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Research Note #4

Quality and Performance of LED Flashlights in Kenya: Common End User Preferences and Complaints

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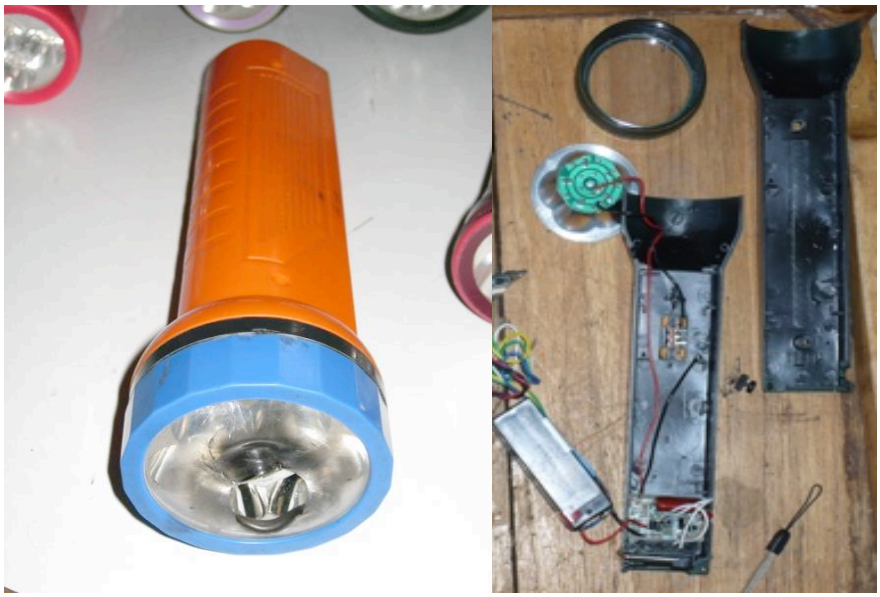

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Background

Flashlights that use LED technology have quickly emerged as the dominant source of portable lighting in Kenya. While flashlights do not normally provide a substitute for kerosene and other highly inefficient fuels, they are an important early manifestation of LED lighting in the developing world that can serve as a platform – or deterrent – to the diffusion of the technology into the broader off-grid lighting market. The lead acid batteries embedded in flashlights also represent an important source of hazardous waste, and flashlight durability is thus an important determinant of the rate of waste disposal.

Low-cost LED flashlights with prices from $1 to $4 are now widely available in shops and markets throughout Kenya. The increased penetration of LED technology in the flashlight market is significant, as over half of all Kenyan households report owning a flashlight (Kamfor, 2002). While this shift from conventional incandescent technology to modern LEDs may appear to be a promising development, end users that our research team interviewed expressed a number of complaints about the quality and performance of these new flashlights. This raises concerns about the interests of low-income flashlight users, and it may also indicate the onset of a broader market spoiling effect for off-grid lighting products based on LED technology (Mills and Jacobson, 2008; Lighting Africa, 2007). The quality of low-cost LED flashlights can contribute to market spoiling because these products appear to represent the first contact that most Kenyans have with LED technology.

In this report, our team uses interviews with 46 end users of flashlights to collect information about their experiences, perceptions, and preferences. We focus especially on highlighting common complaints from respondents about the flashlights that they have used, as well as on noting the features that they indicated were important when evaluating the quality of a flashlight. In previous laboratory tests, researchers from our team found a wide range of quality and performance among battery powered LED lights (Granderson, et al. 2008).

Field Methods

We interviewed three distinct groups of flashlight users in the context of the study: night \watchmen, bicycle taxi drivers, and households. These groups were selected because they are frequent and – in some cases – intensive – users of flashlights. A total of 46 individuals (15 watchmen, 15 bicycle taxi drivers, and 16 household members) participated in a short survey about flashlight use patterns. In the context of the survey interviews, they shared their experiences with the flashlights that they use. Our colleague Maina Mumbi and one of the authors (Jenny Tracy) conducted the surveys over a three-week period during June and July 2009. See Appendix B for a copy of the survey forms.

Night Watchmen: Towns that serve as an overnight stopping point for lorry truck drivers generally have crews of night watchmen that provide security while drivers sleep. The night watchmen that we interviewed reported that they direct and monitor lorry trucks in work shifts that last from 7pm to 7am, seven days per week. Each watchman that we surveyed owned at least one flashlight that was used on a nightly basis. The watchmen surveys took place in a small truck stop town, Maai Mahiu (population ~10,000), located in Kenya's Rift Valley Province, approximately 46 miles northwest of Nairobi. All of the watchmen participants were male and

had an average monthly income between 3,500 and 4,000 Ksh, approximately $46-52 (Appendix A. Photo 1).

Bicycle Taxi Driver: In some of Kenya's towns, bicycle taxis provide transportation services to the general public within town limits. Those that we surveyed indicated that they operate primarily between the hours of 5am and 2am. We focused on surveying drivers that worked during the evening hours (anytime between 6pm and 2am). They use flashlights mounted on the frames of their bicycles seven nights per week. The Bicycle Taxi Driver surveys took place in Nakuru, a larger town of 300,000 people 86 miles north-west of Nairobiwhere bicycle taxis are common. All of the Bicycle Taxi Drivers participants were male and had an average monthly income of 9,800 Ksh, approximately $130 (Appendix A. Photos 2-3).

Households: The surveys of households took place in Maai Mahiu with members of off-grid households. Specific monthly earnings were not ascertained for the household participants, but prior research in the area suggests that the average income is around 5,000 Ksh (approximately $65). Although the households reported using flashlights for shorter periods of time than the watchmen and bicycle taxi drivers, they did nonetheless use them on a regular basis (Appendix A. Photos 4-5).

Flashlights Used by Survey Respondents:

Four types of flashlights were reported to be in use by the survey participants: LED flashlights powered by a rechargeable sealed lead-acid (SLA) battery, LED flashlights powered by dry cell batteries, incandescent flashlights powered by a rechargeable SLA battery, and incandescent flashlights powered by dry cell batteries (Figures 1-4). LED flashlights have recently permeated the market and appear to be replacing the flashlight market that until the past few years was dominated almost exclusively by incandescent bulb flashlights that used dry cell batteries. LED technology generally provides efficiency and performance benefits relative to incandescent bulbs, and low cost LEDs have achieved price levels that make them cost competitive with conventional lighting sources for a number of applications (Mills, 2005). Rechargeable SLA batteries are also becoming more prevalent, although people with limited access to grid electricity still rely on dry cell battery technology. Flashlights using rechargeable SLA batteries tend to be less expensive to operate over a two-year period than a flashlight using dry cell batteries (Radecsky, 2009). The overall price paid for flashlights used by the participants ranged from 80 to 480 Ksh ($1 to 6). Rechargeable LED flashlight prices ranged from 130 to 180 Ksh ($1.70 to $3.70) and dry cell LED flashlight prices ranged from 80-480 Ksh ($1.05 to $6.30). Price generally reflects the number of LEDs; the 80 Kshflashlight had three LEDs while the 480 Ksh flashlight had 10. For the incandescent bulb flashlights, the rechargeable ones ranged in price from 100-120 Ksh ($1.30 to $1.60) and the dry cell powered flashlights were 120 Ksh ($1.60). In addition to the initial cost of the flashlights, users must pay ongoing costs associated with recharging the rechargeable flashlights or buying replacement dry cell batteries. The average cost reported to recharge the SLA batteries in flashlights was 20 Ksh ($0.26) and the average cost reported to purchase one dry cell battery was 30 Ksh ($0.40); note that the majority of flashlights using dry cell batteries required two batteries. The total cost of ownership (over the product lifetime) is dominated by the cost of replacement batteries or charging fees (Mills and Jacobson, 2008).

Figure 1. Rechargeable LED flashlights

Figure 2. Dry Cell LED flashlights

Figure 4. Rechargeable incandescent flashlight

Figure 5. Dry cell incandescent flashlight

The majority (64%) of survey participants reported using rechargeable LED flashlights (Figure 5). LED flashlights powered by dry cell batteries, used by over one-forth of the participants, were the next most common. Incandescent bulb flashlights that used either rechargeable or dry cell batteries were used by less than 10% of those surveyed. When the data are broken down on a per group basis, it is interesting to note that only the household participants used incandescent bulb flashlights. Three of the watchmen did report using LED flashlights with dry cell batteries, but most of the dry cell torches were found in households (n=11). The households use flashlights with dry cell batteries to a greater extent than flashlights with rechargeable batteries. While the size of our sample is too small to draw firm conclusions, this may represent a conscious choice related to the fact that the household members that we interviewed lived further from grid electricity than the other respondents. Living further from the grid made use of a rechargeable flashlight less convenient. All three groups used LED flashlights with rechargeable batteries, but the bicycle taxi driver's are the only group that used that type exclusively. This may be because the drivers are based in a larger town where rechargeable LED flashlights are more readily available than the other types.

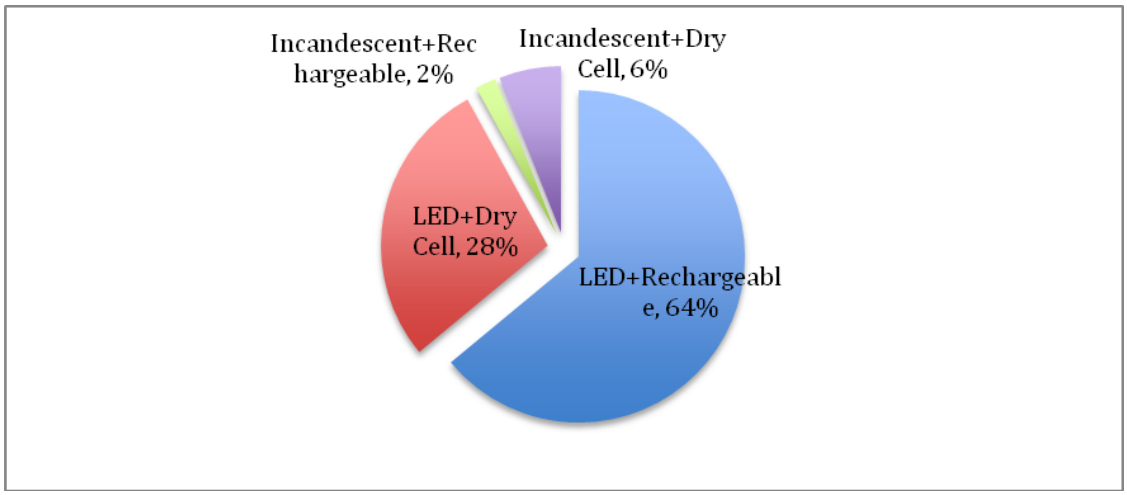

Figure 5. Four types of flashlights were reported to be in use by the study participants. The 46 respondents surveyed included 15 night watchmen, 15 bicycle taxi operators, and 16 household members. LED flashlights powered by rechargeable sealed lead-acid batteries are the most popular choice followed by dry cell battery powered LED flashlights. Incandescent bulb flashlights are the least common.

Results and Discussion

A total of 87% of those surveyed reported having problems with their flashlights in the previous six months. The number of Night Watchmen and Household participants reporting problems in the last six months was approximately 20% higher than the rate for Bicycle Taxi Drivers (Figure 6). The reported useful lifetime for flashlights (i.e., the time before they no longer worked) ranged from one week to eighteen months. The most frequently reported flashlight lifespan was two weeks and the average flashlight lifespan was just over three and a half weeks. These results suggest severe and widespread quality problems in the Kenyan flashlight market.

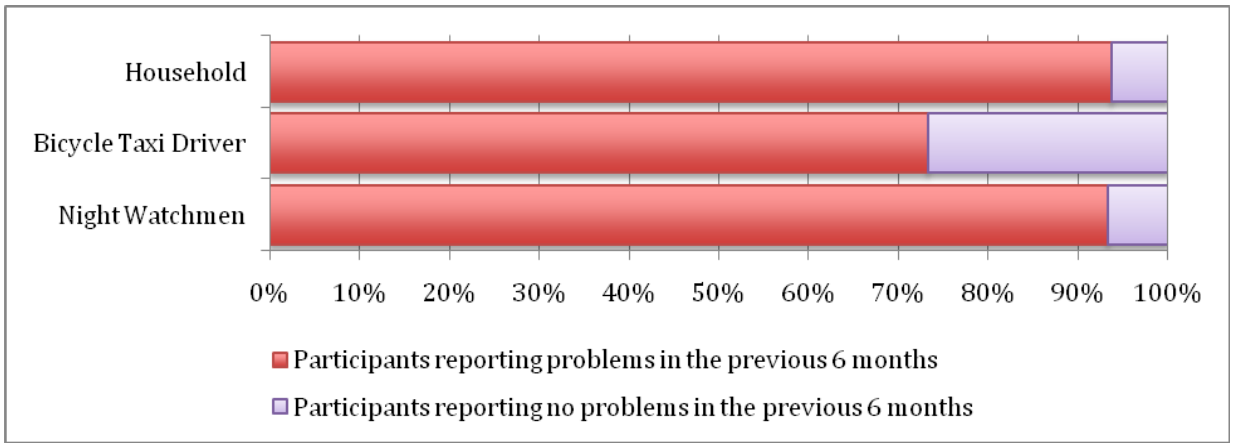

Figure 6. Fraction of 46 survey respondents reporting problems with their flashlights that occurred in the past six months. Overall, 87% of respondents reported having problems

When asked about their experiences with the flashlights, failure of LEDs[1] was the most common complaint, closely followed by water leakage leading to corrosion and electronic component failure (Figure 7). Four main categories made up over 75% of the complaints. These included the two categories mentioned above as well as a problem in which the battery was no longer able to maintain a charge (thus requiring more frequent recharging events) and switch failures (likely a result of weak solder joints that break, disconnecting the wire linking the switch to the lighting circuit). Three other categories were less frequently mentioned, though together they contribute to approximately 25% of the complaints: dry cell batteries being too expensive to replace, the charging mechanism on the rechargeable flashlights failing to operate, and the flashlight body being brittle so that when it drops it breaks.

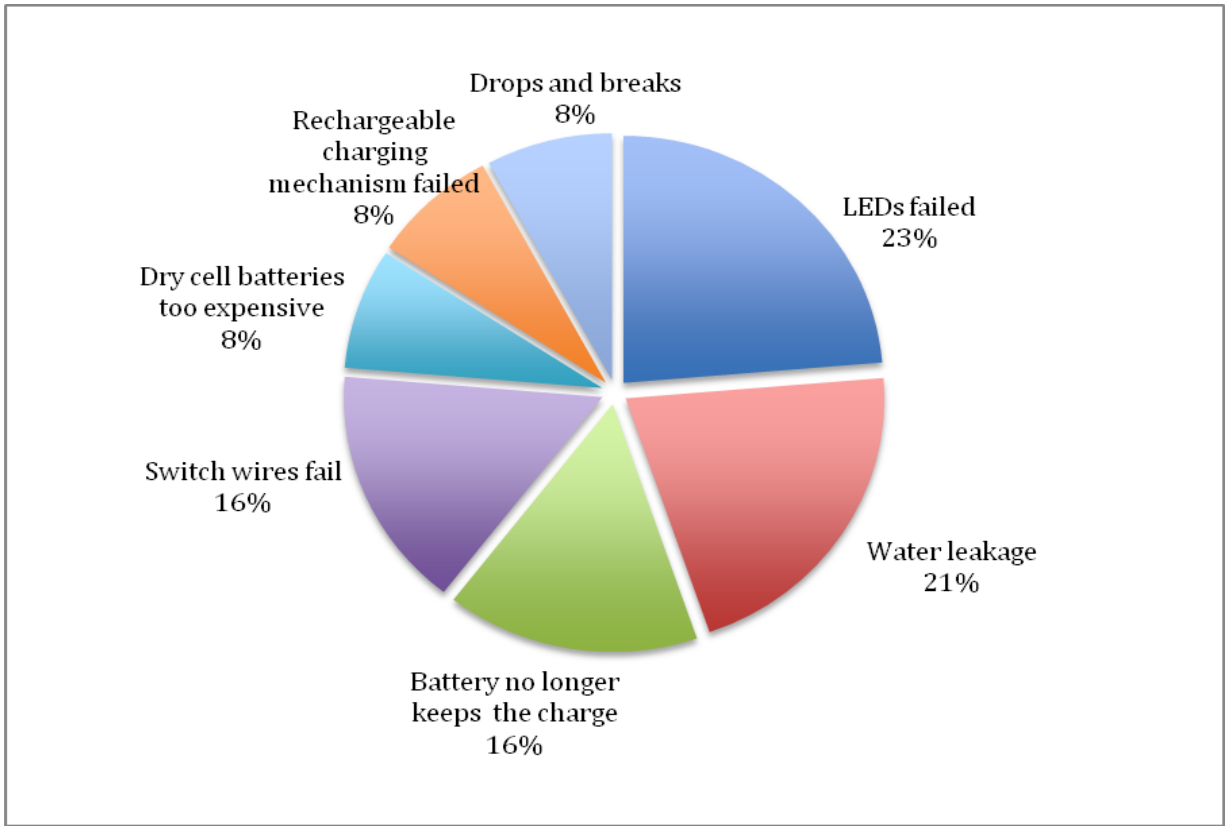

Figure 7. Summary of common problems experienced by 46 flashlight users surveyed in Kenya. Four criticisms regarding flashlight performance by surveyed end-users in Kenya make up 75% of the reported complaints; LED failure, water leakage, the batteries no longer keeping the charge as they initial had, and the switch failing.

The fact that respondents frequently cited rapid LED failure as a problem is particularly worrisome given that many manufacturers market the flashlights with claims that the LEDs will last a very long time compared to incandescent bulbs (e.g., claims of 50,000 or 100,000 hour

[1] Respondents who indicated that the LEDs in their flashlight had "failed" were referring to the fact that the LEDs ceased delivering light. In many cases, this failure may have been due to a bad wire or solder connection, corrosion on the circuit board, or faults other than actual failure of the light emitting diode itself.

lifetimes for the LED lights are commonly found on the packaging for these torches). In practice, quality control and quality assurance in manufacture of LEDs varies widely, and few – if any – of the LEDs in the flashlights used by the respondents in this study delivered light for more than a few thousand hours. In fact, descriptions of flashlight failure modes suggest that LEDs commonly ceased delivering light after only a few hundred hours of operation. While the cause of the problem may or may not have been related to actual failure of the diode itself, many end-users that we interviewed appeared to interpret the fault as a problem with the LED.

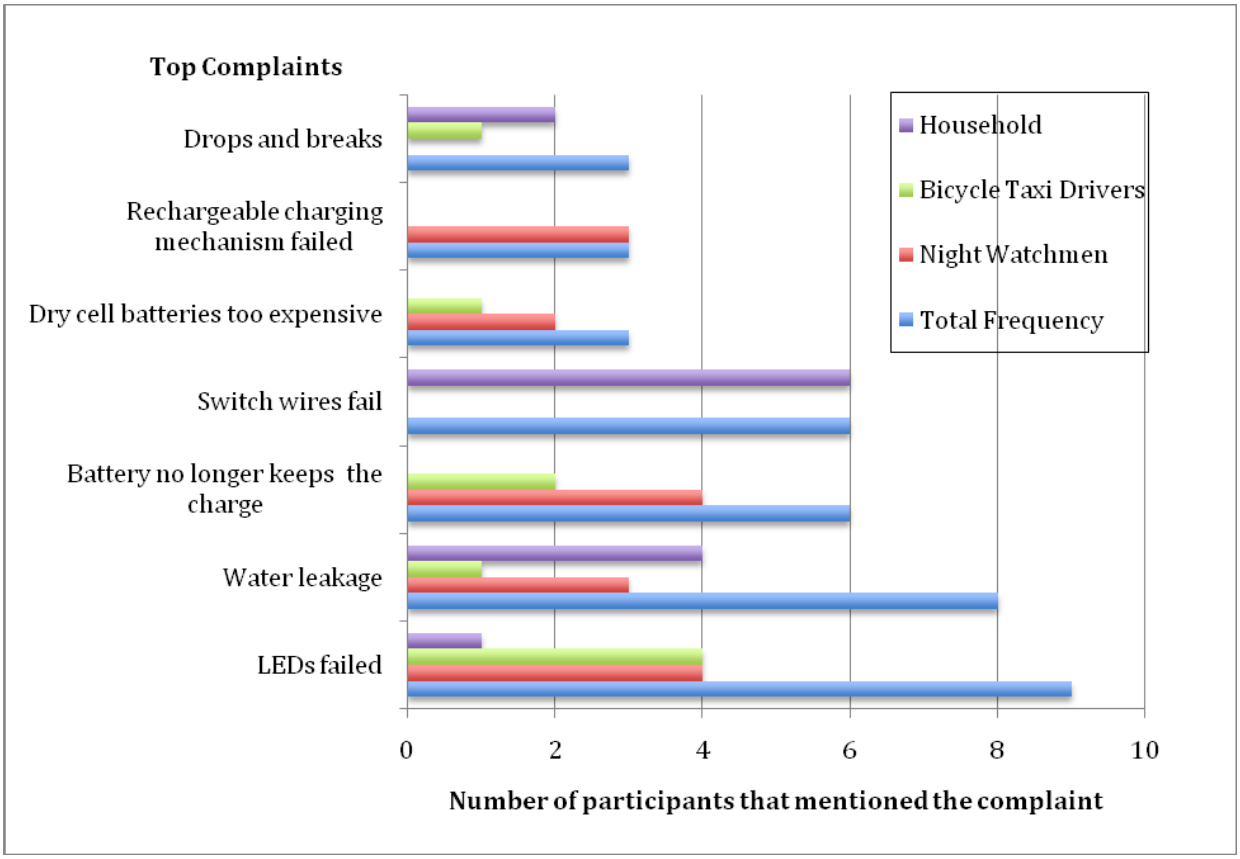

Figure 8. Top complaints broken down by each of the three groups. Total frequency includes all participants within the three groups surveyed. LED failure and water leakage were the only complaints reported by all groups.

When prompted to describe what features a good quality flashlight should have, the survey participants mentioned 20 different attributes (Figure 9). The most commonly cited feature was a battery with a larger capacity, so that it could be replaced or recharged on a less frequent basis. This is a logical request given inconvenience and cost of charging batteries, combined with the fact that charging fees vary little if at all as a function of battery size across the range of batteries commonly used in flashlights. Four other frequently mentioned categories comprised another 45% of the preferred features: (i) a more durable housing that does not break when dropped, (ii) a sharper (more focused) beam, and (iii) a more durable switch that does not break and from which the wires do not disconnect, and (iv) higher levels of light output (i.e. "brighter"). Eleven features were only mentioned by two or fewer participants categorized on the graph as "Features with a frequency of 2 or less". This group consists of the following features: a longer flashlight

lifespan, a light that emits a warm color, a better charging mechanism on the rechargeable flashlights, an alarm, a better battery mounting platform that prevents the battery from shifting within the flashlight, better wire connections that do not become disjointed, an integrated holder so it is easier to mount the flashlight on a bicycle, a bubble level, LEDs in multiple locations (not just on one side), blinking light option, and rust prevention.

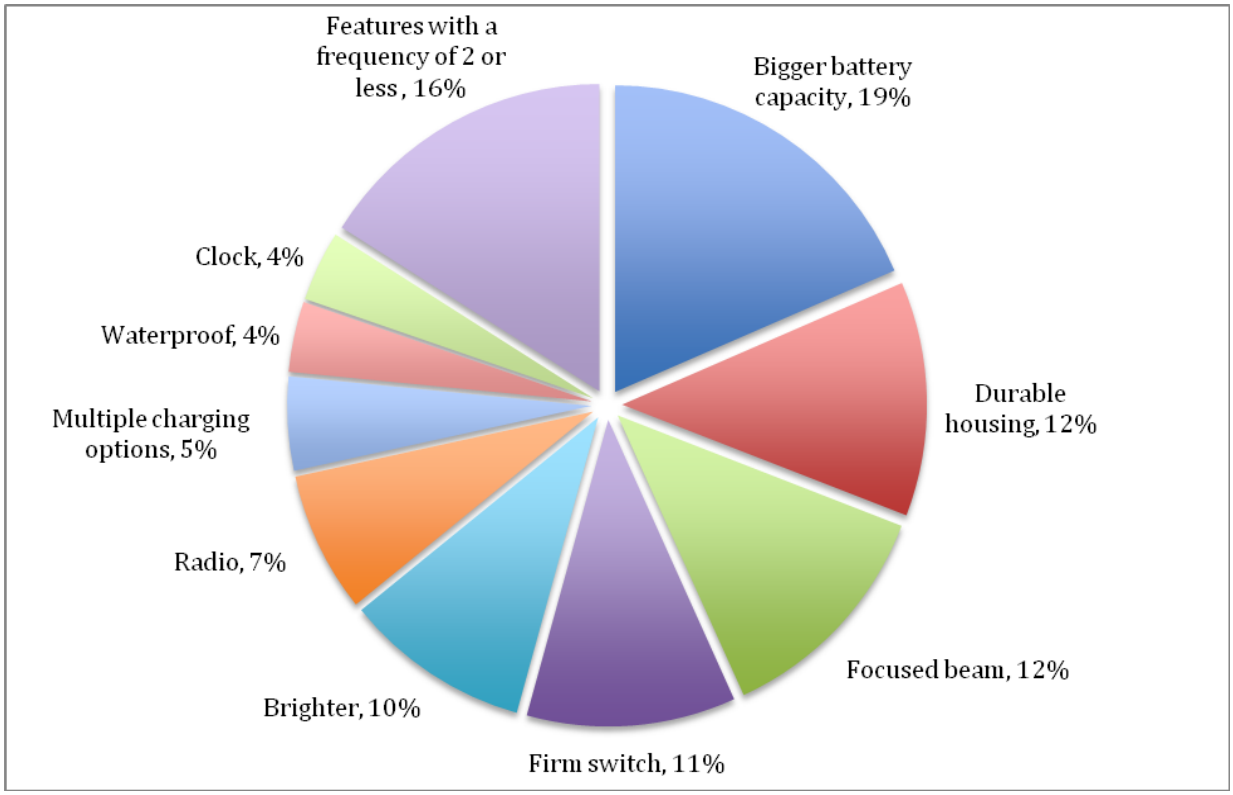

Figure 9. Summary of attributes the 46 survey respondents felt were the most important in a quality flashlight. Five dominant categories made up 64% of the preferred features: a battery with a larger capacity, a more durable housing that does not break when dropped, a sharper more focused beam, and a more durable switch that does not break.

Conclusion

An understanding of the most common complaints of flashlight users in Kenya and their input concerning preferred features of a quality flashlight product are central for manufacturers wishing to improve their products as well as to those who are working to develop policies and institutions aimed at ensure the success of the off-grid lighting market. The results included in this report indicate serious quality problems with LED flashlights, which are the LED products that have achieved the greatest levels of market penetration. This highlights the need for a quality assurance program that helps to protect the interests of low-income end users such as the flashlight users that participated in the study. Potential elements of the testing component of such a program have been discussed and illustrated by Mills and Jacobson (2008).

References

Granderson, J., J Galvin, D. Bolotov, R. Clear, A. Jacobson, and E. Mills. 2008. "Measured Off-Grid LED Lighting System Performance." Lumina Project Technical Report #4. [http://light.lbl.gov/pubs/tr/lumina-tr4.pdf]

Kamfor, Ltd. (2002) "Study on Kenya's Energy Demand, Supply and Policy Strategy for Households, Small-Scale Industries and Service Establishments," report for Ministry of Energy, Nairobi, Kenya.

Lighting Africa (2007) *Product Quality Assurance forOff-Grid Lighting in Africa*, Conference Proceedings from the Lighting Africa Product Quality Assurance Workshop, Airlie Conference Center, Arlie VA, October 14-16, 2007.

Mills, Evan (2005) "The Specter of Fuel-Based Lighting,"*Science* 308:1263-1264, 27 May, 2005. [http://light.lbl.gov/pubs/specter.html]

Mills, Evan and Arne Jacobson (2008) "The Need for Independent Quality and Performance Testing of Emerging Off-Grid White-LED Illumination Systems for Developing Countries," *Light and Engineering*, v16, n2, pp.5-24. [http://eetd.lbl.gov/emills/pubs/pdf/mills-jacobson-lande.pdf]

Radecsky, Kristen (2009) *Understanding the Economics Behind Off-Grid Lighting Products for Small Businesses in Kenya*, Masters Thesis in the Energy, Environment, and Society option of the Environmental Systems Graduate Program, Humboldt State University.

Appendix A. Photo Gallery of flashlights and their users in Kenya

Photo 1. The group of Night Watchmen study participants.

Photo 2. Bicycle Taxi Driver transporting clients. The center bicycle has an orange flashlight mounted on the handlebars.

Photo 3. Bicycle Taxis with flashlights mounted on the handlebars.


Photo 4. Corrosion from water and battery leakage.

Photo 5. A Household flashlight that had a failed switch and was rewired by the user.

Appendix B. Survey Forms

I. Night Watchmen Survey

Survey Form
Portable Lamps in Kenya
June, 2009

Askari SURVEY

Survey by: Arne Jacobson
Humboldt State University
Arcata, CA 95521, USA

Section 1: General Information (filled in prior to starting interview):

1.1 Name of person(s) administering survey: _____

1.2 Date & time of interview: _____

1.3 Town: _____

1.4 Participant ID # _____ **1.5 Torch ID # _____**

##########

1.6 What is the **name** of the person being interviewed?

Name: _____

1.7 **Gender:** ☐ Female (1) ☐ Male (2)

1.8 Who do you work for? **Employer**: _____

1.9 Where in town are youstationed? **Location**: _____

1.10How long have you **worked** as an Askari?

1.11 Note their monthly income: _____

Section 2: Torch Use

2.1 What **brand** of torchdo you **currently** use? (Describe the torch if no name, i.e. number of LEDs, rechargeable/dry cell, number of light settings).

2.1.1 How long ago did you **start using** the torch you use now? **# Months** _____

2.2 What **brand** of torch did you use **previous** to the one you currently use? (Describe the torch if cannot remember the name, i.e. number of LEDs, rechargeable/dry cell, number of light settings).

2.2.1 How long did that torch **last**? **# Months** _____

2.2.2 Why did you **replace** it?

2.3 In the last 6 months, how many torches have you **used**?**#** _____

2.3.1 In **your opinion**,of the torches you have used in the past, which one was the**best**? **Why** was it better?

Best torch: _____

Why better: _____

_____

2.4 How do you **get** your torches?

☐ I buy (1) ☐ Employer gives (2) ☐ Other _____ (3)

2.5 How much do the torches **initially cost**? **Cost:** _____

2.6 If the torch is rechargeable, how do you **charge**it AND how often do you charge? If it uses dry cell batteries, what type of batteries AND how often do you **replace** them?

☐ Rechargeable (1) Charging Method: _____

How often recharge: _____

☐ Dry Cell (2) Brand Name: _____

How often replace: _____

2.6.1 **Who pays** for the charge/batteries?

2.6.2 What is the **cost** to charge or to buy replacement batteries? **Cost: _____**

2.7 Approximately how many **hours per night**is the torch turned on? **# Hours: _____**

Section 3: What would be an ideal torch?

3.1 How much would you **pay** for a better quality torch that lasted for at least 2 years?

☐ More than1000 [1] ☐ 800-1000 [2] ☐ 600-800 [3]

☐ 400-600 [4] ☐ 200-400 [5] ☐ Less than 200 [6]

3.2 Would you prefer a **rechargeable** torch or one that used **dry cell** batteries?

☐ Rechargeable [1] ☐ Dry Cell Batteries [2]

3.2.1 If you prefer rechargeable, would you prefer to **charge** a torch by

☐ Grid [1] ☐ Solar [2] ☐ Both Grid & Solar [3] ☐ Crank [4]

3.2.2 How **often** would you be able and willing to **charge** the torch?

☐ Everyday [1] ☐ Every 2 days [2] ☐ Every 4 days [3]

☐ Once per week [4] ☐ Once every two weeks [5]

3.2.3 What factors may **limit** you from charging?

☐ Security of Solar [1] ☐ Access to the Grid [2] ☐ Grid Charge Cost [3]

Other Limiting Factors: _____

3.3 What **features** would you like the torch to have?

II. Bicycle Taxi Driver Survey

Survey Form
Portable Lamps in Kenya
June, 2009

Torch Use: Boda Boda SURVEY

Survey by: **Error! Reference source not found.**
Humboldt State University
Arcata, CA 95521, USA

Section 1: General Information (filled in prior to starting interview):

1.1 Name of person(s) administering survey: _____

1.2 Date & time of interview: _____

1.3 Town: _____ **1.4 GPS point** _____

1.5 Participant ID # _____

##########

1.12What is the **name** of the person being interviewed?

Name: _____

1.13**Gender:** ☐ Female (1) ☐ Male (2)

1.14Who do you work for? **Employer**: _____

1.15Where in town are youstationed? **Location**: _____

1.16How long have you **worked** as a Boda Boda driver?

1.17 Note their monthly income: _____

Section 2: Torch Use

2.8 What **brand** of torchdo you **currently** use? (Describe the torch if no name, i.e. number of LEDs, rechargeable/dry cell, number of light settings).

2.8.1 How long ago did you **start using** the torch you use now? **# Months _____**

2.9 What **brand** of torch did you use **previous** to the one you currently use? (Describe the torch if cannot remember the name, i.e. number of LEDs, rechargeable/dry cell, number of light settings).

2.9.1 How long did that torch **last**? **# Months _____**

2.9.2 Why did you **replace** it?

2.10 In the last 6 months, how many torches have you **used**?**#** _____

2.10.1 In **your opinion**,of the torches you have used in the past, which one was the**best**? **Why** was it better?

Best torch: _____

Why better: _____

_____

2.11 How do you **get** your torches?

☐ I buy (1) ☐ Employer gives (2) ☐ Other _____ (3)

2.12 How much did you current torch **initially cost**? **Cost: _____**

2.13 If the torch is rechargeable, how do you **charge**it AND how often do you charge? If it uses dry cell batteries, what type of batteries AND how often do you **replace** them?

☐ Rechargeable (1) Charging Method: _____

How often recharge: _____

☐ Dry Cell (2) Brand Name: _____

How often replace: _____

2.13.1 **Who pays** for the charge/batteries?

2.13.2 What is the **cost** to charge or to buy replacement batteries? **Cost: _____**

2.14Approximately how many **hours per night**is the torch turned on? **# Hours: _____**

Section 3: What would be an ideal torch?

3.4 How much would you **pay** for a better quality torch that lasted for at least 2 years?

☐ More than1000 [1] ☐ 800-1000 [2] ☐ 600-800 [3]

☐ 400-600 [4] ☐ 200-400 [5] ☐ Less than 200 [6]

3.5 Would you prefer a **rechargeable** torch or one that used **dry cell** batteries?

☐ Rechargeable [1] ☐ Dry Cell Batteries [2]

3.5.1 If you prefer rechargeable, would you prefer to **charge** a torch by

☐ Grid [1] ☐ Solar [2] ☐ Both Grid & Solar [3] ☐ Crank/Dynamo [4]

3.5.2 How **often** would you be able and willing to **charge** the torch?

☐ Everyday [1] ☐ Every 2 days [2] ☐ Every 4 days [3]

☐ Once per week [4] ☐ Once every two weeks [5]

3.5.3 What factors may **limit** you from charging?

☐ Security of Solar [1] ☐ Access to the Grid [2] ☐ Grid Charge Cost [3]

Other Limiting Factors: _____

3.6 What **features** would you like the torch to have?

III. Household Survey

Survey Form
Portable Lamps in Kenya
June, 2009

Torch Use: Household SURVEY

Survey by: **Error! Reference source not found.**
Humboldt State University
Arcata, CA 95521, USA

Section 1: General Information (filled in prior to starting interview):

1.1 Name of person(s) administering survey: _____

1.2 Date & time of interview: _____

1.3 Town: _____ **1.4 GPS point**: _____

1.5 **Household ID # _____**

##########

1.6 What is the **name** of the person being interviewed?

Name: _____

1.7 **Gender:** ☐ Female [1] ☐ Male [2]

Section 2: Demographic Information

2.1 What are the major sources of income for your household (check all that apply and indicate the greatest source with a **#1**)?

☐ Business (kiosk / shop / selling goods / etc.)>*type:* _____ [1]
☐ Jua Kali (mechanic / carpenter / dress making / etc.) [2]
☐ Salary / Professional work (ex: teacher) >*source*: _____ [3]
☐ Farming [4]
☐ Remittance [5]
☐ Other _____ [6]

2.2 How many **people** are in your household? #_____

2.3 Do you have **grid** electricity at home? ☐Yes [1] ☐ No [2]

2.4 Do you have grid electricity at your business?

☐ Yes [1] ☐ No [2] ☐ Not Applicable (does not have business) [3]

Section 3: Torch Use

3.1 In the last 6 months, how many torches have you **bought**? **# Torches: _____**
3.2 How long did the torch you used previous to your current torch last? **# Months: _____**

3.3 What are the **main problems** that you have experienced with torches?

Failure of: ☐ LEDs/Bulb [1] ☐ Battery [2] ☐ Switch [3] ☐ Drops & breaks [4]

Other Problems experienced: _____

_____

3.4 Of the torches you have used in the **past**, which one was the**best**? Why was it **better**? (Describe it if cannot remember: # of LEDs, rechargeable/dry cell, # of light settings).

Best torch: _____

Why better: _____

Section 4: What would be an ideal torch?

3.7 How much would you **pay** for a better quality torch that lasted for at least 2 years?

☐ More than1000 [1] ☐ 800-1000 [2] ☐ 600-800 [3]

☐ 400-600 [4] ☐ 200-400 [5] ☐ Less than 200 [6]

3.8 Would you prefer a **rechargeable** torch or one that used **dry cell** batteries?

☐ Rechargeable [1] ☐ Dry Cell Batteries [2]

3.8.1 If you prefer rechargeable, would you prefer to **charge** a torch by

☐ Grid [1] ☐ Solar [2] ☐ Both Grid & Solar [3] ☐ Crank [4]

3.8.2 How **often** would you be able and willing to **charge** the torch?

☐ Everyday [1] ☐ Every 2 days [2] ☐ Every 4 days [3]

☐ Once per week [4] ☐ Once every two weeks [5]

3.8.3 What factors may **limit** you from charging?

☐ Security of Solar [1] ☐ Access to the Grid [2] ☐ Grid Charge Cost [3]

Other Limiting Factors: _____

3.9 What **features** would you like the torch to have?