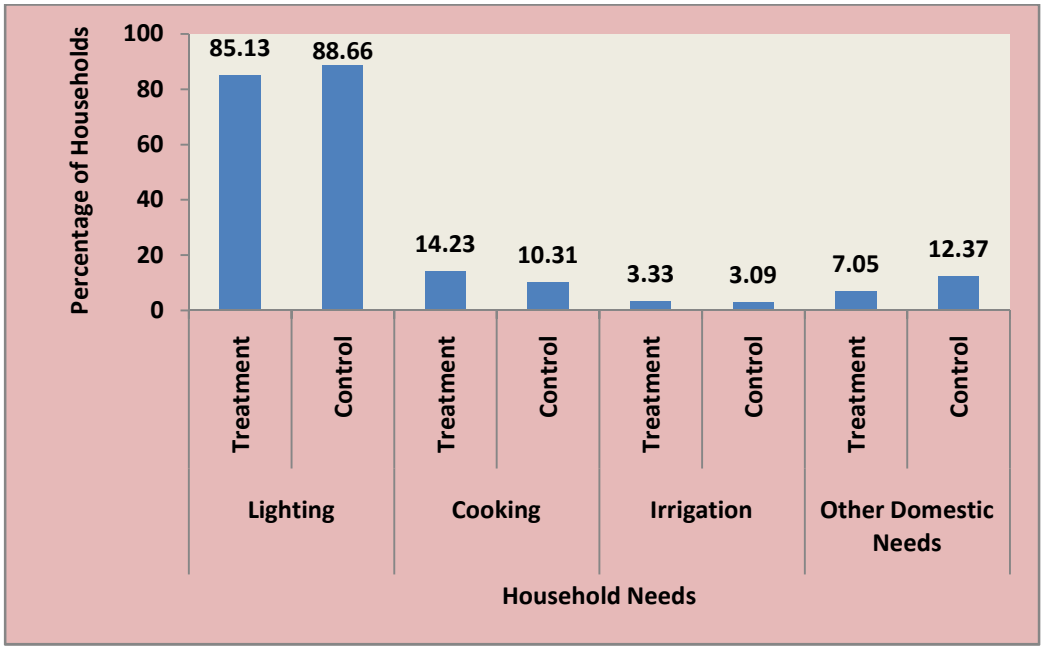
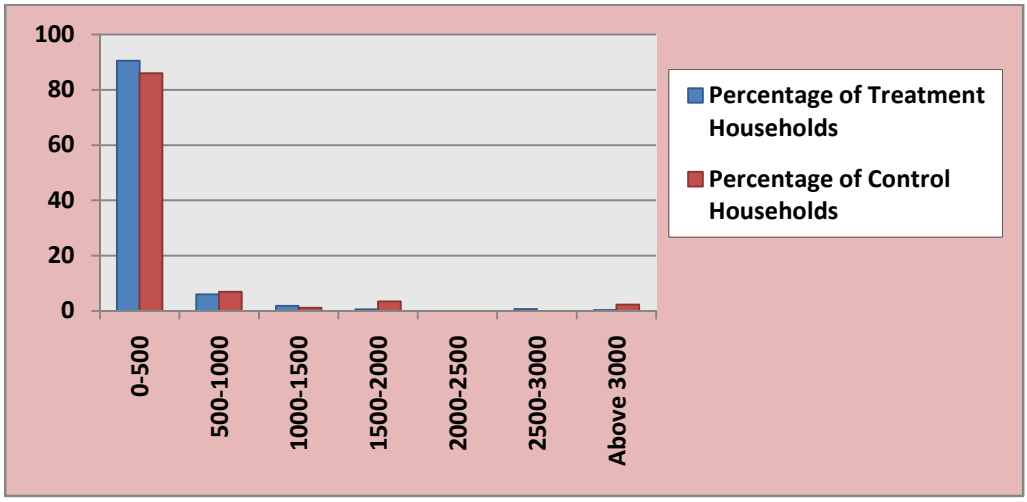


Figure 8: Percentage of Households expressing Needs that are to be addressed by Solar Technology



As observed from the figure 9 below, amongst the households that expressed need for solar lighting, in both the groups maximum percentage of household showed willing to pay up to Rs. 500. For cooking, 53.15 percent of treatment households were willing to pay upto Rs. 500, while for 30 percent of control households were willing to pay the same amount. The need for solar based pump for irrigation was reported by less than 4 percent households in both treatment and control households and maximum percent of households in both groups were willing to pay upto Rs. 5000 for solar irrigation pump.

Figure 9: Willingness to Pay for Lighting Needs



Chapter 4. Conclusions and Recommendation

Much has been written in the literature over the energy access and energy poverty. MSP is one such initiative that works on targeted approach to eliminate the darkness from school childrens lives. The evaluation has show mixed to positive results with observed kerosene expenditure lower within the households of SoUL users as against the non-users. As a simple device, the SoUL has impacted various facets of life of the users. For one, school going children are now able to study in safer environment. Better luminosity provided by SoUL has enabled a sense of freedom amongst the children. Though the results do not indicate difference in study hours from both groups, however the dependence on kerosene devices is very less in the treatment sample as compared to control samples. Having said, indirect health benefits accrued cannot be disregarded as children have less strain on eyes and less exposure to soot arising out of kerosene wick lamps due to use of SoUL. Kerosene purchase is seen to be lesser in the treatment group as compared to the control group which further advances our stance that SoUL lamp has positive impact kerosene consumption and overall household expenditure on lighting. Overall total lighting expenditure as observed is higher in control group as compared to treatment group with results showing significance at 99 percent confidence. The difference observed in terms of savings can be argued by some to be small, but however overall lighting need seem the household is much larger (with multiple rooms) and SoUL is able to fulfill only a part of such need. The households generally consists of 2 or more rooms, thus there is need for kerosene for lighting in emergency situation which can be one reason for not complete eradication of use of kerosene. SoUL also aids household activities through providing lighting to accomplish tasks like cooking, cleaning, etc which has been reported by large percent of households. While difficult to quantify, such results only point towards the multi-purpose usability of SoUL.

One alarming result from the survey which was consistent in every survey block was the high non-functionality rate of the SoUL. The non-functionality rate may hamper the

confidence of the rural communities on the technology. Long term sustenance of the technology based solution to rural people depends upon multiple factors including provision of on-site service. The project has tried to address it through establishment of SoUL Repair Centre (SRC), however lack of information about SRC amongst the users seems to be main reason for SoULs not being repaired rather than inability of SRCs to provide post sale provisions. Appropriate Information, Communication and Education (ICE) needs to be designed so as communicate every facet of the programme to the beneficiaries. Given the demand and willingness to pay for solar products only shows how the technology has the potential to be drawn on wider scale looking at different needs of the communities. Demonstration of solar technology on such large scale and relative impacts observed only induce confidence in the technology and Million SoUL Programme structure which was drawn to make such solutions available at affordable rates. Support through appropriate institutional and financial mechanism is necessary for wider adoption of solar technology in order to eradicate the energy poverty persisting in rural communities.

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Annexures

A1. Household Impact Survey

State	[Pre-printed]	District	[Pre-printed]	Block	[Pre-printed]

Form Number													Interviewer's Name	Date	Gram Panchayat	Village	Hamlet
			/					/									
Block code [Pre-printed]			/	Village code				/	Serial number								

A. Household Details						
A1	Full Name of respondent		A3	Full Name of head of household		
			A4	Sex of head of household	◯ Male	◯ Female
A2	Relation of the respondent to the beneficiary		A5	Mobile Number		
			A6	Number of Members in the Family		
			A7	No of rooms in the house(including kitchen)		

B. Children's Details (Irrespective of receipt of SoUL lamp, applicable to all children from 5 to 17 years or up to 12th Class)										
	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
S. No.	Full Name	Age	Sex (M/F)	Does he/she go to school? (Yes/ No)	Class	Has he/she received SoUL lamp? (Yes/ No)	If **"Yes" for B6**, specify the **lamp code** here. If only one child has bought and others are applicable why other children have not brought SoUL?*	Which devices** do you use for studying (Specify all the devices, else specify the reason for not studying in the dark hours)	If, **for B8**, one of the devices is SoUL lamp, specify **time** of **study using SoUL lamp**. If, **for B8**, none of the devices is SoUL lamp, specify the **reason for not using SoUL lamp** for studying	If the SoUL is working, and the child is using Chimni/Electricity with SoUL, mention the reason for using the same?
1										
2										
3										
4										
5										
6										

*If unable to obtain the lamp code, state the reason in B7

** If studying in street light or community light (in temple) etc. then specify in B8

C. Performance of SoUL lamp (Interviewers can themselves check SoUL lamp for following details)											
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
S. No.	Lamp Code	Is the SoUL lamp working? (Yes/ No) **If "Yes" go to C4**	If No, for how much time did it work? (days/weeks/ months) **Specify and go to E1**	Is the Switch working? (Yes / No)	Is LED working? (Yes / No)	Is red light in indicator working properly? (Yes/ No)	Is green light in indicator working properly? (Yes/ No)	After one day of charging, for how much time SoUL lamp works?	Is there any loose connection? (Yes/ No)	Is the panel broken? (Yes/ No)	State other problem, if any. If SoUL is not working; then state the problem with it?
1											
2											
3											
4											

D. Usage of SoUL lamp									
D1 Lamp code	D2 Do you charge SoUL lamp with mobile charger? (Yes/ No)	D3 What is the usage of SoUL in hours per day for purposes **other than Studies**?	D4 For what other purposes **other than Studies** SoUL lamp is used & used by whom **(Relation to the beneficiary)**						
			Other purpose 1	Used by whom	Other purpose 2	Used by whom	Other purpose 3	Used by whom
E. Repair and Maintenance of SoUL									

S. No.	E1 Lamp code**(Repeat the lamp code again if R&M availed more than once)**	E2 Have you availed R&M service?[#] (Yes/ No) **If Yes, Go to E4**	E3 If **E2 is "No"**, & SoUL lamp is not working then why service is not availed? **Specify and go to E11**	E4 If **E2 is "Yes"**, what was the problem in the SoUL lamp before repair?	E5 Was it repaired at SoUL R&M centre? (Yes / No)	E6 Where was it repaired? (Shop name, Village name, Gram Panchayat name)	E7 When did you avail R&M? (Month & year)	E8 In how many days was SoUL lamp repaired?	E9 How much did you pay for it? (Rs.)	E10 Are you satisfied with R&M service? (Yes/ No)
A										
B										
C										
D										
E										
F										

E11 If any of the SoUL lamps have been repaired at home (yourself), was it successful? (Yes/ No):

E12 Specify which component was not working before repair at home (yourself):

F1 Kerosene Purchased					
S. No.		Litre/s per month	Avg. Price per litre	Frequency (Number of trips for purchase per month)	Generally collected by whom? (specify whether Adult woman/Adult man/ Girl child/boy child)
1	Purchased from Govt. Ration shop - PDS				
2	Purchased from Market				

F2 Kerosene Used				
	Lighting	Cooking	Heating water	Other (Please specify)*
Consumption (litre/s per month)				

*Other use may also include resale, in vehicles, etc.

F3 Usage of other oil for lighting (For example, if used for lighting purpose, any of the cooking oils like groundnut, mustard, sunflower, etc.)			
Name of oil	Consumption (litre/s per month)	Avg. Price per litre	Device/s used

F4 Devices using kerosene/ other oil					
S. No.	Device	Do you use the device? (Yes/ No)	Quantity used*	Number of hours per day	Number of days per month
1	Chimni (Simple wick lamp)				
2	Hurricane lamp				
3	Wick stove				
4	Other (Please specify)				

*By "Quantity used" we mean number of devices they are actually using for lighting purpose and NOT the number of devices they possess.

F5 Do you have electricity at home? If "No" go to F10	◯ Yes	◯ No
F6 Do you have electric meter/ one point connection/ shared connection?	◯ Yes	◯ No

F7 Interval of electricity bill receipt		
◯ Not applicable	◯ Every month	◯ Every 3 months
◯ Every 6 months	◯ Every year	◯ Other (Please specify)

F8	**Electricity bill amount paid as per the above mentioned interval (Rs)**	

F9 Features of electric lighting devices (bulbs/ tubes) used at home				
S. No.	Type of device	Number of devices	How much period (days/weeks/ months/ years) does this device last for?	Avg. price of device (Rs per unit)
1	Incandescent bulb			
2	CFL			
3	Tubes			
4	LED			
5	Chargeable torch			
6	Other (Please Specify)*			

* If using torch in mobile phone specify that also as other electric lighting device.

F10 Features of candle		
Number consumed/ month (Specify candle or pack)	Usage in hours per day	Avg. price of candle or pack (Rs per unit)

F11 Features of battery torch at home (non-rechargeable)				
	Number of cells	Number of times cells replaced per month	Avg. price of torch (Rs per unit)	Maintenance Cost (Rs per unit)**
Torch 1				
Torch 2				
Torch 3				

** If use-and-throw (Chinese) torch, then in 'Maintenance Cost' write **not applicable**

F12 Features of renewable energy devices other than SoUL used at home								
S. No.	Name of device	Purchase inspired by SoUL lamp (Yes/ No)	Number	Capacity	Initial investment (Rs)*	Working (Yes/ No)	Maintenance Cost (Rs per unit)	Year of purchase
1								
2								
3								

* If no investment has been made (grant/ donation), then in 'Initial investment' write **not applicable**

G. Willingness to pay for other Solar Products (Please tick in the appropriate circle)			
G3	**What are the solar energy related needs**	**Energy Needs**	**As you are aware, actual cost of SoUL lamp is Rs 500 but due to subsidy it is available for students**

	of the household?		**at Rs 120. Keeping this in mind, how much you are willing to invest for the following uses?**
		◯ Lighting	
		◯ Cooking	
		◯ Irrigation	
		◯ Others (Please specify)	
		◯ None	

G.3.1 Preference of Lighting in the household			
G3.1	**What is the preferred source of lighting for the Household- Electricity; Kerosene Source; Solar Product? (Eg. Rank1 given to first preferred source etc.)**	**Energy Needs**	**Preferred Source of Lighting**
		Rank 1	
		Rank 2	
		Rank 3	
		Remarks (if any)	

G.3.2 Solar Needs		
G3.2	**Does SoUL lamp satisfy your child's study lighting needs? If No, then why?**	

H. Community Details (Please tick in the appropriate circle)		
H1	**Type of Card Holder (Please tick in the appropriate circle)**	
◯ Below Poverty Line (BPL)	◯ Antyoday	◯ Other (Please specify)
◯ Above Poverty Line (APL)	◯ No card	

H2	**Primary Source of Income (Please tick only one)**	
◯ Agriculture	◯ Labor	◯ Agriculture + Labor
◯ Service	◯ Dairy	◯ Skill-based occupation (carpentry, pottery, etc.)
◯ MGNREGS	◯ Remittance	◯ Other (Please specify)

H3	**Religion (Please tick only one)**		
	◯ Hindu	◯ Muslim	◯ Christian
	◯ Sikh	◯ Buddhist	◯ Jain
	◯ Other (Please specify)		

H4	Social Group (Please tick only one)	
	◯ Scheduled Tribe (ST)	◯ Scheduled Caste (SC)
	◯ Other Backward Caste (OBC)	◯ Nomadic/ Denotified Nomadic Tribe/ Vimukta Jati Nomadic Tribe (NT/ DNT/ VJNT)
	◯ Open (General)	◯ Other (Please specify)

H5	Name of caste/ tribe you belong to	

H6	Wealth Indicator					
Name of the asset	**#**	**Name of the asset**	**#**	**Name of the asset**	**#**
Radio		table		other asset 1	
Bicycle		chair		other asset 2	
motorcycle/scooter		mattress		other asset 3	
washing machine		bullock cart			
Fans		thresher			
Heaters		tractor			
colour television		buffalo			
b/w television		Cow			
telephone set/ mobile phone		bullock			
sewing machine		goats			
pressure cooker		cock/hen/duck			
Watches		Pigs			

H7 Household type: Tick the correct option		
Kacchha	**Semi- Pakka**	**Pakka**

H8: Preferred Activity for the children in the family					
How do all *MALE* children spend their non-schooling hours? Enlist three activities in which he spends most of his time and the number of hours spent on the same	**Activities**	**No. of Hours**	**How do all *FEMALE* children spend their non-schooling hours? Enlist three activities in which he spends most of his time and the number of hours spent on the same**	**Activities**	**No. of Hours**
Remarks (if any)			**Remarks (if any)**		

Signature of the respondent		Signature of the interviewer	

Please note the suggestions and complaints by the respondent below.

Interviewer's Notes:

A2. Household Control Survey Form

State	[Pre-printed]	District	[Pre-printed]	Block	[Pre-printed]

Form Number													Interviewer's Name	Date	Gram Panchayat	Village	Hamlet
			/					/									
Block code [Pre-printed]			/	Village code				/	Serial number								

A. Household Details						
A1	Full Name of respondent		A4	Full Name of head of household		
A2	Mobile Number		A5	Sex of head of household	◯ Male	◯ Female
A3	Number of Members in the family		A6	No of Rooms in the House(including Kitchen)		

B. Children's Details (Irrespective of receipt of SoUL lamp, applicable to all children from 5 to 17 years or up to 12th Class)								
	B1	B2	B3	B4	B5	B6	B7	B8
S. No.	Full Name	Age	Sex (M/F)	Does he/she go to school? (Yes/ No)	Class	Why has he/she not received SoUL lamp? (Specify the reason)	Which devices* do you use for studying (Specify all the devices, else specify the reason for not studying in the dark hours)	If, **for B7**, devices are used for studying, specify **time** of **study (mins/hours)**. If, **for B7**, no devices are used for studying, **go to C1**
1								
2								
3								
4								
5								
6								

*If studying in street light or community light (in temple) etc. then specify in B7

C1 Kerosene/ Other oil Purchased					
S. No.		Litre/s per month	Avg. Price per litre	Frequency (Number of trips for purchase per month)	Generally collected by whom? (specify whether Adult woman/Adult man/ Girl child/boy child)
1	Purchased from Govt. Ration shop - PDS				
2	Purchased from Market				

C2 Kerosene Used				
	Lighting	Cooking	Heating water	Other (Please specify)*
Consumption (litre/s per month)				

*Other use may also include resale, in vehicles, etc.

C3 Usage of other oil for lighting (For example, if used for lighting purpose, any of the cooking oils like groundnut, mustard, sunflower, etc.)			
Name of oil	Consumption (litre/s per month)	Avg. Price per litre	Device/s used

C4 Devices using kerosene/ other oil					
S. No.	Device	Do you use the device? (Yes/ No)	Quantity used*	Number of hours per day	Number of days per month
1	Chimni (Simple wick lamp)				
2	Hurricane lamp				
3	Wick stove				
4	Other (Please specify)				

*By "Quantity used" we mean number of devices they are actually using for lighting purpose and NOT the number of devices they possess.

C5 Do you have electricity at home? If "No" go to C12	◯ Yes	◯ No
C6 Do you have electric meter/ one point connection/ shared connection?	◯ Yes	◯ No
C7 Do you have inverter at home?	◯ Yes	◯ No
C8 Do you have generator at home?	◯ Yes	◯ No

C9 Interval of electricity bill receipt		
◯ Not applicable	◯ Every month	◯ Every 3 months
◯ Every 6 months	◯ Every year	◯ Other (Please specify)

C10	**Electricity bill amount paid as per the above mentioned interval (Rs)**	

C11 Features of electric lighting devices (bulbs/ tubes) used at home

S. No.	Type of device	Number of devices	How much period (days/weeks/ months/ years) does this device last for?	Avg. price of device (Rs per unit)
1	Incandescent bulb			
2	CFL			
3	Tubes			
4	LED			
5	Chargeable torch			
6	Other (Please Specify)*			

* If using torch in mobile phone specify that also as other electric lighting device.

C12 Features of candle		
Number consumed/ month (Specify candle or pack)	Usage in hours per day	Avg. price of candle or pack (Rs per unit)

C13 Features of battery torch at home (non-rechargeable)				
	Number of cells	Number of times cells replaced per month	Avg. price of torch (Rs per unit)	Maintenance Cost (Rs per unit)**
Torch 1				
Torch 2				
Torch 3				

** If use-and-throw (Chinese) torch, then in 'Maintenance Cost' write **not applicable**

C14 Features of renewable energy devices used at home

S. No.	Name of device	Number	Capacity	Initial investment (Rs)*	Working (Yes/ No)	Maintenance Cost (Rs per unit)	Year of purchase

1							
2							
3							

* If no investment has been made (grant/ donation), then in 'Initial investment' write **not applicable**

D. Willingness to pay for other Solar Products (Please tick in the appropriate circle)			
D1	**What are the solar energy related needs of the household?**	**Energy Needs**	**As you are aware, actual cost of SoUL lamp is Rs 500 but due to subsidy it is available for students at Rs 120. Keeping this in mind, how much you are willing to invest for the following uses?**
		◯ Lighting	
		◯ Cooking	
		◯ Irrigation	
		◯ Others (Please specify)	
		◯ None	

D.2 Preference of Lighting in the household			
D.2	**What is the preferred source of lighting for the Household- Electricity; Kerosene Source; Solar Product? (Eg. Rank1 given to first preferred source etc.)**	**Energy Needs**	**Preferred Source of Lighting**
		Rank 1	
		Rank 2	
		Rank 3	
		Remarks (if any)	

E. Community Details (Please tick in the appropriate circle)		
E1	**Type of Card Holder (Please tick in the appropriate circle)**	
◯ Below Poverty Line (BPL)	◯ Antyoday	◯ Other (Please specify)

◯ Above Poverty Line (APL)	◯ No card	

E2	Primary Source of Income (Please tick only one)		
◯ Agriculture	◯ Labor	◯ Agriculture + Labor	
◯ Service	◯ Dairy	◯ Skill-based occupation (carpentry, pottery, etc.)	
◯ MGNREGS	◯ Remittance	◯ Other (Please specify)	

E3	Religion (Please tick only one)		
	◯ Hindu	◯ Muslim	◯ Christian
	◯ Sikh	◯ Buddhist	◯ Jain
	◯ Other (Please specify)		

E4	Social Group (Please tick only one)	
	◯ Scheduled Tribe (ST)	◯ Scheduled Caste (SC)
	◯ Other Backward Caste (OBC)	◯ Nomadic/ Denotified Nomadic Tribe/ Vimukta Jati Nomadic Tribe (NT/ DNT/ VJNT)
	◯ Open (General)	◯ Other (Please specify)

E5	Name of caste/ tribe you belong to	

E6	Wealth Indicator					
Name of the asset	**#**	**Name of the asset**	**#**	**Name of the asset**	**#**
Radio		table		other asset 1	
Bicycle		chair		other asset 2	
motorcycle/scooter		mattress		other asset 3	
washing machine		bullock cart			
Fans		thresher			
Heaters		tractor			
colour television		buffalo			
b/w television		cow			
telephone set/ mobile phone		bullock			
sewing machine		goats			
pressure cooker		cock/hen/duck			
Watches		pigs			

E7 Household type: Tick the correct option		
Kacchha	**Semi- Pakka**	**Pakka**

E8: Preferred Activity for the children in the family					
How do all *MALE* children spend their non-schooling hours? Enlist three activities in which he spends most of his time and the number of hours spent on the same	**Activities**	**No. of Hours**	**How do all *FEMALE* children spend their non-schooling hours? Enlist three activities in which he spends most of his time and the number of hours spent on the same**	**Activities**	**No. of Hours**
Remarks (if any)			**Remarks (if any)**		

Signature of the respondent		Signature of the interviewer	

Please note the suggestions and complaints by the respondent below.

Interviewer's Notes:

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