Consumer Preferences for Off-Grid Lighting Products

Insights from a Study in Bihar and Odisha

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INDIA

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Executive Summary

Nearly 400 million people in India do not use grid electricity as their primary source of lighting. According to the Census of India, 2011, 43 percent of rural households still use kerosene as a primary source of fuel for lighting. A variety of modern off-grid electric lighting technologies have emerged globally over the last decade. These technologies are popular because they are cost-effective, robust, and use small amounts of energy. The emergence of a large market for these technologies has led to efforts to develop the market for them.

IFC's Lighting Asia/India program is a market-transforming program aimed at promoting, both in value and presence, modern off-grid lighting among the off-grid population in rural India. Modern off-grid lighting includes solar lighting appliances, home systems, and connections to renewable energy mini-grids. The program is designed as a series of interventions to alter market behavior by removing specific barriers that include market spoilage created by poor products, lack of information on distribution channels, lack of financing for companies and consumers, and lack of awareness that quality solar appliances are affordable, viable solutions.

This study on consumer preferences was undertaken by to the Lighting Asia/India Program to gain insight into consumer expectations from products on parameters such as brightness and daily hours of use. This, in turn, will help manufacturers make product design decisions and distribution companies select which products they should carry. The information in this study will also help organizations, from development institutions with energy access programs to private sector companies, to better understand the benefits of introducing clean off-grid lighting technologies.

This study is based on focus group discussions (FGDs) conducted in India's Bihar and Odisha states during February and March 2013 to gain insight into consumer preferences for off-grid lighting products. Field sites were selected to determine whether preferences varied significantly between regions with different characteristics. While both states have large off-grid populations, income levels and population densities in the study area in Bihar were significantly higher. Twelve FGDs were conducted in these two states involving 113 respondents.

Below are some of the key results of the field study:

- **On an average, daily number of hours (run-time) that respondents expect from an off-grid lighting product is 6.3 hours.**
- **85 percent of respondents would be satisfied with a low-cost lamp that provides at least 25 lumens of light for room lighting applications. Similarly, around 85 percent would be satisfied with a low-cost lamp that provides at least 40 lux on a task surface for applications such as reading.**[1]
- **Women preferred higher minimum illuminance levels for task lighting than men.** The average minimum illuminance level for women in the focus groups was 35 lux, while the average for male respondents was 20 lux. This result was statistically significant at 99 percent confidence level.
- **In comparison to a five-country Africa study, the minimum ambient brightness preferences in this study were somewhat higher than the countries surveyed in Africa.** This difference is reversed for task lighting, where, on an average, respondents in India were satisfied with lower minimum task lighting levels.[2]

1 The lumen is a measure of total amount of light produced by a light source in all directions. A typical candle produces about 12 lumens of light. The lux is a metric of illuminance. It is the amount of light that is incident on a surface. One lux is equivalent to one lumen per square meter. The note is available at http://www.lightingglobal.org/download/category/4-briefing-notes?download=22:light-emitting-diode-led-lighting-basics-technical-note-issue-0.

2 Lighting Global (2013),Minimum Quality Standards and Recommended Performance Targets for Lighting Global, Lighting Africa, and Lighting Asia/Stakeholder Outreach for Program Transition, June 7, 2013.
Available at http://www.lightingafrica.org/index.php?option=com_docman&task=doc_download&gid=448&Itemid=

- **The five most common purchase decision criteria, besides product cost, were brightness, warranty terms, robustness, ability to charge mobile phones, and run-time.**
- **The three main sources of light used by respondents in Bihar and Odisha were hurricane lamps, simple wick lamps, and flashlights.**
- **Kerosene use for lighting varied greatly between respondents of the two states.** On an average, respondents in Bihar reported using 5.7 liters of kerosene while respondents in Odisha used 3.7 liters.
- **The average cost of kerosene under subsidy was relatively similar in the two states.** Approximately Indian rupees 18-19 ($0.28-0.30) per liter; however the reported unsubsidized market price of kerosene in Bihar was Indian rupees 40 ($0.64) per liter, as compared to Indian rupees 25 ($0.40) per liter in Odisha.[3]
- **In Bihar, around 53 percent of respondents used mobile phones, against 12 percent in Odisha.**

3 $1 = Indian rupees 62.43 (February 12, 2014; Reserve Bank of India)

Background

Nearly 400 million people in India do not use grid electricity as their main source of lighting. According to the Census of India, 2011, 43 percent of rural households still use kerosene as a primary source of fuel for lighting. A variety of modern off-grid electric lighting technologies have emerged globally over the last decade. These technologies are popular because they are cost-effective, robust, and use small amounts of energy. The emergence of a large demand for these technologies has led to efforts to develop the market for them.

This study on consumer preferences was undertaken by to the Lighting Asia/India Program to gain insight into consumer expectations from products on parameters such as brightness and daily hours of use. This, in turn, will help manufacturers make product design decisions and distribution companies select which products they should carry. The information in this study will also help organizations, from development institutions with energy access programs to private sector companies, to better understand the benefits of introducing clean off-grid lighting technologies.

Field research was carried out in February and March 2013 to collect information on consumer preferences in off-grid lighting products for the Lighting Asia/India Program, the Lighting Global quality assurance framework, and other stakeholders in the off-grid lighting market.[4] The study was conducted across a cross-section of markets in Bihar and Odisha states, which have large potential markets for clean off-grid lighting solutions.

The sample size of people and regions was not large enough to confirm whether the results are broadly representative of the off-grid population in India. The study can, nonetheless, provide key insights. For example, if results indicate that consumer preferences in relation to a particular parameter are consistent across the two sites, it could suggest a broadly-held perspective. In contrast, if results indicate substantial differences across the sites, it could suggest that variations in income, culture, or other factors are important for the parameter in question.

The information collected in these markets is useful for policy decisions related to quality assurance and consumer outreach activities for the Lighting Asia/India program. It can also provide manufacturers and vendors of off-grid lighting products with information about consumer requirements and preferences. Insights on common purchase decision criteria of end-consumers are useful in companies' branding and marketing strategies. Data on consumer expectations of off-grid lighting product performance parameters such as brightness and daily hours of operation can help manufacturers make product design decisions and help distribution companies select which products they will carry.

In addition, this study provides baseline information on monthly income, kerosene consumption, and currently used traditional lighting technologies. This provides broader context of the potential end-users who participated in the study. The study also includes information on mobile phone use. This is relevant as many off-grid lighting systems provide mobile phone battery charging options, which has emerged as a key value addition in solar-charged off-grid lighting systems. The information in this study will help organizations, from energy access programs at development institutions to private sector companies, to better understand the benefits of introducing clean off-grid lighting technologies.

The research methodology for this study included focus group discussions (FGDs) and questionnaire surveys in off-grid villages with a representative population of early adopters of off-grid lighting. The methods used were based on successful field research conducted under a five-country Africa study (Kenya, Tanzania, Ghana, Senegal, and Mali). Consequently, the data enables comparison of consumer preferences.

4 Lighting Global is a joint IFC/World Bank program that manages the quality assurance framework and testing for the regional Lighting Asia and Lighting Africa programs. Lighting Global maintains a set of minimum quality standards, which off-grid lighting products must meet to access program services.

Research Questions

The research was directed at collecting consumer-based insights to develop key metrics in the quality assurance framework for the Lighting Asia/India Program. The work focused on identifying consumer preferences for brightness (light output) and daily hours of lighting (run-time) from affordable off-grid lighting products. A large part of the research effort was aimed at understanding end-user preferences for minimum acceptable lighting levels for ambient room lighting and task lighting applications.[5] Information was also collected on the number of hours of lighting that end-users expect from off-grid lighting products and what information they felt should be available to them at the time of purchase.

Two key questions were asked:

- What are end-user preferences with respect to run-time and light output levels in off-grid lighting products?
- What information does the consumer want to have when purchasing an off-grid lighting product to help her/him make an informed decision?

Fieldwork Methods

The research methodology included focus group discussions and questionnaire-based surveys in off-grid villages in Bihar and Odisha. The subjects were representative populations of early adopters of off-grid lighting. The focus group discussions were conducted after dark in homes (when possible) or at common gathering places (schools and panchayat offices) within the villages (Image 1).[6] The questionnaires collected baseline data regarding socio-economic backgrounds, types of lighting products used, and kerosene use for lighting (see Appendix A for a sample questionnaire).

Image 1: Focus group discussions with the respondents

Overall, twelve FGDs (and two pilot FGDs) were conducted in the two states, involving 113 respondents.[7] The selection criteria for respondents for the FGDs are shown in Table 1. The target population for this study was people living off-grid with a mix in terms of age, occupation, income, and education. The FGDs were divided along gender and socio-economic categories[8] in order to ensure equal gender participation and to be able to map differences in preferences within separate socio-economic categories. The FGD format was used to facilitate discussions around consumer preferences of light output levels, run-time requirements, and information available to consumers at the time of purchase to enable them to make informed decisions.

5 Ambient lights are generally products that have very wide or omni-directional light output used for illuminating a room or work space. Task lights are generally products that have narrow, focused, or directed light distribution used on desktops or for specific tasks like reading and writing.

6 A panchayat is a village-level governing body serving in an administrative capacity.

7 The two pilot FGDs were used to test and finalize methods before the actual study.

8 The socio-economic categories (SEC) were divided into high, medium, and low based on the dwelling type of participants as well as education and incomes of chief wage earners in the households. The SEC used in this study are defined as R1=High, R2 & R3=Medium, and R4 & R5=Low (see Appendix B).

Given the importance of brightness, major portions of focus group discussions were dedicated to understanding consumer preferences regarding light output levels. This was done by administering minimum brightness level tests. The tests were administered to determine minimum illumination levels for task and ambient lights that would satisfy respondents. Sessions were carried out at night in a dark room with a variable, calibrated light source. The light source was adjusted upward incrementally using a control box, and respondents were asked to indicate when they would be satisfied with light from low-cost, quality-assured lamps (Image 2). The lamps were controlled using a custom power supply that allowed the light output to be adjusted in small increments. The increments were determined based on the eye's ability to distinguish changes in illuminance. The lamps were set up in a local house or community space, representative of the size of rooms seen in the village. For more information on the methods see Appendix C.

Image 2: Minimum brightness level tests conducted with participants during focus group discussions

Table 1: Selection criteria for respondents of focus group discussions

Participant Characteristics
1. Participants had to be living off-grid.
2. Equal numbers of men and women as the study envisaged separate focus group discussions for men and women.[9]
3. Participants had to represent high, medium, and low income households within the region.
4. Respondents were selected in terms of age (20-80), occupation, income, and education.
i. Age groups were divided into 20-39 (3-4 per group), 40-59 (3-4 per group), 60-70+ (2-3 per group).
ii. Professions of respondents were roughly representative of the off-grid community.
iii. Levels of income and education of respondents were roughly representative of the community.
5. A mix of respondents with and without prior experience with LED lighting technology was selected.

Demographic Information about Focus Group Respondents

Both Bihar and Odisha rank very low in terms of access to clean and reliable household energy sources. As per Census of India, 2011, 88 percent of rural households in Bihar and 63 percent in Odisha still use kerosene as the primary lighting fuel (Image 3). Comparatively, Odisha has a much lower density of population and slightly higher poverty levels (in terms of percentage of population below poverty line) than Bihar.[10]

9 Each focus group discussion had only men or only women participants to ensure gender equality in participation during the research study.

10 House Listing and Housing Census Data Highlights, Census of India (2011), Government of India, Ministry of Home Affairs. Available at: www.censusindia.gov.in/2011census/hlo/hlo_highlights.html

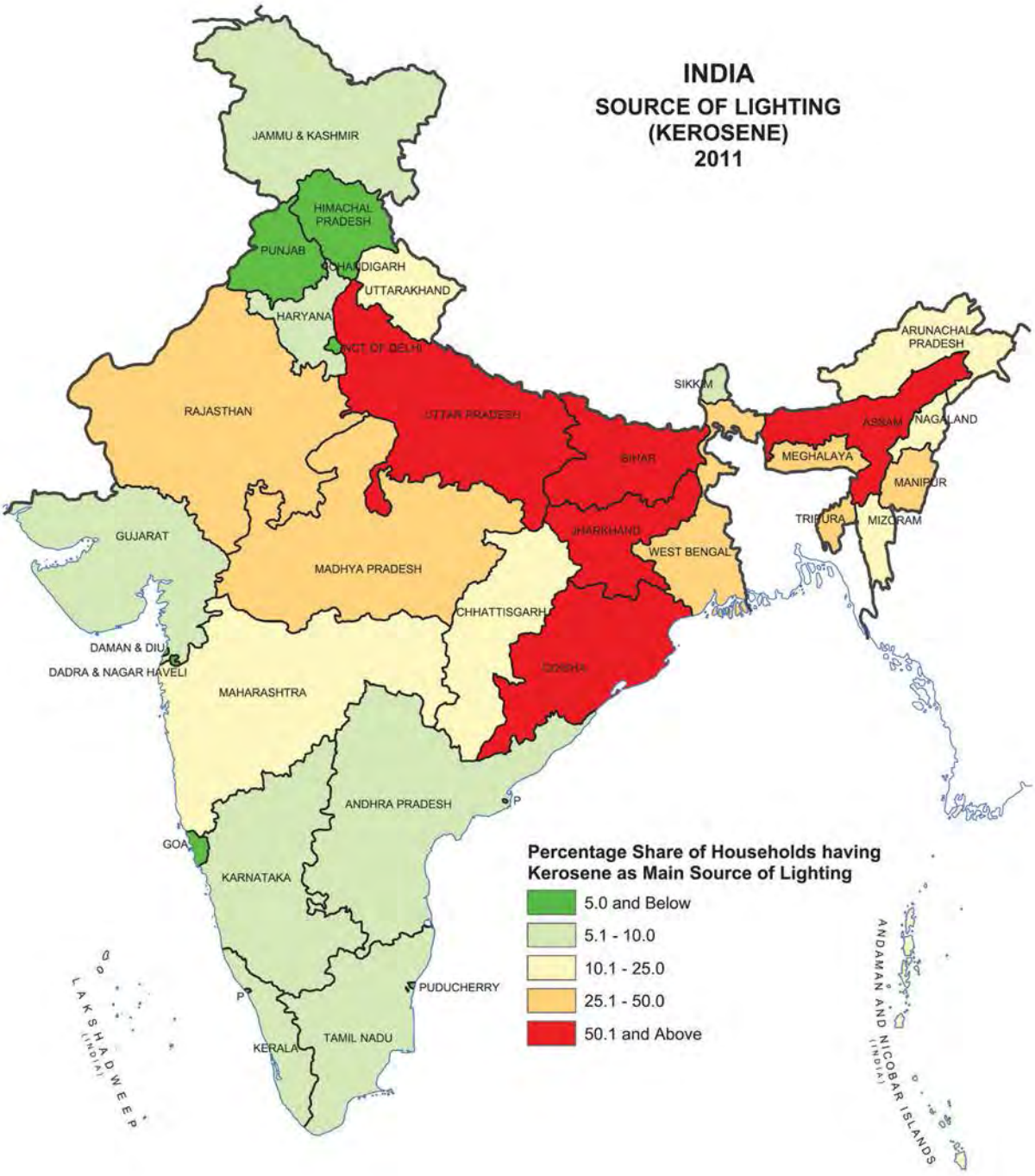

Image 3: Percentage of households that use kerosene as the main source of lighting across all Indian states (Census of India, 2011)

FGDs were conducted in the districts of Patna in Bihar and Kalahandi in Odisha (Image 4). Kalahandi has around 400,000 households with only 23 percent using electricity as the main source of lighting and 75 percent depending on kerosene (Census of India, 2011). In Patna district, around 57 percent of 1,000,000 households use electricity for lighting and 42 percent use kerosene (Census of India, 2011). These figures show key differences between the two districts, with the population studied in Kalahandi being highly energy deficient and even more dependent on kerosene than the population in Patna.

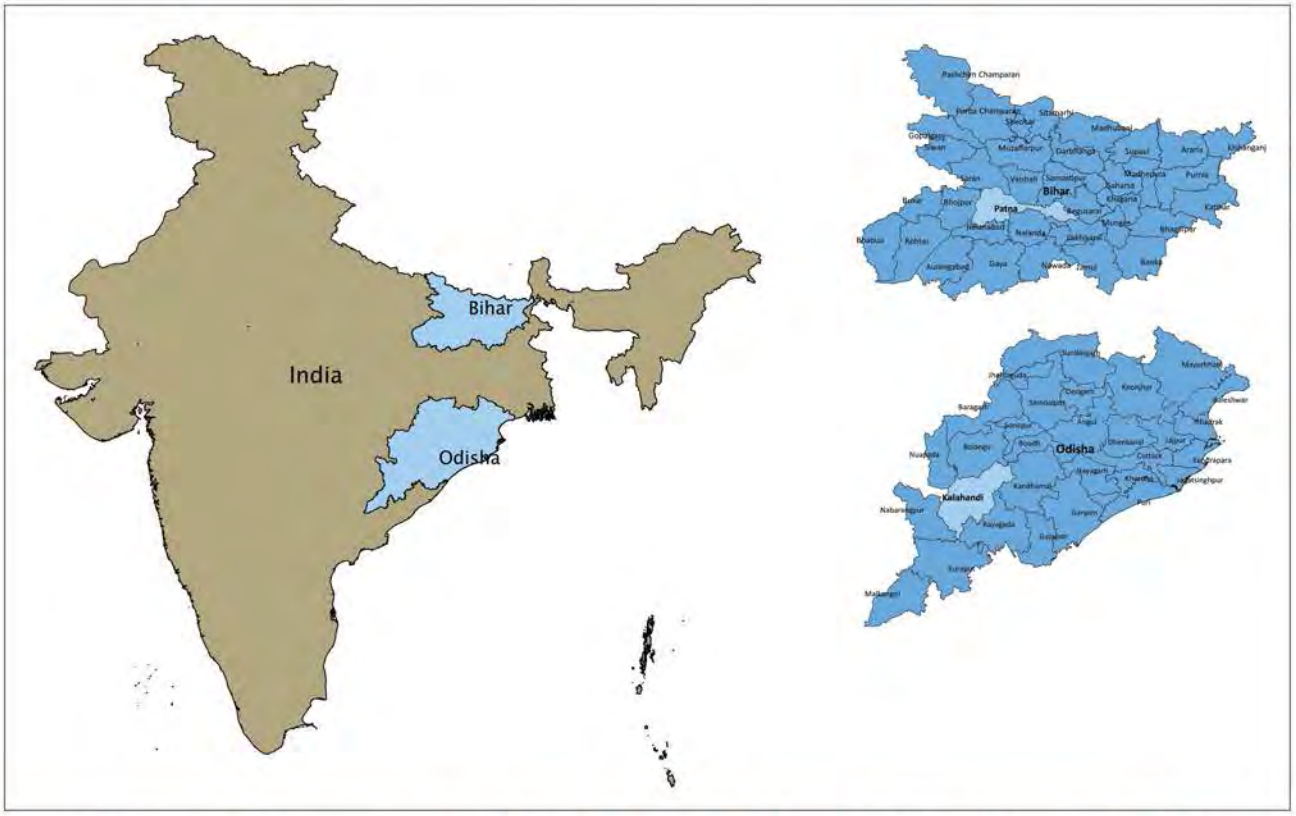

Image 4: Focus group discussions were conducted in the districts of Patna in Bihar and Kalahandi in Odisha

Aggregate demographic characteristics of the 12 focus group discussions are presented in Table 2.

Male respondents were mainly engaged in farm work while female respondents spent most of their working hours on house work. The median income of respondents in Bihar (Indian rupees 3000; $48.05) was double the median income of respondents in Odisha (Indian rupees 1500; $24.03). Distances of households from the electric grid in Bihar ranged from 1 to 4 kilometers, with a median of 2 kilometers. In Odisha, distances from the grid ranged from 0.5 to 5 kilometers with a median distance of 2 kilometers.

Kerosene use for lighting varied greatly between respondents of the two states. On average, respondents in Bihar reported using 5.7 liters of kerosene, spending Indian rupees 205 ($3.30) per month, while respondents in Odisha reported using 3.7 liters, spending only Indian rupees 75 ($1.20) per month. This amounted to around 7 percent of median monthly incomes of respondents in Bihar and around 5 percent in Odisha. On an average, households in Bihar said they got 2.75 liters and households in Odisha 2.82 liters from ration (government subsidized) shops every month. These figures indicate that respondents in Bihar bought larger amounts of kerosene from the unsubsidized market to meet lighting needs than respondents from Odisha.

The average cost of subsidized kerosene was relatively similar in the two states (approximately Indian rupees 18-19; $0.29-0.30); however, the unsubsidized market price of kerosene in Bihar was Indian rupees 40 ($0.64) per liter, compared to Indian rupees 25 ($0.40) per liter in Odisha. These estimates were from a sample of 113 respondents from the two states and may not be representative of the broader population. Anecdotal information from respondents in Odisha indicated they faced more irregularities in the availability of kerosene when compared to respondents in Bihar. Demographic information also showed income levels of respondents in Odisha were lower than those in Bihar. Irregularities in kerosene availability and lower income levels in Odisha may have contributed to the lower use of kerosene in that state despite lower per unit prices of unsubsidized fuel, although other factors may also have played a role.

Table 2: Demographic information of focus group discussion respondents

FGD Participant Characteristics	Bihar	Odisha
Number of focus group discussions	6	6
Total number of respondents (females/males)	55 (28/27)	58 (29/29)
Dominant age group (years)	20 to 30	20 to 30
Chief occupation (females)	House work	House work
Chief occupation (males)	Agricultural work	Agricultural work
Median monthly income (Indian rupees) (SEC*: high/medium/low)	3000 ($48.05) (3000/3000/2000)	1500 ($24.03) (--[11]/1600/1500)
Monthly income range (Indian rupees)	500-25000 ($8-$400)	1000-8000 ($16-$128)
Median distance of grid from household (kilometers)	1	2
Kerosene use for lighting per month (liters)	5.7	3.7
Cost of kerosene (Indian rupees) (subsidized/market)	19 ($0.30)/40 ($0.64)	18 ($0.30)/25($0.40)
Total cost of kerosene for lighting per month (Indian rupees)	205 ($3.28)	75 ($1.20)
Average percentage of monthly income spent on lighting	7 percent	5 percent

*Socio-economic category

Several off-grid lighting systems provide mobile phone charging options, which has emerged as a key value addition. To better understand this, questions on mobile phone use patterns were included in the survey questionnaire (Table 3). In Bihar, around 53 percent of respondents reported using mobile phones, compared to 12 percent in Odisha. Respondents in Bihar said they spent around Indian rupees 260 ($2.16) on talk-time and traveled around 2.7 kilometers to buy it. In Odisha, respondents spent around Indian rupees 145 ($2.32) per month on talk-time and traveled around 6 kilometers to buy it. On an average, respondents from both states went to the shop around four times per month to buy talk-time.[12]

The distance traveled to buy talk-time was similar to the distance traveled to get their phones charged. The average cost per month to charge mobile phone batteries was around Indian rupees 44 ($0.70) in Bihar and Indian rupees 19 ($0.30) in Odisha. This reflects actual charging costs because many respondents said they walked or combined their battery charging activities with other work. Additionally, these results are averaged across participants that pay as well as those who do not pay fees to get their batteries charged. Participants that did pay to charge their batteries said they spent an average of Indian rupees 6.60 ($0.11) per charge in Bihar and Indian rupees 5 ($0.08) per charge in Odisha. On an average, respondents from both states visited the shop around nine times a month to charge their batteries.

11 There were very few high income category participants in Kalahandi (Odisha) where the study was conducted and hence focus group discussions were not conducted with this socio-economic category. Instead, high income category was replaced by a medium income category FGD with male and female participants.

12 The results mentioned above are averaged across participants that pay as well as those who do not pay a fee for charging batteries of their mobile phones. For participants that do pay for charging their mobile batteries the expenditure is on an average Indian rupees 6.60 ($0.11) per charge in Bihar and Indian rupees 5 ($0.08) per charge in Odisha.

Table 3: Mobile phone use patterns

Mobile phone usage	Bihar	Odisha
Number of respondents using mobile phones	29	7
Expenses incurred on talk-time per month (Indian rupees)	262 ($4.20)	146 ($2.34)
Distance traveled to buy talk-time and to charge mobile phone (kilometers)	2.7	5.9
Expense incurred on charging mobile phones per month (Indian rupees)	44 ($0.70)	19 ($0.30)

Results and Discussion

The focus group discussion format facilitated discussions around consumer preferences surrounding light output levels and run-time requirements; as well as information that is needed to be available to consumers to help them make informed purchase decisions. This section discusses the results obtained from focus group discussions conducted in Bihar and Odisha. It also compares the results of this study and the five-country Africa study conducted in 2011.

Run-time Results

Two sets of data collected during the field work provide information on run-time requirements of consumers. During focus group discussions, respondents were asked about their preferences for run-time of lighting products, considering both evening and early morning activities. Results from the discussions showed that, on an average, desired run-time was 6.3 hours (Figure 1). The data showed that there were no significant differences in run-time preferences between the two states, male and female focus groups, or between socio-economic categories.[13]

Using a questionnaire, baseline information on the use of lighting products was collected from respondents. This data is also useful to estimate hours of light required from off-grid lighting products. Most households surveyed in the two states used multiple products to meet lighting needs (Figure 2). The three main sources of light in Bihar and Odisha were hurricane lamps, simple wick lamps, and dry cell torches (flashlights). In Bihar, a majority (~90 percent) of households surveyed used hurricane kerosene lamps, compared to only around 18 percent in Odisha. This trend was reversed with simple wick lamps; around 90 percent in Odisha reported using wick lamps, compared to around 50 percent in Bihar. Additionally, 36 percent of households in Bihar and 22 percent in Odisha used flashlights as a source of light.

13 An analysis of Variance (ANOVA) test was conducted to evaluate whether statistically significant relationships existed with respect to run-time preferences between the two states, gender groups, and socio-economic categories. No statistically significant differences were detected.

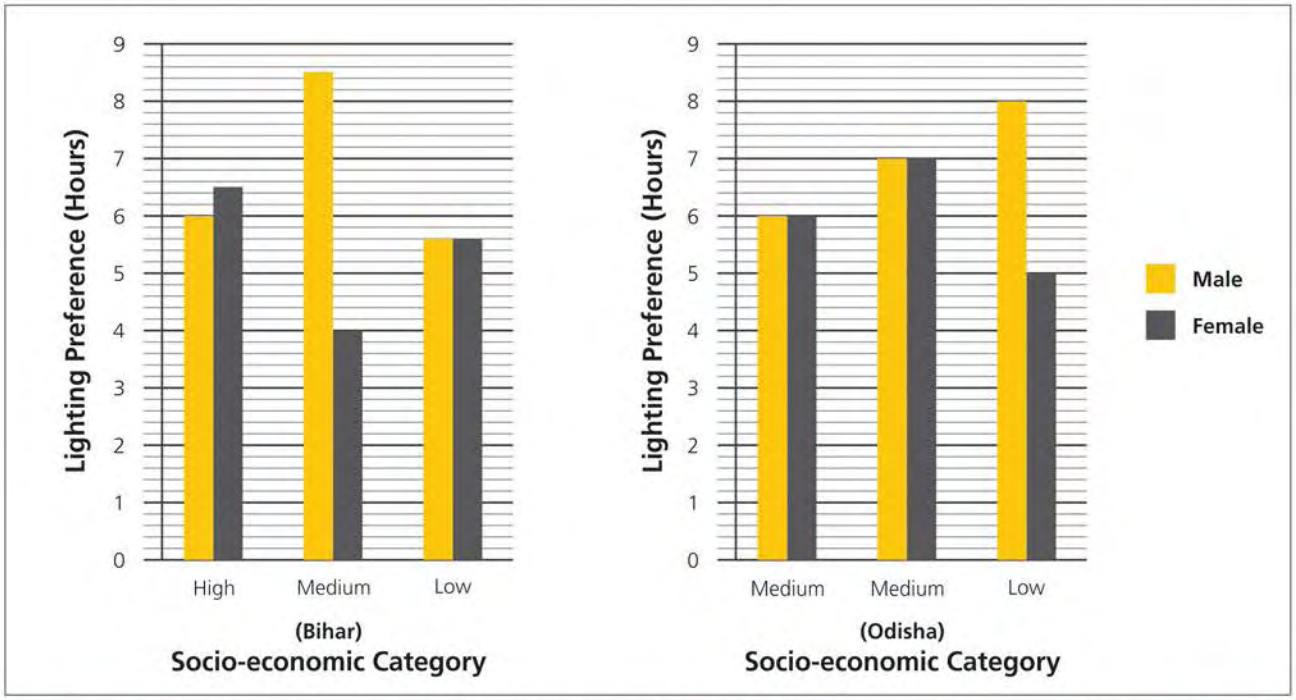

Figure 1: Respondent preferences for hours of light from off-grid lighting products. (Refer to footnotes 8 and 11)

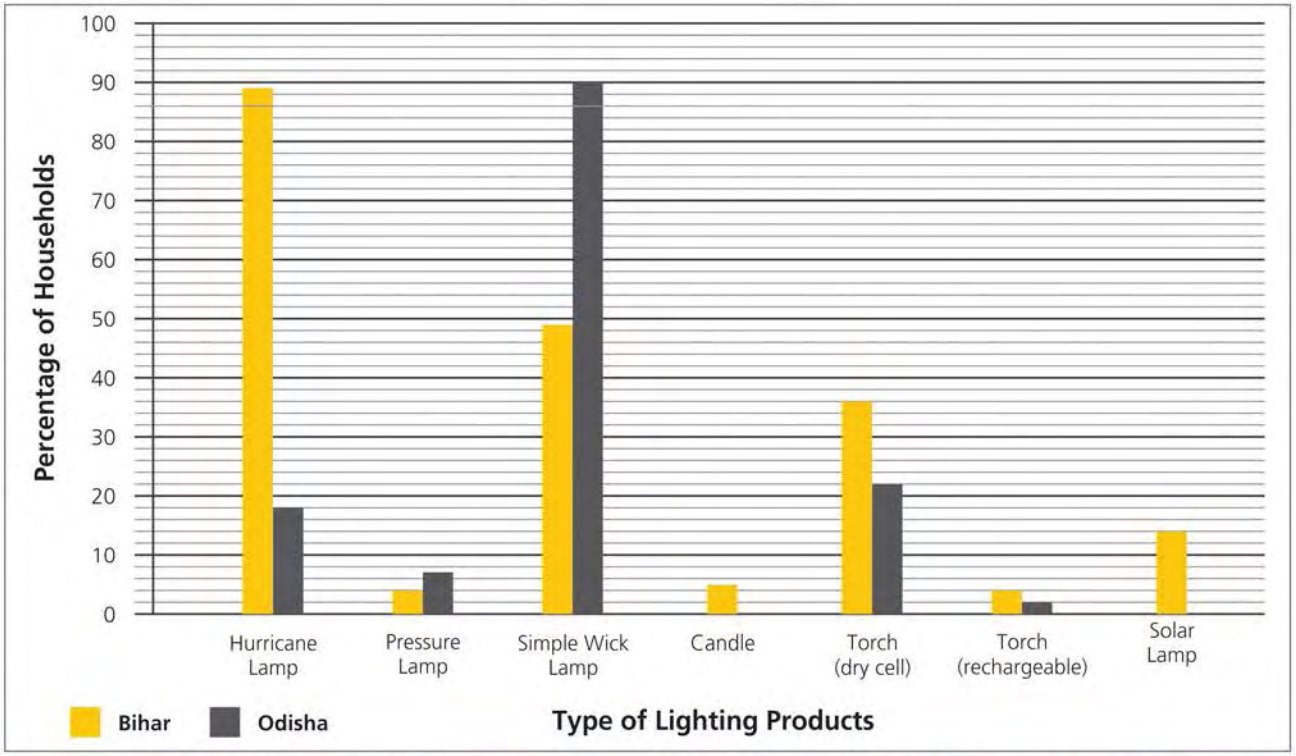

Figure 2: Percentage of respondents using a particular lighting products in each of the two states. Most households use multiple products

In comparison to the Indian market, the Lighting Global five-country study in Africa found a much larger use of low-cost LED lamps, including LED torches and lanterns. The other main lighting products used in Africa - as indicated from the percentage of households that utilized them - were hurricane lamps, simple wick lamps, and candles.

The median number of hours of light used daily with existing baseline technologies was around six hours in the households surveyed in India. This involved multiple lighting products.[14] The median daily use of hurricane lamps, simple wick lamps, and dry cell torches was 5.5 hours, 4 hours, and 1 hour respectively. Interestingly, the expressed preference for daily lighting use (6.3 hours per day) corresponded closely with existing baseline practice (6 hours per day). Additionally, statistical analysis confirms that average household use of hurricane and simple wick lamps (the main sources of lighting for respondents) exceeds four hours daily (Figure 3).[15]

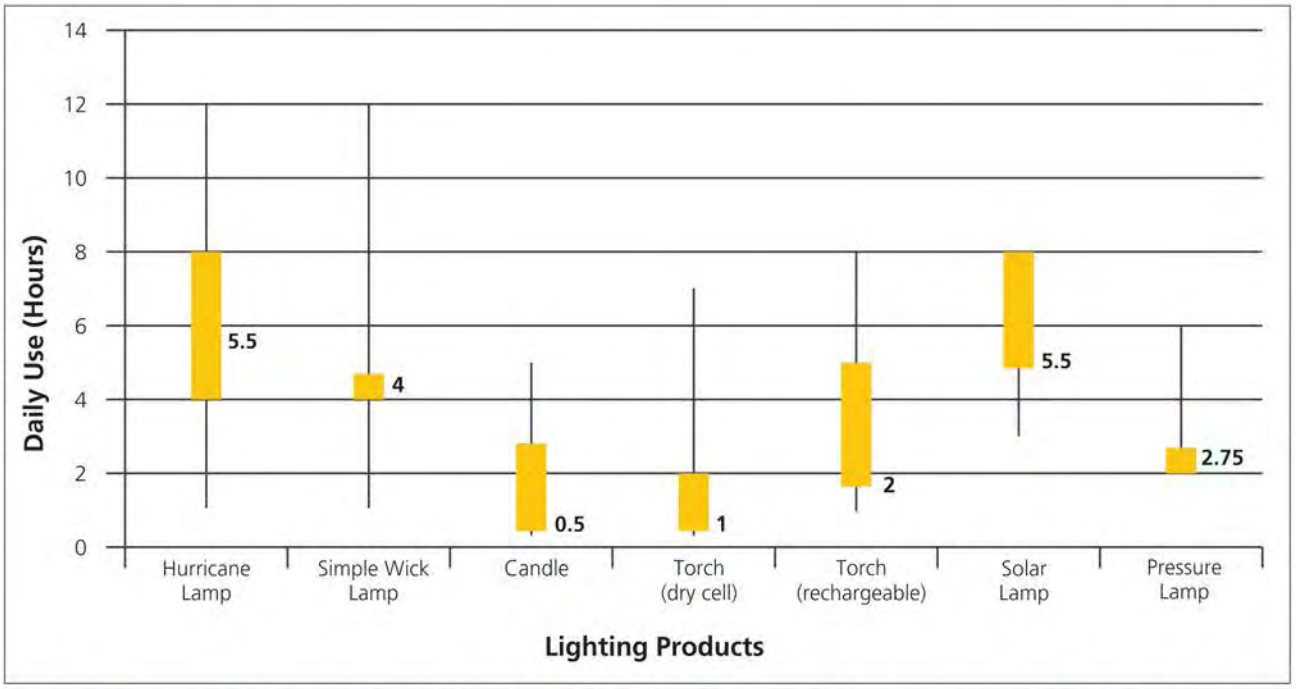

Figure 3: Reported daily hours of use of different lighting products. The boxes represent the 25 to 75 percentile for hours of use with the median represented as a numerical value outside the box. The lines represent the minimum and maximum values (hours of use) in the data set.

Run-time preferences from this study are comparable to those in Africa. Generally, in the African off-grid lighting market, hurricane lamps are used for around 5 to 6 hours per night, compared to around 6 hours in India. Simple wick lamps are used for around 3 to 5 hours in four of the five African countries. This is also similar to the daily average use of around 5 hours in India (Table 4).

Table 4: Comparison of the number of hours lighting products are used in India and in five African countries (source for Africa data: Lighting Global, 2013)

Type of lamp	Average hours a lighting product is used per day					
	India	Kenya	Tanzania	Ghana	Mali	Senegal
Hurricane lamp	6	4	6	5	5	5
Simple wick lamp	5	4	7	5	-	3
Low-cost LED Lamp (Dry Cell)	-	2	2	8	4	4
Candle	2	2	2	1	5	3
Number of respondents	113	74	47	32	66	65

14 This is calculated by adding the total number of hours of use across all lamp types in a day for a given household; then a median number of hours is calculated over all of these households (n = 113 participants).

15 A-Z test was conducted to determine if average use was over 4 hours.

Brightness Results

Respondents in the focus group discussions were asked to indicate minimum light levels that would meet their expectations for both room and task lighting applications if they purchased a low cost, quality assured off-grid lighting product. The methods used in these sessions are described in Appendix B.

The study found that the average focus group participant is satisfied with products that delivered at least 28 lux to a surface for tasks such as reading (Figure 4). For ambient room lighting applications, the average minimum acceptable lighting level was 18 lumens (Figure 5). Moreover, 85 percent of respondents across the two states indicated they would be satisfied with affordable products that delivered at least 40 lux to a task surface and 25 lumens for room lighting applications (Figure 6 and 7).

Interestingly, women indicated a preference for higher minimum illuminance levels for task lighting compared to men. The average minimum illuminance level for women in the focus groups was 35 lux, while men were willing to accept 20 lux. This result was statistically significant at a 99 percent confidence level. While the average minimum light level for ambient room lighting applications in the women's focus groups (20 lumens) was also higher than the average value recorded for men (15 lumens), the difference between women and men was not statistically significant for this particular application.[16]

The study did not collect information about the reasons for women's preference for higher illuminance levels for task lighting, but this may be related to the respective roles of women and men within the home. Most women in the survey indicated that their primary occupation was housework, which often involves activities that benefit from task lighting. In contrast, the primary occupation reported by men, agricultural farm work, involves activities that typically take place outside the home. Women may also be more attuned to lighting needs related to their children's education. Further study is needed, however, to identify the reasons for the difference. Results from the analysis of variance (ANOVA) did not indicate statistically significant differences in lighting level preferences between the states or among socio-economic categories.

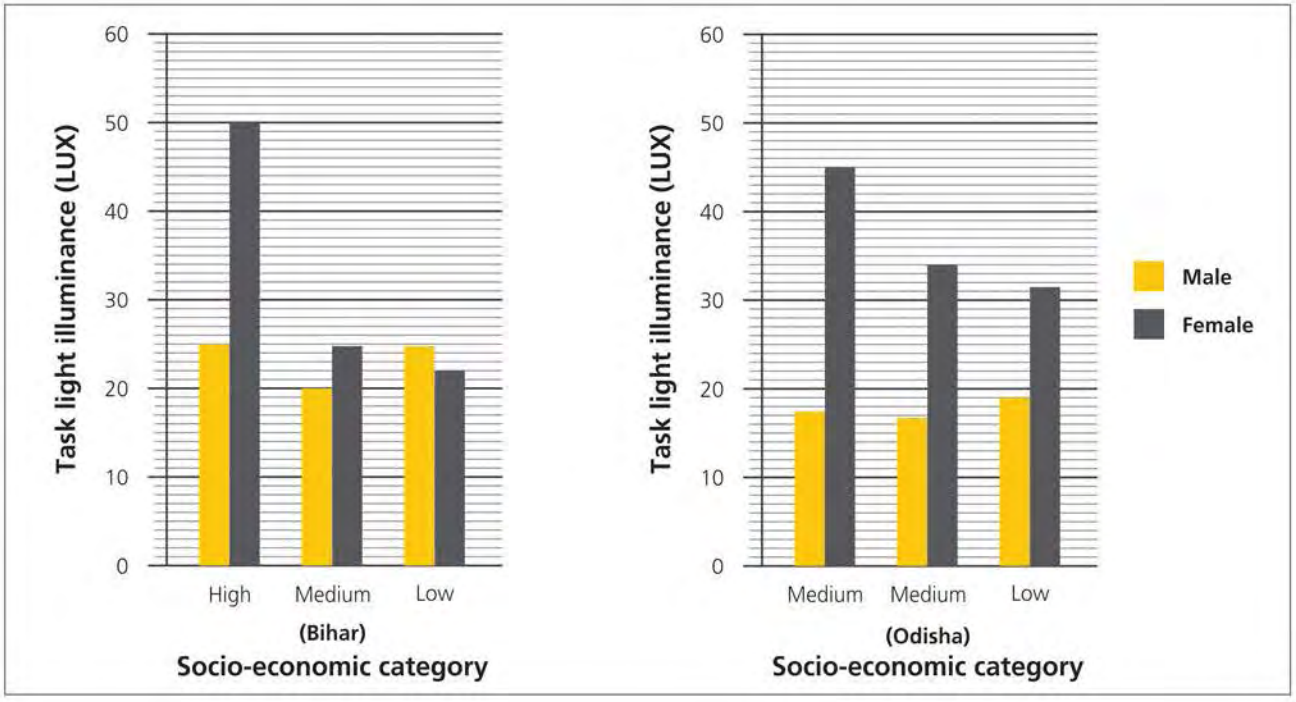

Figure 4: Task lighting level preferences among respondents in the two states (Refer to footnotes 8 and 11)

16 An ANOVA test and t-test were conducted to study the significance of interrelationship of gender with task and ambient lighting preferences.

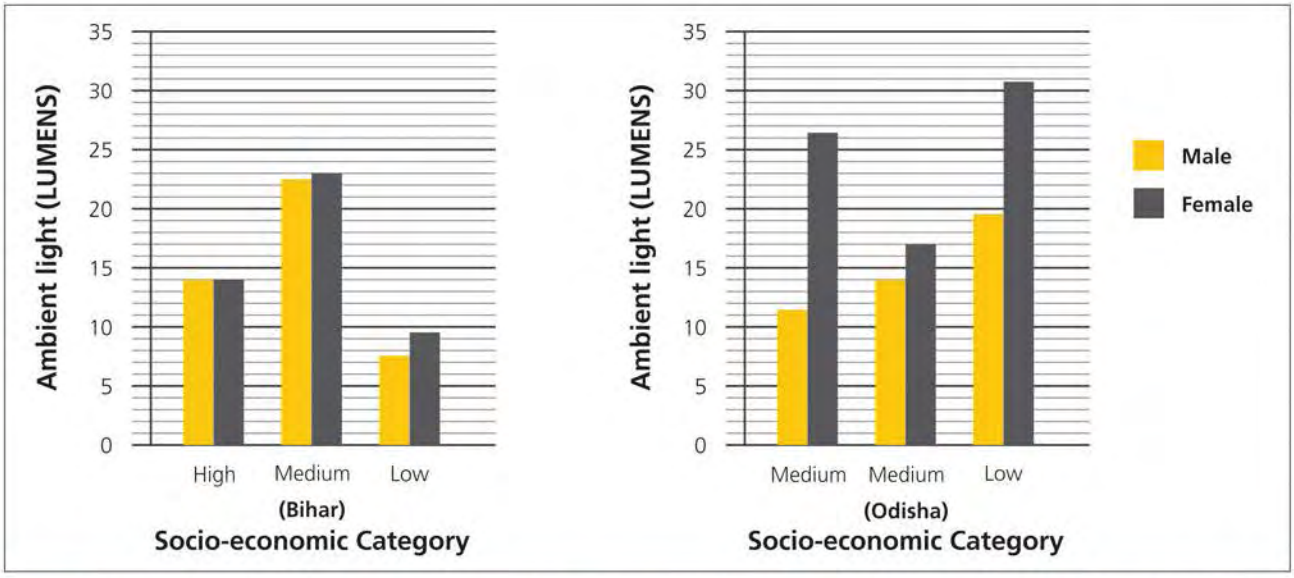

Figure 5: Ambient lighting level preferences among respondents from Bihar and Odisha (Refer to footnotes 8 and 11)

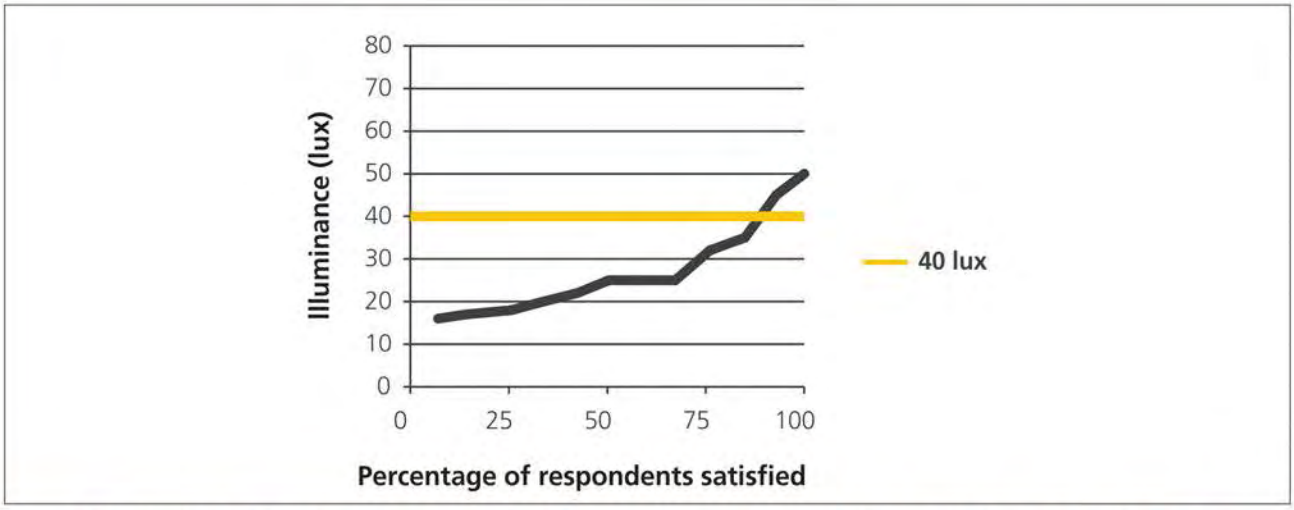

Figure 6: Percentage of respondents that would be satisfied with increased task lighting illuminance levels. The yellow line indicates the level that would satisfy 85 percent of focus group respondents

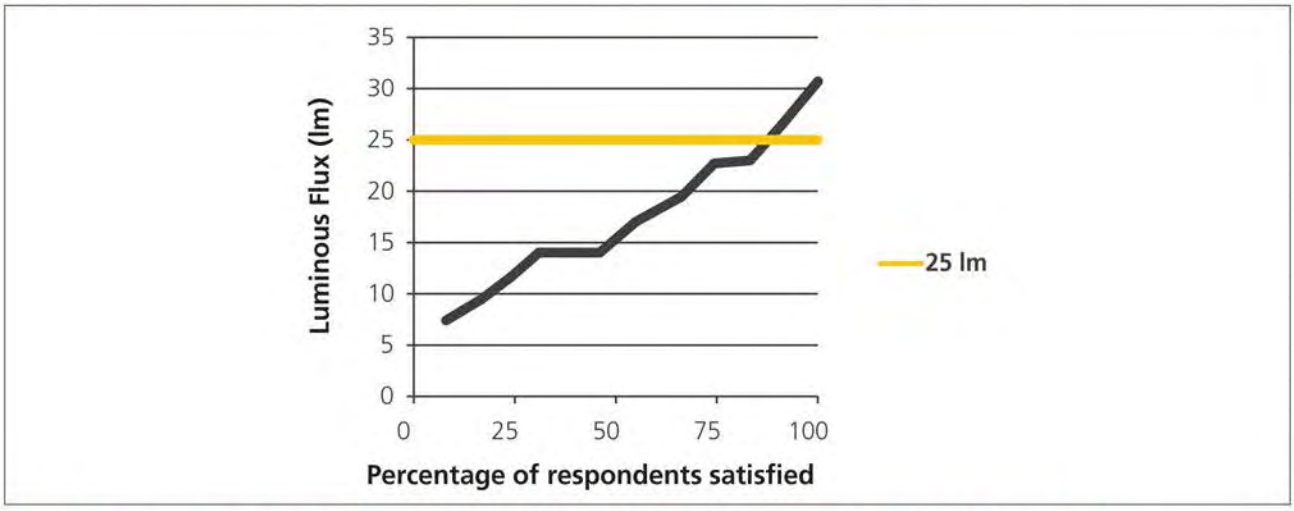

Figure 7: Percentage of respondents who would be satisfied with increased ambient lighting levels. The yellow line indicates the level that would satisfy 85 percent of focus group respondents

On an average, consumer preference for ambient lighting levels for respondents in India was somewhat higher than in the five countries studied in Africa. In contrast, respondents in India were satisfied with lower minimum task lighting levels than respondents in four of the five countries in the Africa study (Figure 8).[17]

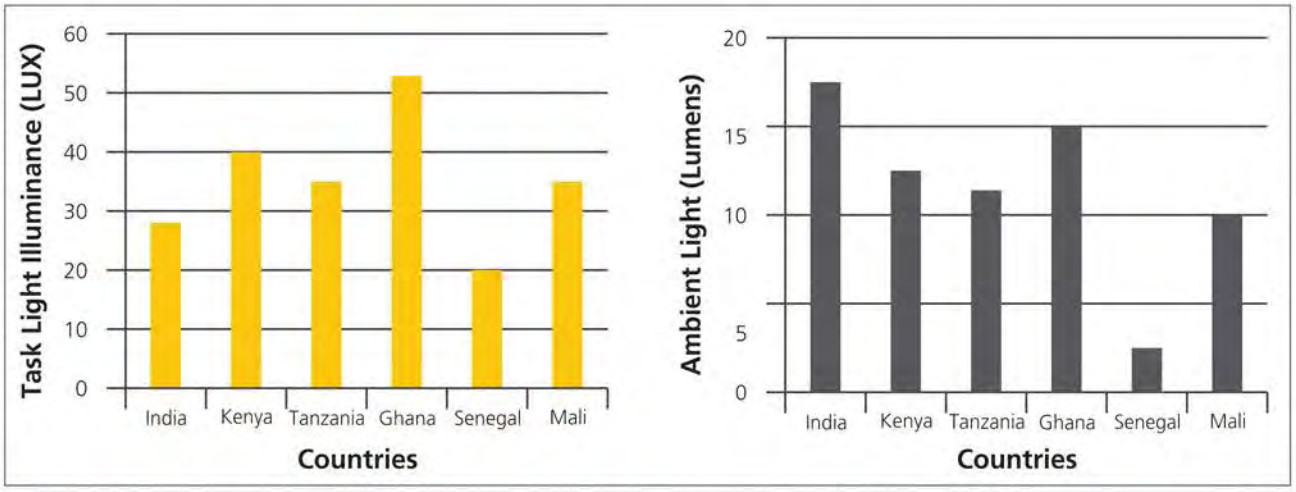

Figure 8: Consumer preferences for brightness of task and ambient lights in six countries. The graph on the left (yellow bars) shows preferences for task applications such as reading, and the graph on the right (grey bars) shows preferences for ambient room lighting applications

Information Required at Time of Purchase

During each focus group session, a discussion was conducted on the information needed to be available to consumers so they could make informed purchases of off-grid LED lighting products. This related to information on features such as brightness, run-time, and warranties. Respondents were asked to identify what information they would like to have and then rank it according to importance (Table 5).

For respondents in India, the most important piece of information was lighting output (brightness). This was followed by information about the type of charging mechanism, robustness (or lifetime), and run-time. In addition, information about whether a product could charge a mobile phone and warranty terms were jointly identified as fifth most important.

Interestingly, respondents in India and in Africa displayed high levels of agreement on this, both groups quoting these five pieces of information as most important. This confirms the importance of delivering clear and accurate information about these parameters to buyers across multiple countries and regions.

Table 5: Top five items of information required at time of purchase (listed in order of importance) for India

Rank	Information required at the time of purchase
1	Light output (brightness)
2	Type of charging (mainly information on solar charging)
3	Robustness/lifetime
4	Run-time
5	Ability to charge a mobile phone and warranty terms (tied for fifth place)

17 The methods used in the two studies were almost identical. One difference of note is related to the price level that was used to describe the hypothetical lighting products in the respective studies. In both cases, participants were asked to indicate the minimum acceptable lighting levels for task and ambient room lighting applications in a situation where they had purchased an affordable, quality-assured, off-grid lighting product. In the India study, participants were told that the hypothetical task lighting product was priced at Indian rupees 350 ($5.61) while the ambient room lighting product was priced at Indian rupees 650 ($10.41). In the five-country study in Africa, participants were told that both types of lights were priced at the local equivalent of approximately Indian rupees 650 ($10.4).

Key Findings

A key objective of this study was to collect information on user preferences for daily run-time (hours of operation) and light output (brightness) from off-grid lighting products. This information is valuable to manufacturers, distributors, and other stakeholders in the off-grid lighting sector.

A summary of key findings from the study is given below.

- **On an average, daily number of hours (run-time) that respondents expected from an off-grid lighting product was 6.3 hours.** This is the same as their existing hours of lighting from sources such as kerosene lamps and low-cost dry cell torches (flashlights). Notably, current practices involve use of multiple lighting products, so some consumers may be satisfied with an off-grid lighting product that can deliver six or more hours of lighting over multiple brightness settings. Other end-users may prefer more than one product to meet their needs. Statistical analysis shows no significant differences in run-time preferences between the two states, male and female focus groups, or between socio-economic categories.

- **Evidence from this study suggests that 85 percent of respondents would be satisfied with a low-cost lamp that provides at least 25 lumens of light for room lighting applications. Similarly, around 85 percent would be satisfied with a low-cost lamp that provides at least 40 lux on a task surface for applications such as reading.** These results were generated during an evening-time focus group session in which respondents were asked to specify the minimum lighting levels they would find acceptable for ambient room lighting and task lighting applications. Analysis of variance or ANOVA analysis did not find statistically significant differences in lighting level preferences between the states or among socio-economic categories.

- **Women preferred higher minimum illuminance levels for task lighting than men.** The average minimum illuminance level for women in the focus groups was 35 lux, while the average for male respondents was 20 lux. This result was statistically significant at 99 percent confidence level. While the average minimum light level for ambient room lighting applications in women's focus groups (20 lumens) was also higher than the average value for men (15 lumens), the difference was not statistically significant for this particular application. While the study did not collect information about the reasons for women's preference for higher illuminance levels for task lighting, they could be related to the respective roles of women and men. Most women in the survey indicated that their primary occupation was housework, which often involves activities that benefit from task lighting. In contrast, the primary occupation reported by men, agricultural farm work, involves activities that typically take place outside the home. Women could also be more sensitive to lighting needs related to their children's education.

- **In comparison to a five-country Africa study,** the minimum ambient brightness preferences in this study were some what higher than all five countries surveyed in Africa. This difference is reversed for task lighting, where we find, on an average, respondents in the India study were satisfied with lower minimum task lighting levels.

- **The five most common purchase decision criteria, besides product cost, were brightness, warranty terms, robustness, ability to charge mobile phones, and run-time.** These results are consistent with similar research conducted in the five-country Africa study.

- **The three main sources of light used by respondents in Bihar and Odisha were hurricane lamps, simple wick lamps, and flashlights.** In Bihar, a majority (~90 percent) of households surveyed used hurricane lamps, compared to around 18 percent in Odisha. This trend was reversed with wick lamps; around 90 percent of households surveyed in Odisha used it compared to around 50 percent in Bihar. Additionally, 36 percent of households in Bihar and 22 percent in Odisha used flashlights as a source of light.

Conclusion

Consumer preferences detailed in the study is useful for policy decisions related to implementation of quality assurance and consumer outreach activities for programs focusing on improving energy access in India.

The information will also provide manufacturers and distributors with important information that can be used to adjust product design and marketing, as they try to meet needs and expectations of end-users. Insights on common purchase decisions by end-consumers are useful in branding and marketing strategies. Insight into what consumers expect from products in terms of parameters such as brightness and daily hours of use will help manufacturers make product design decisions and distribution companies select which products they should carry.

In addition, the study provides baseline information on monthly income, kerosene consumption, and currently used traditional lighting technologies. This provides broader context of potential end-users who participated in the study. The study also includes information on mobile phone usage. This is relevant as many off-grid lighting systems provide mobile phone battery charging options, which has emerged as a key value-addition in this segment.

The information in this study will help development institutions to better understand the benefits of introducing clean off-grid lighting technologies.

Appendix A. Survey Form for Respondents in the Focus Group Discussion Sessions

Lighting Asia/India off-grid Lighting participant survey (filled out prior to Household Focus Group Discussion), Bihar and Odisha, January 2013

Participant ID # _____

Participant's Name _____

Mobile # _____

1. Gender: ☐ Female ☐ Male
2. Age: ☐ 20-30 ☐ 30-40 ☐ 40-50 ☐ 50-60 ☐ 60+
3. Profession: _____
4. Main Source of Household Income _____
5. Average Household Income per Month _____
6. Do you have grid electricity at home? ☐ Yes ☐ No
7. How far is the grid connection from your home (kilometers)? _____
8. How far do you have to go to charge something (kilometers)? _____
9. Are you familiar with using LED lighting? ☐ Yes ☐ No
10. How much of kerosene did your house use in the last 30 days? How much was used for lighting?
11. How much kerosene did you purchase from the ration shop, at what price?
12. How much kerosene did you purchase from the market, at what price?
13. Do you face any difficulty around purchase and use of kerosene for lighting?

14. Mobile Phone Usage

    a. Do you have a mobile phone? What do you mainly use the phone for, mobile to mobile calling, FM/Radio, songs etc.? (will give us info on how usage co-relates to the frequency of charging)

    b. How much do you spend on talk-time per month? What service provider do you use?

    c. Where do you go to get talk-time and how many times a month do you get talk-time?

    d. How far do you have to go to get talk-time and how much do you spend on travel (time and money)?

15. Mobile Phone Charging

    a. Where do you go to charge your phone and how much do you spend on travel (time and money)?

    b. What is the cost you spend to get your phone charged?

    c. How many times a month do you go to charge your phone or after how many days do you need a charge for your phone?

16. Mark **each** of the lighting sources you use, how many hours each day you use it and how much you spend on it each week.

Lighting Source	**In Use?**	**Hours of use per day**	**Cost per week**
Hurricane Lamp	☐	_____	_____
Pressure Lamp	☐	_____	_____
Simple Wick Lamp	☐	_____	_____
Candle	☐	_____	_____
Torch (dry cell)	☐	_____	_____
Torch (rechargeable)	☐	_____	_____
Solar Lamp	☐	_____	_____
Generator Powered Bulbs	☐	_____	_____
Grid Powered Bulbs	☐	_____	_____
Other _____	☐	_____	_____

Appendix B. Socio-economic Category (SEC) Definitions

This appendix includes a summary of the classification used to assign respondents to socio-economic categories (SEC).

Table B.1. SEC demarcation criterion is based on education and employment of chief wage earner of household

RURAL						
			Kutcha			
			Education of CWE			
Occupation of CWE			Illiterate	Semi Literate	Literate	SSC-HSC	College Grad-PG
			1	2/3	4	5	6/7/8/9
Unskilled Workers		1	R5	R5	R5	R4	R4
Skilled Workers		2	R5	R4	R4	R3	R3
Petty Traders		3	R5	R4	R4	R3	R3
Shop Owners		4	R4	R4	R3	R3	R2
Businessman/Industrialists		5	R4	R4	R3	R3	R2
Self employed Professionals		6	R4	R4	R3	R3	R2
Clerk/Salesman		7	R4	R4	R3	R3	R2
Supervisory Level		8	R4	R4	R3	R3	R2
Officers/Executive-Junior		9	R4	R4	R3	R3	R2
Officer/Executive-Senior		A	R4	R4	R3	R3	R2
Zamindar/Landowner+ cultivator		B	R5	R5	R5	R4	R4
Zamindar/Landowner+ cultivator	Upto 2 acs	B	R5	R4	R4	R3	R3
Zamindar/Landowner+ cultivator	2.5 acs	B	R4	R4	R3	R3	R2
Zamindar/Landowner - non cultivator	5+ acs	C	R5	R4	R4	R3	R3
Zamindar/Cultivator but not Landowner		D	R5	R5	R5	R4	R4
Agricultural labourer		E	R5	R5	R5	R4	R4
Herdsmen/Fishermen/Poultry		F	R5	R5	R5	R4	R4
Artisan/Craftsman		G	R5	R5	R5	R4	R4
Others		H	R5	R4	R4	R3	R3

the participant belongs to as well as dwelling type of the participant.

SEC

Type of House									
Semi Pucca					Pucca				
Education of CWE					Education of CWE				
Illiterate	Semi Literate	Literate	SSC-HSC	College Grad-PG	Illiterate	Semi Literate	Literate	SSC-HSC	College Grad-PG
1	2/3	4	5	6/7/8/9	1	2/3	4	5	6/7/8/9
R5	R5	R4	R4	R3	R4	R4	R3	R2	R2
R4	R4	R3	R2	R2	R3	R3	R2	R2	R1
R4	R4	R3	R2	R2	R3	R3	R2	R2	R1
R3	R3	R2	R2	R1	R2	R2	R1	R1	R1
R3	R3	R2	R2	R1	R2	R2	R1	R1	R1
R3	R3	R2	R2	R1	R2	R2	R1	R1	R1
R3	R3	R2	R2	R1	R2	R2	R1	R1	R1
R3	R3	R2	R2	R1	R2	R2	R1	R1	R1
R3	R3	R2	R2	R1	R2	R2	R1	R1	R1
R3	R3	R2	R2	R1	R2	R2	R1	R1	R1
R5	R5	R4	R4	R3	R4	R4	R3	R2	R2
R4	R4	R3	R2	R2	R3	R3	R2	R2	R1
R3	R3	R2	R2	R1	R2	R2	R1	R1	R1
R4	R4	R3	R2	R2	R3	R3	R2	R2	R1
R5	R5	R4	R4	R3	R4	R4	R3	R2	R2
R5	R5	R4	R4	R3	R4	R4	R3	R2	R2
R5	R5	R4	R4	R3	R4	R4	R3	R2	R2
R5	R5	R4	R4	R3	R4	R4	R3	R2	R2
R4	R4	R3	R2	R2	R3	R3	R2	R2	R1

Appendix C. Focus Group Discussion Format and Methods

This section gives additional information on the methods and equipment used during the fieldwork in Bihar and Odisha.

Focus Group Discussions

The FGD format was used to facilitate discussions around consumer preferences of light output levels, run-time requirements, and information needed by consumers to enable them to make informed purchase decisions. This section discusses the flow and details of the FGDs.

Purchase Point Information

After participants filled out questionnaires, the FGD started with a discussion of the important factors surrounding the purchase of an off-grid LED lighting device (for example, brightness, run-time, and warranty). Several samples of off-grid lighting products were displayed to stoke an informed and healthy discussion. A typical question posed to the respondents would be:

"If you were to buy an off-grid lighting product similar to what we have shown you today, what would you like to know about the product before you make the purchase? What would help you make a decision on which lamp to buy?"

Respondents were asked to describe the most important information they would need at the point of purchase of the device. Individual answers were recorded and the group would then rate the five most important items on the list.

Minimum Brightness Level Test

The minimum brightness level test was administered to determine the minimum illumination levels for task and ambient lights below which the light output is considered inadequate. The methods adopted in the research study were based on the five-country study in Africa in 2011. Sessions were carried out at night in a dark room, with a variable, calibrated light source. The light source was adjusted upward incrementally and respondents were asked to indicate when they would be satisfied with light from a low-cost, quality-assured lamp. The customized equipment used consisted of two LED lamps: one designed to deliver light for a task lighting application and the other to deliver light for ambient room lighting (see Appendix D for details about the device). The lamps were controlled using a custom power supply that allowed the light output to be adjusted in small increments. The small increments were determined based on the eye's ability to distinguish a change in illuminance. The lamps were set up in a local house or community space that was representative of the size of rooms seen in the village.

The task lamp was hung 0.75 metres above the ground and the test proceeded with respondents sitting around the light source. The ambient lamp was hung 2.25 meters above the ground and the test was administered similar to the task lamp. The respondents were given details about the reasons behind the test and the differences between the task and ambient lights. These details were provided just before administering the test and in complete darkness to enable the respondents' eyes to adjust to low light levels.

The following message was then communicated by the enumerator

> "We will be doing two separate tests. We want you to tell us what amount of light you would be satisfied with if you just bought the task lamp for Indian rupees 350 ($5.61) and the ambient lamp for Indian rupees 650 ($10.41) and knew both had passed a quality check. Remember, that this price includes the solar panel, battery, and lamp, all of which come with a two-year warranty. We want to know, if you were to bring

home this light and turn it on, would you be satisfied with the level of light - or would you be dissatisfied with your purchase of this low-cost quality-assured solar lamp because it is not as bright as you think it should be? The light used in this test can get very bright, but we do not want to know what level you like the best. We first want to know the minimum light level with which you would feel satisfied with your purchase. The first test will be with a light we call the task light. This light is meant to be used for activities such as reading, studying, selling goods, etc. Let us know what minimum level of light you are satisfied with for a product that has passed a quality check."

After this message was understood by the respondents, the task lamp was connected to the power supply and switched on at the lowest setting. The light level was increased after an interval of around 20 seconds until the respondents indicated a minimum acceptable brightness level. At this point an illuminance measurement was made using a hand-held meter. A similar approach was used to determine minimum acceptable ambient light output levels.

To arrive at a general consensus, a discussion was started at the point when the first individual(s) reported acceptable light output. Other respondents were asked whether they would like to join the person(s) initiating first response. The initiators were given the opportunity to change their mind if they agreed with the others that the output was not enough. Eventually, the measurement would be recorded once a general consensus was achieved through a discussion.

Run-time Discussion

After the minimum illuminance test, respondents were asked their preferences for the number of hours that an off-grid lighting product should operate each day (daily run-time), considering both evening and early morning activities. Respondents were asked to mention their daily run-time preferences only for active or non-sleep hours. This was described to respondents as the hours in the night and early morning when some work/activity for which light is necessary took place inside or outside the home. Individual preferences for the daily run-time were recorded.

Appendix D. Description of the Light Cube

The device that was used in the study consists of two LED lamps; one designed to deliver light for a task lighting application and the other to deliver light for ambient room lighting (Image D.1). The lamps were controlled using a custom power supply that allowed the light output to be adjusted in small increments.

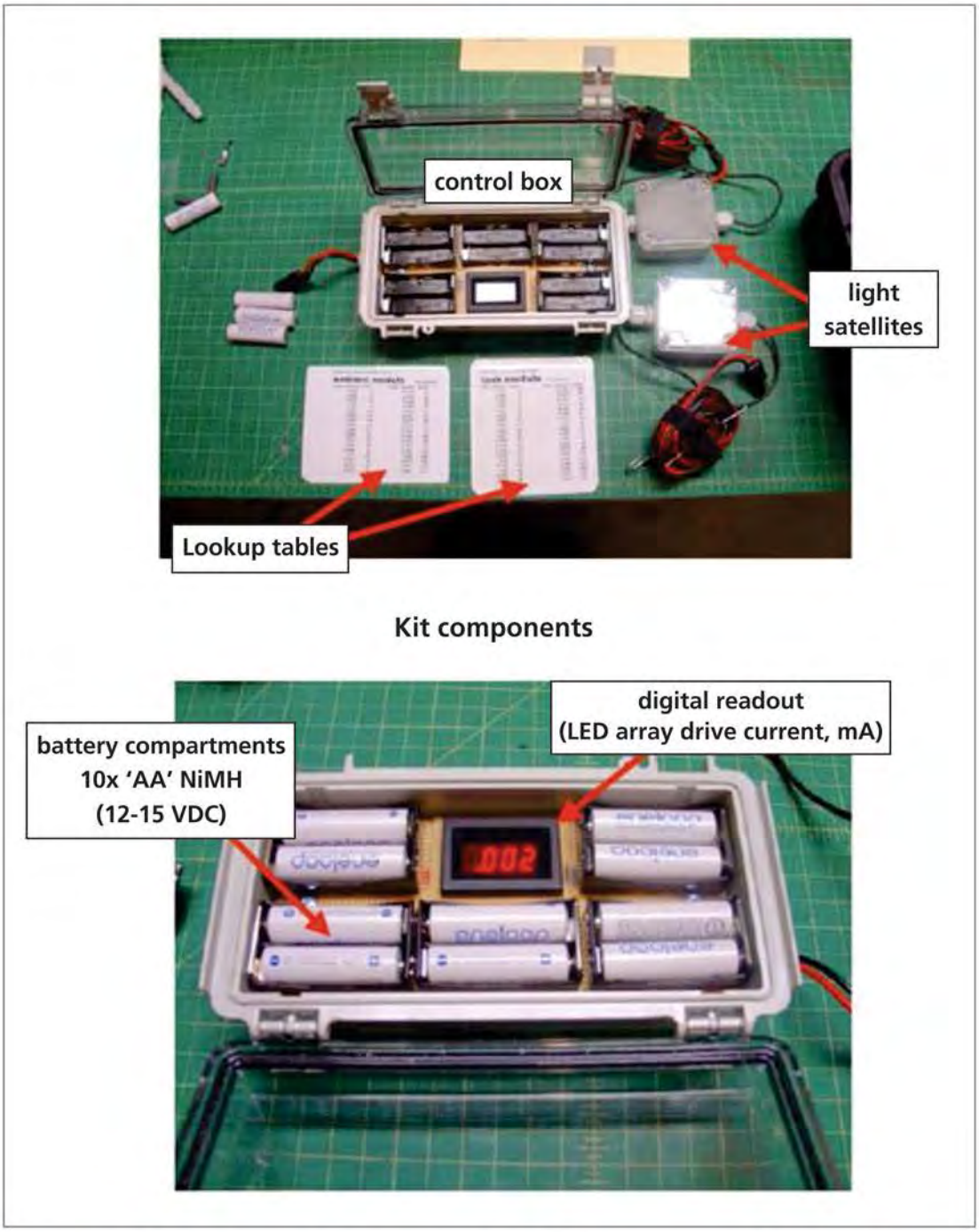

Image D.1: A calibrated, variable output, battery-operated LED light source was used to administer minimum light output field tests. The customized device allowed light output to be adjusted in small increments. The image on top shows the two light sources (used for gauging consumer preferences for ambient and task lighting applications, respectively), the control box (used to control lighting levels), and the look-up tables (used to correlate the digital value obtained from the control box to the actual light output based on prior calibration measurements). The image at the bottom shows the batteries used to power the device as well as the LCD display that indicates the drive current for the two lamps

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About Lighting Asia/India

Lighting Asia/India is a market-transforming program with the objective of promoting the value and presence of modern off-grid lighting among two million people in rural India. Modern off-grid lighting includes solar lighting appliances, home systems, and connections to renewable energy mini-grids. The program is designed as a series of interventions to alter market behavior, reach two million people, and displace at least 64,000 tons of CO_2 by the end of 2015.

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About Lighting Africa

Lighting Africa, a joint initiative of IFC and the World Bank, accelerates the development of markets for clean off-grid lighting products in sub-Saharan Africa. The program mobilizes the private sector to build sustainable markets that will provide millions of people in Africa not connected to grid electricity with clean, affordable, quality lighting products, most of which are solar powered.

For more information, visit www.lightingafrica.org

About Lighting Global

Lighting Global is a joint IFC/World Bank program which manages the quality assurance framework and testing for the regional Lighting Asia and Lighting Africa programs. Lighting Global maintains a set of Minimum Quality Standards which off-grid lighting products must meet to access program services.

For more information, visit www.lightingglobal.org

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