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RESEARCH NOTE 7

Illumination Sufficiency Survey Techniques:
In-situ Measurements of Lighting System Performance and a User Preference Survey for Illuminance in an Off-Grid, African Setting

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Summary
Efforts to promote rechargeable electric lighting as a replacement for fuel-based light sources in developing countries are typically predicated on the notion that lighting service levels can be maintained or improved while reducing the costs and environmental impacts of existing practices. However, the extremely low incomes of those who depend on fuel-based lighting create a need to balance the hypothetically possible or desirable levels of light with those that are sufficient and affordable.

In a pilot study of four night vendors in Kenya, we document a field technique we developed to simultaneously measure the effectiveness of lighting service provided by a lighting system and conduct a survey of lighting service demand by end-users. We took gridded illuminance measurements across each vendor's working and selling area, with users indicating the sufficiency of light at each point. User light sources included a mix of kerosene-fueled hurricane lanterns, pressure lamps, and LED lanterns.

We observed illuminance levels ranging from just above zero to 150 lux. The LED systems markedly improved the lighting service levels over those provided by kerosene-fueled hurricane lanterns. Users reported that the minimum acceptable threshold was about 2 lux. The results also indicated that the LED lamps in use by the subjects did not always provide sufficient illumination over the desired retail areas. Our sample size is much too small, however, to reach any conclusions about requirements in the broader population. Given the small number of subjects and very specific type of user, our results should be regarded as indicative rather than conclusive. We recommend replicating the method at larger scales and across a variety of user types and contexts. Policymakers should revisit the subject of recommended illuminance levels regularly as LED technology advances and the price/service balance point evolves.

Introduction
In the context of off-grid lighting in developing countries, there are large efforts under way to speed the transition from fuel-based to rechargeable, electric lighting with both market-based and giveaway type programs. The programs are typically motivated by some combination of greenhouse gas mitigation, public health improvement, productive use in work or educational settings, and economic justice – all of these are moot points if the lighting service provided by 'improved' lighting is insufficient for the immediate needs of the user. Lighting service requirements are highly contextual; the requirements for a school-aged child doing homework are different from their mother in a night market kiosk and from the night watchman who patrols a gate. As is the case in developed countries, estimates for the lighting service required in various contexts can help to drive the development of well-suited and affordable lighting systems to meet the needs of users while not wasting valuable lumens – that must be paid for by consumers – where they are not needed.

In this report, we document a field technique we developed to simultaneously measure the effectiveness of lighting service provided by a lighting system and conduct a survey of lighting service demand by end-users in their personal contexts. We worked with a population of night market vendors in rural Kenya. The study involved engagement with participants in a larger, ongoing study by the Lumina Project on the impacts of LED-based lighting adoption. By aggregating the responses of several users in a similar context, night market stands in this case, we show how one can use the measurements to estimate the population-level demand for lighting service for similar users.

Off-grid Illumination

Nearly 1.5 billion people continue to burn expensive and dirty kerosene lamps, candles, wood, and other inefficient lighting fuels because the service they provide is a basic human need. In developed countries where grid electricity is ubiquitous, the presence of standards for lighting service levels are an indicator of the value that is placed on sufficient lighting in a range of public settings, from operating rooms to streets at night. Standards for lighting service vary widely, but are as of the late 1990s were generally between 100-700 lux for typical public spaces, like schools, offices, and retail shops (Mills and Borg 1999). For detail-oriented manual work, like drafting, surgery, or sewing, the standards tend to be higher – on the order of 1000 lux or more. The wide additional diversity of illuminance-level recommendations across countries (and across time for a given country) indicates that even within industrialized world there is no consensus regarding the "right" or "adequate" levels of lighting service.

In contrast, we measured the lighting service from fuel-based sources and found only one device capable of reaching illuminance levels near industrialized country standards: a pressurized kerosene lamp, which is costly, sometimes dangerous to operate, and provides illumination of 75 lux at 1 meter distance (Radecsky et al 2008). Other fuel-based lighting sources, like unpressurized wick-based kerosene lamps, candles, and wood, provide much lower levels of lighting service, less than 5 lux at 1 meter (Radecsky et al 2008, Mills 2003). Off-grid electric lighting with LEDs or fluorescent technology can deliver much more light than those at similar costs of ownership (Mills and Jacobson 2007).

There is evidence that people who switch from fuel-based to modern lighting can "make do" with lighting service levels much lower than standards in industrialized nations, meaning that emerging, efficient lighting technologies do not necessarily need to meet industrial illuminance benchmarks to be acceptable. In 2007 the Lumina Project conducted focus groups in Western Kenya with a variety of off-grid lighting consumers and found that the typical illumination from fuel-based lights (1-5 lux) was insufficient, in other words there was significant 'suppressed lighting demand' across users of fuel-based lights. Nonetheless, the real demand threshold was not as high as industrialized country standards. Night market vendors there informally identified 15 lux as a reasonable level of lighting, but there was no systematic assessment of their preference for lighting levels (Mills and Jacobson 2007). A study of home lighting in a rural Nepali village led to recommended levels in the 5-15 lux range for general-purpose lighting, primarily for cooking and socializing (Bhusal, et al. 2007). The dominant baseline technology in the village was burning Jharro (resin soaked pine sticks), which provided on the order of 2 lux and was deemed insufficient by the authors for tasks other than moving about the room. Interviews with villagers who switched to LED-based lighting showed they were satisfied with an average illuminance of 5 lux, but that 3 lux was inadequate. Reading is a task with special requirements for comfortable execution; it is critical to school childrens' work, and visually demanding tasks such as this should be considered separately from general illumination. In the Nepali village context, the authors suggest a level of ≥25 lux based on interviews and testing with children in the village (Bhusal, et al. 2007). A study on reading in low light by young adults in Indonesia found that people could read in light levels ranging from 0.1 lux to 15 lux, depending on the font size, contrast, and distance of the reader (Atmodipoero and Pardede 2004). The study controlled for the reader's general age (older people tend to need higher illuminance for any task), which was a factor that we identified as critical to low-light reading when we pilot tested a similar study in January 2009.[2] However, the reading task was on an instantaneous basis and long-term eye strain was not accounted for. With that in mind, the 25 lux level suggested by Bhusal, et al. for reading is likely a reasonable number. For general-purpose illumination lower levels might be acceptable; a range of 5-15 lux has been reported in the literature thus far (Mills and Jacobson 2007, Bhusal, et. al 2007). We wish to emphasize that these thresholds are minimum service levels rather than optimal or desirable levels where cost is not an object, and are often arrived at through informal research methods with small samples of people. Moreover, users' feedback was largely informed by a dimmer baseline light source and without reference to potentially brighter sources than the particular LED lamps that were made available to them by the researchers at the time or the benefit of having long-term experience using improved lighting technology.

Six months before the data for this report were collected, we conducted a similar survey of lighting service needs for night market vendors with a narrower focus, identifying the illuminance at 1 meter that triggered a user to charge their lamp (Johnstone, et al. 2009). The purpose of the survey was to inform economic models of lamp use by people who pay a fixed price to recharge. Using the result we could make good estimates of the number of days a user could go between charges. The population we drew from was the same as those in this report, i.e. night market vendors in rural Kenya who are participating in an ongoing study of LED lamp adoption. We found that a safe estimate for the illuminance at 1 meter that triggered charging for the users was 2 lux. It is recognized that users' decisions as to when to recharge are a combination of lighting adequacy and ability to pay for charging along with the convenience of recharging, rather than a "pure" indicator of desired illuminance levels.

Improved lighting service is a top priority among people who are considering a switch from fuel-based lighting to modern lamps (Mills and Jacobson 2007, Lighting Africa 2008). All other things being equal, the brightness of a lamp is strongly tied to cost, a critical factor for the cash poor people who are the target of lighting technology interventions, and is highly scalable with LED sources. Therefore, a product that is designed to meet user needs at least cost will provide sufficient light (as the users define it) and not more. Fortunately, as LED efficiencies rise and costs decline, it will be possible to affordably offer increased lighting services to these users, even beyond what they might initially define as sufficient based on their baseline experience with fuel-based lighting. A clear assessment of low-income, off-grid minimum illumination needs would help lighting designers and policymakers craft better solutions for the fuel-based lighting problem. Policymakers should revisit the subject of recommended illuminance levels regularly as LED technology advances and the price/service balance point evolves.

Field Methods

The 'illumination field survey' technique we developed is designed to measure the illuminance provided by a lighting system on a working surface(s) and to simultaneously capture the user's assessment of its illumination effectiveness. At each point where we measure illuminance, the user is asked if there is sufficient light available. The data can be used to compare the effectiveness of alternative lighting technologies and to develop estimates of the demand for light from a population

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[2] We abandoned using reading as a test for the required illuminance level in rural Kenya for several reasons: the test became a de facto literacy and eye test, as age was a strong factor for performance, and reading is a very specific task that many adults report is not among their most frequent uses of off-grid lighting.

of users. While the method we developed was pilot tested with night market vendors, it could be easily applied across a range of lighting situations with common-sense modifications.

The four people we surveyed as a pilot test for this report are night market vendors in the rural Kenyan town of Maai Mahiu. They were selected from the participants in an ongoing study of LED adoption by off-grid fuel based lighting users.[3] We conducted this portion of the study one year after offering LED lamps at market prices to the vendors. All of the vendors whose preference for lighting service is documented here purchased an identical LED gooseneck-style lamp, but two of them did not use it at their place of business and continue to use kerosene lamps. One of them continued to use a brighter pressurized kerosene lamp and decided to use the LED lamp for home illumination; the other used her LED lamp at her business until it was damaged and she reverted to the hurricane lamp she used before.

A few days in advance, we asked the survey participants if they were willing to participate in a nighttime survey. We informed them that the survey would take about 15 minutes and might be somewhat disruptive to their business. In practice we were able to be accommodating of any customers who came through during the measurements and did not create too much of a spectacle.[4] The illumination field surveys began at night; we arrived at a participant's stand after they turned on their lamp and situated it to illuminate their business. With a goal of capturing typical lamp placement and use, we did not warn the participants about the specific night we would do the survey.

Once we arrived at a stand, we asked the vendor to leave their lamp as it was before we came and began to prepare for the illumination survey. The equipment for the survey was minimal: a digital camera for documenting the scene, masking tape, an illuminance meter,[5] a meter stick (with appropriate sub-meter marking), a clipboard with the survey form[6], and a writing implement. We worked with the participant to identify each of the ways the lamp was being used and whether the working surface(s) lent itself to being measured with a single point (e.g., task lighting for cutting vegetables) or a multipoint plane (e.g., a table on which fruits are displayed or a wall with merchandise on display).

Before measuring lighting service, we characterized the light source(s) in use. For each source we noted the type, peak illuminance at 1 meter distance (by holding the illuminance meter 1 meter away and finding the peak), and any notes. If it was possible to easily measure the background (i.e. without the user's lamp(s)) illuminance, we did that as well.

For the single point surfaces we made a quick measurement with the illuminance meter in either a horizontal or vertical orientation (depending on how the surface was used by the vendor), noted the light level and measurement type (horizontal or vertical), and asked the user if enough light was available for the illumination task ("OK or "Not OK"). For example, we measured the single-point

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[3] The larger study that this work is a part of has been approved by the Humboldt State University Human Subjects Institutional Review Board, approval code#07-88.
[4] A group of American researchers with illuminance meters is not a common sight in any night market, much less those in developing countries. We always strive to be cognizant of the impact our presence might have on our study participants' businesses. In some cases, the vendor might reap additional customers who are curious to see what we are doing. In others, people may be reluctant to approach while we are there or impeded from viewing goods.
[5] Extech 401036
[6] Included in Appendix 2

illuminance in a horizontal plane where a woman was finely slicing greens into a bowl for later packaging and sale to her customers. We put the illuminance sensor close to where she held the knife and stood in the same place she stood during her work. We did our best to accurately simulate the whole lighting scene during the measurement, including lamp placement, reflection from the surroundings (including us), and any background lighting that is normally present (such as stray light from a nearby streetlight). Measurement of lighting service in the field is an art as well as a science.

For multipoint surfaces, we began by specifying appropriate grid spacing for the measurements. In our cases, we generally used ~0.25 meter spacing between measurements on surfaces ranging from 0.5 to 1.5 m^2, resulting in about 12-20 measurements for each. We laid out a relatively evenly spaced grid[7] with masking tape pieces and asked the user to identify points that were adequately lit and those that were not. Those that were inadequate were marked. After establishing the user's satisfaction at each point we measured illuminance at each point, recording the values and removing the markers as we went.

Findings – Illumination Service and Demand from Night Market Vendors

We measured illuminance and asked for vendors' impression of the lighting service sufficiency at 102 points among the four participants in the survey. The detailed results are documented in Appendix 1, where we include a montage of photographs, illuminance maps with sufficiency at each point, and a summary table for each vendor that includes the average illuminance level achieved. The details of these surveys are illustrative of the lighting needs of night market vendors. Larger surveys of lighting preference would not require such a detailed analysis of each individual's results.

Vendor 1 (see Appendix 1) operates a vegetable stand that is illuminated with a gooseneck-style LED task lamp. On the night we surveyed her, the lamp had not been charged for several days and was operating at significantly below its peak performance level (3.8 lux at 1m, compared to 20 lux for a freshly charged lamp). She situated the lamp to provide task illuminance for slicing greens[8] and potatoes inside her "back room," with the spillage illuminating the sales table on the outside where customers could view her wares. For the cutting task she said that 3.1 lux was sufficient, but over the 0.5 m^2 sales table only one third of the points we measured were "OK."

Vendor 2 purchased an LED lamp but continued to operate his (much brighter – 50 lux @ 1m) pressurized kerosene lamp at his vegetable stand because he was accustomed to its higher level of lighting service. Also, he was illuminating a relatively large area, a 1.2 m^2 two-tiered vegetable sales table, and required task lighting for slicing greens. The pressure lamp provided sufficient light across the table (an average of 33 lux) and for his task area (41 point measurement.

Vendor 3 normally used an LED lamp to light his kiosk, and set up his old hurricane kerosene lamp in its previously typical arrangement as a point of comparison for us. The results in Appendix 1 include both light sources. He sold fruit, vegetables, juice, candy, and cigarettes, among others. The hurricane lamp (operating at 5 lux @ 1m) provided an average of 1.1 lux over his 1.5 m^2 table; none

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7 The nature of the surfaces we measured was "bumpy" – they were covered in fruit, piles of lettuce, etc. We aimed for a uniform grid but accepted that in practice we would need to measure "around" some features of the surface.

8 Many night market vendors we worked with pre-slice greens (usually kale, known locally as "skuma") as a way of adding value to the product for their customers. The work requires a very sharp knife and careful work; customers prefer to have very finely sliced greens. The sliced greens are sold in pre-packed bags, ready to cook.

of the points were sufficient by his standard. These results were likely skewed since he was happy with his LED lamp and viewed the hurricane lamp as a sub-standard light source. His disapproval of its lighting service was blanket in spite of some points being brighter than those that he later claimed were sufficiently illuminated by his LED lamp. When we measured the illumination from his LED lamp it was operating at a peak illuminance of 8 lux @ 1m, and sufficiently illuminated three fifths of the table with an average illuminance of 3.1 lux. We have included a simulation of the lamp operating at full power, 20 lux @ 1m, where it appears that ~90% of the sales table would be sufficiently illuminated with an average expected illuminance of 7.5 lux.

Vendor 4's LED lamp was irreparably damaged by a technician who was attempting to fix a loose connection, so she had reverted to using her hurricane lamp to illuminate her kiosk. Its peak illuminance at 1 meter was 1.9 lux on the night we measured. There were two surfaces she needed to light: a $1.2 m^2$ inside wall where she displayed packaged foods and a $0.9 m^2$ outside sales table for vegetables. Neither surface was well lit by the hurricane lamp. Only one forth of the inside wall points (average 0.9 lux) and none of the outside table points (average 0.1 lux) were sufficiently illuminated, according to her.

Table 1 is a summary of all the surfaces (single and multipoint) we surveyed. For all but the pressurized kerosene lamp, the average illuminance levels are far below industrialized country standards, but the vendors felt that at least parts of their stands were sufficiently illuminated.

Table 1: *Summary of surfaces that we surveyed: description, light source, and lighting service provided.*

Vendor #	Surface	Lamp Type	Illuminance @ 1m (lux)	Area (m^2)	Average Illuminance (lux)
1	Vegetable Stand (outer table)	LED	3.8	0.5	0.6
	Vegetable Stand (task area)	LED	3.8	0.1	3.1
2	Vegetable Stand (2-tiered table)	Pressure	50	1.2	33.0
	Vegetable Stand (task area)	Pressure	50	0.1	40.6
3	Kiosk	Hurricane	5	1.5	1.1
	Kiosk	LED	8	1.5	3.1
	Kiosk	LED (simulated full charge)	20	1.5	7.5
4	General Kiosk inside wall)	Hurricane	1.9	1.2	0.9
	General Kiosk (outside table)	Hurricane	1.9	0.9	0.1

Considering the aggregated results across the four vendors, as shown in the probability plot below (Figure 1), an illuminance level of about 2 lux emerges as the sufficiency breakpoint for illuminance for this particular context and group. The plot shows that 95% of the "Not OK" responses were below 2 lux, and 90% of the "OK" were in response to levels above 2 lux. Only one point above 5 lux was "Not OK," the outlier from Vendor 3 who gave a blanket "Not OK" assessment to illumination from the hurricane lamp he replaced with an LED lamp. It seems likely that 5 lux may be high enough for general illumination across the population of night market vendors in Kenya, and a higher level may be required for tasks. Our sample size is much too small, however, to reach any conclusions about the population-wide requirements.

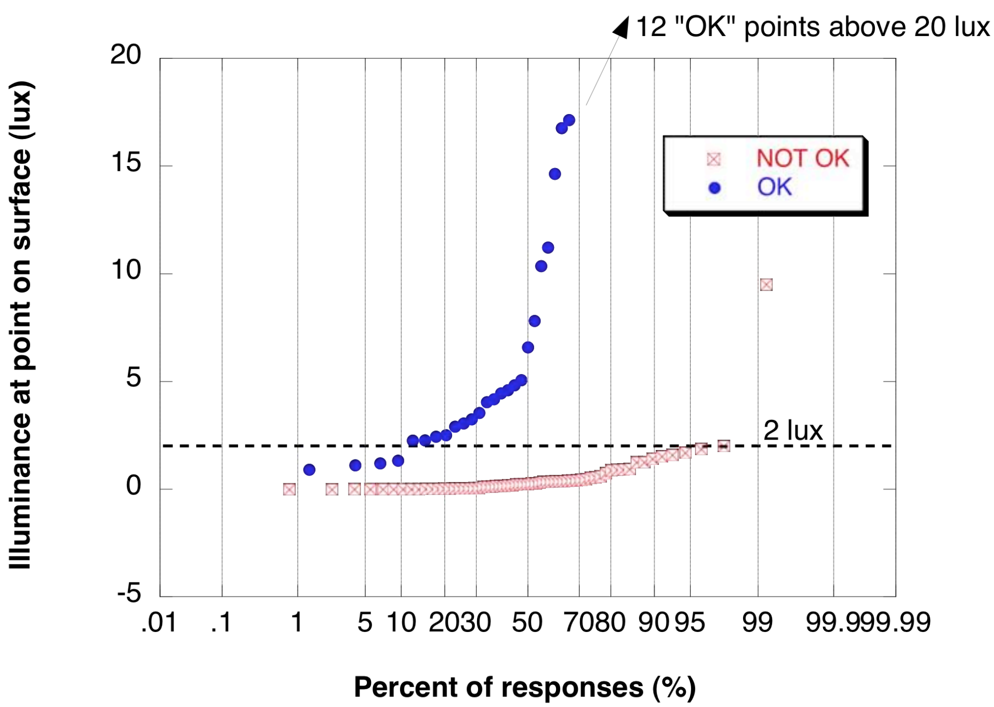


Figure 1: *Aggregate responses from vendors about the sufficiency of lighting service at night market stands illuminated by a variety of fuel-based and LED lighting sources.*

Combining the individual and aggregate results, we can take an alternative view of the surface-by-surface data and estimate the suppressed lighting demand on each surface. This represents demand for lighting that is not being met by the current light source and which any improved lamp should meet. To estimate the total incident light (lm), the average illuminance (lux or lm/m^2) is multiplied by the surface area (m^2); this calculation is valid because the points across each surface were evenly spaced and each represents the same percentage of the overall surface area. The suppressed illuminance demand at each point can be defined as follows, using the "community defined" threshold for illuminance we established using Figure 1, 2 lux:

$$E_{v,\sup} = \max\left[(E_{v,thresh} - E_{v,meas}), 0\right]$$

where:

$E_{v,sup}$	=	suppressed demand at each point (lux)
$E_{v,thresh}$	=	the community illuminance threshold (1.4 lux)
$E_{v,meas}$	=	the measured illuminance at the point (lux)

We estimate the total suppressed demand for light on each surface (lm) in the same manner as the total incident light, by multiplying the average suppressed demand by the surface area. Table 2 summarizes the analysis of incident light and suppressed demand. A listing of the fraction of points that were "OK" on each surface is also included in the table. The fraction is also representative of the fraction of the area that was sufficiently illuminated. Hurricane lamps tended to provide only limited lighting service; in total only 3 of 48 points were "OK" for hurricane lamp users. Vendor 2, who used a pressure lamp, was completely satisfied with the light levels that it provided. The LED task light users had mixed success meeting their lighting needs; 15 of 32 general lighting points were sufficiently illuminated and the woman using her LED light to cut greens (a true task lighting application) was satisfied with the illumination.

Table 2: *Total incident light, suppressed lighting demand and the level of satisfied demand for each surface.*

Vendor #	Surface	Lamp Type	Total Incident Light (lm)	Suppressed Demand (lm)	Fraction of points that are "OK"
1	Vegetable Stand (outer table)	LED	0.31	0.75	3/12
	Vegetable Stand (task area)	LED	0.31	0.00	1/1
2	Vegetable Stand (2-tiered table)	Pressure	39.55	0.05	20/20
	Vegetable Stand (task area)	Pressure	4.06	0.00	1/1
3	Kiosk	Hurricane	1.70	1.86	0/20
	Kiosk	LED	4.68	0.81	12/20
	Kiosk	LED (simulated full charge)	11.25	0.44	n/a
4	General Kiosk inside wall)	Hurricane	1.13	1.61	3/12
	General Kiosk (outside table)	Hurricane	0.08	1.72	0/16

Conclusions

The question, "What lighting level is sufficient?" is a complex one. Application-specific lighting recommendations in industrialized countries are based on detailed ergonomics studies and rules of thumb that ensure a majority of people will be comfortable with the lighting level and may include consideration for energy efficiency (and economics), but generally are not tempered by economic factors. The method and analysis techniques we have described here could be deployed on a large scale to estimate the demand in the context of the off-grid, low-income developing world, where users are much more cash poor and the balance between lighting service and cost is very different from an industrialized country setting. Illuminance might not tell the whole story; the color of light, user's eyesight fitness (often correlated with age), and localized luminance (peak levels from the user's viewpoint and reflecting from the working surface) are also key to perception and could be included in future applications of this technique. However, additional measurements would add expense to the survey (higher cost instruments, more time required) and would be more burdensome for participants.

For users like the might market vendors we surveyed, much lower recommended levels than industrialized country levels may be appropriate; according to our limited user responses, light levels on the order of 2 lux for general lighting were sufficient in the pilot study group. A level of 5 lux might be universally acceptable, but our sample is too small to make statistically significant estimates. Even at these low demand levels, fuel based lighting is not satisfactory and suppressed demand remains. The LED task lights we offered for sale performed better than hurricane lamps but left significant suppressed demand unmet. Emerging LED lamps will need to meet the suppressed demand, not just provide an economical, clean alternative to fuel-based lighting.

References

Atmodipoero, R.T. and Pardede, L. *Research on minimum illumination as a function of visual performance.* Energy and Buildings 36 (2004) 644-649

Bhusal, P., Zahnd, A., Eloholma, M., and Halonen, L. *Replacing Fuel Based Lighting with Light Emitting Diodes in Developing Countries: Energy and Lighting in Rural Nepali Homes.* Leukos vol. 3 No. 4 (April 2007) 277-291

Johnstone, P., A. Jacobson, E. Mills, and K. Radecsky. 2009. *Observed Minimum Illuminance Threshold for Night Market Vendors in Kenya who use LED Lamps*. Lumina Project Research Note #3. http://light.lbl.gov/pubs/rn/lumina-rn3-illum-threshold.pdf

Lighting Africa, 2008. *Lighting Africa Market Research in Ethiopia, Ghana, Kenya, Tanzania, and Zambia: Quantitative Summaries.* Available online: http://www.lightingafrica.org/node/191/

Mills, E. and N. Borg, 1999. *Trends in Recommended Illuminance Levels: An International Comparison.* Journal of the Illuminating Engineering Society, Winter 1999

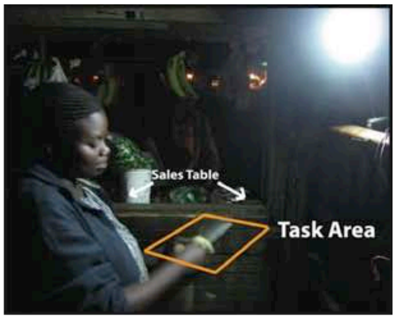
Mills, E. 2003. *Technical and Economic Performance Analysis of Kerosene Lamps and Alternative Approaches to Illumination in Developing Countries.* Lawrence Berkeley National Laboratory Report. http://eetd.lbl.gov/emills/pubs/pdf/offgrid-lighting.pdf

Mills, E. and A. Jacobson, 2007. *The Off-grid Lighting Market in Western Kenya: LED Alternatives and Consumer Preferences in a Millennium Development Village.* Lumina Project Technical Report #2.

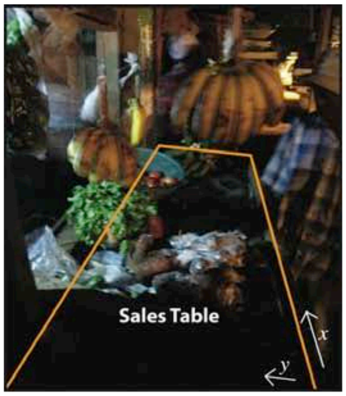
Radecsky, K., P. Johnstone, A. Jacobson, and E. Mills. 2008. *Solid-State Lighting on a Shoestring Budget: The Economics of Off-Grid Lighting for Small Businesses in Kenya.* Lumina Project Technical Report #3. http://light.lbl.gov/pubs/tr/lumina-tr3.pdf

APPENDIX 1: Detailed Survey Results

1) Vegetable Stand, LED Gooseneck Lamp (3.8 lux@1m)



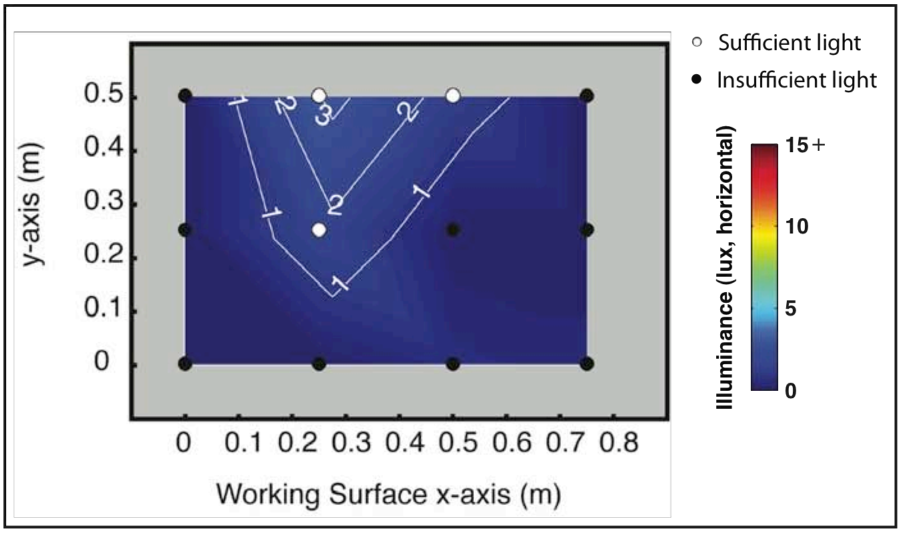
(A) *Photograph of task area (taken previously)*



(B) *Photograph of sales table from the time of measurement*

(C) *Lighting service summary table*

Surface	*Area (m^2)*	*Average Illuminance (lux)*
Task Area	~0.1	3.1
Sales Table	0.5	0.6



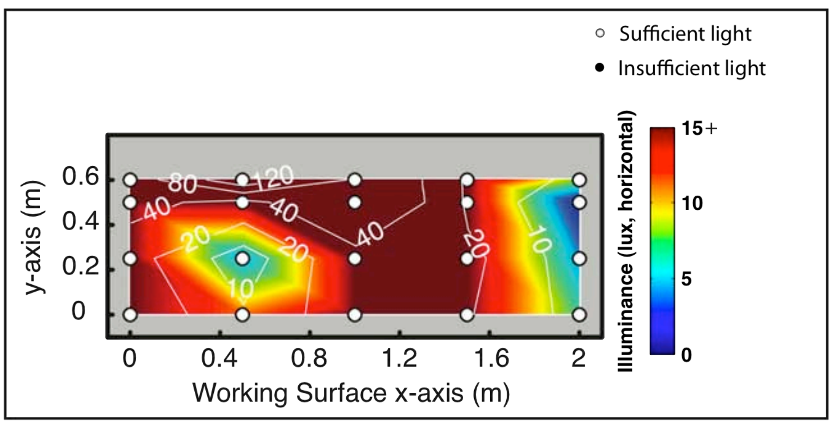
(D) *Sales Table Illuminance Map*

2) Vegetable Stand, Kerosene "Pressure" Lamp (50 lux@1m)

(A) *Photograph of stand from the time of measurement*

(B) *Lighting service summary table*

Surface	*Area (m^2)*	*Average Illuminance (lux)*
Task Area	~0.1	41
Vegetable Stand	1.2	33



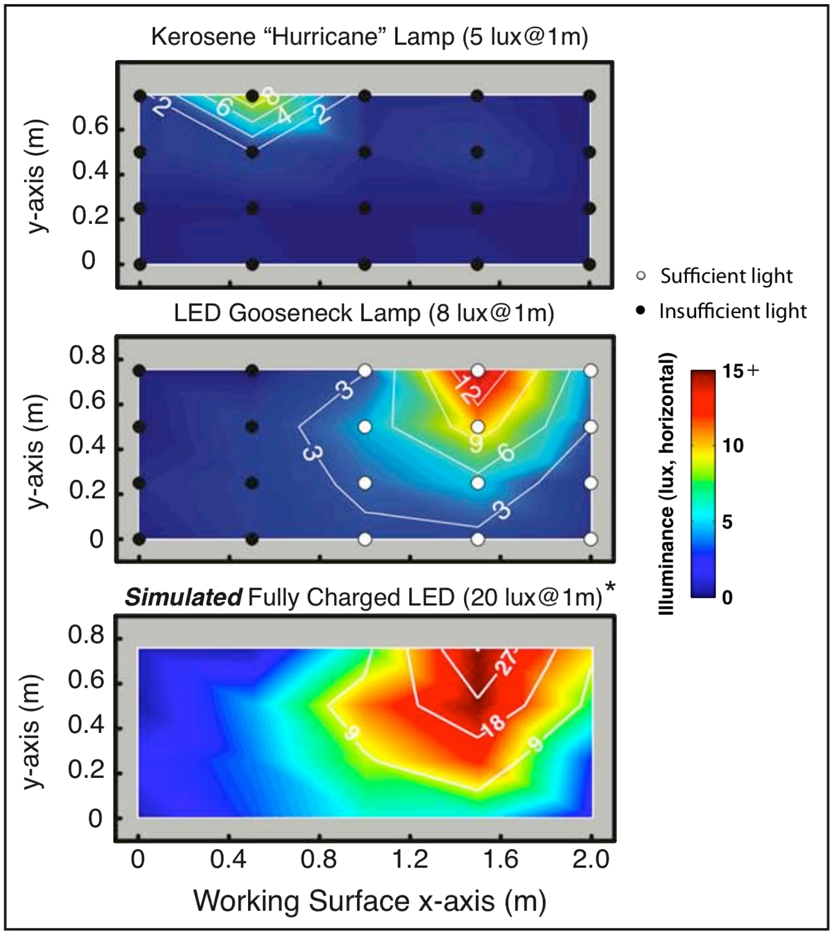
(C) *2-tiered Vegetable Stand Illuminance Map*

3) Kiosk, Kerosene "Hurricane" & LED Gooseneck Lamp

(A) Photograph of kiosk during the day

(B) Lighting service summary table

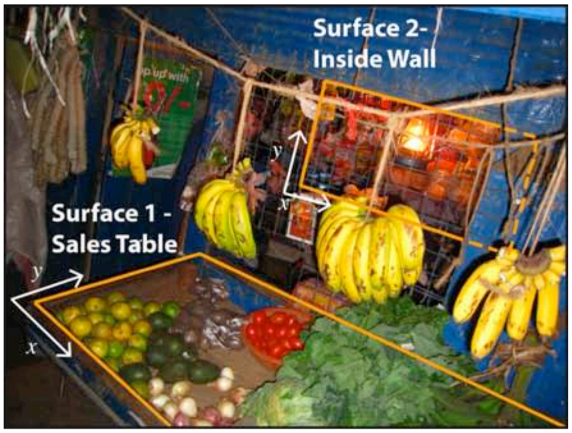
Surface [light source]	*Area (m^2)*	*Average Illuminance (lux)*
Sales Table [Hurricane]	1.5	1.1
Sales Table [LED, 8 lux@1m]	1.5	3.1
Sales Table* [LED, 20 lux@1m]	1.5	7.5



(C) Sales table illuminance maps for various light sources, both measured and simulated

*These results include "simulated" illuminance for a fully charged LED lamp as a point of reference. I simulated a brighter source by applying a linear multiplication factor equal to 20/8 across the task plane as it was measured with the dimmer lamp after correcting for background illuminance.

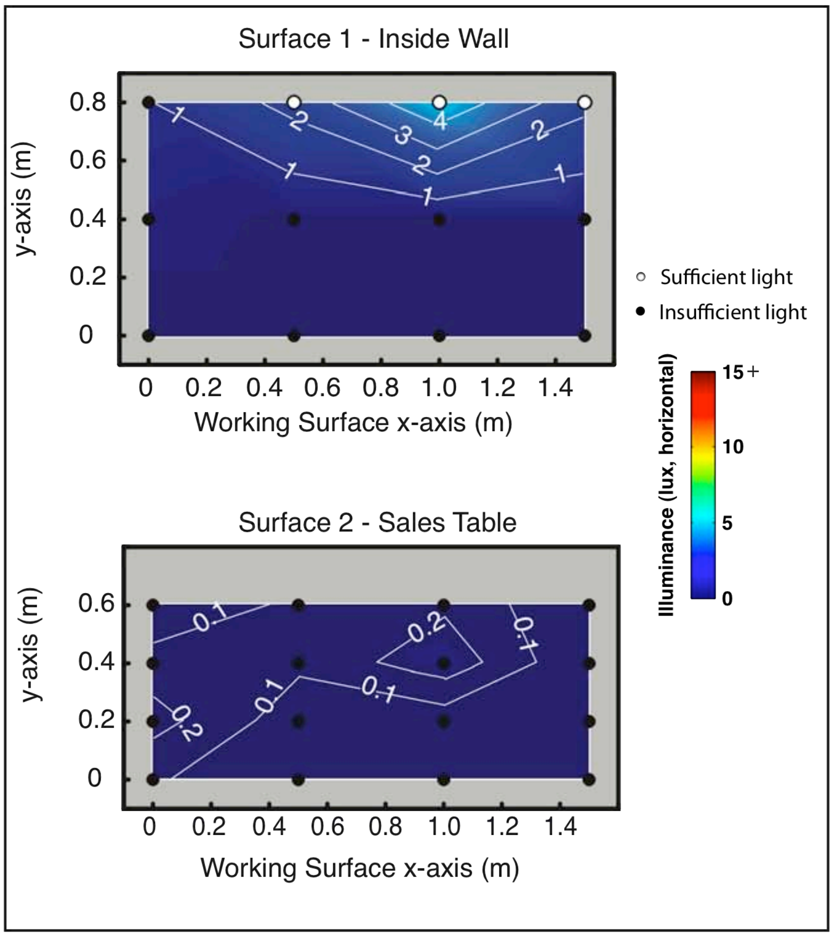
4) General Kiosk, Kerosene "Hurricane" Lamp (1.9 lux@1m)



(A) Photograph of kiosk at the time of measurement (with flash)

(B) Lighting service summary table

Surface	*Area (m²)*	*Average Illuminance (lux)*
Inside Wall	1.2	0.9
Sales Table	0.9	0.1



(C) Inside Display Wall and Sales table illuminance maps

APPENDIX 2: Survey forms

The survey forms are attached to this document.

Survey Form
Portable Lamps in Kenya
June, 2009

Illuminance Field Survey

Survey by: Peter Johnstone
Humboldt State University
Arcata, CA 95521, USA

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

1.1 Name of person(s) administering survey: ______________________________

1.2 Date & time of interview: ____

1.3 Province: ___________________ District: _____________________

Town: ____________________ Village or area: _______________

1.4 Participant # _________ (if applicable)

###

2.1 Lighting Application Type:

0 Market Stall 0 Kiosk

0 Small Shop 0 Home

0 Other____

3 **User input on light**

3.1 Is this lighting set up typical?

0 Yes 0 No

3.1.1 If not, how is it different?

____

____

____

4 *List all light sources, measure E_v:*

#	Source Type (see codes below)	Illuminance at 1 meter (lux)	Background Illuminance (lux)	Notes
1				
2				
3				

Fuel Based Lamps	***Code***
Kerosene Wick	W
Kerosene Hurricane	H
Kerosene Pressure	P
Candles	C

Electric Lamps	**Type**	**Code**
Form Factor	Torch	T
	Lantern	L
	Array (or Strip)	A
	Gooseneck Lamp	G
Bulb	LED	LED
	Incandescent	INC
	Fluorescent	FLO
	CFL	CFL
Battery	Rechargeable	R
	Dry Cell (mawe)	D
Ex: T-LED-D		

4.1 ***Define / Measure Task Planes:***

Single Point Areas:

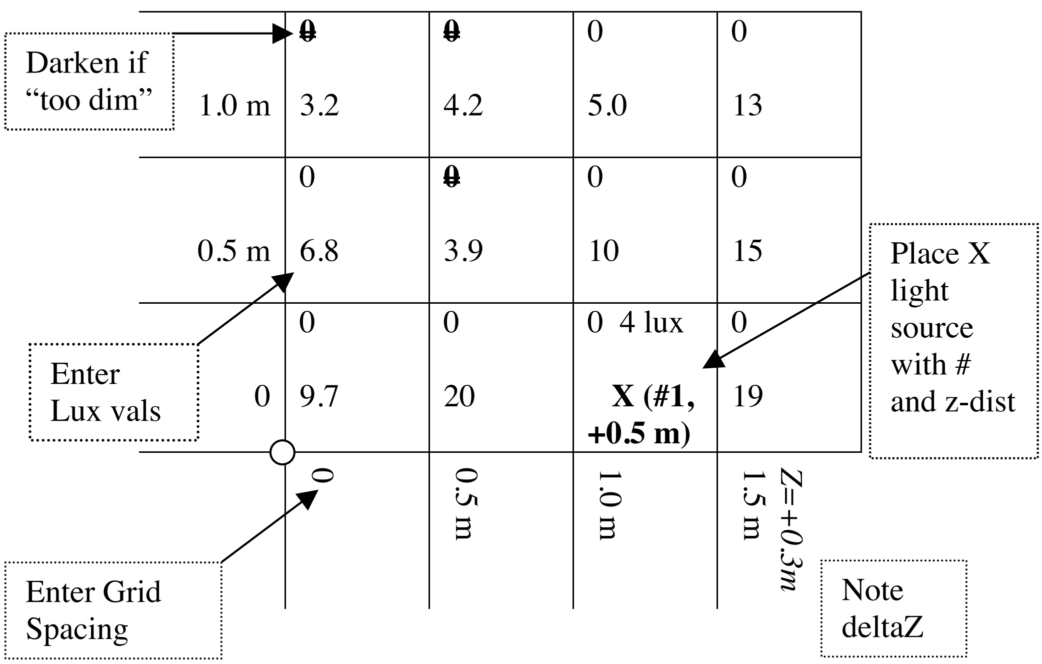
Description	**Closest Source (#)**	**Distance from Source (meters)**	**E_v (Lux)**	**Bright Enough? (yes/no)**

Attach Sheets for Multipoint Task Planes. List Sheet ID#'s here:

____

4.2 For each task area, ask the user to identify the areas that are not bright enough. (Indicate on single-point task planes and on multipoint sheets)

Multipoint Task Plane Example below:



Multipoint Task Plane Datasheet

Date________________________ Sheet ID#____________________________

	0	0	0	0	0
	0	0	0	0	0
	0	0	0	0	0
	0	0	0	0	0
	0	0	0	0	0
	0	0	0	0	0
0 (origin)	0	0	0	0	0
	0 (origin)				

Note: ____

____