

LIGHT UP MADHYA PRADESH

IMPACT ASSESSMENT

BY PHILIP MURPHY • KOPERNIK FELLOW • AUGUST 2015

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Table of Contents

EXECUTIVE SUMMARY	2
AIM	4
PROJECT BACKGROUND	4
Project Objective.....	4
Kopernik	4
Our Local Partner - CDC	4
Snapshot of Location	4
PROJECT IMPLEMENTATION	9
The Technology	9
Pricing & Payment and Product Distribution Approach.....	10
IMPACT ASSESSMENT	11
Process & Methodology	11
Overall User Satisfaction	12
Health Benefits	14
Safety Benefits.....	15
Economic Benefits	16
Environmental Benefits	20
Effectiveness of Product Sales Strategies	20
EFFECTIVENESS OF PROJECT DELIVERY	21
Effectiveness of Pricing	22
Effectiveness of Delivery Methods.....	24
Effectiveness Aftersales Service.....	24
Local Partner and Project Implementation	25
Meeting Community Needs.....	25
Barriers to Purchase	21
FUTURE KOPERNIK OPPORTUNITIES	27
Clean Water.....	27
Clean Cooking	28
CONCLUSION	30
RECOMMENDATIONS	30
REFERENCES	40
ANNEX	32

Executive Summary

Since November 2014, Kopernik in partnership with Community Development Centre (CDC), has delivered over 200 d.light solar lights to last mile communities in rural India as a part of the Light Up Madhya Pradesh project. This project is ongoing and will distribute a further 100 solar lights to households, making a total of 306 solar lights at the project's completion.

In June 2015, Kopernik Fellow, Philip Murphy conducted an impact assessment with the primary objective of identifying and measuring the effects of solar lights on the lives of people located in the last mile. This assessment involved interviewing 50 solar light users (25 percent of the total user population) and working directly with the local partner, CDC, to collect data.

The assessment found that users were very satisfied with the solar lights and overall the interviewed sample rated the solar products four out of five stars. The strong performance of solar lights can be attributed to the benefits experienced by technology users. The assessment identified the following benefits:

- **Health** – Since using the solar light, respondents have experienced a perceived improvement to their health with **97 percent identifying at least one improvement in their health outcomes**, such as a reduction in eye irritation and respiratory issues.
- **Safety** – Respondents feel safer when using the solar light, as opposed to their old lighting sources, with **84 percent perceiving the likelihood of a fire has been significantly reduced**. The same percentage of respondents also believes the possibility of burn injuries has also been significantly reduced.
- **Productivity** – The majority of respondents reported an increase in their productivity with **80 percent stating their productivity (or work efficiency) had increased significantly and 32 percent stating the solar light had significantly saved them time**. The positive productivity impacts are not limited to parents; children are also benefiting from the solar light and on average, school students are studying one hour and 45 minutes with the d.light per night. This equates to 16 days of study for a primary school student over a year.
- **Lifestyle** – The solar light has made improvements to the lives of technology users with 60 percent stating the d.light has significantly improved their lives. Respondents also indicated that they were free to undertake new nightly activities, with **94 percent of respondents indicating they conducted at least one new nightly activity since purchasing the solar light**.

- **Economic** – On average surveyed **households who ceased using kerosene lamps and flash lights saved INR81 (US\$1.28) per month**. On average, this saving is enough to pay back the value of the d.light S20 in eight months and a S300 in 23 months.

The assessment found the solar lights are priced affordably, however a significant portion (55 percent) of the solar light owners were unable to meet the repayment timeframe of three instalments over six months. A repayment schedule over a 12 month period would be more suitable for the lowest income households and will be adopted for the remaining sales.

The assessment found that 42 percent of respondents interviewed are using solar lights in addition to their original source of lighting (mainly kerosene lamps or electricity). The main reason for this behaviour is that a single d.light lacks the capacity to meet the demands of a household simultaneously. Almost all respondents (95 percent) who continue to use old sources of lighting and d.light, indicated that lighting is required for multiple nightly activities such as allowing children to study, a mother to cook and someone to tend the farm. There is a clear need for multiple sources of household lighting and it is suggested that future projects address integrated and affordable household-wide lighting solutions, complementing previous d.light purchases rather than making them redundant.

The provision of a simple solar light has made a positive impact on the everyday lives of technology users in the last mile. It is therefore suggested that Kopernik, in partnership with CDC, consider a second phase distribution of solar lights with the aim of making solar lights the primary source of lighting in the target last mile communities, completely replacing dangerous or expensive alternatives.

Aim

The aim of this impact assessment is to:

- assess the extent to which solar lights have created benefits for last mile communities
- assess whether the solar lights have met the needs of the community
- determine the effectiveness of project delivery mechanisms.

Project Background

Project Objective

The objective of the Light Up Madhya Pradesh project was to provide last mile communities in the project location with a clean, affordable and life improving lighting solution as a part of CDC's efforts to contribute to a just and sustainable society.

Kopernik

Kopernik is a non-profit organisation that focuses on distributing life-changing technology to last mile communities. Kopernik balances a philanthropic and business approach to distributing technology. Our donors fund the upfront costs of introducing technologies and creating micro-business opportunities in remote communities. The money raised from product sales is reinvested in more technology for the last mile.

Our Local Partner: Community Development Centre

CDC is a grassroots development organisation based in Madhya Pradesh, central India. CDC actively supports and works towards developing a just and sustainable society. In addition to the Light Up Madhya Pradesh project, CDC is actively involved in combating malnutrition, ensuring the safety of children, and conserving native woodland and wildlife. CDC has been globally recognised for its efforts in combating malnutrition receiving the runner up prize from Americare in their combating malnutrition awards. The success, to date, of Light Up Madhya Pradesh can largely be attributed to CDC's experience and local network.

Snapshot of Location

The Light Up Madhya Pradesh project is distributing solar lights in various locations in the Seoni and Balaghat districts. As seen in Figure 1, the main field office for the project is located in the village of Garhi within the Balaghat district and as such, this impact assessment was completed in that region, located on the south eastern boundary of the central Indian state of Madhya Pradesh.

The nearest international airport is located in Nagpur, 186 km (115 miles) away. Balaghat is accessible by train along the South East Central Railway and by bus from Bhopal, Nagpur, Indore Jabalpur and Raipur.

Figure 1. Map of India and Madhya Pradesh



Source: Charles, 2015

Balaghat has a total population of just over 1.7 million, with 1.4 million (85 percent) living in rural areas (Census India, 2011). According to the last census, men and women are equally represented in the district with children (ages 0-6) accounting for 13 percent (186,683) of the rural population.

Poverty Level

In 2006, the Balaghat district was listed by the Indian Government as one of the 250 most 'backwards' provinces¹ in India (Ministry of Panchayati Raj, 2009). The term 'backwards' recognises the poor socio-economic outcomes in the district where 46 percent of the rural population live in poverty (Samvad, 2013). This is higher than the national poverty level where 22 percent of the population lives below the poverty line (Reserve Bank of India, 2012).

Economy

Agriculture is a key economic driver in Madhya Pradesh with 86 percent of the total workers in rural areas dependent on agriculture for their livelihood (Shri. M.M. Upadhyaya, 2014). The main crops produced in Balaghat are rice and wheat (Department of Agriculture and Cooperation, 2013). There

¹ There are 676 provinces in India.

are two main harvest seasons, in March/April and in October/November. Due to the reliance on agriculture, many households do not have a set monthly income and must budget from harvest to harvest.

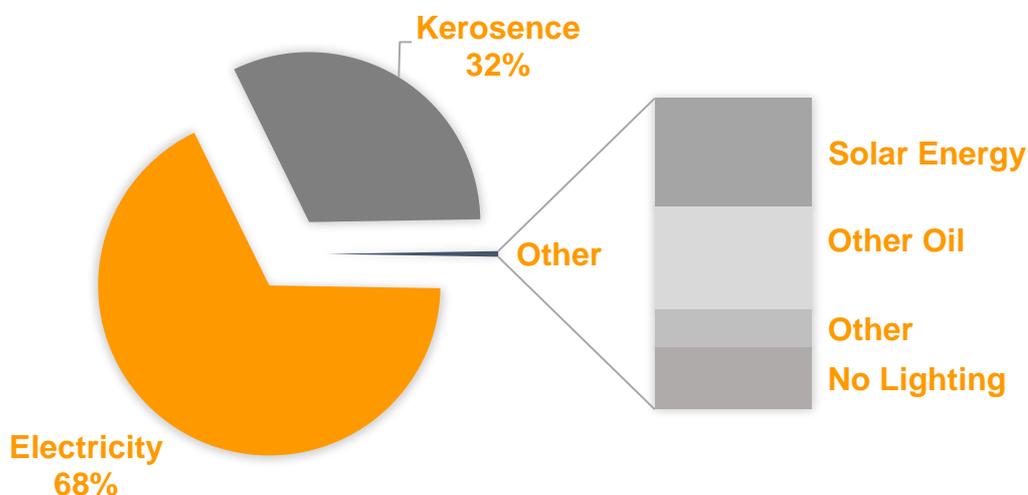
Common Practices Related to Technologies

Kopernik’s range of technology distribution projects aim to make a meaningful difference to people’s lives by promoting the use of simple, clean household products such as solar lighting, water filters and clean cookstoves.

Lighting

As shown in Figure 2 the most common source of light within the project region is electricity followed by kerosene (Census India, 2011).

Figure 2. Main Sources of Lighting in Rural Balaghat



From April 2014, the state of Madhya Pradesh has had a two percent shortage of power supply and blackouts are a daily occurrence. As such, the supply of electricity is unreliable and costly (Charles, 2015).

The impact assessment survey results indicated that monthly power costs vary greatly without warning. The monthly differences per household of the surveyed population, ranged from INR280 (US\$4) to INR1210 (US\$19).

The local partner indicated that solar lighting projects had been conducted in the region over the last ten years. However, these projects failed to produce even short-term changes to behaviour or quantified benefits to communities, as is evident in the case study below.

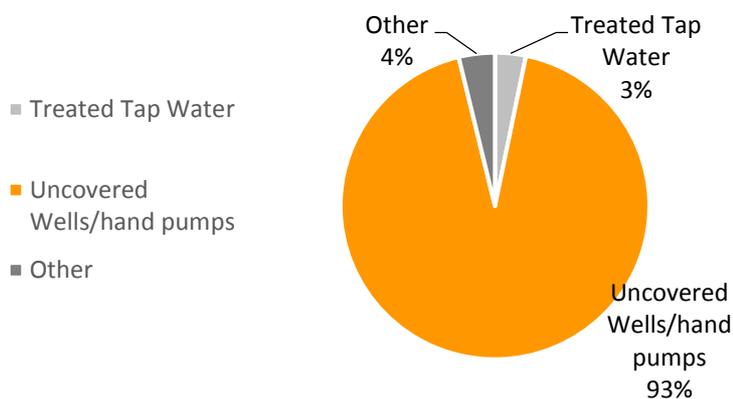
Previous Solar Project

- In 2010, communities in rural Balaghat were given a free solar light that required daily charging from a communal charging point.
 - Under this scheme users would drop off the light in the morning and then pick it up later that afternoon. The charging service was not free.
 - The ongoing cost and the extra burden of delivery and subsequently collecting the light led to the eventual failure of the project six months after it commenced.
 - The failure of this project shows technology users value convenience, and further validates the social enterprise approach as users are less likely to dispose of a light that they have invested money in.
-

Access to Drinking Water

As at the last census in 2011, only 2.3 percent of households in rural Balaghat had access to treated tap water and only 0.92 percent of households had access to treated tap water within their premises (Samvad, 2013). As depicted in Figure 3, the vast majority of households (93 percent) rely on uncovered wells and hand pumps as their main source of water (Samvad, 2013).

Figure 3. Main Sources of Drinking Water in Rural Balaghat

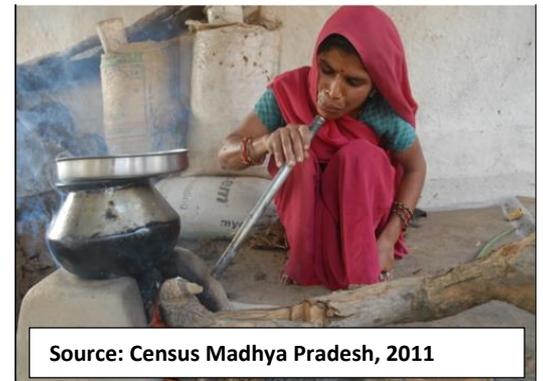
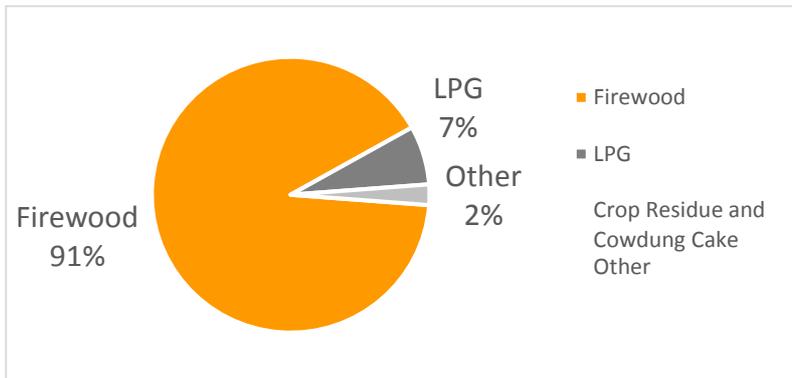


The region’s reliance on untreated water has led to poor health outcomes and deaths. In August 2014, it was reported that “270 people [had] died of diarrhoea and 131,400,000 people [had] been affected by diarrhoea in the last three years in Madhya Pradesh” (Gaur, 2014).

Cooking Practices

As Figure 4 shows the main source of cooking fuel within Balaghat is firewood with 91 percent of households indicating wood as their primary fuel source in 2011 census (Census Madhya Pradesh, 2011).

Figure 4. Main Cooking Fuels in Balaghat



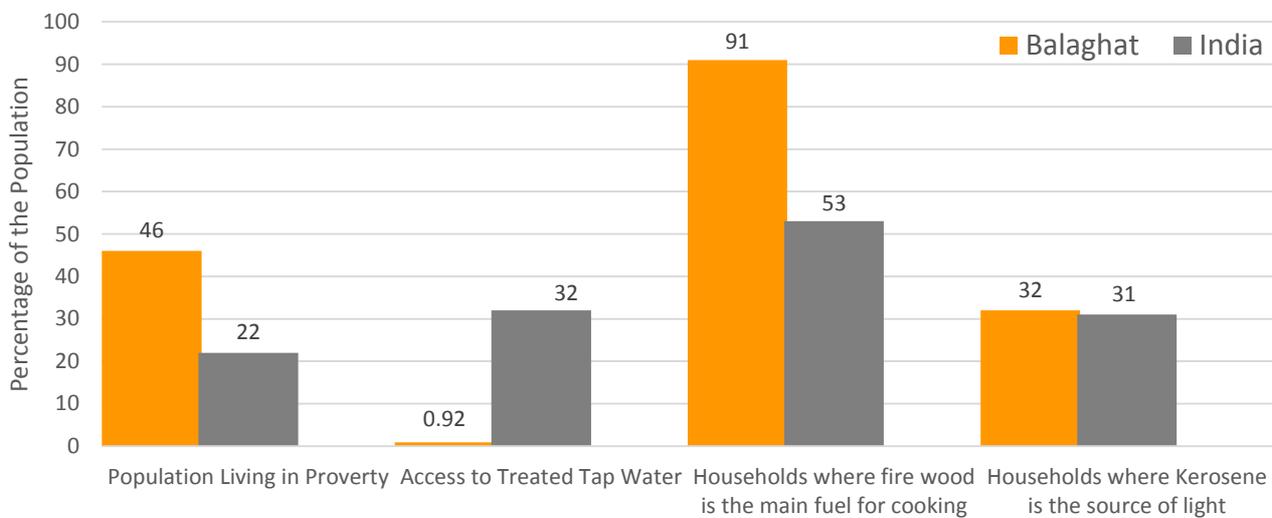
The combustion of firewood exposes households to fumes and carbon residue that is harmful to the health of the occupants. These harmful emissions are the leading cause of acute lower respiratory infections, chronic obstructive pulmonary diseases, lung cancer, cataracts and other illnesses (Dalberg Global Development Advisors, 2013).

Traditional cooking practices contribute significantly to indoor air pollution. It has been estimated that indoor air pollution kills 875,000 people every year in India (Dalberg Global Development Advisors, 2013).

Balaghat Compared to India

As seen in Figure 5, Balaghat performs poorly against the rest of India. The percentage of the population living below the poverty line in rural Balaghat is more than twice that of India.

Figure 5. Balaghat district compared to India



Source: Census India and Census Madhya Pradesh, 2011

Less than one percent of households have access to treated tap water within their residence in rural Balaghat, resulting in rural Balaghat performing very poorly against the rest of India where 32 percent of households have access to treated tap water within the residence.

Similarly, 91 percent of households in Balaghat use firewood as their main source of cooking fuel as opposed to the rest of India, where 53 percent of households use firewood as their main source of cooking fuel.

Project Implementation

The Technology

The d.light S20 solar light model:

- provides eight hours of light on a medium setting and four hours of light on a high setting when the battery is fully-charged battery
- is 3-5 times brighter than a traditional kerosene lamp
- is portable only weighing 250 grams
- has a product life span of greater than five years with a two year warranty
- is impact and weather resistant, and has a glow in the dark on/off button.



The d.light S300 solar light model:

- provides a bright white light at a wide angle which can illuminate an entire room and has four brightness settings providing four hours of light at the brightest setting and 100 hours of light at the lowest (bed-light) setting
- is portable only weighing 350 grams
- has a product life span of greater than five years with a two year warranty
- includes a solar panel with a four metre long cable and can be charged by solar panel or AC home power
- has a USB port to charge mobile phones
- is impact and weather resistant, and has a glow in the dark on/off button.



Pricing & Payment and Product Distribution Approach

Pricing and Payment

In the remote, last mile communities of Madhya Pradesh, people could purchase the solar lights from CDC in full, or over three instalments. The payment schedule was:

- **d.light S20 solar light** – Full payment of INR600 (US\$9) or three instalments of INR 200 (US\$3) over six months with repayments scheduled every two months.
- **d.light S300 solar light** – Full payment of INR1800 (US\$28) or three instalments of INR 600 (US\$9.30) over six months with repayments scheduled every two months.

Product Distribution Approach

The solar lights were primarily marketed through 15 product demonstrations conducted by CDC staff at schools and community meetings. CDC periodically schedules community meetings to promote their other livelihood and sustainability initiatives. Solar light demonstrations were conducted at the end of these meetings.

Community meetings were considered to be the most successful demonstrations as the audience at the meetings were generally the household decision makers. The audience were able to purchase a solar light at the product demonstration.

Impact Assessment

Process & Methodology

Over three weeks (8 - 28 June 2015), 50 solar light users (approximately 25 percent of total technology users) were interviewed for this impact assessment. The sample population included 44 users of the d.light S20 and all 6 users of the d.light S300.

Before conducting the interview, the English version of the survey was reviewed by the Executive Director of CDC to translate the survey into Hindi and to refine the questionnaire based on their feedback. CDC and Kopernik staff were also interviewed to ensure the impact assessment assessed the whole project cycle rather than just examining end user satisfaction and standard of living improvements.

A focus group of four non-users was conducted to determine the barriers to purchase. The impact assessment presents consolidated findings from both models of solar lights (S20 and S300), and where applicable, identifies impacts attributable to the individual models.

Demographics of the Sample

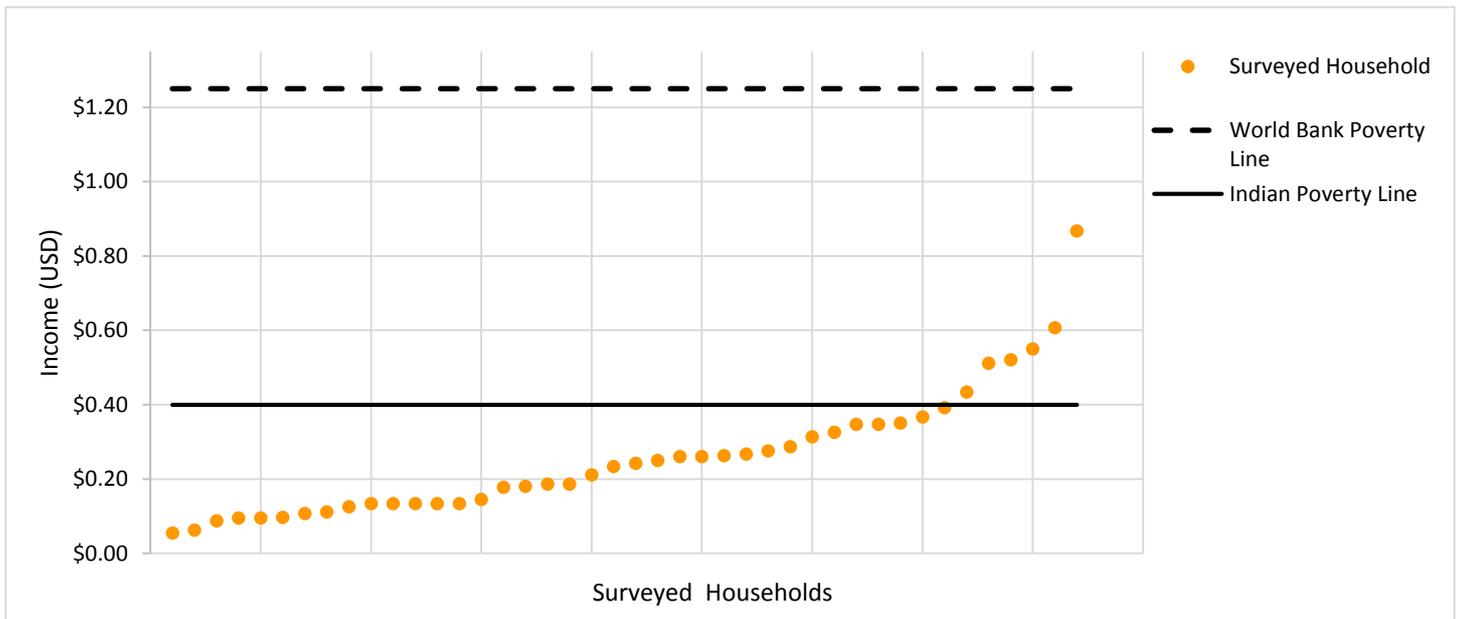
Gender	71% of the respondents were male. This aligns with gender of product decision makers where 67% of product decision makers were male.
Marital Status	96% of the sample were married
Household size	The average size within the sample is six people
Age	The average age of the sample was 36 with a maximum age of 65
Education level	77% have attained at least a primary level education
Income sources	36 households (70%) indicated agriculture as their main source of income
Income	The average adjusted income is INR2278 (US\$36) per month with an upper range of INR4936 (US\$78). ²

The average daily income per capita of the sample population is INR16 (US\$0.26). This is well below the World Bank's poverty line set at US\$1.25 and the poverty line set by the Indian

² The five highest income earners were removed from the analysis as the gap between the 5 highest earner and the 6th highest earner was USD\$65. This income difference is 45% higher than the average wage of the 42 lowest income households. These respondents were not considered to be representative of the target population. Three households provided no response to this question.

Government at INR26 (US\$0.41). Figure 6 below illustrates that all the surveyed households (adjusted) live in what the World Bank would describe as poverty, with only six houses living above the Indian poverty line.

Figure 6. Per capita daily income and poverty level of sample population (n=42)



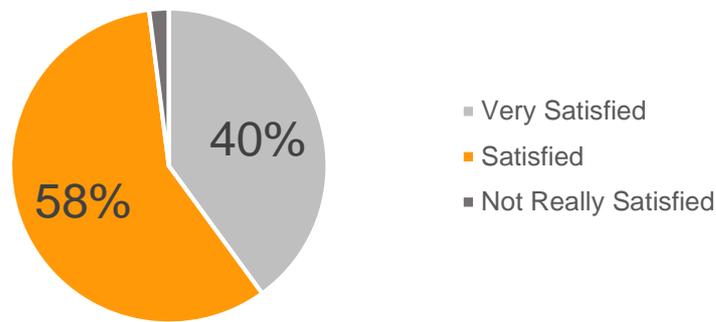
Key Impact Assessment Findings:

- **98% of respondents are either very satisfied or satisfied with the solar light**
- **84% of respondents would like to buy another solar light**
- **96% of respondents have or will recommend the d.light solar light to others**
- **92% of surveyed households use the d.light solar light every day**

Overall User Satisfaction

The overwhelming majority of users surveyed were satisfied with their solar purchase, as shown in Figure 7, which presents combined responses for the S20 and S300 models. One user exclaimed that ‘many people want this [d.light].’

Figure 7. Satisfaction levels with solar lights (n=50)



Respondents also highly rated the d.light for its qualities of brightness, battery life and durability.

Five Star Performance Ratings of the d.light

Brightness ★★★★★

Battery Life ★★★★★

Durability ★★★★★

Overall d.light Rating ★★★★★

Throughout the interviews, solar light users cited the ready-to-use design and glow in the dark on/off button as important and valued features of the d.light solar light.

The strong satisfaction results among the sample population indicate technology users value the d.light with 92 percent of respondents using the light every day.

Key Fact:

The World Bank estimates that using a kerosene lamp as the main source of light is equivalent to consuming two packets of cigarettes day. (Lighting Africa, 2010, p. 15)

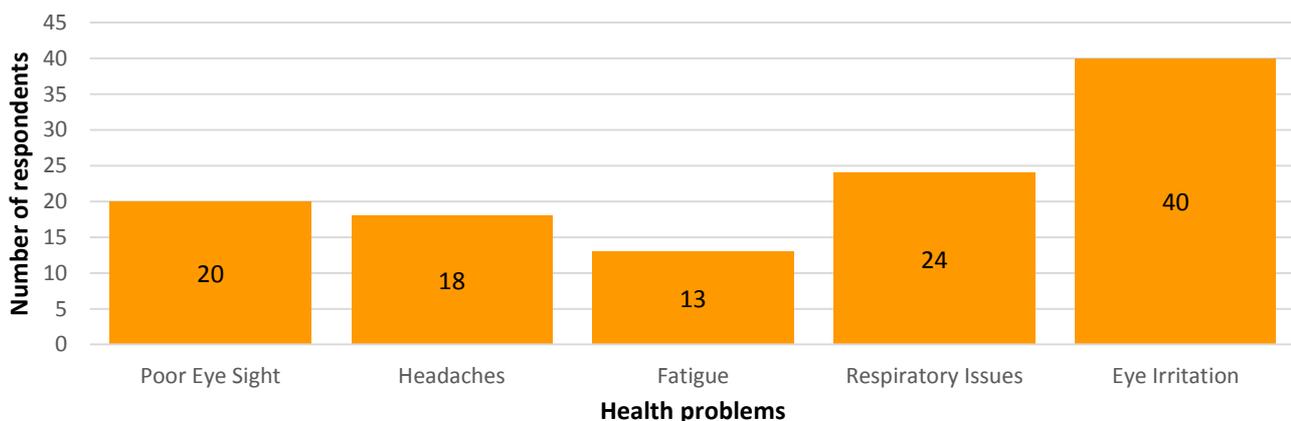
Health Benefits

Through the provision of 200 simple solar lights, Light Up Madhya Pradesh has helped 133 people, including 58 children, significantly reduce their exposure to kerosene fumes, which on average is equivalent to quitting a 40 cigarette a day habit (Lighting Africa, 2010). This has significantly reduced their risk of illnesses and respiratory problems associated with air pollution.

The replacement of kerosene lamps with the d.light, has led to an improvement in household air quality amongst the surveyed households, with 76 percent of respondents believing they are now inhaling “significantly less” fumes.

The reduction in fume inhalation has led to a reduction in perceived health problems with 72 percent of respondents indicating a reduction in at least two problem health areas. The full distribution of responses is listed in Figure 8 below, where respondents could select more than one health issue.

Figure 8. Reported reduction in health problems after using the solar light (n=50)



Kopernik, with local partner CDC, has improved the health outcomes of technology users in last mile communities in Madhya Pradesh. This is reflected in the stories of respondents like, Fulwanti, a mother in Garhi, who no longer has “carbon filling her nostrils as she works.” Fulwanti is not the only woman to benefit from the d.light. An analysis on the d.lights positive effects on women and future opportunities to make a lasting positive impact in the outcomes of women in last mile communities is addressed in Annex A.

Key Fact:

“In India alone, 2.5 million people suffer severe burns due to overturned kerosene lamps annually.” (Lighting Africa, 2010, p. 15).

Key Impact Assessment Findings:

- **84% of respondents believe that the risk of fire and burns is significantly reduced when using the d.light.**

Safety Benefits

Solar light users feel safer when working with the d.light. During the interviews, many solar light users told stories about the dangers of the kerosene lamps. One respondent said she felt her children were safer ‘as they no longer can [mistakenly] put petrol in the kerosene lamp’.

Severe burns caused by kerosene lamps is common in India. The Light Up Madhya Pradesh project does not only provide light to last mile communities; the project also reduces the risk of kerosene related fires and burns to the people located in last mile communities.

**Key Facts:**

- **The monthly per capita expenditure in rural Balaghat, to meet the basic cost of living is INR368 or (US\$5.78)** (Samvad, 2013).
- **The average household size in rural Balaghat is five people** (Vital Statistics Division, 2012).

Key Impact Assessment Findings:

- **58% of respondents have stopped using kerosene lamps as a source of light.**
- **17 respondents who ceased using kerosene lamps still purchase kerosene to use as an ignition source for cooking, they save INR19 (US\$0.28) per month.**
- **The 42 lowest income households save on average INR23 (US\$0.36) per month from reduced kerosene consumption, this is enough to buy 21 days of rice for one person.***
- **On average, households who have ceased purchasing kerosene and batteries save INR81 (US\$1.28) per month which is enough to purchase a months' worth of rice for two people.***
- **Surveyed households saved a minimum of INR11 (US\$0.17). This is enough to purchase 10 days of rice for one person.***

*(*figures calculated based on a rural Madhya Pradesh consumption model from the Household Consumption of Various Goods and Services in India 2011-12 report produced by the National Survey Office)*

Economic Benefits

The impact assessment found that just over half the surveyed households (55 percent) stopped using kerosene as a lighting source as a result of having the solar light. On average, these households that used kerosene lamps and flashlights before purchasing a d.light solar light, saved enough money (INR81 / US\$1.28) to pay back the value of a d.light S20 in eight months.³

Agriculture activities are the main source of income for technology users in Madhya Pradesh. The household income is generated from harvest to harvest. Madhya Pradesh has two main harvest seasons, in March/April and in October/November. Due to the reliance on the harvest, technology users have no set monthly income. The March/April harvest of 2015 produced poor crop yields for the farms across the project area due to hail damage. These low crop yields led to a reduction in household incomes and placed households in financial stress (Charles, 2015). It is anticipated that the savings generated by the d.light will reduce the financial stress placed on households in the future.

³ Calculations are based on the average cost of kerosene is INR19 (USD\$0.30) per litre and the average cost of one battery is INR11 (USD\$0.19).

Key Facts:

“Several studies in developing countries show that access to proper lighting (of high enough illumination to enable reading and doing household and business-related activities) has significant positive impact on productivity broadly and income-generating activity specifically.” (Lighting Africa, 2010)

Key Impact Assessment Findings:

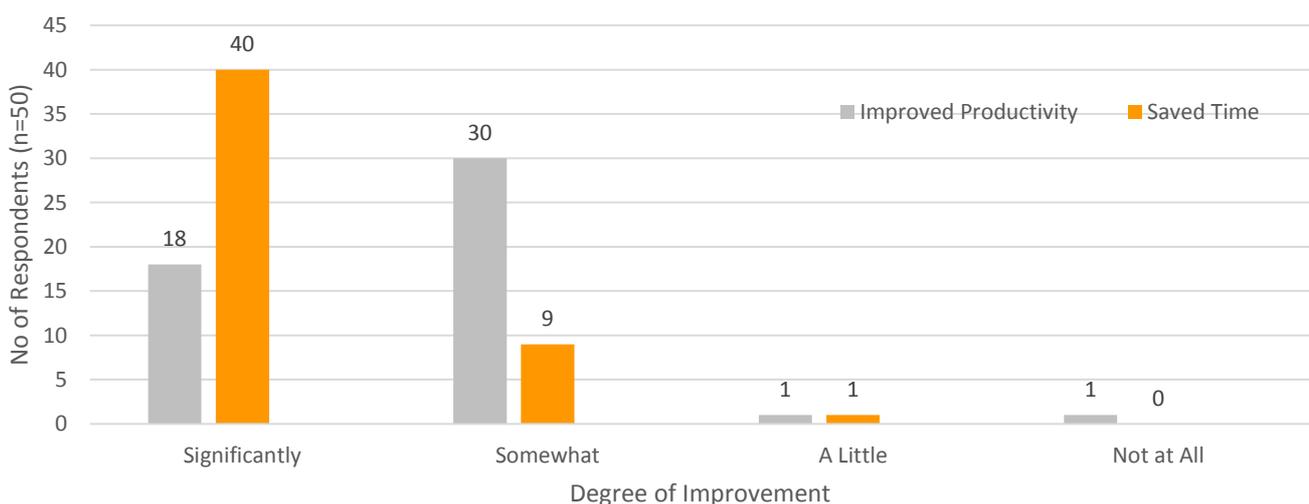
The d.light has:

- significantly saved time for 80% of respondents
- significantly improved productivity for 36% of respondents
- somewhat improved productivity for 60% of respondents
- allowed 77 children, in 76% of surveyed households, to study for one hour and 45 minutes each school night
- enabled 80% of respondents to work at night

Productivity and Lifestyle Benefits

Through the provision of a simple solar light, Light Up Madhya Pradesh has helped households become more productive and save time (as seen in Figure 9).

Figure 9. Perceived improvements and time saved since using the d.lights (n=50)



Increased productivity and time efficiency give the opportunity for household members to invest more time to income generating activities.

Due to insufficient supplies to meet demand and long queues it can take a household up to two days a month to purchase kerosene. Households who no longer purchase kerosene can now use this time for income generating activities (See Annex B for the “Story of Kerosene”).

Users were able to use the solar lights to work at night in the fields as the light is water and wind resistant.

The solar light gives their users time, without any financial cost by:

- reducing the amount of unproductive time, such as the 30 minutes to prepare a lamp per day or the days spent queuing up for kerosene
- extending working hours, whether a couple of hours in the morning or couple of hours at night

Key Facts:

- *“A study of portable solar lighting impact in India found that the introduction of solar lighting raised average study hours of students per household from 1.5 hours to 2.7 hours, with a correlative effect on school performance.”* (Lighting Africa, 2010)

Key Impact Assessment Findings:

- **60% of respondents indicated that access to the d.light has ‘significantly’ made their lives easier**
- **74% of respondents indicated the d.light allowed them to conduct two or more nightly activities that were previously unavailable**

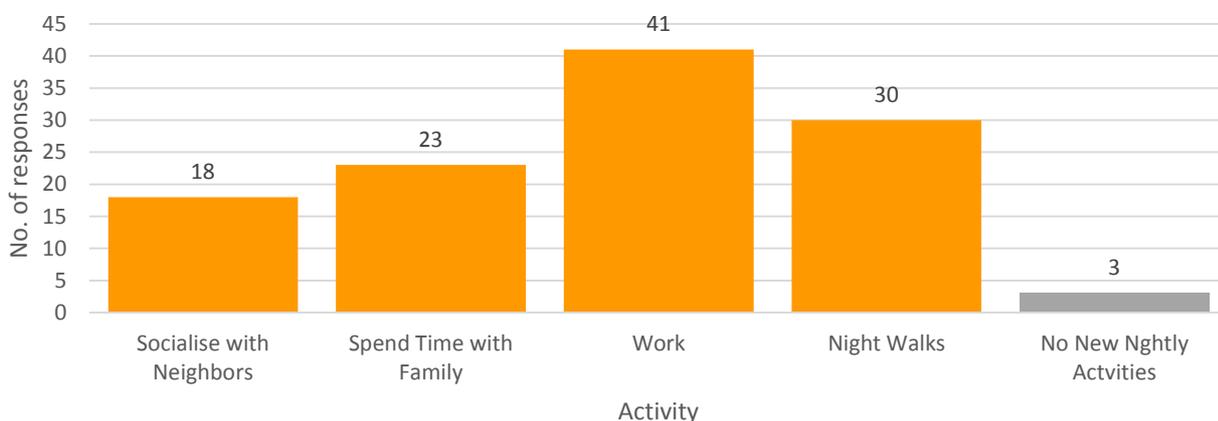
The productivity benefits are not restricted to adults, children have benefited from the solar lights too. The d.light allows children to study with a clean, renewable and reliable light. Prior to the d.light, children were often exposed to unreliable power and/or to harmful fumes.

On average, primary school children are using the d.light for one hour and 45 minutes per night, which equates to 388 hours, or over 16 days, of study a year.

Children are no longer exposed to harmful fumes, 19 of 77 children who studied with the d.light belong to households who ceased using kerosene lamps for lighting altogether. The d.lights will therefore prevent these 19 children from inhaling fumes that are the equivalent to smoking 648 cigarettes, over the primary school year (Lighting Africa, 2010). (An analysis of the benefits of the d.light to children is at Annex C)

Technology users spoke of the new activities open to them, such as socialising with neighbours and conducting night walks to tend their fields or meet with friends (see Figure 10). One user commented that the light allowed him stay out in the fields all night to guard his crops from animals.

Figure 10. New nightly activities using the d.light (n=50)



Note: Respondents could select more than one activity

Respondents told stories of how the d.light has ended the need to rummage in the dark looking for a torch or to light a kerosene lamp. Now, users just have to find and turn on the d.light, this is easy with the light's glow in the dark on/off button.

One user exclaimed that 'the d.light had decreased family tensions' as now they always have a portable source of light that is reliable and doesn't extinguish in the wind.

Key Fact:

- One kerosene lamp emits up to one tonne of carbon over five years. (Solar Aid)

Environmental Benefits

Through the provision of a simple solar light, Light Up Madhya Pradesh has helped reduce local carbon emissions. At the time of this report, 200 solar lights had been distributed, which is equivalent to an estimated reduction in carbon emissions by 200 tonnes over five years. It is estimated that this is equivalent to taking 42 cars off the road for one year.⁴

Effectiveness of Project Delivery

Product Sales Strategies

Key Impact Assessment Findings:

- **90% of respondents made their decision to buy the light after a discussion with Kopernik's local partner**
- **80% of respondents were interested in the ability of the d.light to save money**
- **55% of respondents were interested in the d.light because of its appearance**
- **9% of respondents were interested in the d.light because of its health benefits**

CDC employed a team of six staff to demonstrate the d.light at 15 prearranged and routine community forums conducted by CDC for other programs. Solar light demonstrations were also conducted in local schools, however these were not as successful as community demonstrations, as children were not the empowered to make purchasing decisions.

The Kopernik fellow observed two product demonstrations (one at a high school and another in a remote forest village, Guitola). The observed demonstrations highlighted the strong performance of the d.light against the performance criteria of brightness, charging speed and durability – where the d.light was dropped on the ground in front of the crowd.



⁴ This is based on the assumption that one kerosene lamp emits one tonne of carbon dioxide over five years and that the use of a solar light replaces the usage of one kerosene lamps. This was calculated using the US Environmental Protection Agency's online calculator: <http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results>

The demonstration emphasised the reliability of the light, its international distribution and the availability of a two-year warranty.

CDC staff did not appear to have a standardised or prearranged script for product demonstrations. Whilst this is not a major issue the use of a prepared script would have ensured uniformity of product demonstrations. CDC Balaghat and future partners should be encouraged to develop a standardised demonstration script and format.

Barriers to Purchase

A focus group of four non-users was conducted to determine the reason(s) why people were not interested in purchasing the d.light solar light. The members of the focus group were randomly selected from the town of Garhi. Three interviewees derived their main income from agricultural activities whilst the fourth member was a small business owner.

The group were interested in the light, however, with the exception of the small business owner, they were not intending to purchase the light. The group identified the availability of other cheaper light sources such as rechargeable torches. These torches retail for INR150 (US\$2.37). Solar systems are also available in Garhi. A small household solar system is available for INR1200 (US\$19). A medium household system is available for INR6000 (US\$95). The small business owner was interested in the d.light solar light as a back-up source of light during the frequent blackouts in the community.

Key Impact Assessment Findings:

- **86% of respondents believe the d.light is “relatively affordable/reasonable”**
- **The sales register for the 112 units distributed in Garhi and neighbouring villages indicated that 55 percent of technology users (who purchased the d.lights from November 2014 – January 2015)⁵ are behind in their re-payment instalments**

Effectiveness of Pricing

Only four technology users (8 percent), of the sample population, characterised the d.light as expensive and the d.light was described as cheap by two users. The remainder of the sample population, 44 users, considered the d.light to be affordable. The strong response and the way users described their positive experience show that the d.light represents value for money.

While the vast majority of the sample population considered the d.light to be affordable, a significant portion (55 percent) of technology users were unable to meet the current repayment schedule. CDC staff visited each village each week as a part of their malnutrition program and use these routine visits to collect repayments.

The socio-economic situation of the region and the data collected on household income suggest that a significant population are unable to meet the current repayment schedule. This inability has been exacerbated by a drop in household income from poor crop yields and the scaling down of government employment schemes (Charles, 2015).

Socio-Economic Context

- The average monthly household income (adjusted) surveyed was INR2291 (US\$36).
 - Therefore the daily income of the household is INR76 (US\$1.20).
 - The average occupancy of the 42 households is six people, as such, each household can spend INR16 (US\$0.26) on each member of the household per day.
 - The above figure is well below the poverty line set by the Indian Government of INR26 (US\$0.40) per day and even further below the poverty line set by the World Bank of INR79 (US\$1.25). (India Today, 2011)
-

The above figures depict how constrained household budgets are within the region. These figures should be used in conjunction with other socio-economic data to best determine the most feasible repayment schedule.

The figures do show that a six monthly instalment period together with a price of INR600 (US\$9) for a d.light S20 is not feasible for a significant portion of the target population.

A repayment schedule of 12 months, for the d.light S20, is more feasible than one of six months as households can use the monthly savings to meet some, if not all, of the INR50 (US\$0.80) month repayment cost.

The d.light S300 is beyond the budget of the 42 lowest income households with a payback period of 78 months and this is only if the household ceases the purchase of batteries and kerosene.

Recommendation One:

The repayment periods are determined by considering local socio-economic conditions and are reviewed as necessary, throughout the project.

Recommendation Two:

Phase two of Light Up Madhya Pradesh should be limited to the d.light S20. The need to provide access to the d.light S300 should be reviewed for subsequent phases beyond phase two.

Keys Impact Assessment Findings:

- **CDC received the consignment of d.lights on time and with all units in working condition**
- **All but one technology user in the sample received their d.light on time**
- **All technology users received their d.light in working condition**

Effectiveness of Delivery Methods

Kopernik's supply chain to the local partner is reliable with all units received in good condition within the agreed timeframe. CDC's supply chain is also reliable as all respondents indicated that their lights were in working condition on delivery and all but one respondent indicated that the d.light had arrived on time.

Keys Impact Assessment Findings:

- **Six d.light S20 owners reported a faulty unit during the survey period.**
 - **The common fault reported by five respondents was the fading out of light after two hours on the lowest setting.**
 - **One respondent reported that the solar panel was not charging their unit, the respondent had to charge their unit utilising a Nokia phone charger.**
- **Two of the three S300 users reported that their d.light was not charging their mobile phones.**
- **Prior to the surveys, none of the eight users with faulty units notified CDC about their technical issues with the lights.**

Aftersales Service

Aftersales service could not be assessed as those who had experienced problems with their units did not notify CDC staff. Both CDC staff and users were unaware of the common fault finding processes for each device. Most users were unaware of the warranty period. Both CDC staff and users were unaware of the process to lodge a warranty claim.

Recommendation Three:

An aftersales service pack should be provided to local partners, preferably in their native language. The pack should contain:

- everyday care and maintenance instructions
- common fault finding techniques
- what is covered by the warranty and
- the process to make a warranty claim

Local Partner and Project Implementation

The Executive Director of CDC believes that Light Up Madhya Pradesh is beneficial to their organisation and to technology users and indicated that CDC has learnt new skills as it transitioned from a charity to a social enterprise. They believe the social enterprise model benefited the technology users as they are the owners of the product and will care for the product. CDC's involvement in the Light Up Madhya Pradesh project has been a positive one, with CDC eager to continue the partnership with Kopernik.

Keys Impact Assessment Findings:

- **42% of respondents use the d.light in addition to old sources of light and**
- **95% of those who used the d.light with another source of light explained that a d.light lacked the capacity to meet the demands of their households.**

Meeting Community Needs

While the solar lights have made a positive impact on last mile communities, the impact assessment also found that a single solar light only partially met the lighting needs of last mile households.

Survey respondents indicated multiple lights are needed to simultaneously illuminate multiple activities. Most commonly to enable children to study, parents to cook and to allow a household member to tend to the field at night.

Users also indicated that the d.light S20 is good at dispersing light but cannot focus light, like a flashlight, as such some farmers use flashlights to check their stock and to ensure animals are not eating their produce.

The stories of the technology users suggest they need a multipurpose household system, which can illuminate multiple rooms and can still provide a portable light. d.light already produces a home solution, the D20. The D20 includes a standalone solar panel, two wall mounted switches, two networked work lights and one portable light. This system retails at INR5900 (US\$93). Due to its price the D20 is inaccessible to the poorest households. Technology users need a household solution as depicted in Figure 11, a solution that builds on their previous d.light purchases rather than making them redundant.

Figure 11. Proposed Household Lighting Solution



Recommendation Four:

A design concept be proposed to d.light for an affordable household solution that can be purchased and used in stages. The system should:

- allow d.light S20s to connect to a standalone solar panel (the solar panel is purchased separately)
- have the ability to charge personal electronic devices
- a separate cup attachment capable of focusing a light

This design concept is shown at Figure 11

Future Kopernik Opportunities

Key Facts:

- **As of the last census only 2.3% of households in rural Balaghat had access to treated tap water (Census India)**
- **93% households in rural Balaghat rely on untreated water from hand pumps (Census India)**

Clean Water

The reliance on untreated water as the primary source of drinking water in rural Balaghat has led to poor health outcomes and even fatalities throughout the region.

A prevalent water filter in Madhya Pradesh is the 'Milton Water Filter,' which retails online for INR1251 (US\$20) to INR2759 (US\$43). In Balaghat City, water filters retail for INR925 (US\$15). However, traveling to Balaghat can be prohibitive for last mile communities and costs INR300 (US\$4.50) for a return bus trip from the project location.

The lack of an affordable water filter has forced families to boil water. The process of boiling water increases resource usage, deforestation and exposure to carbon monoxide leading to poor health outcomes.

The local partner, CDC, has indicated an interest in distributing water filters in partnership with Kopernik, which could be a viable phase two project after the Light Up Madhya Pradesh project.

Key Facts:

- **The most common fuel used in Balaghat for cooking is wood with 91% of households using it in local Chula stoves (Census of India)**
- **Chula stoves are usually hand made from clay in a distinctive U shape, with a coating of dung and it can use any form of biomass or solid combustion as a source of heat. The Chula is however inefficient and produces harmful particulate matter (Dalberg Global Development Advisors, 2013)**

Clean Cooking

During the interviews with solar light owners, many respondents (especially women) and the local partner expressed an interest in clean cooking technology.

This interest is shared by the Indian Government with the Ministry of New and Renewable Energy (MNRE) establishing test sites to identify cookstoves that will be eligible for a government subsidy.

One approved model is a forced draft intermediate standard cookstove. This model has a thermal efficiency two times greater than a Chula oven (traditional mud oven) and emits 80 percent less carbon monoxide and 72 percent less particulate matter emissions than a Chula oven. The lowest cost observed for this cookstove was INR2700 (US\$42).⁶⁷ As of 2013, this stove price would be reduced to INR1900 (US\$28.60) under the MNRE subsidy program.

The local partner expressed doubts on their ability for a future cookstove project implemented by CDC gaining access to the government subsidies (Charles, 2015). Therefore if Kopernik and CDC planned any future cookstove project they would be competing with subsidised competitors, in this example with cookstoves at a price of INR2700 (US\$40.62). The price is in excess of four times greater than the cost of the d.light S20. At current income levels, it will take 107 months or close to nine years for the surveyed households (adjusted sample) to fully pay off this cookstove.

At the current product pricing and income levels of the targeted last mile communities, it is assessed that the provision of cookstoves is not a financially feasible follow up project to Light Up Madhya Pradesh. Potential future cookstove projects will need to carefully consider the affordability of these products to last mile communities.

⁶ Particulate matter refers to a complex mixture of extremely small particles and liquid droplets.

⁷ The name of this product has been withheld in order to prevent future bias should Kopernik select a local supplier of cookstoves. There are 32 MRNE approved models from 23 suppliers as such there are several options available for Kopernik's selection.

Recommendation Five – Future Projects

Kopernik should develop a strategic partnership with CDC to stagger the distribution of technologies to create a holistic improvement in the lives of last mile communities. The local partner has expressed an interest in developing a long term, strategic partnership with Kopernik focused on achieving the following:

Method: Improvements in health and overall daily lives of the target communities will be achieved by providing staggered access to clean and affordable home lighting, water treatment and cooking technology. This method will limit the financial stress experienced by consumers as the savings generated by the first technology can be reinvested in the next. Concurrently local businesses will be geared up, with the help of Kopernik and the local partner, to support the technology beyond the project distribution cycle.

Clean Lighting

The distribution of affordable solar lights to last mile communities in rural Balaghat in order to make solar lights the main source of light.

Result

- Improved living conditions and productivity
 - Savings generated from decreased resource use are reinvested in to new life changing technologies.

Clean Water

The distribution of affordable and durable water treatment technologies to last mile communities in rural Balaghat in order to provide households with access to clean water.

Result

- Improved living conditions
- Improved productivity due to a decrease in lost working days
- Decrease in resource use and smoke generation as water no longer needs to be boiled
- Development of a relationship between technology users and providers that will be used to set an appropriate pricing model for the distribution of water filters
- A reduction in the risk of technology users failing to pay due to a pre-existing relationship.

Clean Cooking

The distribution of clean cookstoves to target last mile communities in rural Balaghat in order to reduce resource consumption during the preparation of food.

Result

- Improved perceived health outcomes amongst technology users, due to a reduction in household carbon monoxide and particulate matter emissions
- Reduction in resource use
- Reduction in manual labour injuries associated with gathering fuel
- Reduced risk in households unable to repay the cost of the cookstove due to existing relationships and the tailoring of pricing models.

Developing a Local Business Network

The gearing up of local businesses to support the new technologies.

Result

- A supply chain and aftersales support network, independent of Kopernik and CDC Balaghat, to support the clean technology demands of target last mile communities after the initial project lifecycle.

ENDSTATE. The holistic improvement in the lives of the target last mile communities in rural Balaghat with a business network capable of supporting the demands of technology users beyond the initial project lifecycle.

Conclusion

The d.light solar lights have made a significant impact on the lives of those who have purchased and use it regularly. The solar lights have led to perceived and tangible improvements in the daily lives of households in the last mile communities. Solar light owners generally reported feeling healthier, safer and more productive; with users believing their daily lives are easier.

This improvement does however come at a financial cost, a cost that is eventually offset by the savings generated from the use of the solar light over a 9-month period but is sometimes a struggle upfront. The current six monthly repayment schedule is beyond the reach of the poorest users, as such it is suggested that the repayment reschedule be extended to 12 months to relieve the financial pressure on the lowest income households.

Kopernik is presented with the opportunity to make a holistic positive impact to the technology users beyond the five-year life span of the d.light in rural Madhya Pradesh. CDC is a capable local partner with the desire to continue its work with Kopernik. Together with CDC, Kopernik can make a positive impact over the next five to ten years if it adopts a longer term strategic outlook. This strategic approach will not only provide the technology but develop an independent system of aftersales support to ensure communities continue to experience the benefits of clean technologies beyond Kopernik and CDC's initial partnership.

Recommendations

1. The repayment periods are determined by considering local socio-economic conditions and are reviewed as necessary throughout the project.
2. Phase two of Light Up Madhya Pradesh should be limited to the d.light S20. The need to provide access to the d.light S300 should be reviewed for subsequent phases beyond phase two.
3. An aftersales service pack should be provided to local partners, preferably in their native language. The pack should contain:
 - a. everyday care and maintenance instructions
 - b. common fault finding techniques
 - c. what is covered by the warranty
 - d. the process to make a warranty claim

4. A design concept should be proposed to d.light for an affordable household solution that can be purchased and used in stages. The system should:
 - a. allow d.light S20s to connect to a standalone solar panel (the solar panel is purchased separately)
 - b. have the ability to charge personal electronic devices
 - c. a separate cup attachment capable of focusing a light

5. Kopernik should develop a strategic partnership with CDC to provide staggered access to clean and affordable home lighting, water treatment and cooking technology. This method will limit the financial stress experienced by consumers as the savings generated by the previous technologies can be reinvested in the next. Concurrently local businesses should be geared up, with the help of Kopernik and the local partner, to support the technology beyond the initial project lifecycle.



Annex

Annex A - A cleaner and brighter future

IMPACT STORY - Fulwanti

Fulwanti is 23 year old woman from Dhaniyajor. She spends her days looking after her household and five children whilst her husband tends to the fields. The d.light has saved Fulwanti's family INR95 (US\$1.50) a month. This is enough money to buy 17 days of rice for her five children.



Fulwanti also told me of the health benefits of the d.light. Since using the solar lantern, Fulwanti no longer has carbon building up in her nose which has led to an improvement in her breathing. As Fulwanti told me this story I noticed the persistent cough her son had - he had been coughing throughout the interview. Whilst I could not say what caused this cough I did wonder what it was like growing in world of lit by kerosene and how it could be improved

The provision of a simple solar light is the first step in providing a brighter and safer future for children in last mile communities.

“Kerosene ingestion is the primary cause of child poisoning in the developing world” (Mills, 2012).

The use of kerosene lamps is perilous to children. Kerosene ingestion is the most common cause of child poisoning in the developing world, (Mills, 2012). Kerosene is often decanted into unmarked bottles and stored in common areas, especially in the food preparation areas of the household. As such kerosene is easily accessible to children. The health impacts from consuming kerosene can be long lasting. The ingestion of 1ml can have harmful side effects such as Pneumonia. In larger quantities kerosene poisoning can lead to death (Mills, 2012). The provision of solar lights will reduce the risk of kerosene poisoning, among children, by reducing or eliminating the household demand for kerosene.

“In India alone, 2.5 million people suffer severe burns due to overturned kerosene lamps annually.” (Lighting Africa, 2010, p. 15)

The risk of burns from a kerosene lamp is an ever present risk in rural Balaghat households. The risk is significantly high for children. Studies in southern India have identified burns as the second highest cause of childhood injury-mortalities, with almost half caused by kerosene lamps (Mills, 2012). Children are at risk because they study with lamps and they play around lamps. The Light Up Madhya Pradesh project has helped to eliminate the risk of burns to children by providing a clean and safe source of light. A source of light that will not maim or kill its users.

‘A study of portable solar lighting impact in India found that the introduction of solar lighting raised average study hours of students per household from 1.5 hours to 2.7 hours, with a correlative effect on school performance.’ (Lighting Africa, 2010)

The impact assessment found that on average children studied each night with the d.light for one hour and 45 minutes. This equates to 16 full days of study a year for a primary school student. The d.light has allowed children to study each night free from blackouts and harmful fumes of kerosene - equivalent to smoking 648 cigarettes over a school year. This additional study time and the health improvements is expected to improve the school performance for child technology users. This improvement can be attributed to increased productive days from improved health and increased knowledge uptake due to longer periods of nightly study. The d.light is expected to make a positive improvement in the education outcomes of children.

The provision of a simple solar light, as a part of the Light Up Madhya Pradesh project is expected to improve the future of child technology users. Children will experience better health and safety outcomes, which will result in more productive days. The access to a reliable light for study may also improve academic performance. The improvement to health and education is an important step in providing child technology users with the possibility of a cleaner and brighter future.

Annex B - The Story of Kerosene

IMPACT STORY - Tektram

Tektram is 65 years old and lives in Kukarra with his wife and son. Neither Tektram nor his wife decided to buy the d.light. The decision to buy the d.light was made by their eldest daughter who is a school teacher. Tektram's daughter convinced her parents to buy the solar light to allow her brother to study with a clean source of light. The d.light has however benefited the whole household. Tektram and his wife now save INR95 (US\$1.50) a month. This is enough to purchase rice for their whole household for 30 days.



During the interview Tektram retrieved his old traditional kerosene lamp and demonstrated the process to assemble it for use. Tektram first refilled the lamp, then prepared a new wick, replaced the old wick and lit the lamp. I instantly noticed a small black tower of smoke as the lamp burned, this sparked my curiosity and I began to wonder what the true story of kerosene was.

“I couldn't have electricity in the house, I wouldn't sleep a wink. All those vapours floating around”
Dowager Countess, aka Maggie Smith
Downton Abbey

The Dowagers sharp wit, and Maggie Smith's flawless delivery hides the cruel irony of the quote where kerosene lamps should be the cause of a sleepless night for the deadly vapour they emit.

The Dowagers words also remind me of the great divides in this world. In my world, kerosene lamps started disappearing over a century ago when Edison gave the world the first long lasting electric light bulb. In my world, a kerosene lamp is an antique that a hipster can convert into a hanging herb garden. However, for the people in Balaghat, central India, kerosene is a necessity of life, a necessity that is affecting their health with every breath.

The World Bank estimates people, who are using kerosene lamps as the main source of light, are inhaling the equivalent of two packs of cigarette per day. (Lighting Africa, 2010)

Kopernik, with CDC Balaghat, has helped at least 133 people (58 of which are children under 18 years old) escape harmful kerosene fumes that has been estimated as the equivalent of smoking two packs of cigarette a day. This statistic was a rude awakening for me as I realised that such mundane rituals of our lives; like cooking at night, reading a book at night or even studying at night is slowly killing people. This is happening every night here in the rural area of Balaghat where 109,048 households burn kerosene for light (Census India, 2011). On average, each household has 4.4 residents (Vital Statistics Division, 2012), which means that close to half a million people, within rural Balaghat, have a 40 cigarette a day habit without even smoking one cigarette in their lives. The provision of a simple solar light is expected to improve the health outcomes of technology users.

It is estimated that one kerosene lamp emits up to one tonne of carbon over five years (Solar Aid)

Kerosene lamps are not just poisoning people, they are polluting the planet. CDC Balaghat will take the equivalent of 236 passenger cars off the road over a five year period once all of the 306 solar lights are distributed.⁸ Kopernik and CDC Balaghat have already made a sizable reduction in carbon emissions. Over the next five years, their efforts in distributing 200 solar lights, will reduce carbon emissions by 200 tonnes, this is equivalent to taking 42 passenger cars off the road for a year.

We can safely assume kerosene lamps are bad news; they are slowly killing people and contributing to climate change. Kerosene lamps are also a burden to operate. Getting kerosene is not like getting more gas or coal for your Sunday barbeque. You and I would get into the car go to the nearest shop where we would swipe a credit card and 'hey presto' we can have a barbeque. This is not the case for lamp users in the last mile. Getting access to kerosene is a lamp user's first hurdle. Kerosene is in high demand in rural Balaghat. This demand creates huge crowds at the stores that sell kerosene. These stores are only open two days a week. Families gathered to tell me of their struggle to access kerosene, they could be lucky and only wait for two hours in the line for kerosene, or they can wait

⁸ Results calculated at <http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results>
Light Up Madhya Pradesh Impact Assessment August 2015

a day. If they were unlucky they may have to wait a day only to be told to come back the next day to battle the crowds once again or they could be really unlucky and wait for two days only to be told to come back next week. The efforts continue in the home.

To use a kerosene lamp is not as simple as finding a match and lighting the wick. The women of Seoni described the 30 minute daily ritual of preparing a kerosene lamp; first they had to clean the carcinogenic black soot from the previous night, then refill the lamp, prepare a new wick, remove the old wick, install the new wick and once that is done they can light the lamp. This 30 minute process will be repeated for each lamp and is a time consuming daily ritual.

Mamta in Seoni and Fulwanti in Garhi, told me how their faces would become black with soot and their nostrils filled with carbon when using a kerosene lamp for cooking or cleaning, yet they continued to use the lamp every night. Like millions of others they used the poisonous lamps because they had no alternative. Now they do have an alternative, both Fulwanti and Mamta have stopped using kerosene lamps.

The slight cost Mamta and Fulwanti US\$9 (paid over 6 months), they will recover their money in the savings the lights generate over a seven month period, but the benefits of the solar light to their family is priceless. How do you value the extra years of life? How do you value the knowledge and education their children receive? And how do you value their contribution to the battle against climate change? You cannot, the provision of light is priceless.

Annex C - How a simple light can be the first step in improving the lives of women

‘Two-thirds of adult females with lung cancer in developing nations are non-smokers’ (Khator, 2014)

The above fact does not surprise me after hearing stories from solar technology users within the last mile communities of rural Balaghat, central India. During my time here, I have learnt how solar lights were improving the health outcomes of technology users. I expected these stories before I started my assignment, what I didn't expect was the significant impact the lights had on women and the true scale of their exposure to indoor air pollution.

Women of Seoni

Mamta, Sunita and Rajkummari are the women of Seoni who told me that “women's health is greatly improved [since using the d.light] due to the nature of their work.”



All these women have saved on average INR68 (US\$1.08) per month since they have stopped the use of Kerosene lamps. These economic savings are significant however the true value of the d.light can be seen in the perceived health and lifestyle benefits. These women told their stories with passion and excitement, they spoke of their improved health, especially in the improvement in eyesight corresponding with a reduction in eye irritation. These energetic and passionate stories encouraged me to find out more about the lives of women in last mile communities and to identify opportunities and technologies to further improve their lives.

One of the most notable stories throughout my time in rural India was from a group of women in the small town of Seoni. These women could not contain their excitement for the d.light and the subsequent improvement to their lives. Women benefited from the d.light more as they are the primary users of light in confined spaces where they prepare food and clean the house. These women, before the arrival of the d.light, were unknowingly inhaling indoor air pollution equivalent to smoking two packets of cigarettes a day (Lighting Africa, 2010). Unsurprisingly the vast majority of women in Seoni reported at least two areas of improvement to their health since using the d.light, such as an improvement in eyesight with a corresponding reduction in eye irritation. For many of these women, this is their first experience of a renewable energy product and their positive experience of the d.light has only sought to fuel their eagerness to access new life changing technologies.

I realised, as I wrote the assessment that the Light Up Madhya Pradesh project was only tip of the iceberg when it came to improving the lives and health of women. The main source of indoor air pollution in India is produced from the combustion of wood in traditional Chula cookstoves. Cooking is usually done by women, and it's been estimated that women spend on average 3.7 hours cooking each day (Dalberg Global Development Advisors, 2013). As they cook, women are exposed to toxic fumes that cause acute lower respiratory infections, chronic obstructive pulmonary diseases, lung cancer, cataracts and other illnesses (Dalberg Global Development Advisors, 2013). In addition to exposure to indoor air pollution, women also face increased risk of burns from cookstoves and open flames, with an estimated 500,000 women suffering moderate to severe burns in India every year (Dalberg Global Development Advisors, 2013). In rural India daily tasks, such as preparing dinner, are potentially harming women's longer-term health.

The dangers of cookstoves go beyond the home. Women spend twice as much time as men collecting firewood. Families in India will spend five to eight hours a week collecting firewood (Dalberg Global Development Advisors, 2013). During this time, women carry 20 – 30kg of firewood on their head or shoulders. Regularly carrying heavy loads for long durations can expose women to head and spinal injuries, pregnancy complications and maternal mortality (Dalberg Global Development Advisors, 2013). The provision of simple clean energy technologies will reduce the need for firewood. The distribution of water filters will decrease the demand for wood, as households will no longer be forced to boil their water. The provision of more efficient cookstoves will limit smoke emission as well as reduce fuel consumption and the need to collect and transport firewood. The provision of water filters and cookstoves to last mile communities in rural Balaghat can improve the lives of women.

The Light Up Madhya Pradesh project is the first step in improving the lives of women. The project has had a significant positive impact on last mile communities and especially the lives of women. However an enduring impact can only come with a sustained and longer-term reduction in fuel dependence. The reduction in the use of kerosene and firewood can be achieved through distribution of simple clean energy technologies such as water filters and efficient cookstoves in addition to the solar lights.

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