Developing the Means for the Use of Modern Lighting:
How can WLED technology bring high quality,
affordable light to India's poor?

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Executive Summary

India is home to one-third of the world's unelectrified population. The vast majority of these people obtain their basic lighting needs from fuel-based technology such as kerosene lanterns. The energy efficiency and downward scalability of white light emitting diodes (WLEDs) make them an excellent candidate to be a leapfrog technology, much like cell phones, for the rural developing world. However, in order to stimulate this market, it is important for light manufacturers, financiers and the end-users to recognize its potential.

The objective of our work was to investigate the means by which WLEDs can benefit India's unelectrified and under-electrified population. We worked in 34 households across two villages, Sudhamavaas and Paiya, in the Kutch district of Gujarat with help of Sahjeevan, a local NGO.

We found that only two households did not use any form of light at all. Of the rest, all used some type of kerosene lamp as their primary source of light. The most common kerosene lamp was a home made wick lantern that was used by 26 households. A flashlight product with incandescent bulbs powered by dangerous wet lead acid batteries was the most common lighting source outside of kerosene lamps. All the families spent approximately Rs. 90 (USD 2.5) each month for lighting, which made up between 3 and 10 percent of each family's income. The most common uses of their lights were cooking and for night time security. The median duration of light use for just these two tasks was 6 hrs / night. Most households reported difficulty in accomplishing any task with their existing sources of light and expressed a desire for better light quality. Among the 12% of households that were involved in home based income generation (making of handicrafts), all expressed a strong desire for improved lighting for that activity.

All households reported that every task was easier with their randomly assigned WLED product. Almost all families switched to using the WLED product for the tasks of highest priority like cooking and security at night. However most families continued to use their kerosene lanterns although all of them used those for substantially shorter durations each day. Each of the WLED products was rated as either good or very good by all respondents. Families showed a strong aversion to renting any of the WLED products and preferred to own with a one-time payment. All families were willing to pay a higher amount for the WLED product that they used than they do presently for any light sources.

Finally, we found that local retailers of light products expect a six month manufacturer guarantee and 20 to 30% markup over wholesale prices. Further, supply chains reach the Indian hinterland over poorly paved roads in trucks where goods are poorly protected.

Overall, we found unanimously positive responses to WLED lights and an active willingness to pay for them. It is clear that product designs need improvement, the specifics of which we have conveyed to each manufacturer. It is also clear that there is enough room in the market for each manufacturer to produce multiple products each targeted at a different use. If both manufacturers and financial intermediaries find a way to overcome the challenges of product distribution, they can benefit commercially while meeting a basic human need for billions.

Project Summary & Research Questions

Currently, 500 million people in India lack access to electricity, making it home to nearly a 1/3 of world's unelectrified population (*Source: Census of India 2001*). The energy efficiency of WLEDs makes them a candidate to be a leapfrog technology (like mobile phones) in rural communities.

The objective of our work was to investigate the means by which WLEDs can benefit India's unelectrified and under-electrified population. Our research questions included the following:

1. What WLED products are appropriate and useful in rural Indian communities?
2. What is the consumer feedback on these products?
3. What is the willingness to pay (WTP) for these products?
4. What are the key considerations for developing a business model for their dissemination?

Study Design

Our goal was to provide original research around WLED product design and business model innovations that will assist local NGOs and WLED product manufacturers in making WLED technologies available to communities that have been unable to afford efficient, clean, and high quality lighting.

We worked with Dr. Evan Mills at the Lawrence Berkeley National Laboratory to standardize our survey questions and format so that it can be used for future projects. Moreover, previous Bridging the Divide fellows also provided invaluable advice on fieldwork study design.

Our study included 34 households across two villages in Kutch: Sudhamavaas and Paiya. The project was designed as a three-part survey with product testing. First, to gather background information, we designed a pre-fieldwork survey to be completed by the staff at Sahjeevan. This pre-fieldwork survey was designed to identify and prioritize the key issues facing the people in the two villages. The next two phases of our study involved the actual fieldwork. We developed an initial household survey to assess current lighting use and needs. The results from this survey would establish the baseline for our needs assessment. At the end of this initial household survey, interviewees were randomly assigned one of four WLED products to use. Product testing occurred for 8-11 days.

At the end of the product testing, we would return to the villages to conduct a final exit survey. This survey was designed to gather feedback about the products tested as well to gather information about their willingness-to-pay for the products. We also sought to gauge preferences for a range of prices, rent vs. buy option, and installment payment plans.

Finally, we spoke with local retailers and our NGO partners to better understand, at a qualitative level, marketplace conditions as well as distribution options, especially in terms of charging.

Technical Product Testing

In the Spring semester of 2007, one of our team members, Joshua Apte traveled to our villages to assess the baseline lighting use and lighting needs for the communities. In addition to Josh's lighting needs assessment, Sahjeevan conducted preliminary, informal exploratory surveys addressing baseline conditions with respect to economics, access to energy infrastructure, village education levels and the priority of lighting for each family. Using both the lighting needs assessment and the survey results, we selected 10 lighting products to test under lab conditions in Berkeley.

In order to accurately characterize the lights currently used by the villagers, we tested the light distribution and kerosene consumption of two lanterns that we purchased from the same shops from which the villagers purchased theirs. As a result of these tests we had a clear understanding of the existing light service and cost, both of which would have to be bettered by WLED products. These data are a key output of our work since it is invaluable to all parties who are interested in the elimination of fuel-based lighting.
Kerosene lamps are the current dominant lighting technology in these communities. We conducted some in-situ light intensity measurements for each of these lanterns. Three types of kerosene lanterns are typically used:

1. *"Chimney"* wick kerosene lamp. This is a very large wick kerosene lamp and the most prevalent in the community. The wick is a bundle of fabric 1-1.5" across and perhaps 4-6" tall, mounted in a metal can that has a small handle brazed on. It gives a very large, dancing, and very smoky flame. We measured fuel consumption to be ~80 g / hr in somewhat windy conditions. This lamp appeared to be used more often outdoors than indoors, perhaps due to the large flame it produces. This lamp appears produces the most soot of the three lamps found in the settlement due to its large, uncontrolled flame. Most of these Chimney lamps are home made. Hence, we did not test one of these because there is no standard model and there is wide variation in both light output and fuel use from one unit to the next.

2. *"Hurricane-style"*. This lamp design is common throughout the developing world and is mass-produced in China. The lamp has a thin, wide wick (0.75"-1" wide), and is enclosed in a glass wind-protector to keep the flame steady. By adjusting the wick height, the lamp's brightness can be varied. This lamp is very easily carried around using its metal handle, and can conveniently be hung to cast a wider, if dimmer, light. This lamp seems to be used both indoors and out. At its lowest setting, it is commonly used as a night light. At its highest setting, the glass enclosure quickly darkens from soot production; optimal light output is actually achieved by a less-sooty flame of medium intensity. We purchased one of these lanterns for Rs 120 in the Mundra Bazaar (Mundra, Kutch District, Gujarat). We tested fuel consumption and light output for this lamp in Berkeley.

3. *Petromax style*. This is a pressurized Kerosene lantern that uses a mantle to give a very bright light. After preheating an element in the lamp, it provides gasified fuel to the mantle, which leads to relatively efficient combustion, low soot output, and an intense white light. Like the hurricane lantern, this lamp has a handle, making it somewhat portable, although the mantles used in the lamp are quite fragile and must be handled carefully. This lamp is considerably more expensive to own and operate,

and thus not used for many tasks. The lamp costs roughly Rs 350-450; we tested light output and fuel consumption in Berkeley.

(Left and Center) *Petromax lanterns, (Right) Hurricane style lantern.*

Chimney

The "chimney" illuminates an area roughly 1m in diameter, the average light levels on the ground were 5-15 lux. Outside of this directly illuminated area, there is a broad area that is dimly lit at 1 lux or below. One's eyes can actually adjust to these levels quite well, though, so there is a relatively large area where one can at least make out large objects. The light levels change constantly as the flame blows in the wind, and the light takes on a very orange glow. Light levels also depend on where the lamp is used; if it is placed on a metal pot or stand (as is sometimes done), the light will spread farther, but also be weaker. These lamps effectively provide light for one or at most two people. When used indoors, these lamps are often the sole source of light.

(Left) A "Chimney" seen indoors. 10-12 Lux were found on the brightest spot on the wall, lux levels of 2-3 lux were found towards the right edge of the rug in the center of the picture. Note that the lamp is elevated on a storage tin. (Right) Note the copious smoke produced by the Chimney.

Hurricane Style
We were unable to measure hurricane-style lanterns in use outdoors. Indoors, they are frequently used for nighttime security lighting at low flame; this provides illumination of 0.5 – 1 lux.

Petromax Lantern
Petromax lanterns are the brightest commonly available kerosene lantern in India. Crude lux measurements here suggest that light levels of 10 to 30 lux were available over a useful area with a 3-4 m diameter.

The above shows at least 4 people using light from one Petromax lantern. Note that it's hung from an overhead shelter.

<u>Other Existing Lighting Sources</u>:

- **Kisan Torch**: This is a low quality incandescent flashlight that is powered by a wet lead acid battery. This light costs about Rs. 150 and has an expected life that is less than 3 months. The wet lead acid battery is a very old technology and deteriorates rapidly with each charge-discharge cycle. In addition this battery is hazardous since it contains concentrated sulfuric acid that can easily spill if the battery is damaged or overheated.

Above: A Kisan torch

- **Solar CFL lantern**: Our partner Sahjeevan had a program to rent out solar charged CFL lanterns in some villages near ours. The program was not very successful but some families did purchase the same solar CFL lanterns from retailers. The cost of each is around Rs. 2500. This product is manufactured in Bangalore by Tata BP Solar.

Above: Tata BP Solar's CFL Lantern found in village.

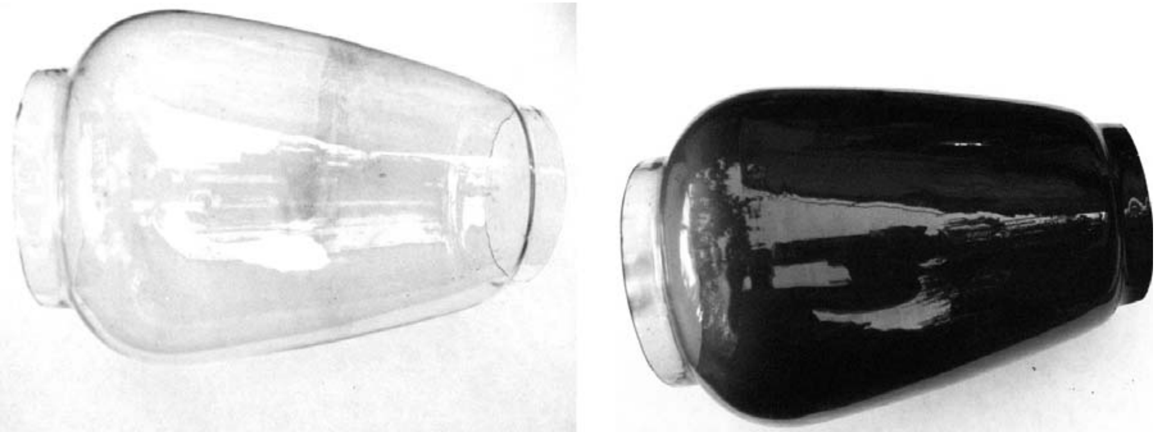
- **Disposable WLED penlights**: To our surprise we found that LED technology had beaten us to the villages. We found a few cheap cigarette lighters and pens that had LED lights included. These were low quality LEDs that lasted for a short time and had to be disposed of with the object in which they were housed.

We measured fuel consumption of kerosene lanterns using a mass-balance technique, weighing a lantern before and after use, and dividing the mass of fuel consumed by the time elapsed. We assumed that wick burnup and soot deposition made negligible contributions to the overall mass balance, both reasonable assumptions for the lamps tested. Except for the Chimney, which was field tested in India, lamps were sheltered from a moderate outdoor wind, so our results represent relatively still conditions. Hence, our fuel consumption measurements are actually a lower bound when compared to actual field conditions.

We obtained the following results:

Lamp Type	Fuel Consumption Rate (g/hr)
Hurricane Lantern (medium flame)	12
Hurricane Lantern (high flame, sooty)	20
Petromax	62
Chimney (windy)	80

We tested the Hurricane-type lantern at a typical wick height, as well as at high wick height, which represents an upper bound for fuel consumption. This mode results in very high soot production, as shown in the photograph below.



Glass housing for Hurricane type kerosene lantern, before (left) and after (right) 45 minutes of runtime at high flame. Note the large amount of soot buildup.

Fuel consumption testing of Kerosene lanterns in Berkeley, May 2007.

Once we selected 10 lighting products as the most promising for the villagers' needs subject to their economic and social constraints, we wanted to select the best four according to the following criteria:

1. Intensity and uniformity of light distribution (lux). Lights that had high intensity that was spread more evenly over a surface were rated higher since this increases its usefulness and also reduces glare.
2. Discharge characteristics: a plot of time against light intensity at a fixed point. Lights that hold intensity close to the maximum for as long as possible are rated higher than those that lose intensity regularly.
3. The overall cost of ownership with high discount rates since many villagers were in debt. This includes up front cost and running cost of charging.
4. The durability of the product.
5. The options available to charge the product, (eg: grid only, solar PV, etc). Rural areas differ vastly in their access to energy infrastructure, hence, lights that have multiple charging options are rated higher.

Since, the WLED market for off-grid lighting in the developing world is in its infancy, we do not want our tests to drive opinions about various manufacturers since many of them are still very much improving their products. Hence, throughout this report, we will not reveal the true names of any product line. Instead, we use proxies for each product. Below are brief descriptions of all the products we tested.

We tested four LED flashlights. Three of these are manufactured and marketed in India and in the US. One of them has an integrated solar panel for charging. Two of the Indian products were powered by regular AA batteries but had no charging option. The third product Indian had an in-built rechargeable battery that was charged by a wall outlet. We tested four other products that loosely resemble lanterns. Three of them could be charged only by an external source, like the grid. One of them had a wind-up charger in addition to the grid. We also tested one headlamp and one other Indian product that resembled a regular indoor light fixture.

After the tests, we selected the top four products based on the criteria mentioned above to take to India to run a field test. The results of the tests for all the products are too lengthy to include here. However, the light distribution plots for the top four products are in the appendix.

Product Selection

Fortunately for us, the manufacturers of the products we selected were all in the early stages of product development and were eager to work with us to advance innovation. Below are brief descriptions of each of the selected products.

Product A – Handheld flash light with a hook to hang the light and a built-in solar panel. This product is designed in the US.

Product B – Sturdy metal lamp with one LED angled to shine over a large 180 degree area, had a hook to hang or carry light. This product is designed and manufactured in India.

Product C – Lamp with one LED attached to a battery pack with a long cord to allow easy placement of lamp piece. This product is designed and manufactured in India.

Product D – Multiple LED lamp with handle to prop light up at an angle or carry lamp, indicator light to indicate low battery and charging. This product is designed in the US.

Given the various stages of market readiness of the four companies (3 companies were currently developing their next-generation products while one was still in initial prototype phase) with whom we were working, we did not have equal numbers of each product to test. In total, we tested 17 units of Product A, 9 of Product B, 3 of Product D, and 5 of Product C. Sahjeevan advised us that the people in Paiya tended to be more cooperative. As a result, we opted to test all four product lines among the 16 households surveyed in Paiya (3 Product D, 5 Product C, 4 Product A and 4 Product B). In comparison, among the 18 households in Sudhamavaas, we tested two product lines (12 Product A and 6 Product B).

Field Research & Survey Design

Our intention in the field was to get a sense for how well each product fit the needs of the household, what light products it might replace, what additional tasks might be accomplished with the new light, and what an appropriate price would be for each product. To do this, we worked closely with Sahjeevan to test the lighting products in two villages. The experience of Sahjeevan was absolutely critical to success in the field. Sahjeevan is an NGO that works on a variety of community issues, and has a unit dedicated to energy solutions. This unit knew the leaders of the two villages and was able to prepare the village for our arrival by notifying the village leaders, helping to randomly select the households who would participate, and setting expectations for the survey work we would do.

Sahjeevan staff carefully reviewed our household surveys and worked with our translators to make sure that the surveys were clear, concise, and conveyed what we intended. Sahjeevan staff members also conducted the community level survey (see Appendix A) with the village leaders to get a sense of the general situation in the community so that we could make sure our household surveys were appropriate for the audience and did not ask too many irrelevant questions.

In order to maximize the diversity of our respondents within the constraint of our fieldwork, Sahjeevan selected two villages that differed substantially in terms of socio-economic status, dominant means of livelihood and the dominant religion.

Sudhamavaas was 30 minutes outside of Bhuj (the regional city centre) and the inhabitants were mostly jats - a historically Hindu warrior caste. The community had been resettled after the 2001 earthquake, which destroyed their original village and severely damaged the city of Bhuj. Livelihoods are primarily earned through day labor in the various construction sites in Bhuj that were the result of the 2001 earthquake. Some additional household income is generated through the sale of embroidered handicrafts. Their homes were small one-room cement structures with thatch roofs that had been constructed with the help of government subsidies. The median household size was 5.5 (3 children), and the median household has 100% of eligible children enrolled in school. There, 17% of families own cell phone and 56% of families own a battery-operated radio. We worked in 18 households in Sudhamavaas

Paiya was two hours outside of Bhuj, and the inhabitants were Muslim charcoal makers. There were several vehicles in the village and a higher prevalence of cell phones (50% of households own cell phones) that were used for facilitating charcoal sales. Homes in this village were either cement or made from branches lashed together with a thatched roof. Several of those with the less-secure housing refused to participate in the survey as they were concerned that they could not safeguard the light. The median household size was 6 people (3 children), and the median household has 55% of eligible children in school. We worked in 16 households in Paiya.

Women in both villages wore their traditional embroidered dress, while men mostly wore more modern machine-sewn clothing, though the styles in each village were very different.

When we arrived in the village we asked all the participating households to attend a group meeting where, through translators, we described the experiment, what they could expect if they participated, and asked for their consent to participate. One issue we had to be clear about was that the participants were only getting the light for a short period of time to test, and that we would retrieve them at the end of the testing period. The decision to not leave the lights was a request of Sahjeevan. They would need to work with these communities in the future and did not want to "spoil" the market by giving any lights away for free now, nor did they want villagers to expect freebies every time they worked with Sahjeevan.

Once households had given their consent, we realized that we spent about 45 minutes with each household in administering the initial survey, which was way too long. So we shortened the survey for all subsequent households. The final version is in Appendix B. This survey is still a bit long, especially for communities that are extremely time constrained. After shortening the survey, the survey process went relatively smoothly. One issue was that the person we were surveying was often surrounded by a group of interested onlookers. If we were surveying a woman, this would often lead to others answering for her and we would have to insist that she answer, though it is likely her responses were swayed by the interference. We also noticed that many of our future interviewees were in the crowd of onlookers, so they knew the questions and others' responses in advance, which may have colored their own answers.

After the initial survey, we left the light product with the family for 8-10 days. We randomly assigned a product to each household. We did not give the household specific instructions about how to use the lights beyond basic operation and what to do if the batteries ran out. At the end of the test period we sat down again with the subject and conducted the exit survey (Appendix C).

Results

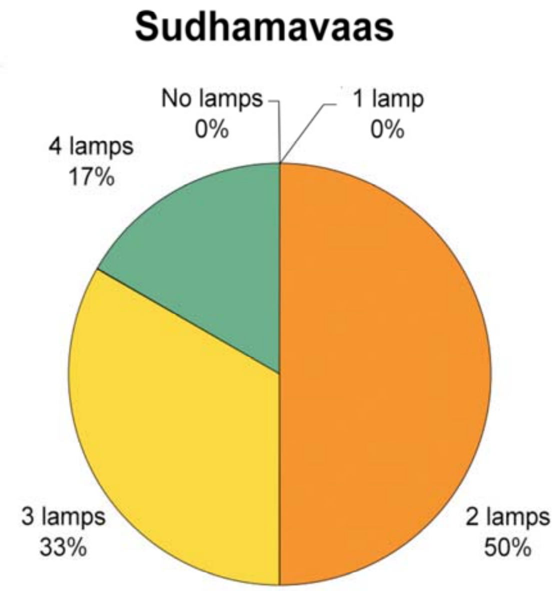
Existing Lighting Situation in Paiya and Sudhamavaas

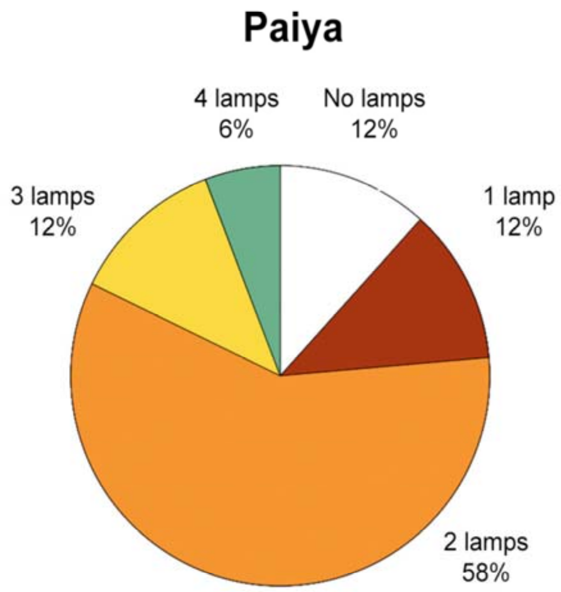
Here, we present an analysis of the "baseline" lighting situation in Paiya and Sudhamavaas. Our survey data allow us to address four key issues in these villages:

a. Existing ownership patterns of lighting devices
b. Existing use patterns of lighting: duration and tasks
c. Desire for improved lighting products
d. Lighting-related expenditures

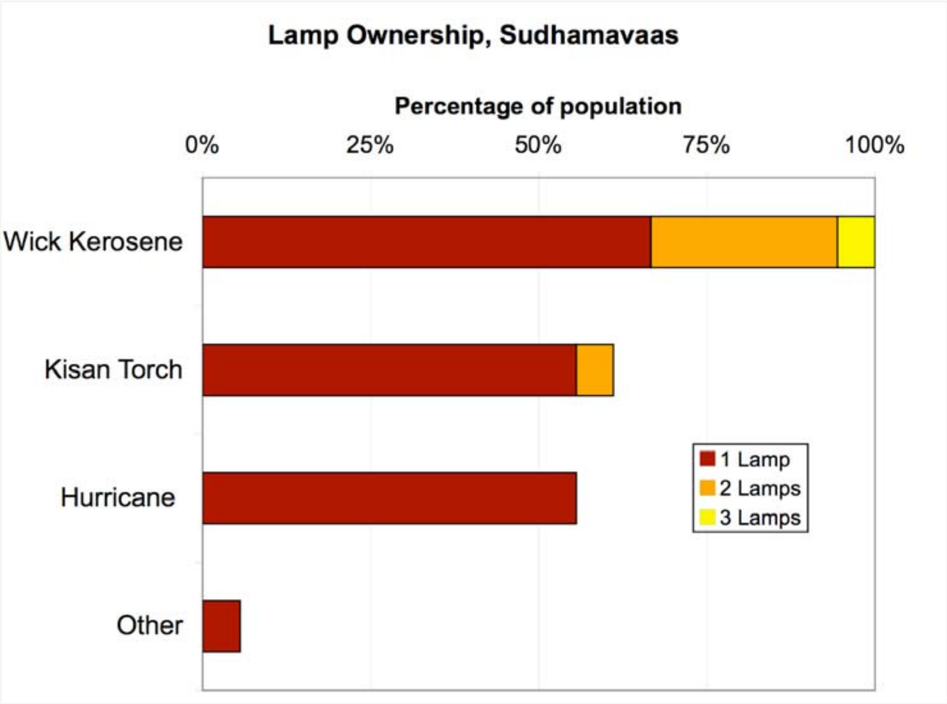
Existing ownership patterns of lighting devices

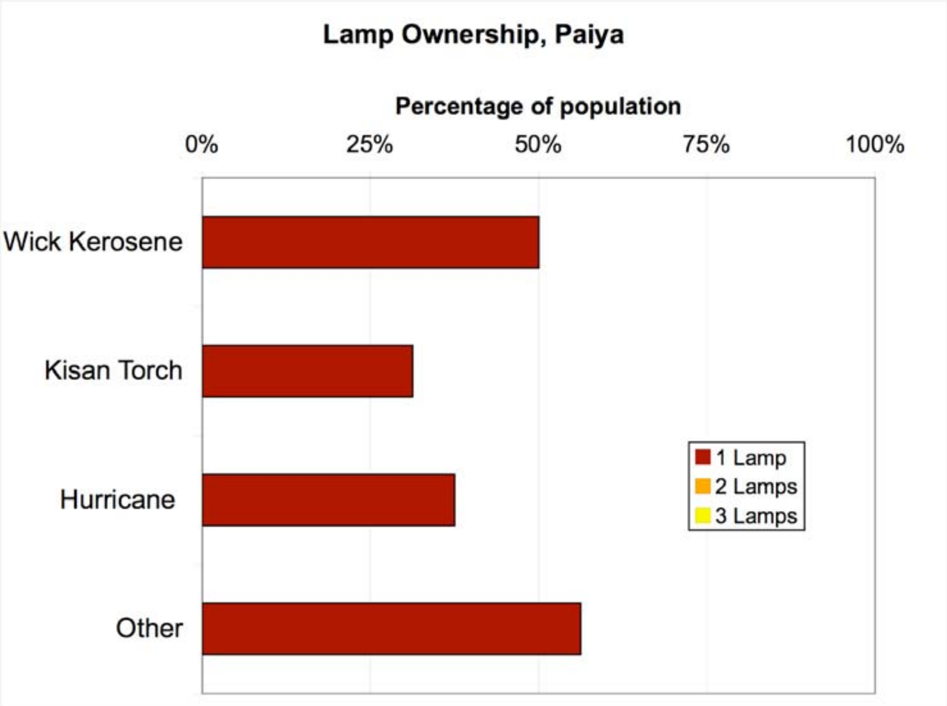
As can be seen in the pie charts below, patterns of lamp ownership are substantially different between Sudhamaavaas and Paiya. Sudhamaavaas, as a generally more prosperous village, has higher lamp ownership overall. In this village. every member surveyed owned at least two lamps, and 50% of respondents owned three or more lamps. In contrast, a full quarter of survey respondents from Paiya own one or no lamps. While the median household in Paiya (like Sudhamavaas) owns two lights, only 18% of respondents own three or more lamps.





There are also key similarities and differences in the dominant type of lamp used in the two villages, as can be seen in the bar charts below. In Sudhamavaas, every household owns at least one wick kerosene lamp, while more than half of households own at least one Kisan torch or hurricane kerosene lamp as well. In Paiya, households are less likely to own any one kind of light; additionally, none of the households surveyed owned more than one of any type of lamp. Notably, a large number of households owned lamps that we classified in the “Other” category. These lights were chiefly dry-cell torches, with a few households owning disposable LED penlights.





Existing use patterns of lighting: duration and tasks

The tables below describe the existing patterns of lighting use in Paiya and Sudhamavaas (pooled sample). The most common lighting tasks that light was used for include security (night left on for protection), cooking, health issues and emergencies, and walking at night. These four tasks were performed by at least two-thirds of all respondents. The fifth-most common use for light, reading, was performed by 38% of all respondents.

For each task that respondents reported using light for, we calculated the median duration of use. When tasks are ranked by median duration, we find a similar ranking to that described above. Of the five most commonly performed tasks, three are also among the top four tasks of longest duration. Note, however, that there is not perfect overlap here. This is because some tasks that are very common don't occur very often, and some tasks that are very time intensive are not widely practiced. For instance, handicraft work, which is done by only 12% of respondents in our survey, had a median duration of 2.1 h/night. Two very commonly performed tasks – health/emergencies and walking at night – do not require much time; we estimate the median time for these tasks to be roughly 10 minutes per day.

Most common tasks	
Security	91%
Cooking	80%
Health / Emergencies	71%
Walking at night	68%
Reading	38%

Tasks of longest duration Median hr/day *(% performing task)*	
Security	4h *(91%)*
Handicraft Work	2.1h *(12%)*
Cooking	2h *(80%)*
Reading	1h *(38%)*
Socializing	0.3h *(23%)*

(Values in parentheses indicate the percentage of respondents performing a given task)

Since the availability of good sources of light can play a key role in enabling childhood education, we were interested in investigating differences in light usage for reading between households with and without school-age children. Unfortunately, this is a question not well answered by our data. Only four study households in our survey had no children attending school, a number of households far too small to provide meaningful insights. Interestingly, none of these households reported using light for reading, but the meaning of this finding is difficult to interpret. Future studies may wish to sub-sample among households with and without school-age children to investigate differences in lighting use for reading.

Desire for improved lighting products

We asked each household two questions to gauge potential desire for improved lighting product. First, for each task requiring light, we asked respondents to rate the task as easy or difficult to do with the most commonly used light for that task. Second, we asked respondents to report whether or not they would like another (improved) lighting product to perform the same task[1].

The following table presents rankings of tasks deemed most difficult with existing light. The left-hand table shows the counts of people reporting a task as difficult, as a fraction of total respondents. Thus, this ranking is influenced by the prevalence of a task; uncommon but uniformly difficult tasks are unlikely to appear in this ranking. The right-hand table indicates the percentage of respondents reporting a task to be difficult as a fraction of total number of respondents performing that task. The right-hand table thus shows niche tasks – such as tending livestock and handicraft work – that are difficult to perform, but not widely enough practiced to make it into the left hand rankings. Still, certain "problem tasks", such as cooking, health/emergencies, and tending livestock, are seen as both difficult and prevalent.

[1] There are appeared to be a considerable amount of confusion over the interpretation of this question among respondents and translators. We believe that respondents interpreted this question variously as "I would like a better lamp for this task", "I would like more lights for this task", and "I would pay for _____". Finally, it should be pointed out that the respondent did not always perform the task described, eg.. a male head of household would respond about cooking, even if his wife was primarily responsible for cooking.

Percentage of all respondents reporting difficult with task	
Cooking	68%
Health / Emergencies	38%
Security	29%
Tending livestock	24%
Reading	18%

Percentage of respondents performing task AND find it dificult	
Cooking	85% *(80%)*
Handicrafts	75% *(12%)*
Tending Livestock	67% *(36%)*
Religious Uses	63% *(24%)*
Health / Emergencies	54% *(71%)*

(Values in parentheses indicate the percentage of respondents performing a given task)

Following the same approach as above, the following table presents rankings of tasks for which people indicated the desire for more/improved lamps.

Percentage of all respondents who would like more lamps for task:	
Cooking	48%
Security	38%
Socializing	20%
Tending livestock	15%
Health / Emergencies	15%

Percentage of respondents performing task AND would like more lamps	
Handicrafts	100% *(12%)*
Cooking	60% *(80%)*
Security	42% *(91%)*
Tending Livestock	42% *(36%)*
Health / Emergencies	41% *(23%)*

(Values in parentheses indicate the percentage of respondents performing a given task)

We were curious about the potential for tasks to be ranked differently depending on whether the respondent was female or male. Given that household tasks are distributed differently between men and women, we expected to see a different prioritization of needs between male and female respondents. However, because the vast majority of our respondents were male, any comparisons were difficult to make. For example, even though cooking is generally done by women, only four female respondents gave any information about cookng. This sample size is far too small to be representative, but similar median cooking times were reported by both women and men.

Finally, based on this needs assesment, we can draw the following conclusions:

- Common and difficult-to-perform tasks, such as cooking and security, are among the top lighting needs for nearly every household.
- Occupation-specific lighting needs can be quite substantial for those who perform light intensive tasks, such as handicrafts and animal husbandry. From our interviews, we believe that lighting may be a significant barrier for these tasks. Indeed, the reason that only a small number of families perform these tasks at night may be related in part to the poor quality of light from existing sources.

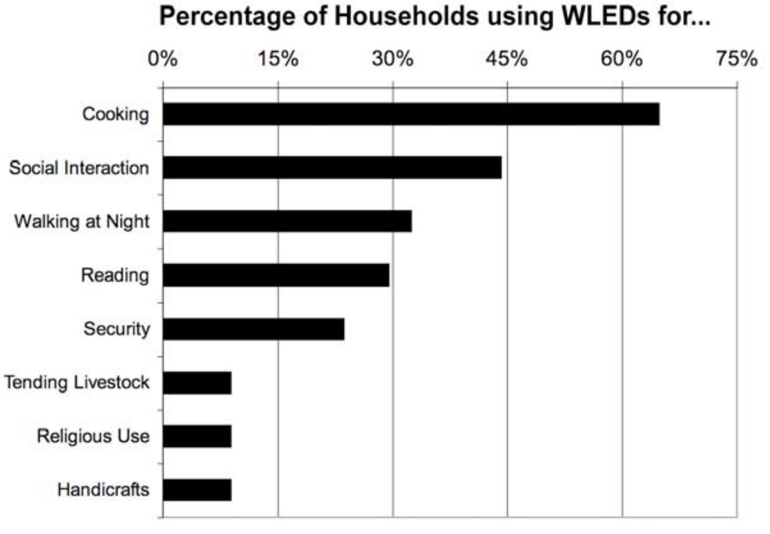
Lighting-Related Expenditures

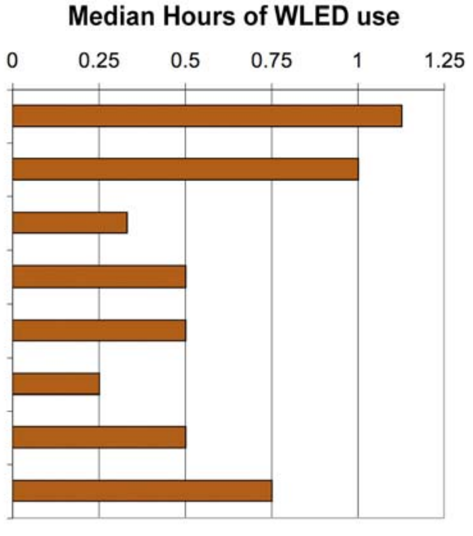
Based on informal survey questions, we estimate household incomes of respondents to be in the range of Rs 1000 to 3000 / month ($25 - $75 / month). A significant methodological difficulty in assessing income has to do with the seasonality of income. Most respondents reported that income varied substantially from season to season. Work tended to be hardest to come by during the monsoon season, with winter and summer providing relatively better income. Due to the particular time we visited the respondents (monsoon season), we found it was diffcult to obtain accurate estimates of income.

Like income, we have anecdotal evidence that lighting use is somewhat seasonal. Generally, respondents reported using more light during the rainy season and winter than in summertime. However, this may not have a strong affect on lighting expenditures. Nearly every household interviewed reported using their complete subsidized kerosene allotment of 10L at the typical price of Rs 9.5/L. We found that the median household kerosene expenditure was Rs 90 (~$2) / month. Quite in contrast to our initial expectations, households using rechargable battery lamps (such as Kisan torches) appeared to be able to charge their lamps at no cost. Households using dry-cell battery torches were unable to give very reliable estimates on battery usage and costing, but our impression is that their expenditures for batteries are in the range of Rs 50 – 100 / month. Thus, total household expenditure for lighting is typically in the range of Rs 100 – 200 /month. Based on these data, it appears that households spend between 3% and 10% of their monthly income on fuel and batteries.

Exit Survey Results

The following charts give a high-level overview of usage patterns reported for the four WLED products over the 8 – 11 day test period. As can be seen, cooking was the dominant use for the WLED lamp, with 65% of households using the lamp, with a median usage duration of 1.1 hrs. Other key uses included social interaction, walking at night, and reading.





For all tasks, respondents nearly uniformly indicated that the lamps they tested were bright enough for the task at hand. Likewise, respondents uniformly indicated that the lamps made every task they reported easier to do. However, most respondents were clear to indicate that different products performed better at some tasks than others, something that we discuss in our product recommendations section. Thus, while the WLED products were clearly considered to be an improvement over existing products, they were not always sufficiently bright for every task to be completed with ease.

Finally, we surveyed respondents about potential willingness to pay for WLED products. The results from these questions are summarized in the "Pricing and Business Model" section.

Recommendations

Products

We collected feedback on each LED product during the exit survey and shared the details with the respective product manufacturers. Since we are masking product names and manufacturers in this report, we will not present those product-specific findings here. However, there are some universal product related issues that apply to this market segment as a whole, which we present below.

1. Even the among the poorest communities there is room for more than LED product. In fact, designing different lights for different uses appears to be a more effective marketing method than an attempt to make one product that is highly versatile. This is because the extra versatility is likely to take the product beyond many customers' willingness to pay for it.
2. It is crucial for every product to clearly indicate multiple battery charge levels beginning as early as four hours before full discharge. Since, charging may involve substantial costs (a trip to town, etc.) it is a great advantage to the family to be able to prioritize light use based on how many hours of light they have left.
3. Providing an option to charge directly using DC power is another inexpensive adaptation that will make the product substantially more attractive. Once again, since the cost associated with charging can be substantial, versatility in charging options is a highly valued feature.
4. A light that doubles as a universal charger can probably capture a large market since many rural areas in India now have mobile phone coverage. However, the success of such a product will depend inversely on the price premium for this feature.
5. Variable light settings are another feature that is highly valued and since this is inexpensive to design using LEDs, this feature will have a very high benefit-cost ratio.
6. Longer power cords are also valued since wall outlets are frequently found at inconvenient locations.
7. Switches are the most common point of failure in rural areas and hence they must be designed to be very durable and rugged.

Pricing & Business Model

Pricing

During the exit survey, we sought to identify respondents' willingness-to-pay (WTP). Specifically, responders were asked the following question: *What do you think is a fair price to pay for the LED light, NOT including charging?* See table to the right for overall breakout. See Appendix D for a breakout of individual responses by product.

Lamp /# responses	Min	**Median**	Max
Product A (17)	100	**300**	1000
Product B (9)	250	**450**	4000
Product C (5)	1500	**1750**	2750
Product D (3)	400	**550**	1000

In analyzing these results, two important considerations are worth mentioning. First, the total sample size of 34 (as well as the sample sizes among the 4 products) is not large enough to make strong claims. To that end, the absolute numbers for WTP are less important than their relative ranking. From our initial household survey, we determined that the median household expenditure for kerosene was Rs 90 with an additional expenditure of Rs 50 - 100 per month by households using the Kisan torch. The WTP figures for all the WLED products tested are higher than current monthly household expenditures for lighting, suggesting that people do assign a higher value and premium on the services offered by the WLED products.[2]

Second, the prices people stated do not include the cost of charging. The question of charging costs merits further research and analysis. Given the limited time of our study's product testing (the range was 8 -11 days), survey responders did not have adequate time to experience and react to the potential costs (time and financial) associated with charging. In all but two cases, the products still had charge left when we returned to collect them and conduct the exit survey. Consider, too, the following verbatim from a Paiya survey responder who was testing the Product D (he did not receive the solar charger attachment for the product). He noted that he hardly used the light because he didn't know how long it would last. He said that he can only make a trip to town every 10 days and pays Rs 5-10 for charging, so he would prefer solar to avoid this.[3] From our initial household surveys, it appears that there is much variation in the difficulty and cost for charging existing products (such as cell phones and Kisan torches). In some cases, people are able to charge these devices for free at local stores, such as the Chai shop across the street from the Sudhamavaas. In other cases, people are easily able to charge in town for a small fee (5 - 10 Rs). Additional research around charging is warranted.

Business Model Implications

While the total cost of ownership for WLED products is lower than existing lighting options, these products do require a larger upfront capital investment – an amount which is not insignificant for households whose incomes averaged between Rs 1000 – 3000 per month. To that end, we asked questions during the exit survey to gauge potential interest in renting and/or installment pay options.

Interestingly, we discovered a very strong aversion to renting: 26 of the 34 responders said that they were not interesting in renting the light. In some cases, the interviewer did ask a follow-up question to try to understand why the responders were not interested in renting.

The following verbatim (translated) noted:

- Not interested in renting since product is not worth enough to rent
- Does not want to rent since children might break light
- Value perceived to be too low to rent
- Concerned about breaking and having to pay for it

For household use of WLEDs, ownership is preferred to renting.

[2] Interestingly, the median price for the Product C was three times the actual cost we paid for it.
[3] Given the small size of the community, it is highly likely that he saw the other products being tested by neighbors. For example, during exit interviews, many responders couched their product feedback with comparison to the other products being tested in the village, (this product is bright, but not as bright as <other product>.) In the case of his comment about preferring solar, it is likely that he saw Product A, which has a solar panel integrated into the product design.

Upfront Payment vs. Installments?

The answers to the option for installment payments were more varied. Payment preferences depended on the actual product price. For example, two responders noted that if the price is less than Rs 500, they would prefer to pay all at once. Again, depending on the price, said they would prefer the range of weekly or monthly payments. Some key insights:

- Ten out of the 34 responders replied that they were not interested at all in an installment payment plan option.
- When asked whether they would prefer to pay upfront or in installments, 12 out of the 34 preferred installments.
- Preferred frequency for installment payments varied from daily to weekly to monthly.
- From a village perspective,
    - Sudhamavaas - 3 households out of 18 wanted to own after paying installments.
    - Paiya - 9 households out of 16 wanted to pay in installments; rest wanted to own outright

A subsequent discussion with members of our local NGO partner, Sahjeevan, was instructive. Sahjeevan had mixed results from an experiment with an installment model for a solar CFL light system with PV panel. The experience in Paiya suggests some optimism around this business model. The Paiya paid Rs. 4,950 for a communal solar lantern for their mosque. They paid in three installments, which were repaid on-time – early, in fact. However, when Sahjeevan attempted a similar model with smaller, solar CFL system for households in Sudhamavaas, there, were extensive problems with late payments. In fact, some late penalties became as high as the payments themselves. Sahjeevan noted that many issues arise when a NGO tries to sell to a community they serve. Because of potential conflicts of interest, many NGOS prefer to avoid selling products directly to the communities.

Product Guarantee

One Paiya survey responder who tested the Product A commented that he was not interested in owning if there is no guarantee. Interestingly, during our project debrief with the Sahjeevan renewable energy unit, a similar concern was voiced regarding product guarantees. The issue of product guarantees will be further explored in the next section.

Sales and Distribution

In order to better understand key components to the retail environment, we spoke with a lighting retailer in Bhuj, the provision storeowner in Paiya, the provision storeowner in Sudhamavaas, and the owner of the Sudhamavaas Chai shop.

Profit Margins

While the final exit survey captures some key insights about customers' WTP, the expected sales margins of local distributors is another key pricing consideration. Profit margin expectations vary by customer type, according to storeowners. They segment customers into two main categories: retail and regular (e.g.: frequent customers with whom they have a relationship). Few found that for retail customers, they expect to make 20 – 30% margins over wholesale prices. In contrast, for regular customers, they expect only a 10% margin over wholesale. Product manufacturers should keep these profit margin expectations as they consider the cost of goods for their products as well as customer WTP.

Credit Options
Retail customers are expected to pay with cash. However, regular customers may also be extended credit. Credit terms vary by individual store and business. For example, terms might be 8 – 15 days or 1 to 2.5. We did not get any data on what, if any, interest fees may be charged on this credit. There are, of course, some instances of loan default.

Supply chains
To reach more remote areas, it is important to understand how local distribution networks work as well as to tap into the powerful word-of-mouth marketing that surrounds them. Storeowners hear of suppliers mainly through the owners of other similar shops. Frequently, suppliers are located very far away (> 500 km) and goods are delivered over poorly paved roads by truck where they are poorly secured and so, can suffer damage or theft enroute.

Product Guarantees
Product guarantees – typically for 6 months – are common, especially as a benefit that storeowners will extend to regular customers.

Lessons learned from fieldwork

In order to assist future researchers in designing their fieldwork, we have compiled list of key lessons that we learned in executing our fieldwork in Gujarat. This list is not meant to be exhaustive and is very specific to the cultural context of rural Gujarat.

1. When asking questions pertaining to a particular light, place it in full view of the respondent so you can frequently point to it when needed.
2. It is almost impossible to conduct one-on-one interviews so this should be kept in mind when designing surveys and in framing of questions to ensure that you can filter out the respondent’s answer as separate from the onlookers.
3. It is extremely difficult to create unbiased interview conditions for women. The best way to interview women is to isolate them and have the interview conducted by female interviewers.
4. It is important to make sure that translators have a very clear understanding of each question.
5. Surveys should not take more than 20 minutes to administer.
6. It appears to be more effective to quantify income through consumption rather than by directly inquiring how much income a person or family receives.

Areas that need further research

Given our relatively small sample size and the limited duration of the lamp tests (8 – 11 days between initial and final surveys), there is ample scope for future work. Future survey work should aim to address the following questions:

Willingness to Pay
Although survey respondents indicated a substantial willingness to pay for WLED products even after our short 8-11 day product test period, we anticipate that a longer product test may allow for more accurate estimates of willingness to pay. Some important determinants of willingness to pay include:

Charging - As mentioned earlier, charging options and costs are an important aspect to providing WLED light delivery that merit further research. Since respondents were not responsible for charging lamps in this test, their reported WTP may not reflect the costs associated with charging and maintenance for the lamp.

New opportunities to engage in income-generating activity - Improved lighting may make certain income generating activities possible that were not previously feasible. We expect that users would only recognize the value of improved lighting for such activities slowly and over time. Future studies may be able to more carefully observe the value that users would place on the ability to engage in income generating activities.

Method of eliciting WTP – Different techniques for eliciting willingness to pay are likely to result in different reported WTPs. Future studies may wish to operate on a "kiosk" model, where after some initial trial period, users are given the opportunity to purchase lamps with their own money. By varying the price of the lamp, maximum willingness to pay can be determined. This method has the advantage that since an actual transaction is taking place, willingness to pay is actually revealed, as opposed to stated in an interview setting, where answers may or may not be truthful.

Gender dimensions of lighting

Our study was unable to capture the household gender dynamics of lighting, but we recognize that these are potentially important issues worthy of study. A key barrier for us was the small number of female respondents in our survey. Furthermore, our few female respondents often appeared unable to voice their opinions when in the company of their male relatives. Future studies should attempt to "sub-sample" a larger set of women, who may have different priorities for lighting than those expressed by men.

Effects of lighting on household activities

It is not unreasonable to expect that over the longer term, a high-quality and consistently available light source may lead to changes in household activities. For example, for want of a high quality and affordable source of light, many survey respondents went to bed shortly after sundown (before 9pm). If high quality light were available, perhaps people would be able to engage in cottage industry (eg, handicrafts) after dark. A long term study could be very useful for exploring how the availability of light changes household economics and behavior.

Appendix A – Community-level Survey

Respondent Name:
Organization:
Name of town/village for survey:
Local currency:

1. **Grid availability**
    a. **Grid available?(Please circle)** **Yes** **No**
    b. **Micro-grid available? (Please circle)** **Yes** **No**
    c. **Generator available? (Please circle)** **Yes** **No**
    d. **Describe available infrastructure**

    ____

    ____

    ____

    ____

2. **On average, how often do villagers experience power cuts? (Please circle)**
    a. Several times a day
    b. Once a day
    c. Once a week
    d. Once a month
    e. Not sure

3. **Is there cell phone access in your village? Yes No**
    a. **What percent of villagers have cell phones?** __________

4. **How much do the following cost? (Note: researchers will survey prices while in field as well)**
    a. Kerosene per liter ________
    b. LPG per liter ________
    c. Diesel per liter ________
    d. Most common size candle (in kg) ________
        i. Cost/candle ________
    e. Most common type of battery ________
        i. Cost/battery ________
    f. Most common type of biomass ________
        i. Cost/kg ________
    g. Electricity per kWh ________

5. **What percentage of villagers would you estimate have completed the following level of education (out of 100 percent):**

    a. Grades 1-6 ________%
    b. Grades 7-12 ________%
    c. Trade School or Vocational Training ________%
    d. College or University ________%
    e. Never attended school ________%

6. **What percentage of villagers have basic literacy (can read and write)** ________%

7. **If you had to choose, which would you say are the three most important concerns to families in the village? (Please mark 1 for most important, then 2, and 3)**
    a. Access to safe drinking water ________
    b. Sanitation or clean conditions ________
    c. Access to adequate, safe food ________
    d. Education ________
    e. Lighting ________
    f. Personal safety ________
    g. Paying off Debt ________
    h. Other ________
    i. Not sure or no answer volunteered ________

8. **Which activities do villagers use current light sources for? (Indicate Y/N)**
    a. Reading ________
    b. Cooking ________
    c. Social interaction (eating, talking, ...) ________
    d. Handicraft work ________
    e. Outdoor work ________
    f. Security/Nightlight ________
    g. Walking at night ________
    h. Night time travel (e.g. to night markets) ________
    i. Religious/decorative uses ________
    j. Community rooms ________
    k. Classroom or study hall ________
    l. Retail ("selling") ________
    m. Manufacturing (low-tech factory/assembly contexts) ________
    n. Night markets [vendor-provided versus centralized lighting] ________
    o. Clinic ________
    p. Tending to livestock (e.g. chickens, cattle) ________
    q. Night fishing ________
    r. Preparing the bed
    s. Other (Please specify activity) ________________ ________
    t. Not sure (or no answer volunteered) ________

9. **Who most often procures lights and fuel/charging for these products?**
    a. Male head of household (Father)
    b. Female head of household (Mother)
    c. Children
    d. Neighbors
    e. Village middle-man
    f. Other (please describe) ____

10. **Where do they purchase these lights? (kiosks, market, etc.)**

    ____

11. **Where do they purchase fuel or where are the lights charged? (Is it the same place?)**

    ____

12. **How far away are these places? ____**
13. **What is the frequency of trips to these places? ____________________________________**
14.

a. What, if any, electricity sources are available to charge batteries in the village?

____

____

b. If available, what is the cost of charging?

i. per kWH ________
ii. per minute ________
iii. Other(Please specify) __________________ ________

15.

a. Do people use products [not only lights – products in general!] on a “pay-to-charge” or "rent-to-own" basis? (Are they familiar with this concept?) (Please circle)

Yes No

b. Please describe how this system works

Appendix B – Household Initial Survey

PART I: INITIAL SURVEY FOR ALL TECHNOLOGIES

FOR USE BY SURVEY TEAM

Survey SERIAL Number ____-____-____-____- 1

Format: *<Village> - <Household> - <Iteration> - <Respondent ID> - 1 (Initial Survey)*

Respondent Number ________ (Usually 1 unless this is a different person than last time)

Surveyor's name, email, phone: ____________________________

Survey Date: __________ **Informed Consent Granted?** _______

Location of home: ________________________________

Lamp number provided to household during this visit ______

1. **Name of respondent** ____

2. **Age of respondent** ____________________

3. **Gender of respondent (please circle)**
   Female Male

4. **Cell Phone Usage**
   a. Respondent owns cell phone (please circle)
      Yes No
   b. If yes, how often do you charge your cell phone? _____
   c. How much does it cost per charge? _____

5. **Respondent owns radio (please circle)**
   Yes No

6. **Respondent owns television (please circle)**
   Yes No

7. **Access to grid through electricity service (please circle)**
   Yes No

8. **Access to micro-grid (please circle)**
   Yes No

9. **Household Size**
   a. How many people sleep here and take meals here on a regular basis? _________
   b. Of the household members from 9a., how many are children under age 18? _________
   c. How many of these children under age 18 currently attend school regularly? _________
   d. How many of these children are too young to go to school? _________

Questions about Lights:

Questions 10- 18 should be answered in the chart on the following page..

10. Which types of light do you currently use? (One option is to show a picture card. Another option is to ask them to show you all the light sources that they use. Circle all the answer(s) for which respondent indicates '"yes.")

For each of the types circled in the chart, please answer the following questions.

11. How many lamps of this type are owned by your household?

12. Where did you purchase the lamp? (If more than one place, please indicate what they bought where.)

13. How often do you need to replace this type of light (in years, months, etc…) ?

14. What is the main fuel source that you use for your light? (Some of these answers may include the following items.)

a. LPG
b. Diesel
c. Kerosene
d. Biomass (Please specify – e.g.: wood, dung, crop residues, charcoal) ________________
e. Rechargeable battery (Please include type e.g. 6V or 12V) ________________
f. Dry Cells
g. Solar
h. Electricity from grid
i. Electricity from local generator
j. Other (Please specify)

15. Are there any other ways that you fuel this light / charge this light?

16. How many hours a day do you use this light?

17. How often do you refuel / recharge this light?

18. How much fuel do you use when you refuel / recharge this light?

10. Light Sources	11.	12.	13.	14, 15.	16.	17.	18.
	Number Used?	Where purchased?	How long does light last?	What fuel does light use? [Main, Secondary]	Total Hrs/Day Used?	How often do you refuel / charge it?	How much fuel used per charge / fueling?
A. Flashlights ("Torches")							
B. Kerosene Simple cylindrical wick lamp ("tin")							
C. Kerosene standard hurricane lantern							
D. Kerosene pressurized lantern							
E. Candles							
F. Battery Powered Lamp							
G. Incandescent bulb							
H. CFL bulb							
I. Television (if used as a light source)							
J. Other:							

Questions about Fuel

Important: By fuels in this part, we mean fuels used for ANY use, not just lighting.

19. How much "fuel" do you normally purchase at once for all uses, not just light? How much does it cost for that amount? How many days does it last?

		Amount	Cost	Fuel Lasts
a.	LPG	________	________	_______ days
b.	Kerosene	________	________	_______ days
c.	Diesel	________	________	_______ days
d.	Biomass:	________	________	_______ days
	Type (*wood, etc.*):	____		
e.	Rechargeable battery	________	________	_______ days
f.	Dry cells	________	________	_______ days
j.	Other (Please specify)	________	________	_______ days

Uses for Light

Questions 20- 25 should be answered in the chart on the following page.

20. What activities do you use light for? Ask about each item in the chart. (Circle all that apply).

For each activity where the answer is "Yes", ask the following questions:

21. How many hours per day do you use light for this activity?

22. What is your *primary* source of light for this activity? (Indicate ONE answer for the main lighting source. Use the picture card as necessary.)

23. Are there *any other sources* of light that you use for this activity? (Indicate ANY answer(s) for which respondent indicates "yes".)

24. Is this activity easy or hard to do with your current source of light?

Ask this question only AFTER answering 22-25 for each task that they do.

25. If you had additional lights, what would you use them for? (Circle all the answer(s) for which respondent indicates '"yes.")

20. Uses of Light	21.	22.	23.	24.		25.
	Hours per day?	**MAIN** Light source	**OTHER** light sources	Easy?	Hard?	Uses for additional lights?
A. Reading/studying						
B. Cooking						
C. Social interaction						
D. Handicraft work						
E. Outdoor work						
F. Security / Nightlight						
G. Walking at night						
H. Night time travel (e.g. to night markets)						
I. Religious/ decorative uses						
J. Community rooms						
K. Classroom or study hall						
L. Retail ("selling")						
M. Manufacturing (low-tech factory/assembly contexts)						
N. Night markets [vendor-provided versus						

centralized lighting]						
O. Clinics						
P. Tending to livestock (e.g. chickens, cattle)						
Q. Night fishing						
R. Preparing the bed						
S. Other (Please specify activity)						
T. Not sure (or no answer volunteered)						

Appendix C – Household Exit Survey

PART II: EXIT SURVEY FOR SINGLE PRODUCT USE

FOR USE BY SURVEY TEAM

Survey SERIAL Number ____-____-____-____- 2

Format: *<Village> - <Household> - <Iteration> - <Respondent ID> - 2 (Exit Survey)*

Respondent Number ________ (Usually 1 unless this is a different person than last time)

Enumerator's name, email, phone: ____________________________

Survey Date: __________ **Informed Consent Granted?** _______

Location of home: ________________________________

Lamp number provided to household during this visit ______

1. **Total number of hours the LED was used each day? ________**

Questions 2-6 should be answered in the chart on the following page.

2. **What activities do you use light for? Ask about each item in the chart. (Circle all that apply).**

For each activity where the answer is "Yes", ask the following questions:

3. **How many hours per day for this activity?**
4. **Previous source of light for this activity or new activity?**
5. **Easier or harder than previous source of light?**
6. **Is the light bright enough for this activity?**

2. Uses of LED Light	3. Hours per day?	4. Previous source of light, or new activity?	5. Easier or harder than previous light source?	6. Was the LED light bright enough?
A. Reading/studying				
B. Cooking				
C. Social interaction				

D. Handicraft work				
E. Outdoor work				
F. Security / Nightlight				
G. Walking at night				
H. Night time travel (e.g. to night markets)				
I. Religious/ decorative uses				
J. Community rooms				
K. Classroom or study hall				
L. Retail ("selling")				
M. Manufacturing (low-tech factory/assembly contexts)				
N. Night markets [vendor-provided versus centralized lighting]				
O. Clinics				
P. Tending to livestock (e.g. chickens, cattle)				
Q. Night fishing				
R. Preparing the bed				

S. Other (Please specify activity)				
T. Not sure (or no answer volunteered)				

7. Who used the LED product? (circle all)

A. Me
B. My husband
C. My wife
D. My children
E. Other family members (please specify)
F. Neighbor / other household
G. Not sure/no answer

Questions 8-10 should be answered in the chart on the following page.

8. What other light sources do you continue to use?

9. How many hours a day did you use each source of light?

10. Did you use each source of light more, less, or the same?

	8. Still Use?	**9. Hours/day**	**10. More**	**Less**	**Same**
A. Flashlights ("Torches")					
B. Kerosene Simple cylindrical wick lamp ("tin")					
C. Kerosene standard hurricane lantern					
D. Kerosene pressurized lantern					
E. Candles					
F. Battery-powered Lamp					
G. Incandescent bulb					
H. CFL bulb					
I. Television (if used as a light source)					
J. Other:					

11. What do you like MOST about this LED product?

12. **What do you like LEAST about this LED product?**

13. **What, if any, problems have you had with the LED product?**

14. **Overall, how much do you like the LED product? Would you say the product is:**
    a. Very good
    b. Good
    c. Neutral
    d. Bad
    e. Very bad
    f. Not sure or no answer volunteered

Orient interviewees that there are several purchasing options that we want to discuss.

15. **If you were to be provided this LED product as a RENTAL….**

    a. How often would you like to pay for the rental service, INCLUDING charging?

    [Daily] [Every Week] [Every 2 Weeks] [Monthly] Other _____________

    b. What do you think is a fair price to rent the WLED light each XXX? (Be clear about terms of this "deal" - this is a renting model)

    c. At this price, how many would you rent? ______________________________________

16. **To own this product….**

    a. What do you think is a fair price to pay for the LED light, NOT including charging?

    b. At this price, how many would you buy? ______________________________________

17. **If you could own this product by paying in installments…..**

    a. How many installments would you like to pay in, and how frequently?

    b. How much do you think would be a fair price to pay for the light in each installment?

18. **Which option do you prefer?** (circle)

    [Rent] [Own with one time payment] [Own with installment payment]

19. **Income questions**

    a. How often does your household get income?

    [Daily] [Every Week] [Every 2 Weeks] [Monthly] Other _____________

    b. Does your income vary by season? How so?

c. List income sources and amount each month:

OPTIONAL QUESTIONS:

20. Does your family get income from handicraft work?

a. How much do you make per piece? ___________
b. How much time does a piece take to make? ___________
c. How many pieces do you make each week? ___________

21. If you have a cell phone

a. How often do you add credit to the SIM card? ___________
b. How much credit do you usually add to the card? ____________

22. What sorts of things does your household rent? How often do you pay for this and how much?

23. If family owns vehicle, how much do they spend on maintenance and fuel each week?

Appendix D Willingness to Pay (Individual Responses by Product)

Exit Survey Question
What do you think is a fair price to pay for the LED light, NOT including charging?

	Product			
	Product A	***Product B***	***Product D***	***Product D***
Survey Response	200	4000	1750	400
	150	450	1750	1000
	400	1000	2750	500
	500	500	2250	
	150	400	1500	
	100	400		
	450	375		
	300	250		
	150	450		
	200			
	350			
	500			
	500			
	150			
	300			
	1000			
	150			
Median	**300**	**450**	**1750**	**500**

Appendix E
Exit Survey: *How did existing product use change with WLED product?*

PRODUCT A

Kisan Torches
- 10 still used them (9 used it less, 1 the same)
- 1 did not use it

Chimney
- 10 still used it (6 used it less, 4 the same)
- 5 did not use it

Hurricane
- 8 still used it (5 less, 3 the same)
- 2 did not use it

Dry Cell flash
- 1 still used it (same)

17 Product A Exit Survey responders: 14 males, 3 females

PRODUCT B

Kisan Torches
- 2 still used it
- 1 less, 1 the same as before

Chimney
- 2 still used it
- Both used it less than before

Hurricane
- 1 still used it
- Used it less than before

9 Product B Exit Survey responders: 6 males, 3 females

Appendix E – continued
Exit Survey: *How did existing product use change with WLED product?*

PRODUCT C

Kisan Torches
- Nobody reported still using it

Chimney
- 1 still used it
- Used it same as before (i.e.: continued to use it overnight)

Hurricane
- 1 still used it
- Used it same as before

Candles
- 1 still used it
- Used it same as before (i.e.: continued to use it overnight)

Other – LED penlight
- 1 still used it
- Unknown whether usage changed

5 Product C Exit Survey responders: 5 males

PRODUCT D

Kisan Torches
- 1 still used it
- Used it the same as before

Chimney
- 1 still used it
- Used it less than before

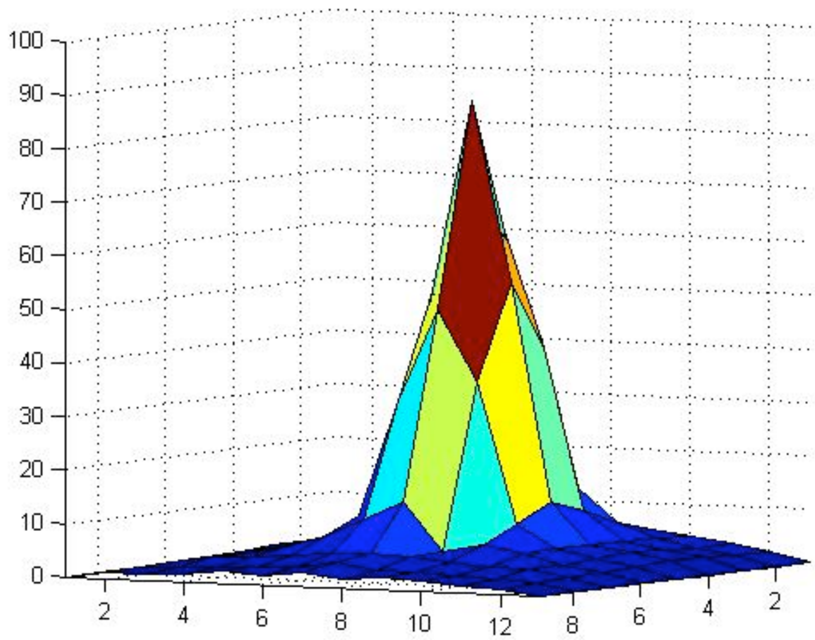
Hurricane
- 1 still used it
- Used it less than before

Other – LED penlight
- 1 still used it
- Used it less than before

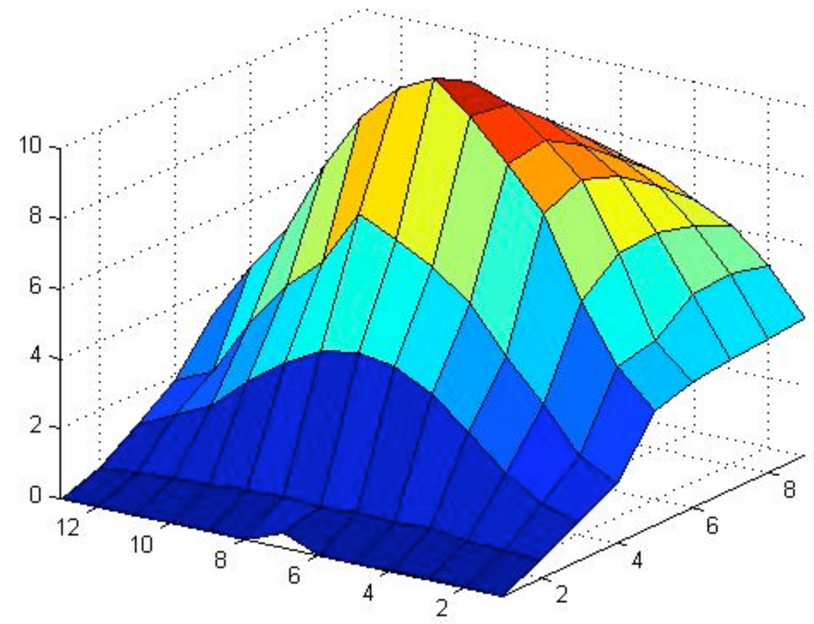
3 Product D Exit Survey responders: 1 male, 2 females

Appendix F – Lamp Test Results

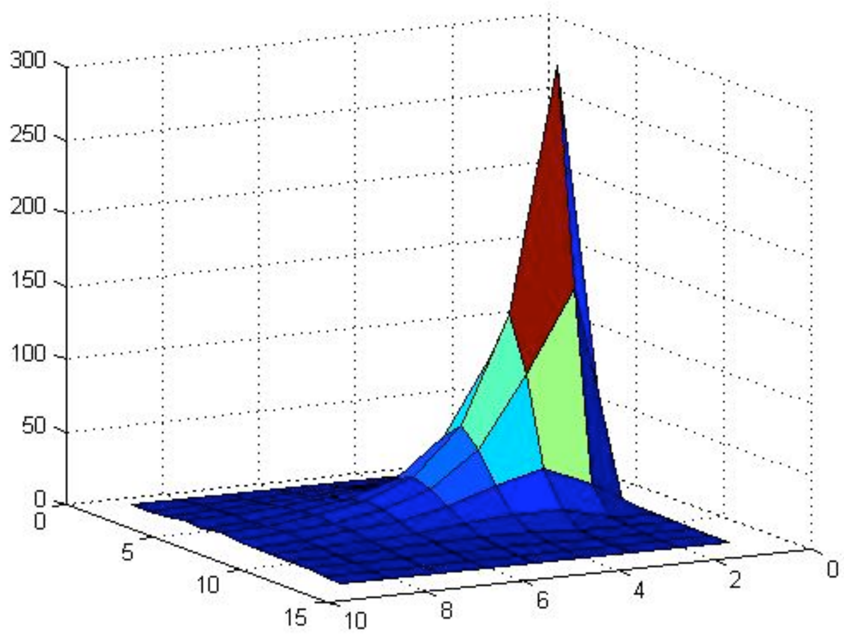
Product A



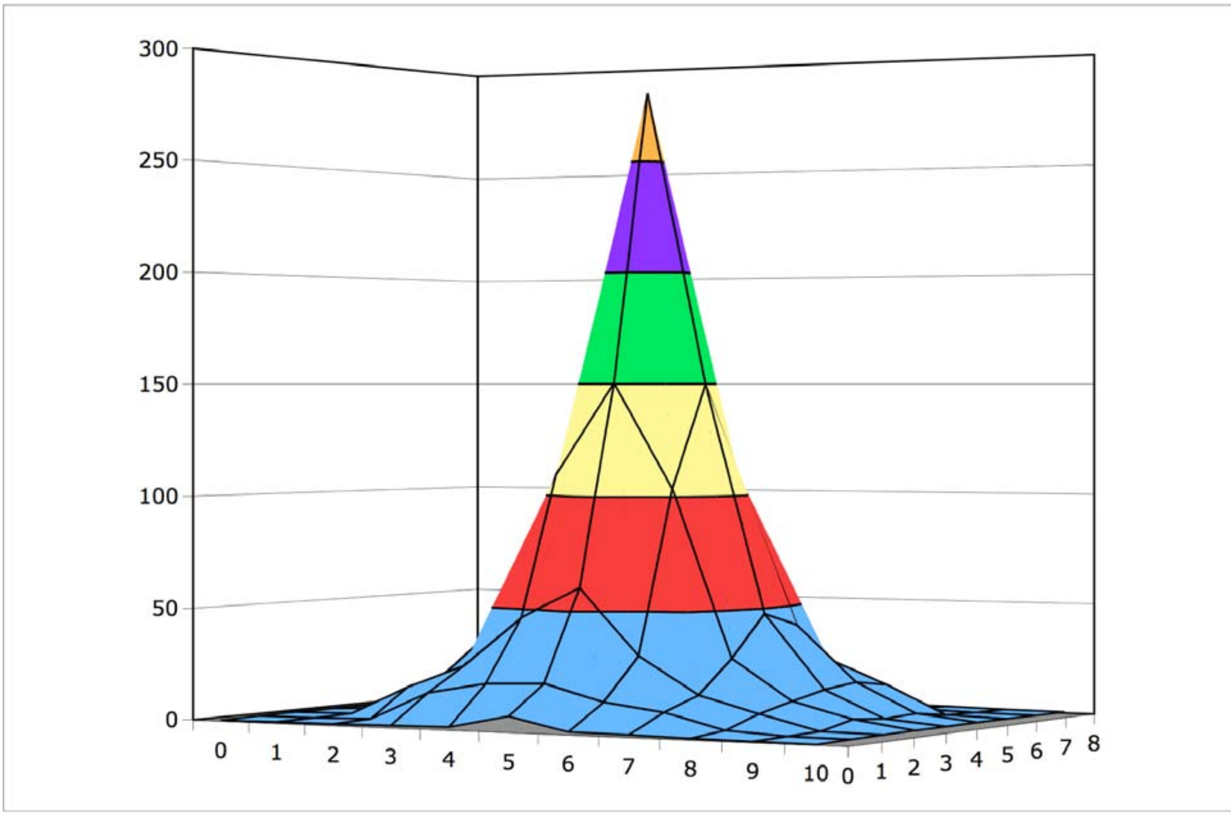
Product B – (pointed at table, 1 m away)
This LED tasklight puts out diffuse light if hung 1m from the table (note that it is made to point down so we did not measure lux when pointed at the wall). The scale is small; however, this light is not really designed to be this far away from the surface it lights up.



Product B – (on table)
When placed directly on the table this light project most of its light onto a very small amount of the space.



Product C



Product D
Product D had the most uniform light distribution of all the products we took to the field. There were no sharp spikes (which imply glare) with usable illumination even at the edges.