THE LUMINA PROJECT

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Technical Report #2

The Off-Grid Lighting Market in Western Kenya:

LED Alternatives and Consumer Preferences in a Millennium Development Village

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Note: Consumer assessments of lighting products by focus group participants reported in this document should not be construed as product endorsements by the authors. The information available to the focus group participants was based largely on rated new product attributes and performance, which can differ significantly from values achieved during actual use and over time. Outcomes can also vary as a function of social and economic conditions. The products market tested were versions available as of May 2007.

Field Photographs:
http://web.mac.com/emills4/iWeb/Millennium-Lighting/Millennium-Lighting-Project.html

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Summary

As an outgrowth of discussions begun in the fall of 2005, the Earth Institute at Columbia University and its Global Roundtable on Climate Change asked Lawrence Berkeley National Laboratory to evaluate the potential for off-grid LED lighting for the Kenyan village of Sauri (one site of the Millennium Villages Project, MVP) and environs. The Rosenfeld Fund of the Blum Center for Developing Economies at UC Berkeley co-sponsored the effort. LBNL joined with Humboldt State University in the work.

The specific goals of the project were to determine product quality,[1] durability, consumer acceptance, and willingness to pay among people at the bottom of the economic pyramid, and to design a market test based on the findings. We began by reviewing data from the Sauri baseline survey and experiences with an existing LED lamp-loan program for students. We also surveyed local markets for prices and availability of LED lights, batteries, etc., observing that a wide variety of grid-chargeable LED "torches" have appeared alongside traditional incandescent ones. We gathered samples for testing. We also measured kerosene use rates for a variety of traditional lanterns as used in local homes and street stalls. Using measured performance data, we developed total cost of ownership estimates for kerosene lanterns and a variety of alternative LED lighting systems, including full price build-up (freight, shipping, duties, VAT, distribution, and profit margins for each party in the value chain—which almost doubles the prices from FOB levels). We discovered that price is not a good predictor of product illumination performance.

We conducted one-on-one and focus-group meetings with about 80 potential users of off-grid LED lighting in Sauri, Yala, and Kisumu. In these sessions, we obtained end-user feedback on various commercially available LED lighting products based on lighting performance and costs of ownership. There was a clear fit between virtually all users and one or more of the lights, and their ability/willingness to pay (without subsidy) was evident. Participants were willing to spend more than they currently do on kerosene for superior lighting. Through discussions with members of the Sauri Energy Committee and the MVP Infrastructure and Enterprise teams, we developed recommendations for a market test, which will be orchestrated by Columbia University. We recommend beginning with an educational phase, in which a few samples are made available to villagers, and then expanded to retail selling of systems through the Energy Kiosk and the Bar Sauri Primary School. Selected buyers should be interviewed to determine their level of satisfaction with the products and resultant energy or battery savings, and the data correlated with demographic information from the existing baseline survey. Sales should occur in December 2007, after harvest when disposable income is relatively high.

We strongly recommend that the products be offered initially to end users at market prices (rather than subsidized as originally planned by Columbia University and the MVP). If ineffective, better information will then be available with which to determine an appropriate level and form of subsidy. A prototype LED lighting system developed by the Columbia University presents sufficient performance problems and high cost that we do not recommend its use in the market test. We suggest focusing the project on the three alternate products that end-users felt provided the best lighting services and have market prices within their willingness to pay, i.e. under approximately $25 including price build-up. Indeed, many end-users expressed considerable eagerness to purchase these lights.

[1] See http://light.lbl.gov/technology-assessment.html for reports and the summary presentation available at http://eetd.lbl.gov/emills/PRESENTATIONS/Mills-QA-Airlie.pdf

Delegation & Formal Meetings

The research team included Evan Mills (Lawrence Berkeley National Laboratory, LBNL), Arne Jacobson (Humboldt State University, HSU), and Maina Mumbi (Maai Mahiu, Kenya). Mills has conducted research on off-grid lighting since 1995 and leads the Lumina Project at LBNL. Jacobson has worked with developing country renewable energy systems for over 12 years; he began work in Kenya in 1999 and speaks Swahili proficiently; Mumbi is a Kenyan native and a solar technician in a small town outside of Nairobi; he has also worked extensively with Jacobson and others on rural energy research projects.

In addition to numerous focus-group discussions with end users, we had meetings with Millennium Village Project (MVP) staff and others, as follows:

In Sauri and Yala:

- Gabriel Oduong – Head of Infrastructure, Sauri Sublocation, MVP
- Daniel Sijenyi Buyu, Energy Committee Chairman
- Jarred Oule – Community Development Facilitator, Sauri
- Alfred Ajuala – Assistant Chairman, Sauri Energy Committee
- James Juma – Coordinator of lantern program at Bar Sauri school
- Joseph Lanyo, Head Teacher, Bar Sauri Primary School
- Monica Oketch – Chairman of the Sauri Executive Committee
- Millicent, Head Teacher, Nyamninia Primary School, Sauri
- Josephine Achleng Jeje – Coke Kiosk owner on main road

In Kisumu:

- Patrick Mutuo, Science Coordinator, MVP
- Peter Koinei, Infrastructure Coordinator, MVP
- Eliud Lelerai, Database Manager, survey development and analysis, MVP
- Patrick Ogaya Okeyo – Logistics, MVP
- David Rotich, Enterprise Coordinator, MVP
- Ashraf Mitha, Mitha Electricals
- Cornel Rakwaro, Sollatek (solar dealer)
- Mehindi Dahya, Punjani Electrical and Industrial Hardware

Elsewhere:

- Samuel K Ndung'u, Solar Electronic Technican. ELSAM Electronics, Naivasha
- Michael Franz, Renewable energy consultant to GTZ
- Myra Mukulu, Project Assistant, GTZ
- Mark Hankins, solar energy consultant, Nairobi

The Millennium Villages Project: Overview of Sauri Sub-location

More than one billion people worldwide struggle to survive on less than $1 a day. By empowering the poorest of the poor, Millennium Villages Project (MFP) seeks to demonstrate that it is possible to escape the cycle of extreme poverty, hunger and disease throughout sub-Saharan Africa. Metrics are based on the Millennium Development Goals.[2]

Goal 1: Eradicate Extreme Hunger and Poverty
Goal 2: Achieve Universal Primary Education
Goal 3: Promote Gender Equality and Empower Women
Goal 4: Reduce Child Mortality
Goal 5: Improve Maternal Health
Goal 6: Combat HIV/AIDS, Malaria and other diseases
Goal 7: Ensure Environmental Sustainability
Goal 8: Develop a Global Partnership for Development

By investing in health, food production, education, access to clean water, and essential infrastructure, these community-led interventions are intended to enable impoverished villages to escape extreme poverty. The hope of the MVP is that once these communities get a foothold on the bottom rung of the development ladder they can propel themselves on a path of self-sustaining economic growth.

The MVP concept was developed by a team of scientific experts at The Earth Institute at Columbia University and the UN Millennium Project. Millennium Promise is working in more than 75 villages in ten different countries: Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, Rwanda, Senegal, Tanzania and Uganda.

Improved lighting can contribute to attainment of some of these goals, e.g. to eradicating poverty by reducing the significant expenditures of households on lighting fuels and batteries, to achieving better education by improving the quality and availability of lighting for evening and early-morning studies, and to promoting gender equality by reducing the cost and time burden on women associated with purchasing and transporting lighting fuels and batteries and by engaging women in enterprises selling improved lights.

The following description of Sauri "sub-location"—the location of our project—is found on the Millennium Villages website:[3]

> *The Millennium Villages in Kenya are located in Yala Division, Siaya District, Nyanza Province in the western part of the country. They are situated just north of the equator in the highlands, west of the Rift Valley and 30 km north of Lake Victoria. The general topography is undulating with ephemeral streams, rivers, and wetlands meandering through rounded hills. Sauri Millennium Village covers 8 km^2 and is a conglomerate of 11 villages.[4] Nearly all citizens are Kenyan from the Luo ethnic group. The main languages spoken are Dholuo, Kiswahili, and English. There is an average household size of 5 people each.*

[2] http://mp.convio.net/site/PageServer?pagename=press_mdg
[3] http://mp.convio.net/site/PageServer?pagename=mv_sauri
[4] Nyamboga, Silula, Nyamninia A, Nyamninia B, Sauri A, Sauri B, Luero, Madiri, Yala A, Yala B, Kosoro, and Yala Town.

The region is beset by hunger, AIDS, and malaria. Malnutrition and poor health plague communities; villagers have limited access to medical care and most cannot afford to buy the few medicines that are available. The average distance to a clinic or medical care prior to the implementation of the Millennium Villages was 5 km over rough terrain. Yala Sub-District Hospital serves more than 96,000 people. There was no medical doctor at Yala until January 2005, when the Millennium Village Project brought one in to split his time between the hospital and the Sauri clinic. Sauri is a holoendemic area for malaria, meaning that malaria is prevalent year-round. Children carry a higher burden of morbidity and mortality than do the surviving adults who become partially immune. In the region, Ministry of Health statistics show that 52% of residents are afflicted with malaria, and 24% with HIV/AIDS.

The Millennium Villages in Kenya have a strong community system, but lack the revenue for basic services necessary to sustain economic growth. Most households are subsistence or sub-subsistence farmers, and many residents rely on remittances from people living and working outside of their village to supplement their meager farm incomes.

In 2004, Sauri became the first Millennium Village selected. The rural community of 5,300 people made a commitment to pulling itself out of poverty, but lacked the means to do so.

As of the 2005 Baseline Study, 79% of the population live below $1 per day and 89.5% live below $2 pe rday, 17% of children under five years of age are underweight, child mortality rate is 149/1,000 live births (under age 5) and infant mortality is 95 per 1000 live births.[5] Sixty-six percent of boys under five and sixty percent of girls test positive for malaria, and malaria is the cause of death in 55% of the cases for the Sauri population at large. Approximately 30% of women aged 15-24 tested positive for HIV. Virtually all villagers use solid fuels for cooking.

Current Lighting Situation in the Sauri Sub-location

Thanks to the Sauri Baseline Survey, a significant amount is known about off-grid lighting in the village. The survey was completed in 2007 (2005 data). While the entire village (approximately 900 households) is covered by most of the Baseline survey, a stratified random sample of 300 households responded to the energy section of the survey.

Electricity is just beginning to come to Sauri, with a few non-household locations electrified, including one of the schools, the clinic, and soon the Energy Kiosk. Less than 1% of the houses in Sauri have grid electricity connections. For those who do have a connection, power outages are a frequent occurrence, with most people we interviewed reporting outages of a few hours a few times a week (but highly variable, with some relatively long periods uninterrupted but punctuated with day-long outages). The electrification rate is higher in Yala.

For non-electrified users, the kerosene-fueled “tin” lantern is the most prevalent type of light. Candles and LPG-based lighting are rarely used. Flashlights powered with disposable batteries

[5] Sauri Baseline Report, page 7.

are commonplace. Some households do not even use kerosene, meaning that what little light they obtain is from their cooking fires.

According to the Sauri Baseline study, 91% of households (Figure 1) report that their primary use of kerosene is for lighting, and lighting expenditures (for kerosene and half of disposable battteries and battery charging) represent about 11% of total non-food household expenditures.[6] Median per-capita expenditures for kerosene are 300 KSh per year (~$4.60),[7] and 154 KSh per year (~$2.40) for batteries; corresponding to about 1800 KSh (~$27) and 924 KSh (~$14) per household, respectively.[8] We noted that this is much lower than the Kenya average. Kerosene represents 71% of the average lower-income Kenya households' cash energy budget (i.e. excluding collected fuelwood), and 29% of the budget for middle/upper income households.[9] Prevailing kerosene prices are 55 to 60 KSh per liter (~$0.90), when purchased in one-liter quantities. More lighting detail is said to be available in the data files, but Columbia/MVP staff in Kisumu and New York have not been able to recover the information.

We were told that some individuals buy multi-liter quantities of kerosene for resale from their homes. It is common for poorer people to purchase this kerosene in very small quantities (e.g. 1 deciliter or less) for two- to three-times the per-liter price (Figure 2). For example, we were told that people pay 5KSh (~$0.08) for 30ml from small vendors in Sauri, or 150 KSh (~$2.30) on a per-liter basis. Average national kerosene prices have increased 132% between 1998 and 2005, including a 25% jump between 2004 and 2005.[10]

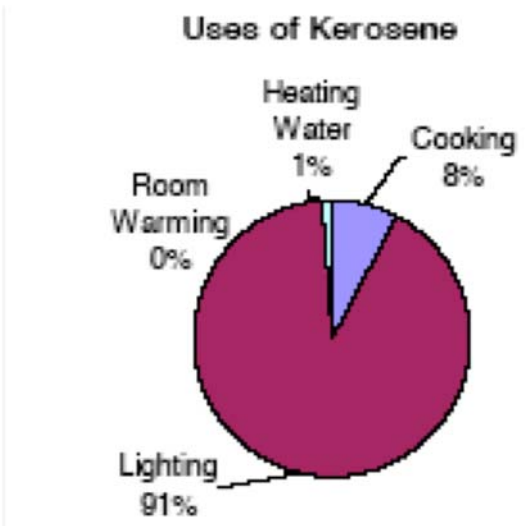


Fig. 1. Primary uses of kerosene. Source: Sauri Baseline Report, 2005 data, N=300 households.

Fig. 2. Child carrying kerosene in Coke bottle (Luanda)

[6] Sarui Baseline Report, Table 24, page 33, and Figure 28, page 78.
[7] An exchange rate of 65 KSh/US dollar is used throughout this report.
[8] Sauri Baseline Report, Table 66, p. 77.
[9] Kenya Statistical Abstract 2006. Kenya Bureau of Statistics, p. 298.
[10] Kenya Statistical Abstract 2006. Kenya Bureau of Statistics, p. 307.

A number of kerosene lantern owners allowed us to test their lanterns to determine actual fuel-use rates. The test method involved weighing the lantern on a digital balance, having the owner light the lantern and burn it for 30 minutes or more, at which time it was re-weighed (Figure 3).

Flg. 3. Determining rate of kerosene use by weighting lamp at two intervals.

A simple conversion using elapsed time and the specific gravity of kerosene yields the fuel-consumption rate. The 10 "tin" lanterns we measured averaged 0.02 liters per hour. The one hurricane lantern tested consumed 0.03 liters per hour.

Night markets take place most days at two or more locations in Yala, with about 30 tin lamps in use for two or so hours. Many of the kiosks also use kerosene lanterns.

Schools are another important locus of kerosene lighting use. As of 2005, there were 1624 students enrolled in primary and secondary schools in the Sauri Sublocation.[11] Some students at and above Grade 4 (age 10) bring kerosene "tin" lamps to school each day for "prep" study periods from about 6:00 to about 7:30 am. Students reported using about 10 KSh (~0.2 liters) (~$0.15) per day for these periods plus their evening studies.

The schools in both Sauri and Yala have night study centers up until about 7:30 pm, where kerosene light is used. One schoolteacher stated that 90% of the students attend 5 days per week. Given the very large population of school-age children, this particular set of kerosene uses is probably quite significant. The head teacher from one school noted that poorer childrens' families often do not have kerosene at home, which means that homework and study cannot be done on those evenings. One school stated that 270 students read by tin lamps each morning (five Columbia University Power Packs are in use at the school during these periods).

[11] Sauri Baseline Report, Table 28, page 38.

Off-grid lighting services are predictably low. We took measurements in night markets at Yala and in Kisumu. Illuminance levels (lux per square meter) ranged from 1-20 lux depending on the type of lantern, height of flame, and distance from light. For comparison, recommendations for retail lighting illuminance levels from a variety of countries surveyed in the early 1990s ranged from 150 to 1000 lux.[12] We also measured *daytime* illuminances in one classroom (Bar Sauri Primary School) (Figure 4). Levels were very low by western standards, i.e. ranging from 35 to 270 lux on the student desks and from 20 to 80 lux on the chalkboard. Recommendations range from 150 to 500 lux for classroom general lighting and 300-750 lux for chalkboard lighting. In addition to the low absolute levels, the wide variations are also undesirable. In some developing countries, parents request for their students to be seated near windows. The variability of light on the chalkboard can create visual strain for both the teacher and students.

Fig. 4. Illuminance measurements in Bar Sauri Primary School.

Market Survey: The Coming of LED Lighting to Kenya

We surveyed markets for lights, batteries, and charging services in Nairobi, Kisumu, Luanda (a market center on the road from Kisumu to Yala and Sauri), and Nakuru (Figures 5-15). A variety of LED lighting products have appeared in Kenya over the past year or so (almost exclusively based on a rechargeable flashlight or "torch" form factor), mostly with built-in SLA batteries. All appear to be imported from China. Prices are typically in the 100-300 KSh range (~$1.50 to $4.50).

[12] Mills, E. and N. Borg. 1999. "Trends in Recommended Lighting Levels: An International Comparison." *Journal of the Illuminating Engineering Society of North America* 28(1):155-163.

Fig. 5. "Tin" lanterns for sale in Luanda market.

Fig. 6. Torches, wicks, dippers, torches, and other assorted goods for sale in Luanda market.

Fig. 8. Kerosene fuel dippers for sale in Luanda market.

Fig. 7. Batteries for sale in Luanda market.

Fig. 9. LED flashlights for sale in Luanda market.

Fig. 10. LED flashlights for sale in Luanda market.

Fig. 11. Batteries for sale in Luanda market.

Fig. 12. Solar and battery-charging store in Luanda.

Fig. 13. Phone-charging service in Luanda. market.

Fig. 14. Wind-up LED flashlight for sale in Kisumu Nakumatt.

Fig. 15. Inventorying battery prices in Kisumu Nakumatt.

We discovered one counterfeit hand-crank flashlight in a street market in Luanda, i.e. when disassembled it contained inexpensive non-rechargeable batteries (Figure 16).

We identified one solar powered torch (which also has a grid-based charging option), for 900 KSh (~$13.85) (after bargaining) at Elsam Electronics in Naivasha (Figure 17). As a reference point, the shop owner said he sells two per month, and does not maintain inventory. He sells 10 normal LED rechargeable torches each month, and about 5 traditional incandescent torches per month. If this is indicative, then LED flashlights have attained a good market share.

Fig. 16. Counterfeit hand-crank light. The small "coin" type batteries are not rechargeable. The lamp will cease to light once batteries are dead.

The existing phone- and battery-charging enterprises are charging these flashlights for ~20 KSh (~$0.30) per charge. It is likely that they are undercharging the batteries, which can shorten battery life.

Fig 17. Solar flashlight for sale in Naivasha.

Some solar technicians in the Nairobi the area are aware of white LEDs and are experimenting with off-the-shelf products and "home-made" assemblies. There is an awareness of and concern about uneven quality. An electrical and solar supply shop in Kisumu had samples of a ~1W LED cluster built into a pin-based halogen reflector (400 KSh [~$6], 12V, via Sanyug in Nairobi). We gathered some of these for quality testing at HSU. Several other solar shops visited did not have any LED lights. While not directly relevant to the current study, it is worth noting that we observed solar panels for sale in Kisumu electrical shops that appeared to be made in China, but were labeled as made in Western Europe. Previous studies by Jacobson *et al*. have shown such panels to considerably under-perform relative to manufacturers' claims.[13]

[13] Duke, R.D., A. Jacobson, and D.M. Kammen, 2002 "Product quality in the Kenya solar home systems market," *Energy Policy*, 30, 477-499. Jacobson, A. and D.M. Kammen, 2007. "Engineering, institutions, and the public interest: Evaluating product quality in the Kenya solar photovoltaics industry," *Energy Policy*, 35, 2960-2968.

In a perhaps indicative anecdotal story, the chairman of the Sauri Energy Committee had recently received a battery-powered LED torch, which had failed within the first couple of months. We diagnosed the problem down to a bad resistor. This is emblematic of the risk of "market spoiling" if inferior products are introduced in place of products that will satisfy end users.

Import duties for some renewable energy and energy-saving products were reduced sharply beginning in 2002 (e.g. from 25% to 5% and then to zero). This includes solar and LED products. The duties for some energy products such as fluorescent lights and batteries remain relatively high, however. A summary of the current duty and value added tax (VAT) rates is included in Table 1.

Table 1. Kenyan Import Duties and Tax Rates for Selected Energy Products

Item	Duty Code #	Import Duty (%)	VAT (%)
Solar Photovoltaic Module	8541.40.10	0%	0%
Light Emitting Diode	8541.40.90	0%	16%
Fluorescent Light	8539.31.00	25%	16%
Portable Electric Lamp		10% (0%)*	16% (0%)*
Lead Acid Battery	8507.20.00	25%	16%
Nickel-Cadmium and Nickel Metal Hydride Rechargeable Batteries	8507.30.00	25%	16%

Sources: i) Kenya Gazette Supplement, Acts, various editions from 2002 – 2007, published by the Government of Kenya; ii) Annex I to the East African Community Customs Union Protocol, 2007 edition, published by the East African Community.

* solar portable electric lamps are free of duty and VAT, while those charged using other means are subject to 10% import duty and 16% VAT.

Three types of LED lanterns have been obtained for evaluation by the MVP office in Kisumu:

- The Columbia Power Pack (assembled from disparate components, at least partly made at least in part in China). This system is grid-charged, and it uses a 12V, 4.5mAh SLA battery and an Altalux Electronix 12x5mm LED task light. The Power Pack is also designed to operate using a 7-Watt CFL light. We estimate the retail price to be ~$62 (4,000 KSh) for the CFL version and $85 (5,500 KSh) for the LED version, respectively, based on wholesale prices provided by the MVP office and price buildup including VAT, import duties, distribution costs, and margins. Prices would be higher if the product is not deemed by import officials to be a portable light, or the SLA battery is dutied separately at 25% (per Table A)
- The "Mighty Light" from Cosmos Ignite Innovations (India). This is a solar-powered torch-style lantern with one super-bright 1-watt LED, adjustable optics, and three NiMH AA batteries. We estimate the retail price to be ~$80 (5,300 KSh).
- The "Thrive" light (India). This is a table-top lantern with 8x5mm LEDs and a 6V SLA battery. It is grid-charged, but has a solar option (extra cost not known). We estimate the retail price to be ~$23 (1,500 KSh).

We included each of these lights in most of our Focus Group meetings (described below), plus a variety of others, described below.

Battery availability, quality, and pricing are integral to the performance and cost of LED systems. We surveyed batteries from street sellers and major stores in Kisumu (e.g. Nakumatt). The costs per rated capacity varied by a factor of six for rechargeable AA and AAA batteries. Costs for larger batteries, such as replacements for the Thrive lantern ranged from 450 to 650 KSh (~$7 to $10). We purchased a wide range of batteries for testing at HSU to determine actual capacity and service life (Appendix C). Following are some issues to bear in mind for systems relying on rechargeable batteries:

- Charging services become non-operational during power outages, which appear to be somewhat frequent in the Sauri area.
- The instructions accompanying one product we brought to Kenya (Barefoot Power)[14] state that their lamps should be charged no less than 12 hours and no more than 24 hours. Given that the existing practice is to charge cell phones for 4 hours (for 20 KSh, ~$0.30) and LED torches for 6-8 hours (also 20 KSh), it is possible that charging shops will undercharge LED lamps that have charging times that exceed these periods.
- Overcharging can damage SLA batteries. None of the systems we have seen have a "full-charge" indicator, and thus under/overcharging is a real likelihood.
- SLAs left discharged for long periods will experience deterioration of functionality.
- Without proper waste disposal, the lead from SLA batteries will be mobilized in the environment. It appears that Sauri residents currently dispose of batteries by dumping them into their latrines.[15]

Sauri School Light Lending Program

For the past year or so, fifteen Columbia University Power Pack (CUPP) lighting systems have been made available to students of three schools in Sauri (Figure 18). Five of these have LED light accessory lights, with the remainder being 7-watt compact fluorescents. The 12v 4.5ah battery packs are charged centrally (at the school) and sent home with students for evening study, as well as used in some cases for early morning study at the school.

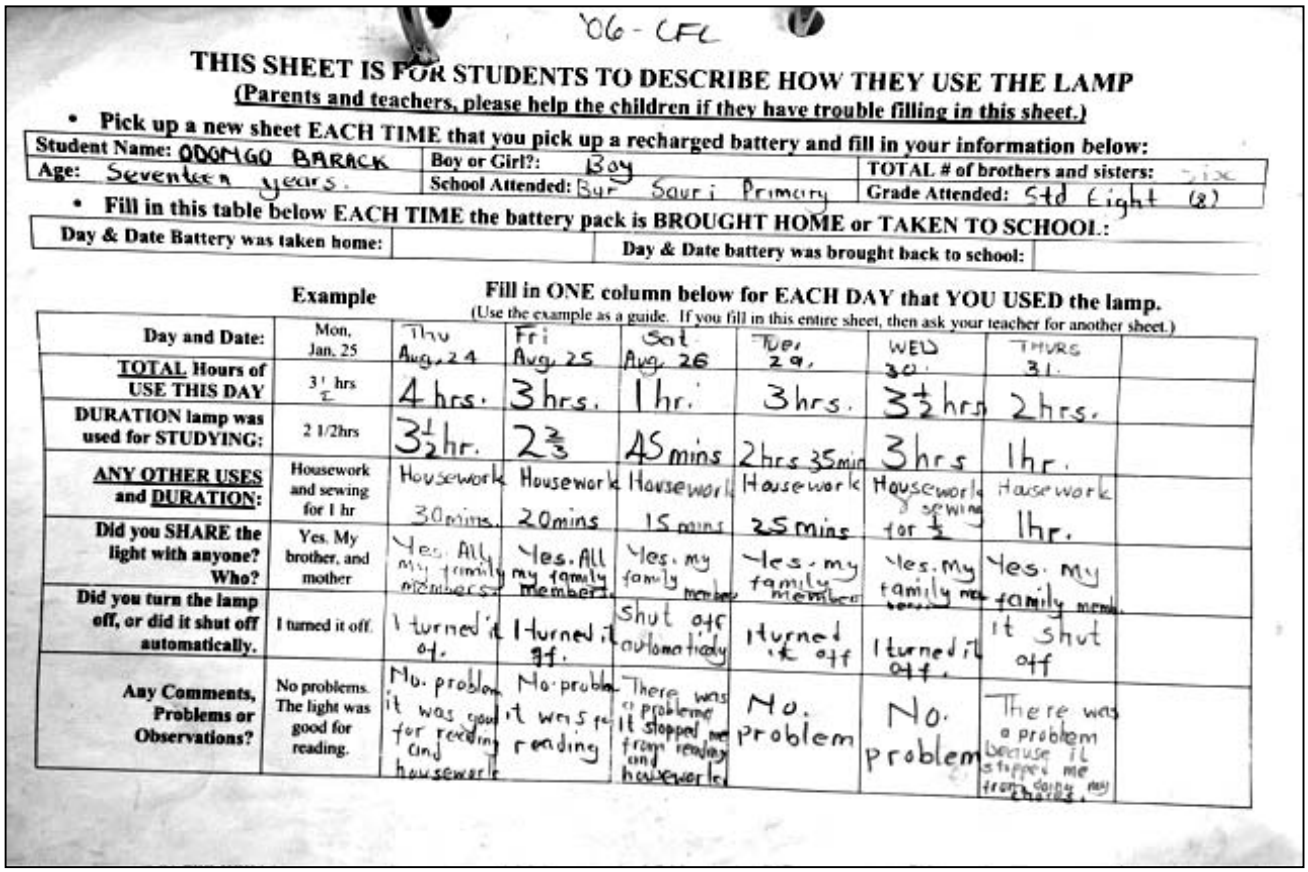
Fig 18. Alfred Ajuala (Assistant Chairman, Sauri Energy Committee) keeps the battery packs (right, rear) charged for the Sauri Schools LED and CFL light-lending project.

[14] Throughout this report, this product, referred to as "Barefoot Power" (the distributor) is a desk lamp manufactured by Yage.
[15] Per email from Gabriel Oduong, June 27, 2007.

A user-data instrument has been prepared and deployed with which students make daily logs of their use of the light and comments about quality or problems (Figure 19).[16]

The lights are much liked by the students, and are used for 2 to 3 hours per day in most cases. Their primary use is for studying, but other uses exist as well, particularly for the CFLs, which have much wider light distribution and can be used simultaneously for study and other purposes. When the CFL is used, the charge lasts for an average of 7.1 hours; when the LED is used the charge seems to last for about 25 hours. Several students that we talked with expressed a preference for the CFL light because it provides more light and can be used for a variety of applications. Two mentioned that the CFL allowed several students to study at once, while the LED was most suitable for a single student.

This lighting service is provided at no cost to the users and so does not yield any information as to the affordability and willingness to pay for purchasing or charging.



'06 - CFL

THIS SHEET IS FOR STUDENTS TO DESCRIBE HOW THEY USE THE LAMP

(Parents and teachers, please help the children if they have trouble filling in this sheet.)

- **Pick up a new sheet EACH TIME that you pick up a recharged battery and fill in your information below:**

Student Name: ODONGO BARACK	**Boy or Girl?:** Boy	**TOTAL # of brothers and sisters:** Six
Age: Seventeen years.	**School Attended:** Bar Sauri Primary	**Grade Attended:** Std Eight (8)

- **Fill in this table below EACH TIME the battery pack is BROUGHT HOME or TAKEN TO SCHOOL.:**

Day & Date Battery was taken home:	**Day & Date battery was brought back to school:**

Example — **Fill in ONE column below for EACH DAY that YOU USED the lamp.**

(Use the example as a guide. If you fill in this entire sheet, then ask your teacher for another sheet.)

Day and Date:	Mon, Jan. 25	Thu Aug. 24	Fri Aug. 25	Sat Aug. 26	Tue. 29.	WED 30.	THURS 31.	
TOTAL Hours of USE THIS DAY	3 1/2 hrs	4 hrs.	3 hrs.	1 hr.	3 hrs.	3 1/2 hrs	2 hrs.	
DURATION lamp was used for STUDYING:	2 1/2hrs	3 1/2 hr.	2 2/3	45 mins	2 hrs 35 min	3 hrs	1 hr.	
ANY OTHER USES and DURATION:	Housework and sewing for 1 hr	Housework 30 mins.	Housework 20 mins	Housework 15 mins	Housework 35 mins	Housework sewing for 1/2	Housework 1 hr.	
Did you SHARE the light with anyone? Who?	Yes. My brother, and mother	Yes. All my family members.	Yes. All my family members.	Yes. my family members	Yes. my family members	Yes. My family members	Yes. my family members.	
Did you turn the lamp off, or did it shut off automatically.	I turned it off.	I turned it off.	I turned it off.	Shut off automatically	I turned it off	I turned it off.	It shut off	
Any Comments, Problems or Observations?	No problems. The light was good for reading.	No problem it was good for reading and housework	No problem it was for reading	There was a problem It stopped me from reading and housework	No. problem	No. problem	There was a problem because it stopped me from doing my chores.	

Fig. 19. Student survey being administered at Bar Sauri Primary School. Students log information each day on hours of use, types of use, loss of charge, and other comments.

[16] These records are kept in a binder at Bar Sauri School and have been analyzed to some degree as indicated by an undated one-page statistical summary, prepared by Edwin Adkins.

The wholesale price for the CUPP is reported to be $45 for the LED version and $33 for the CFL version,[17] which is considerably below a market price (i.e., net of real-market distribution costs, margins, VAT and import duties,[18] and perhaps some labor costs).

The CUPP lantern has the highest annualized replacement battery cost of the lanterns reviewed thus far in the project (approx 1,000 KSh, or ~$15), assuming the batteries perform as advertised; note that the battery is uncommon in Kenya and not yet consistently available for purchase in the nearest city, Kisumu). The second-most costly battery is that for the Thrive lantern, at a local retail price of about 500 KSh (~$8). Systems based on AA rechargables have annual battery replacement costs from 300 to 600 KSh (~$5 to $9).

The CUPP lights also have some standby losses ("self consumption"), which drain the battery even when not in use. This is expected when charge-controllers are present. We measured 1.8 mAh self-consumption, which is equivalent to a daily consumption level of approximately 1% of battery capacity (Figure 20).

Fig. 20. Measuring standby power consumption from the power supply of the Columbia University Power Pack light.

The report from Edwin Adkins notes that fuses are replaced every 6-7 charges (concentrated during one time period, which may indicate power surges from the grid). During our visit, one of the other lights had a blown fuse, which was replaced after we tried to test the light. We also determined that two of five of that school's systems had non-functioning batteries. It was not clear how long these non-functioning lights had been out of circulation.

It should be noted that battery-charging shops would have to purchase a special power supply in order to charge these batteries (it is unlikely that the shops would already own one, as these charging businesses typically handle phones which have dedicated power supplies). The cost of this power supply is estimated at 3,000 KSh (~$46, versus ~$25 in the US free of VAT and import duties). In contrast, most other grid-charging lights come with their own power supplies.

Defining "Optimal" Quality and Performance in the Kenya Context

Based on the results of our focus-group interviews (see next section), the more costly LED options (e.g. Mighty Light (Cosmos Ignite Innovations), Easy Light (Free Energy Europe), X-Ray (Freeplay), CUPP (Columbia University)) are out of reach for the poorest consumers, but will no doubt find niches in the market among users with higher incomes. For contexts like Sauri and Yala, users will make their own calculus of the value of performance (brightness, hours of light output per charge, etc) and quality (acceptable failure rates). Most people we interviewed stated that they would not purchase lights above a price above1,400 KSh (~$21.50).

[17] Email from Edwin Adkins, Columbia University, June 22, 2007.

[18] Lamps imported for Sauri research purposes will be exempt from VAT and import duties, thanks to an import arrangement through ECRAF, but this will not apply when lights are imported and sold in the open market.

This threshold is consistent with feedback obtained by the MVP from the Sauri Energy Committee, which stated they were willing to pay 1,250 KSh (~$19.25) for the CUPP.[19] However, the higher-cost lights may well find a large niche among more well-off buyers in Sauri and beyond. Note that the fraction of the population that may be able to afford the higher cost lights is likely to be larger in many other parts of Kenya than it is in Sauri, where 79% of the households earn cash income of less than $1 per day. For the most price-sensitive market segments, the lower-cost lamps (e.g. those with grid-charged SLA batteries) may be seen as being "worth it" even if they last only two or so years.

Light output and quality (e.g. uniformity) will be a key part of consumer valuation. End-users will be satisfied with light levels well below standards existing in industrialized countries, but it is nonetheless important to provide light at levels that are sufficient to avoid undue visual strain. Night-market vendors were consistently happy with light levels of about 15 lux, which is quite low by Western standards but far higher than the 1 to 5 lux that most of their goods receive when lit by kerosene lanterns. Moreover, the very poor color-rendering of flame-based lighting does not make their goods attractive, whereas LED light provides far superior color rendition.

Focus Groups and End-User Interviews

We presented products to end users based on three broad category groupings, i.e.: torches (flashlights), task lights (e.g. for reading), and ambient lights (e.g. for social interaction). We presented up to 15 lights to each focus group, as shown in Figure 21. The structured part of each session included an introduction of the three visitors (Mills, Jacobson, and Mumbi) with a thumbnail description of each of our backgrounds and why we were visiting the area. Some of the sessions were more open-ended. In some cases we presented the subset of lights to the group that stood the best chance of meeting the participants' lighting needs.

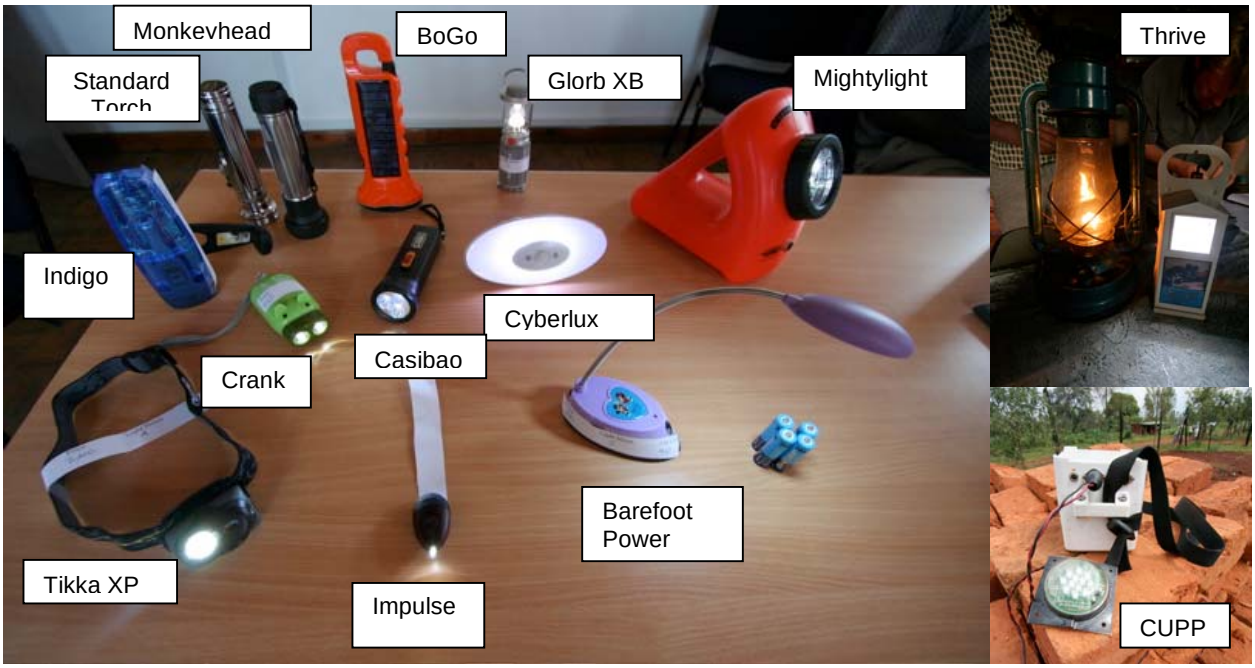


Fig 21. LED lanterns presented to the focus group and interview participants for evaluation.

[19] Email from Peter Koinei, June 18, 2007.

The meetings were held at night or darkened rooms so users could see the full lighting performance of the lamps. We provided a description of all of the lights, including:

- Economics (purchase price estimate), monthly operating cost (for charging), cumulative cost by end of first year, and battery replacement cost (Figures 22-24).
- Function as well as performance (number of hours of light per charge and battery replacement interval).). Note: spot measurements were made on lanterns to estimate their current draw and the number of hours of service provided by a full battery (Figure 25). Performance information given was "as-rated". We know from testing that actual performance can be significantly different.

Fig 25. Measuring current draw for LED lights.

The participants were then able to handle the lights and ask questions. Participants picked their preferred lights, weighing all factors. While we received a wide diversity of responses (as shown in the appendices), there were a few common findings:

1. Given adequate product information, participants were able readily to weigh tradeoffs between low initial cost and high operating costs, on the one hand, versus higher initial costs and lower operating costs, on the other. Figures 22 and 23 indicate that users are willing to spend more than they currently do on kerosene for superior lighting, and from figure 24 that price is not a good predictor of performance, at least as represented by peak illuminance.
2. While there is a need to balance quality against cost, participants were reluctant to adopt products that do not produce enough light or will break prematurely (even if prices are low). Participants inquired about warranty coverage.
3. There is a considerable desire for solar-powered options so as to avoid battery recharging costs and reliance on intermittent grid electricity availability for charging. There is significant price sensitivity to the frequency and cost of battery charging.
4. Participants indicated that alternatives to cash purchases (e.g. installment payments or rental) would make a significant impact on affordability.
5. A "torch" (flashlight) form factor creates an expectation of low price, irrespective of performance or attributes. This came out specifically in the case of the BoGo product, which is solar-charged (thus saving significant recharging costs), and emits more light than typical torches.
6. Not a single participant expressed sentiments that the types of market prices carried by these products would require a subsidy, and, in fact, many participants wished to purchase lamps on the spot at the quoted market prices.

Weighing all factors, the audiences consistently gave the highest rankings to the following lanterns (in alphabetical order):

- BoGo (solar torch) ~ 850 KSh (~$13) estimated initial market price
- Thrive (rechargable room light) ~ 1,500 KSh (~$23) estimated initial market price
- Barefoot Power (rechargable task light) ~ 375 KSh (~$6) estimated initial market price

The MVP Head of Infrastructure received about 20 requests for BoGo and Barefoot Power lights within three weeks of the focus group meetings.[20]

[20] Email from Gabriel Oduong, July 7. 2007.

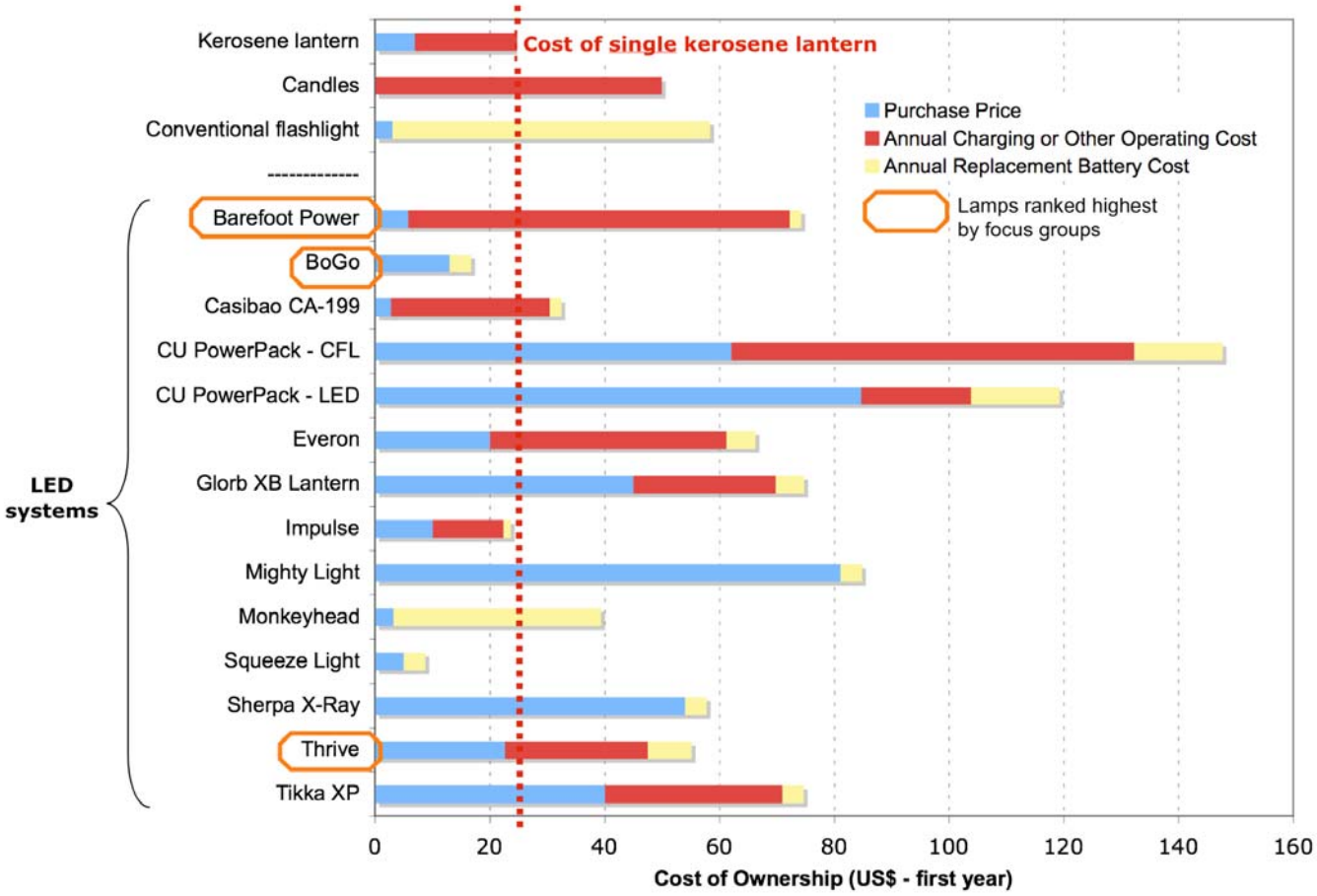


Fig 22. Total yearly cost of ownership for various LED lighting products, with comparison to kerosene lighting and conventional flashlights with disposable batteries – Kenya conditions. Prevailing retail prices used where available; price buildup for other products based on quoted wholesale price plus Kenya-specific VAT, import duties, distribution costs, and margins. Assumes 3 hours/day operation for all system, and ~$0.30 recharging fee for grid-charged products with AA or AAA batteries, and $0.45 for larger sealed lead-acid batteries. Preliminary estimates; results are Kenya-specific assuming a conventional retail value chain, and should not be extrapolated to other markets.

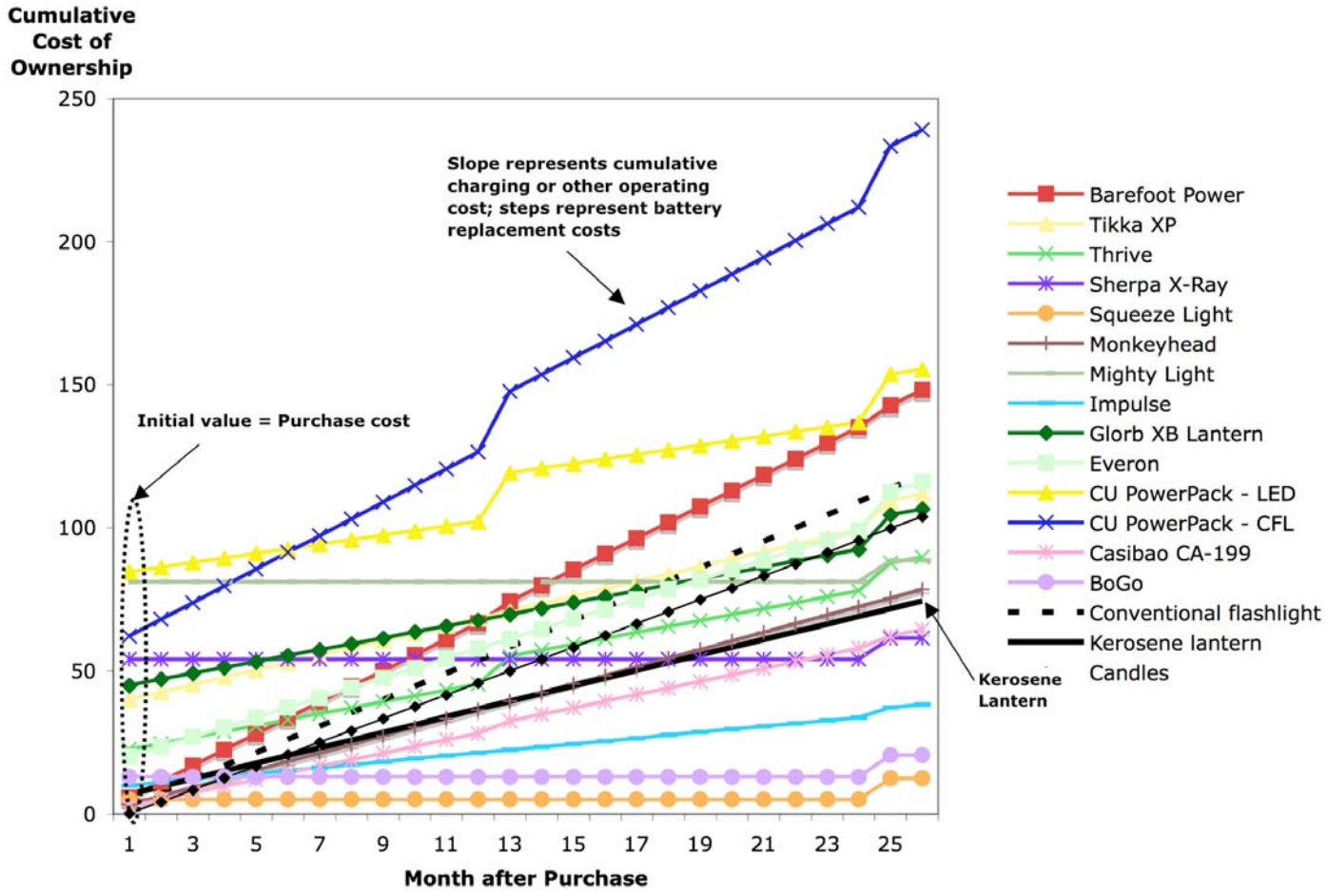


Fig 23. Cumulative cost of ownership for various LED lighting products, with comparison to kerosene lighting and conventional flashlights with disposable batteries – Kenya conditions. Assumes 3 hours/day operation for all system, and ~$0.30 recharging fee for grid-charged products with AA or AAA batteries, and $0.45 for larger sealed lead-acid batteries. Preliminary estimates; results are Kenya-specific, assuming a conventional retail value chain, and should not be extrapolated to other markets.

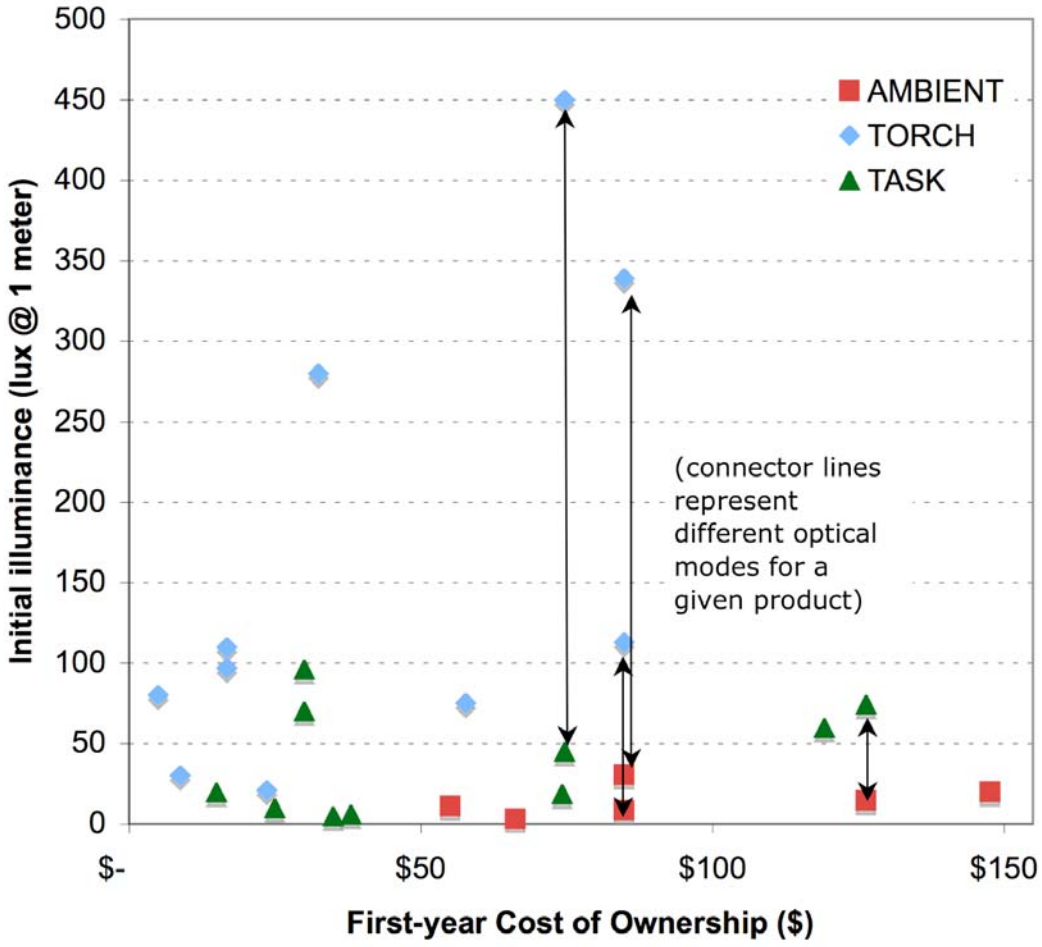


Fig 24. Total yearly cost of ownership versus service level for various LED lighting products, grouped by product type – Kenya conditions. Prevailing retail prices used where available; price buildup for other products based on quoted wholesale price plus Kenya-specific VAT, import duties, distribution costs, and margins. Assumes 3 hours/day operation for all system, and ~$0.30 recharging fee for grid-charged products with AA or AAA batteries, and $0.45 for larger sealed lead-acid batteries. Preliminary estimates; results are Kenya-specific assuming a conventional retail value chain, and should not be extrapolated to other markets.

Focus group participants generally indicated that they liked the solar charging aspect of the BoGo torch. This characteristic allowed for low operating costs, which were highly desirable.

The Thrive light was discussed as a flexible light that could be used as a task light as well as a light that would provide considerable illumination to a room. People also praised the fact that the Thrive light used a relatively large battery, as this allowed for comparatively low operating costs (thanks to less-frequent charging). For those who felt they could afford it, this was often the light that received the highest marks. Many of the kiosk and market stall vendors were particularly interested in the Thrive light. For them, the combination of good illumination, modest initial cost, and low operating costs was very attractive.

The Barefoot Power desk lamp was the first choice of lower-income families who felt that they could not afford the higher initial cost of the Thrive light. People liked the form factor (goose neck desk lamp), the evenly distributed light provided to a reading surface, and the low initial cost of this lamp. A number of people mentioned this light as an ideal reading lamp for children. The main concerns about this light were related to the relatively high operating costs for charging and the possibility that it might not be as durable as some of the others. A number of people expressed interest in the possibility of a light that had the same form factor, but a larger battery and/or solar charging.

Note that these were pilot conversations and more should be conducted, e.g. as part of the community Education process articulated below. The focus group and interviews are summarized here, and described in detail in the appendices.

1 – Teachers, students, some energy committee members, and some interested community members: 17 people (approximately 4/5ths men), assembled in an empty classroom at Bar Sauri Primary School

2 – Diverse group of people from Yala gathering in front of a hardware store on the main street: 23 people (all men)

3 – Diverse group of women and men from Yala, gathering in front of a kiosk on the main road after dark: 7 people (4 women and 3 men), plus another dozen onlookers.

4 – Level-7 and -8 students from a Yala school: 4 children (three girls, one boy), plus about 10 eager onlookers.

5 – Home lighting – meeting village members held at the home of Alfred Ajuala: 20 adults (11 men and 9 women), plus 9 children.

6 – Josephone Achleng JeJe, Coke Kiosk owner in Yala. Very interested in being a test bed for LED trials.

7 – Two repeat evening meetings with seven open-air vegetable and fruit sellers plus one street-food (roast corn) vendor and one small kiosk vendor at Kondele night market in Kisumu: Eight people (seven women) and a dozen or so onlookers.

8 – Joseph Lanyo, Head Teacher at Bar Sauri Primary School and Millicent, Head Teacher at Nyamninia Primary School, Sauri.

Recommended Strategy for Market-Based Sales Test

Columbia University personnel will lead the market test and evaluation, with support from the Kisumu MVP office.

Pricing

A key issue in mounting the project is determining pricing. If the desire is to offer market prices, these have to be simulated or otherwise derived (given that the products are not currently in the local market). This involves a relatively straight-forward process of "price buildup" based on landed costs in Nairobi (i.e. FOB costs plus freight), and then the application of import duties, VAT, distribution costs, and the margins for the various intermediaries. An example of this process, using the Columbia University Power Pack for illustration, is shown in Table 2. One can see that the build-up can be significant, nearly a factor of two in this case. For all products, care needs to be taken not to begin the price build-up with an starting price tailored for "deep-pocket" donors as the target buyers, as such prices often include exceptionally high margins that would not be representative of those in a true competitive market.

Some of the products are not fully in the world market and are instead being produced in small numbers by NGOs. This is a potential problem if scale-up is desired.. This latter group includes the Thrive lantern and the Columbia University Power Pack.

Table 2. Example of price buildup, using Columbia University Power Pack, beginning with landed cost "wholesale" in Mombassa.

Total wholesale cost (USD)	**45 US$**
Shipping, handling, insurance, misc fees.	11%
Import Duties	10%
VAT	16%
Distribution cost and markup (Mombassa to Kisumu)	20%
Retail markup	10%
Estimated retail price	**85 US$**
Local currency	5,250 Kenya Shillings (KSh)

Sources: Tax and duty rates from Table 1, above; supply chain costs and markup values based on personal communication with several different Kenya based import, distribution, and retail businesses (the companies wished to remain anonymous).

The Sauri Energy Committee has stated that Sauri residents would like to pay 1,250 KSh (~$19) for the CUPP lanterns. Although MVP staff have not warranted that this would be the price offered, there has also been discussion at the MVP offices of fixing the price for one or more of the lights. It is of course the end users' job to bargain and otherwise get goods at the lowest possible prices, while it is one of the village leaders' jobs to garner patronage merit points by negotiating low prices for their constituents. Our conversations with potential buyers indicated that there may already be expectations that a subsidy will be provided.

In the spirit of demonstrating strategies at Sauri and Yala that can be scaled up in Africa, we strongly recommend that this project initially offer lanterns (and associated charging services) at market prices without subsidy. Following this test, the MVP office may conclude that they wish to proceed with a subsidy-based strategy, based on what is learned about the preferences for lamps and willingness to pay.

Subsidies certainly can be useful and appropriate under the right conditions. Subsidies for LED lighting products for lanterns and/or their grid charging at this time are, however, problematic and likely unnecessary in this particular case for a number of reasons:

Need and Practical Considerations

- Some WLED products that are now available have price points that are at or below the 1,250 KSh "willingness-to-pay" level that has been requested by the Sauri Energy Committee. The three products we identified as being highly desirable in the focus group sessions all have price points near or below this level. This suggests that there may not be a need to provide subsidy in order to deliver WLED lights at the targeted price levels. In fact, doing so could artificially mask the true price differences among products and thereby bias the experiment in favor of the more costly products.
- A meaningful way to define a subsidy level would be to have it indexed to the mature market prices of emerging technologies that might not be affordable initially. However, there is currently no body of research or analysis that defines the mature market prices of current WLED products.
- A targeted subsidy (e.g. by income) could be implemented in a place like Sauri where their exceptionally rich socioeconomic data thanks to the Baseline Survey, but is not likely to be replicable in ordinary villages.

Scalability

- If the true market price of the CUPP lantern is ~$85, the sizeable ~$65 per-lantern subsidy to bring the price to the 1,250 KSh level would not unlikely to be available for any widespread expansion of WLED lantern sales beyond Sauri. As a result, the use of subsidies limits the scalability of the approach for this and similar products. As a practical consideration, a $20 subsidized price for the CUPP would be quite large compared to the overall per-capita annual budget of $110 for the entire MVP portfolio of technologies and programs.
- A decade or more has been spent promoting $100 solar lanterns in the developing world. Their sales are very slow, even among relatively wealthy end users. The manufacturers have unsuccessfully relied on a subsidy-like business model in which donors purchase these lanterns and give or otherwise make them available to end users. Subsidies were also ineffective in promoting growth of the larger solar home systems in Kenya.

Unintended Outcomes or Side Effects

- The Kenyan solar technician accompanying our delegation noted that if prices were subsidized to certain groups (e.g. by income) and not others, the recipients would likely choose to resell the lanterns at the market price rather than using them.
- The technician also noted that resentments would likely be generated on the part of product retailers in the surrounding areas because they would be viewed as extracting

unreasonable profits when trying to sell products at market prices with appropriate margins.

- Similarly, if recharging-fee subsidies are instituted (as has been proposed), charging enterprises in surrounding villages will likely feel that business is taken away from them.
- Subsidies applied non-proportionally (e.g. through an across-the-board credit or eliminating VAT or import duties) to all products could negate the significant Kenyan incentive for solar lighting currently embedded in the VAT structure (see Table 1
- Subsidizing the battery-charging service would reduce the true differential cost of ownership between solar (or other non-grid charging systems) and grid-charging.
- Subsidies (e.g. implemented in the form of vouchers) offered to all people in Sauri would differentially benefit higher-income families, if it turned out that the poorest village members could not afford higher-priced LED lights even at the subsidized price.
- A subsidy on some products but not others would distort the purchasing behavior and disadvantage products not awarded a subsidy. This practice may also lull low-income buyers into acquiring a system that has unaffordable maintenance costs (e.g. CUPP battery replacement costs of 1,000 KSh after as little as one year).
- Consumers and lose site of the temporary nature of subsidies, and resent the later restoration of prices to market levels. This can be coupled with a mis-perception of price gouging.

Once pricing is resolved, our recommendations for the market-test strategy – to be conducted by Columbia University and Kenya MVP staff - is as follows:

Market Research

This process began with the project team's visit to Sauri in June 2007, and review of product availability and prices in the local and international market (as described in this report). The MVP Baseline Report also provided valuable background data, which may make most of our originally planned baseline survey un-necessary. The baseline survey should be studied in more depth (including data not reported in the published version) and more focus groups should be conducted. The true willingness to pay will not be known until the results of the market test are analyzed.

Product Selection

Product selection should be done by combining laboratory performance and quality tests on all candidate lights with feedback from end users in Sauri.

LBNL and HSU are conducting performance tests on most of the products presented at the focus group sessions, including the three models that were ranked highest by end users (Bogo, Thrive, and Barefoot Power), and are attempting to obtain the solar accessories for Thrive and Barefoot Power for testing as well. We also are testing two of the lights slated for implementation by MVP (Thrive and Mighty Light). The CUPP should be run through the same tests if it is to be included in the market test. Units have thus far not been made available for testing.

As it is not possible to test product durability or "in-field" performance in our laboratories, CU is advised to place small numbers of the final candidate lanterns into service for a period of at least two months to verify adequate performance and to obtain user feedback.

We took an initial step in this direction while in Sauri in June by giving two of our lanterns to Gabriel Oduong, who will deploy them with the help of Alfred Ajuala at the Bar Sauri School. One reading light (Barefoot Power) will be inserted into the lamp-lending program, and one solar flashlight (BoGo) will be deployed for use by the school security guard. CU will follow up.

We also request that one Thrive light be added to the existing school lamp-lending program as soon as possible from those already ordered by the MVP Kisumu office. This will give the project team some information on product performance in the field and user acceptance.

This step should be expanded by adding deployment of about 5 of each of the five lantern types for a period of two months to gather additional information on performance and durability problems.

Education and Market Preparation

At the strong urging of Daniel Sijenyi Buyu, Chairman of the Sauri Energy Committee, it will be important to have a village-based education process underway before the retail stage of the program begins. The Columbia team should provide educational information on product attributes, performance, and cost of ownership in pictorial form to the Energy Committee members for use in their respective sub-villages.

Village-wide Retail Sales

During this phase, the final set of lanterns should be ordered and delivered by MVP staff to sale points in Sauri. Tasks associated with this work include making logistical arrangements associated with inventorying lamps at the MVP office in Kisumu and shipping them to points of sale in Sauri. It will also be important to set up a system for managing warranty claims and related repair services, a bookkeeping system for use at the points of sale, and a program for data gathering. An adequate inventory of replacement batteries should also be secured on a retail basis.

Since the CUPP light is not clearly "commercialized" at this time, if used in the project it will be important to confirm whether it can be restocked in large numbers if it is successful. This is important to ensure that the Sauri project is scalable. All other lights on the "short list" are nominally commercially available. Product availability must be ascertained. Our preliminary efforts to obtain new Thrive lights from the manufacturer have not been successful.

Given the seasonal variations in income for farming-based communities like Sauri and Yala, it is important to time the sales component of the demonstration project to be coincident with periods when residents have relatively more disposable income. There are two rainy seasons followed by harvest. These are April to June and October to November. December is an especially good time for commercial activity given the coincidence of the harvest with the holiday season. The times between harvests are sometimes referred to as "hunger" seasons. We thus propose, if possible, that the main deployment stage take place in December 2007.

Purchasing behavior should be tracked and correlated with the Sauri Baseline survey (income, demographics, etc.) to determine the patterns of adoption and correlation with other indicators such as income and household composition. A post-purchase survey should be administered to buyers to determine satisfaction with the lights and product durability.

From manufacturer-reported wholesale prices, CU will need to estimate price buildup to a retail price point for products to be sold in Sauri. This buildup should include costs associated with shipping, import duties, VAT, in-country distribution, and business profit margins for distributors and retailers as described in Table 2.

The lanterns should be consigned from the MVP office in Kisumu to sale points in Sauri. Funds for lamps sold need to be collected by MVP office (less any markup that the sale points add to the lights). At the end of the project, funds remaining in the account can be distributed back to Sauri in a manner to be mutually agreed. One proposal is to use the funds to invest in energy infrastructure for the village (e.g. equipment for the Energy Kiosk). Another proposal involves remitting these funds to the Bar Sauri school for their annual field trip.

The sale points should also stock replacement batteries, and provide battery-charging services for products that do not include solar-based charging. The sale points should collect any defective lights and deliver them to MVP personnel, who will then seek replacements from manufacturers. Detailed instructions will be provide to the battery charging points on how to properly charge batteries so as to maximize their service life. Sellers should be required to keep detailed records on which lights are sold, gather minimal information on each buyer and price paid for the light, and accept any defective or broken lights from buyers and return to local MVP infrastructure coordinator.

According to MVP personnel, both proposed sale points will have battery-charging services by the end of July 2007. These charging services will be privatized (i.e. will charge for services and cover their own costs). The establishment of this infrastructure will be necessary before the rest of the project can proceed. Joseph Lanyo (Head Teacher, Bar Sauri School) also expressed a desire to sell the lanterns.

Lamps should only be sold to Sauri residents. In addition to cash payments, lamp rental, credit financing, and lay-away purchase options should be offered.

Evaluation

Post-purchase surveys should be conducted for a subset of individuals purchasing the lights. Columbia University will be the lead on finalizing instrument, data collection methodology, analysis, and reporting. It is highly desirable that the evaluation process make an effort to estimate the extent to which prior kerosene use has been offset by the LED light. It is unlikely that this will be a 100% effect, as many households that adopt LED technologies may continue to use kerosene as well. A rough mockup of such a survey is included in Appendix B.

APPENDIX A: Focus Group Reports

<u>Group 1</u> – Teachers, students, some energy committee members, and some interested community members: 17 people (approximately 4/5ths men), assembled in an empty classroom at Bar Sauri Primary School

<u>Lights Shown</u>: Mighty Light, BoGo, Squeeze Light (hand pump torch), Sherpa X-Ray crank light, Barefoot Power reading light, Thrive wall/table light, CUPP (LED and CFL options), Glorb XP Lantern (Brunton), Everon light, Impulse keychain light, Casibao rechargeable torch, Monkehead torch, Eveready incandescent torch, Tikka head lamp, kerosene hurricane lantern, kerosene wick lamp.

<u>Lights Preferred:</u> Barefoot Power, Thrive, Bogo, CUPP

<u>Researchers</u>: Evan Mills, Arne Jacobson, Maina Mumbi (primary presenter). Gabriel Oduong, Head of Infrastructure, Sauri Sublocation, was present for part of the session.

The discussion was divided into three parts according to the form factor of the lights. We began by discussion lights with a torch (flashlight) form factor. Next we discussed task lights, and we finished by discussing ambient room lights. After we had discussed each form factor, we discussed all the lights together. In addition, we had a discussion about delivery models (e.g. cash vs. credit based sales) for the lights.

Discussion of torches:

Preferred lights: Bogo = #1; FreePlay crank light = #2

Key questions asked by audience:

1) How long will the LEDs last?
    a. (people asked about LED failure and how it compared to an incandescent bulb)
2) How do we get the lights fixed when they break?

a. People expressed concern about the life of the batteries, as well as other problems that might occur; they indicated that it is very important to be able to fix the light and to be able to get spare parts.
b. One person (security guard) mentioned that he had a SLA based LED torch similar to the Casibao. It worked well for a few months, but then it broke. We did not get a good sense of the reason that it broke.

3) How long will it take to charge the Bogo with solar to get a good charge?

Key comments:

1) People liked the crank light concept, but they felt that the FreePlay light was very expensive; they would like a less expensive version, but they were cautious of buying something like the "Squeeze Light," as they thought it might break quickly.
2) People commented that it was important for a torch to be able to illuminate something that was far away. That is, they want to be able to get a bright, focused beam that allows them to see far. There was some question about how good the Bogo was on this count. They liked it, but one person asked about this and others agreed that it wasn't as good as some flashlights in this regard.

Discussion of task lights:

Preferred lights: Barefoot Power = #1; Thrive = #2

Comments:

1) People were very impressed by the Barefoot Power light.
   a. They said it would be a very good study light, and that it produced a good amount of light at a very reasonable price.
   b. They liked its flexibility (including the goose neck). In addition to task applications, you can turn it around and use it to light up a portion of the room. You can also carry it and use it like a flashlight.
   c. They liked the small size; it was good to be able to carry it easily.
   d. There was some concern that the battery was small and that the light wouldn't last very long. They asked about the possibility of getting a larger battery.
   e. There was some interest in the possibility of solar charging for the Barefoot Power. Their interest would depend on the price of the solar, but if it were available at a good (i.e. low) price they might be very interested.

2) People liked the Thrive light.
   a. The price was reasonably good (high, but not too high), and people liked the light that it produced.
   b. People liked that it had a large battery, and that it would produce light for a number of days before recharging was required.

3) People thought that the Cosmos Ignite MightLite was good, but that it was too expensive.

a. People asked about how long the solar module would last (i.e. what was its life), as well as about where they would need to put it to get a good charge.

Discussion of ambient lights

Preferred lights: Columbia light (CFL) = #1; Everon = #2

1) People liked the amount of light delivered by the 7 Watt CFL on the Columbia light.
    a. One comment was something to the effect of "…it lights up the whole room, and we can see each other very well. Because of this, we are very comfortable."
    b. Someone else commented that this light was very good for hosting visitors. There was some comments about how important it was to have a light that provided a good setting for having visitors in the home.
    c. There was some question about the price of the Columbia light. The chair of the energy committee mentioned that this light would likely be offered at a subsidized price. He was not sure, however, what this price would be or how the price that we listed compared to that price. He thought ours might be a bit high, but he wasn't sure.
2) The Everon light was the second favorite (though it seemed like a distant second based on comments about its operating cost; see below).
    a. People seemed to like the light that it produced reasonably well, but they were concerned that the charging interval was very short (i.e. it didn't last very long on a set of batteries). This would make the light very expensive to operate. There were several comments about how this was problematic.
    b. One person commented that it would be difficult to turn on and off if it were mounted on the ceiling (how would we reach it?). It would be also hard to change the batteries on a frequent basis (required once every one to two days).
3) The Brunton light did not receive a good review
    a. People thought that it was very expensive, and that it only produced a small amount of light. They were also concerned that the operating cost would be high.

OVERALL preferences: When people were asked to select three lights that they would like to have available for purchase or rent, they recommended these four. Note that they asked to expand the list from three to four to accommodate their preferences.

#1 = Barefoot Power
#2 = Thrive
#3 = Bogo
#4 = Columbia light with CFL and LED

People also commented that the following things were important:

1) It is important to be able to get replacement batteries for whatever lights they use; they were concerned that it is difficult or impossible to get replacement batteries for some lights.

2) People commented that they wanted to have solar charging as an option if the price wasn't too high. Some people might buy the solar panel to avoid the cost of paying for a charge. Other people would not be able to afford this, but it would be good (in any case) to have the option to choose solar charging.
3) The energy committee chairman commented that it would be good to get information about the preferred lights (additional specifications).

Discussion of delivery model / mode of purchasing lighting

1) people thought that cash and credit approaches should both be available
    a. cash is good for inexpensive products and for those who have money
    b. credit is good for others
        i. They thought that credit should be available for any products that cost about 1000 KSh or more.
        ii. For something that costs 1000 KSh, they would like to be able to pay 500 KSh initially, and then 250 KSh per month for two months to finish the purchase (or something along these lines).
        iii. There was some discussion of the possibility for subsidies. Community members, and especially the energy committee chair, mentioned this as something that should be considered for the more expensive options.

<u>Group 2</u> – Diverse group of people from Yala gathering in front of a hardware store on the main street: 23 people (all men)

<u>Lights Shown</u>: Thrive wall/table lamp, Barefoot Power reading lamp, Bogo solar torch, Everon light,

<u>Lights Preferred:</u> Thrive, Barefoot Power, Bogo

<u>Researchers</u>: Evan Mills, Arne Jacobson, Maina Mumbi (primary presenter)

This session was an impromptu discussion that emerged spontaneously after we met some men sitting near the hardware store in Yala. We presented and discussed the subset of the lights indicated above.

Over some discussion, the group came to the conclusion that the Thrive was the best light for both household and small business applications (e.g. kiosk). Their reasoning was linked to the modest initial cost and the low operating cost of this light. They also liked the Barefoot Power light (low initial price, form factor ideal for reading), but it was definitely second in line relative to the Thrive.

Several men asked about the possibility of solar charging for the Thrive and the Barefoot Power. They said that they would be very interested in this possibility, even if it increased the initial cost somewhat. Here, their interest was related to eliminated the operating cost of recharging.

The BoGo light was the third choice of this group. Many liked the solar charging aspect, but said that they would be hard pressed to spend 800-1,000 KSh for a torch.

<u>Group 3</u> – Diverse group of women and men from Yala, gathering in front of a kiosk on the main road after dark: 7 people (4 women and 3 men), plus another dozen onlookers

<u>Lights Shown</u>: Thrive wall/table lamp, Barefoot Power reading lamp, Bogo solar torch, Everon light, CUPP, kerosene wick lamp.

<u>Lights Preferred:</u> Thrive, Barefoot Power, Bogo

<u>Researchers</u>: Evan Mills, Arne Jacobson, Maina Mumbi (primary presenter)

In this session we met with people at a kiosk at the intersection of the main road and a side road that runs to the Yala Guest House. The kiosk was on the Kisumu side of the intersection. The kiosk was next to a set of market stalls at which people sold vegetables. There were also a number of other kiosks nearby. There was also a second night market location in Yala. There were probably about 15 vendors at each of the night market sites. The vendors said that they sold in the evening on a daily basis. They generally began selling around 6:30 pm and they stayed open as long as business was good. They usually closed by 8:30 to 9:00 pm at the latest.

We had a discussion that included seven adults, including a young woman who was working in the kiosk. Three adults were particularly engaged in the conversation. They included the woman who was selling at the kiosk, a second woman who had been selling vegetables at a nearby market stand, and a man who worked at the health clinic in Luanda.

We had several interesting discussions during this session. The key points are summarized below.

a. The first significant discussion was related to the economics of flashlight operation. Maina worked through a cost comparison of the solar powered BoGo and an ordinary incandescent flashlight. His presentation included a discussion of the initial cost to buy each flashlight, as well as the costs associated with operating them. An animated discussion of the pros and cons of each approach followed. In the end, most agreed that 800-1000 KSh was a very reasonable price for the BoGo torch, given the high cost of operating an ordinary torch. The participants noted that the BoGo would pay for itself after about a year. Some participants said that they would be hard pressed to find 800-1,000 KSh to purchase a torch, but they were nonetheless impressed by the value of the device.
b. The second debate was related to the relative merits of the Barefoot Power and the Thrive lights. One woman thought that the Barefoot Power light was the best because it was ideal as a reading light for children, it was small and easy to carry, and it was very affordable (in terms of its initial cost). A man then countered by saying that the Thrive light was preferable because it was less expensive to operate. He also noted that while it was larger than the Barefoot Power, it was relatively easy to carry. He even noted that he would feel safe walking with it at night because if someone tried to attack him he could use it as a defensive weapon. A number of other people offered their opinions on this topic, and the final conclusion was that the Thrive was a better buy for those that could afford the higher initial cost.
c. Several people asked about the possibility of getting a light like the Barefoot Power, but with a larger battery like the Thrive's. They liked the Barefoot Power form factor (gooseneck, desk lamp style design), but they did not like the small battery and the corresponding requirement for frequent charging. In other words, they were asking for a cross between the Barefoot Power and the Thrive. They indicated that they would be willing to pay a bit more for a light like the Barefoot Power, provided that it had a larger battery.
d. The kiosk owner took some time to try out each of the lights in her kiosk. The hands down winner (according to her and the various people assembled at the site) was the Thrive. This was based on the amount of light that it produced, its ability to provide good lighting for the items that she had in her shop, and the ease with which it could be mounted to the front wall of the shop in a location that would illuminate the products in a way that would allow her customers to see the. She said that the price was very reasonable, given the amount of money that the kiosk brought in.

<u>Group 4</u> – Student participants in the Bar Sauri Primary School lamp lending program: 3 students, one male. Level-7 and -8 students from a Yala school: 4 children (three girls, one boy), plus about 10 eager onlookers

<u>Lights Shown:</u> Barefoot Power, Thrive, Mighty Light, CUPP, BoGo

<u>Lights Preferred:</u> Barefoot Power

Session #1: Students from the Bar Sauri Primary School (two girls and one boy; discussions with Arne Jacobson)

We asked these students about their experiences with the Columbia light on the day that we arrived. They also participated in the "Group 1" focus group discussed above. Researcher Arne Jacobson had a follow up conversation with one of the students (the boy) a few days later. These notes encompass all of these interactions.

Overall, the students were very pleased to be able to use the Columbia lights in their homes. They indicated that they were very useful for studying. All three expressed a preference for the CFL light over the LED light. They said that while the CFL lit up the whole room, the LED only illuminated a small space. Two of the three said that they studied with siblings at home. They noted that several children were able to study comfortably at the same time when they used the CFL, but that the LED provided light for only one or two students. They also noted that the CFL provided more light for socializing and other related activities. In any case, though, they said that both the CFL and the LED were much better than kerosene lighting.

The students were quite interested in the Barefoot Power light. They liked its small size and the light that it provided for studying. One of them commented that it was small and inexpensive, and this might allow his parents to buy one for him (i.e. as his own personal light). This was an attractive possibility for him.

Session #2: Students in Yala (discussion with Evan Mills)

These students use one small "tin" of fuel per day. In the morning they read 1-2 hours before school and in the evening 2-4 hours. On Saturday and Sunday they read for 4 hours. Together this amounts to about 10 KSh (~$0.15) per day; they say their parents pay 50 KSh/liter (~$0.77). At school each child has one "tin"; not much sharing among students. The Barefoot Power light was preferred.

<u>Group 5</u> – Home lighting – meeting village members held at the home of Alfred Ajuala: 20 adults (11 men and 9 women), plus 9 children

<u>Lights Shown</u>: Mighty Light, BoGo, Squeeze light (hand pump torch), Sherpa X-Ray crank light, Barefoot Power reading light, Thrive wall/table light, CUPP (LED and CFL options), Everon light, Casibao rechargeable torch, Monkehead torch, Eveready incandescent torch, kerosene hurricane lantern, kerosene wick lamp.

<u>Lights Preferred</u>: Thrive, Bogo, Barefoot Power

<u>Researchers</u>: Evan Mills, Arne Jacobson, Maina Mumbi (primary presenter). Gabriel Oduong, Head of Infrastructure, Sauri Sublocation,was present for part of the session.

The setting was a family compound (known as a "homestead"). There were three residences, and a good number of other villagers (neighbors) joined the discussion.

The discussion was divided into two parts according to the form factor of the lights. We began by discussion lights with a torch (flashlight) form factor. We then discussed task lights and ambient room lights together as a single group. After we had discussed the lights in the various form factor categories, we discussed all the lights together. In addition, we had a discussion about delivery models (e.g. cash vs. credit based sales) for the lights.

Discussion of torches: Preferred lights: BoGo = #1; FreePlay crank light = #2

People liked the BoGo and the FreePlay crank lights. However, they indicated that they were unlikely to be able to purchase either one at the indicated price levels. The BoGo was given a

higher ranking than the FreePlay because its initial price was lower (800 KSh vs. 2,500 KSh). The participants were very interested in the concept of solar based charging, as it eliminated ongoing costs associated with charging.

Discussion of task and ambient lights: Preferred lights: Thrive = #1; Barefoot Power = #2

The Thrive light was the preferred light. People liked the light that it provided as well as the low operating cost. People liked that it could be used as a table light as well as a wall light (i.e. it could be hung on the wall to provide lighting for an area of the room). Many of the people said that it would be difficult to purchase this light at a cost of 1,200 KSh. However, this was still the preferred light given the low operating costs of the unit.

The Barefoot Power light was a close second to the Thrive in this session. People liked the form factor (gooseneck desk lamp; good for children's studying) and the low initial price. There was a long discussion about the relative merits of the Thrive and the Barefoot Power (i.e. high initial cost and low operating costs vs. low initial cost and higher operating costs). Some people said that while they liked the Thrive better, they would be more likely to be able to purchase a Barefoot Power light. Others said that they would focus on getting the money together to buy the Thrive.

Several people asked about the possibility of solar charging options for the Thrive and the Barefoot Power lights. At least one person also asked about the possibility of getting a larger battery for the Barefoot Power light. In both cases, people were motivated by a desire to reduce the operating costs of the lights.

At the end of the discussion, we asked people which lights they would most like to have available for purchase. They said, in order of preference, that the lights should be

1) Barefoot Power
2) Thrive
3) BoGo

The high ranking given to the Barefoot Power was closely tied to its lower initial cost relative to the Thrive. The BoGo was a distant third after the Barefoot Power and the Thrive.

We had a discussion about purchase and financing options. People indicated that they preferred to pay cash or credit. The idea of lay-away was not very welcome. There was a spirited discussion about the merits of cash versus credit. Some people felt that cash arrangements were best, as this kept the price low and there were no complications related to subsequent payments. Others indicated that credit based sales were important, especially for lights that had a relatively high initial cost (e.g. the Thrive light).

In the end, everyone agreed that both cash and credit options should be available. We had a discussion about the fact that the cost of purchasing the light would go up with credit, as it was necessary to include interest payments in the sale. People were not daunted by this, and many still preferred credit based sales. Several people said that they would not be able to purchase a light without some form of credit.

<u>Group 6</u> – Josephine Achleng JeJe, Coke Kiosk owner in Yala

<u>Lights Shown</u>: Mighty Light, Barefoot Power, Thrive

<u>Lights Preferred</u>: Barefoot Power, Thrive

<u>Researchers</u>: Evan Mills, Arne Jacobson, Maina Mumbi

The proprietor of the Coke Kiosk on mainstreet Yala (Josephine Acheng JeJe, c/0 Innocent JeJe, Box 483 Luanda (husband: school teacher)) expressed strong interest in some of the LED lanterns and offered use of her kiosk for a demonstration, in exchange for providing data. She currently uses candles for illumination, about five per day at 5 KSh (~$0.08) each, to provide light from approximately 6pm to 8pm. The candles are approximately 6 inches long and ½ inch in diameter.

We brought lights to the kiosk one evening and developed a layout (two Barefoot Power lights on the exterior (illuminating the sales counter and signage), one Barefoot Power on the interior to illuminate the work area, and one Thrive illuminating the seating areas on each side of the kiosk.

<u>Group 7</u> – Two repeat evening meetings with sellers at Kondele night market in Kisumu: Eight people (seven women) and a dozen or so onlookers. Group included 6 open-air fruit and vegetable sellers, 1 open-air roasted corn seller, and one vendor inside a tiny kiosk

<u>Lights Shown</u>: BoGo, Thrive, Mighty Light, Barefoot Power, CUPP (LED and CFL options), Glorb XB Lantern (Brunton), Everon light, kerosene wick lamp.

<u>Lights Preferred</u>: Thrive, Barefoot Power

<u>Researchers</u>: Evan Mills, Arne Jacobson, Maina Mumbi (primary presenter)

Most popular lanterns: Thrive and Barefoot Power. Some market sellers indicated that they would be hard pressed to find the cash to purchase the Thrive, while others said that the price was very reasonable and that they would be able to come up with the money. There was a strong desire to purchase the lamps. Several people mentioned that they would be used at home as well, e.g. for reading.

The vendors all use the common "tin" lamps, with a very long wick and flame. They consistently reported spending 5 to 10 KSh (~$0.08 to $0.16) on kerosene for each night (5 KSh was the most commonly reported value). They typically work seven days per week. Many complained about the irritating smoke. One reported spending 6 KSh/week (~$0.09) on replacement wicks.

We measured illuminances up to 20 lux immediately next to the lamps, dropping off to zero in approximately one-meter distance.

The Columbia University Power Pack was regarded as well out of range of affordability. The Thrive lantern was the preferred option. The longer interval between charges made it more appealing than the Barefoot Power, despite the higher purchase cost.

The corn roaster reported spending 10 KSh (~$0.15) per day, and operates from 7 to 10pm. Thought the LED lantern (Brunton) was too dim. Very much liked the Thrive, which created only 13 lux on the corn from the desired working distance, but the vastly superior color rendering made the goods much more attractive than the yellowish kerosene light (which yielded about 9 lux).

When the question of purchasing power was raised, the women suggested establishing a buying group where the women essentially guaranty one another. They each contribute 10 to 20 KSh (~$0.15 to $0.30) per night towards the purchase of a lantern. With 20 women in such a group, a Thrive lantern could bought every 3 to 6 days, and all 20 women would have the lanterns within 2 to 4 months. This period would be accelerated in an up-front deposit was paid.

Group 8 – Joseph Lanyo, Head Teacher at Bar Sauri Primary School and Millicent, Head Teacher at Nyamninia Primary School, Sauri

Lights shown: Mighty Light, BoGo, Squeeze Lght (hand pump torch), Sherpa X-Ray crank light, Barefoot Power reading light, Thrive wall/table light, Glorb XP Lantern (Brunton), Impulse keychain light, Casibao rechargeable torch, Monkehead torch

Lights preferred: Thrive, Barefoot Power, BoGo

Researchers: Evan Mills, Arne Jacobson

According to both teachers, some students at and above Grade 4 (age 10) bring kerosene "tin" lamps to school each day for "prep" study periods from about 6:00 to about 7:30 am, and sometimes in the evening before going home as well. Students share the lights if the electric CFL is used (about 6 students per light). When 5 CFL systems are operating, up to 30 students (Level 8) are supported

Lanyo said that the "yellow light" (from kerosene) is bad for the students, as is the smoke. He sees a big benefit in "smoke-free light."

There is no electricity in the classrooms (except for one room at Bar Sauri school), and so candles and wick lamps are used when light is needed. The cost is about 10 KSh (~$0.15) per day per student. Both teachers noted that lack of kerosene at home is common, which means that children cannot do homework.

The teacher expressed a strong desire to have more light for reading-age students. . There are an additional 270 students who read by wick lamp. Typically, there are 2-3 tin lamps per six students.

If there is no kerosene at home (a common occurrence for some families) study is curtailed.

Blackouts are common, sometimes nightly and all day perhaps 3-4 times per week for an undefined period of time.

Focus Group Form for Millennium Lighting Project

Date:

Session Type:

Location:

List of Participants (Names and type of work)

1. Introductions (research team)
   a. Our names & where we come from
   b. What we are doing and our relationship to the Millenium Villages Project
   c. How this work might benefit Sauri
   d. Ask permission to take photographs

2) Introductions (respondents – enter information on the next page)

   a. What are their names?
      What do they do (work)?

3) Introduce Lights (steps for each light listed here)

   a. First, explain that they should not look into the light (LEDs are very bright)

   b. Explain main question for session (to ask at end):
      i. If we were to introduce 1 or 2 of these lights for sale in Sauri, which would you choose?

   c. Then show the lights
      i. Turn each one on and show all light settings
      ii. Explain the characteristics
         1. initial price
         2. hours of operation
         3. use cost
         4. charging method & battery types

   d. pass the lights around and ask people what questions or thoughts they have about them

   e. Ask main question: If we were to introduce one or two of these lights for sale in Sauri, which one would you choose? (#1 choice & #2 choice)

Questions and Recommendations for each category of light sources

4) What type of light should be the first priority for Sauri? (indicate number of people who choose each)

a. Torches _____

b. Task lights _____

c. Ambient lights _____

COMMENTS:

5) What should be the way to make the lights available?

a. Buy with cash _____

b. Buy on credit _____

c. Rent _____

d. Other (specify)

_____

COMMENTS:

6) Closing

a. Do they have any more questions for us?

b. Thank them for participation

APPENDIX B[21]

EXIT SURVEY FOR LED LIGHTING PRODUCT USERS

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				

[21] Developed by Evan Mills, Merrian Fuller, and xx

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 C: Test Results for Batteries Procured in Kenyan Markets: June 2007