Minimum Quality Standards and Recommended Performance Targets for Lighting Global, Lighting Africa, and Lighting Asia

Stakeholder Outreach for Program Transition

June 7, 2013

The Lighting Global Quality Assurance (QA) Framework supports the Lighting Africa and Lighting Asia programs[1] with a range of services that measure, benchmark, and communicate product quality and performance for the off-grid lighting market. Part of the framework is a set of Quality Standards and Performance Targets that are used both by Lighting Global and the regional programs to screen products for engagement and support. This memo outlines a set of draft updates to the Standards and Targets framework.

Brief History

The global QA framework has evolved quickly to serve the needs of a rapidly growing market for pico-power products that include off-grid lighting and energy systems. Early awareness[2] that quality assurance was important to the growing market led to the development of a set of test methods for Lighting Africa (2009) and a system of benchmarks (2010). Lighting Africa maintained two complementary sets of off-grid lighting benchmarks: The Minimum Quality Standards and Recommended Performance Targets. The Standards set a baseline level of quality, durability, and truth-in-advertising to protect consumers. The Targets are a recommended level of performance above the Standards. This QA framework of testing and benchmarks later transitioned to the Lighting Global QA framework (2012) with the launch of Lighting Asia. The global framework continues to support both the Lighting Africa and Lighting Asia initiatives along with other institutions and organizations.

Institutional Transition

Key elements of the global QA framework were recently adopted as an International Electrotechnical Commission technical specification, IEC/TS 62257-9-5, Edition 2.0. The technical specification will be the foundation for the Lighting Global QA program going forward, and it also has potential to serve as the backbone for off-grid lighting quality assurance for a range of other initiatives, private and public sector organizations, and regulatory institutions like the United Nations Framework Convention on Climate Change's (UNFCCC) Clean Development Mechanism.

Lighting Global can support buyers, regulators, manufacturers, and others who would like to adopt or implement IEC/TS 62257-9-5 to ensure the products and manufacturers they support provide good quality and meet performance expectations; please contact us for more information.

[1] Lighting Africa supports markets in Sub-Saharan Africa; Lighting Asia supports the India market; Lighting Global provides global services like quality assurance that are applicable across markets. All three are affiliated, but separate, programs. More information on the programs is available online (lightingafrica.org, lightingasia.org, lightingglobal.org).

[2] e.g., see Mills and Jacobson (2007) Light and Engineering 16(2)

Draft Revisions for Minimum Quality Standards and Recommended Performance Targets
This memo kicks off a new stakeholder outreach process to inform revisions to the Minimum Quality Standards and Recommended Performance Targets. Along with the updates to the global Standardized Specifications Sheet (SSS) program,[3] this transition to updated Standards and Targets is a key next step in a process initiated in 2012 following close consultation with stakeholders in industry and the public sector. That process is described at http://www.lightingafrica.org/qa-consultation-outcome.html.

This memo includes:

- A draft set of new Standards and Targets policies for Lighting Global, Lighting Africa, and Lighting Asia;
- Rationale and supporting information that inform the policy updates:
    - End-user focus group results from Africa and Asia
    - Technology trends
    - Insights from 3+ years of product quality and performance test results

<u>Policy Change 1</u>: *New Structure of Standards and Targets*

In the updated framework, **Lighting Global will maintain a harmonized set of Standards and each regional program—Lighting Africa and Lighting Asia-India—will reference those along with a harmonized set of Targets (Figure 1)**.

Conformity with the Quality Standards and Performance Targets will continue to be evaluated based on results from laboratory testing according to IEC/TS 62257-9-5, Edition 2.0.

The goal of the Minimum Quality Standards is to protect consumers from false advertising and early product failure. The goals of Performance Targets vary depending on context. For the Lighting Africa and Lighting Asia programs, the role of the Targets is to set a minimum threshold of performance that meets consumer expectations with respect to the level of brightness or run time. The Targets are used to qualify for certain aspects of Lighting Africa market support services, including especially participation in consumer awareness campaigns and related consumer-facing activities. A similar scope is envisioned for Lighting Asia subject to program needs.

***Figure 1**: Relationship between the minimum quality standards and performance targets and the Lighting Global, Lighting Africa, and Lighting Asia programs.*

[3] Standardized Specifications Sheets are the public face of Lighting Global test results. Products are issued SSS that are displayed on the Lighting Global website if they meet the Minimum Quality Standards and maintain status with retesting according to the program requirements.

Policy Change 2: *Updates to Standards and Targets Thresholds*

It is important to reassess and update the Standards and Targets periodically for three main reasons:

1. **Keep up with and anticipate market trends.** As the market evolves, best practices for durability and quality are changing, and consumers expect these practices to be followed. The cost of providing modern lighting is rapidly falling due to trends in technology, particularly LED efficacy improvements. The Minimum Quality Standards and Performance Targets reflect the reasonable expectations of consumers in the context of modern technology capabilities and are expected to evolve continually.
2. **Address shortcomings and close loopholes.** Based on operational insights and feedback from the market, we are able to improve the Standards and Targets framework.
3. **Account for new findings and information.** Experience with product test results gives the Lighting Global program unique insights into product and market trends that can be incorporated into the Standards and Targets. New research on human responses to light, including ability to carry out visual tasks in low light conditions, may also be considered.

The **timeline for implementation** is below:

- June 2013 – Stakeholder feedback from across the market
- July 2013 – Finalize framework and supporting policy documents
- July 2013-December 2013 – Grace period for policy transition
- December 31, 2013 – Last day to submit products for testing that will be subject to previous framework (Lighting Global Standards and Targets version 3.1)
- January 1, 2014 – Official launch for updated framework. All products tested are subject to the updated Standards and Targets.

Products that have already met the minimum quality standards and/or performance targets according to the current requirements (i.e. version 3.1 framework) or those that meet them based on testing that starts between now and the end of 2013 will continue to retain that status until their test results expire two years after laboratory testing is completed. Once the test results expire, retesting will be required to prove compliance with the Standards and Targets that are in effect at that time that testing is initiated.

A small note will be included on all future Standardized Specifications Sheets (SSS) indicating which Standards and Targets framework was used to determine whether the product met the associated requirements. Meeting the Minimum Quality Standards is a requirement for participation in the SSS program.

Table 1, below, summarizes the proposed changes to the Standards and Targets compared to the current framework (Lighting Global version 3.1). In the appendix for this memo there are several supporting documents: the detailed (legacy) Standards and Targets for Lighting Global v.3.1; supporting information that informed the draft changes to the Standards and Targets; and drafts of the proposed new Lighting Global Standards, Lighting Africa Targets, and Lighting Asia Targets.

Provide your feedback:

Once you have reviewed the proposed updates to the structure and particular levels for Standards and Targets, we invite you to participate in a stakeholder review process that will determine the final outcomes of this update. Please follow the link below to provide feedback and sign up for email updates on the process:

http://www.lightingafrica.org/qa-consultation-outcome.html

Table 1: *Summary of proposed changes to criteria and thresholds*

Spec	Area	Proposed Change	Rationale	Likely Implications
Lighting **Global** Standards	Overall	*Continue to use existing (legacy) Standards* except where noted.	Program stability is important; the previous Quality Standards have served well overall.	N/A
	Lumen Maintenance	*Stricter passing threshold.* Must maintain at least 85% of initial light output after 2,000 hours for pass (or at least 95% after 1,000 hours for expedited pass).	Lumen Maintenance is better understood by the industry now and few good-quality products fall below this threshold. Longer product lifetimes are important for sustainability. (Supporting Data in Appendix)	Better product lifetimes for consumers. A small number of false positive results from closer tolerance between 1,000 hour and 2,000 hour tests (we expect ~1-3%). See Appendix.
	Battery Durability	*New criteria.* 5 out of 6 samples must pass a battery storage durability test (new tests outlined in updated QA framework and IEC 62257-9-5 Annex BB).	Some batteries fail quickly, leading to loss of service. These tests are designed to detect batteries that are defective from the time of manufacture or that are damaged due to deep discharge during time spent in the supply chain. This test does not necessarily differentiate between batteries that last longer than one year and cannot predict longevity once batteries are in use. (Supporting discussion in Appendix)	Harder for low quality lead acid batteries to pass, protecting end-users from purchasing batteries that may be damaged in the supply chain.
	Hazardous Substances Ban	*No Cadmium or Mercury.* No products that use batteries containing cadmium or mercury at levels greater than trace amounts will pass the Standards. The EU Batteries Directive will be used to guide implementation; manufacturers will be asked to self-declare compliance and supply supporting information as appropriate.	Cadmium is a potent neurotoxin and the hazardous waste collection supply chain in much of the developing world is functionally non-existent. This is a precautionary measure to avoid toxics exposure for people who are exposed to the waste. (Supporting discussion in RoHS Eco Design Note)	A very small number of products that have met Minimum Quality Standards use batteries that contain cadmium. Manufacturers of these products would need to change battery types or have their products excluded.
	Ingress Protection for External PV Modules	*Close loophole.* External PV module junction boxes and electrical connections must be resistant to permanent outdoor exposure.	External PV modules are meant for permanent outdoor use and should be protected from early failure.	Most products meet this Standard easily. There are two we know of that have issues with water leakage into the junction box and this would need to be remedied.
	Warranty	*Increase duration.* The requirement is to have a warranty that is consumer-facing and at least one year in duration.	The previous warranty term of six months is increased to one year to reflect trends in the market.	Several products have split durations for batteries and the rest of the product; currently some only have 6-month battery warranties. These would need adjustment.

Spec	Area	Proposed Change	Rationale	Likely Implications
Lighting **Africa and Asia** Targets targets	Minimum Quality Standards	*Still required to meet Standards* as a prerequisite for Targets. Now will reference Lighting Global Quality Standards as the benchmark.	Harmonize with Lighting Global Quality Standards to provide stability to the market and will have a set of program-specific Performance Targets.	N/A
	Run Time	*25% increase to the current Targets:* 5 hours per day for solar-charged products **and**[4] 10 hours for full-battery run time for products that do not include an individual solar module and are meant for central charging.	Survey data from 2008 in Africa indicate 4 hours / day is the average night-time use. Focus groups in 2012 indicate that the combination of early morning use and longer night-time run times could support a modest increase in the run time Performance Target. (Supporting Information in the Appendix) Evidence from focus groups in Asia indicates ~6 to 8 hours is the preferred daily run time, but this includes some time where lower light levels may be acceptable. This approach achieves harmonized values between the Lighting Africa and Lighting Asia programs (Supporting Information in Appendix)	With a shift to 5 hours per day, some number of products that meet the Targets now would no longer meet them. It is important to note that these products would continue to be supported until the results for each product expire. Combined with increased brightness, a run time increase to 5 hours would lead to a 50% increase in the lighting service requirements. While increasing the requirements influences product costs, technology advances (especially LED lumen efficacy gains) should offset most or all of the need to increase the price of the lowest cost product that can meet the Targets.
	Brightness	*Increased for meeting the ambient and task lighting Target.* To meet Targets, must have total output > **25 lumens** (the ambient light Target) or provide a minimum of **50 lux over an area ≥ 0.1 m²**.	Evidence from focus groups in five countries across Sub-Saharan Africa indicates the majority of people will be satisfied with these levels for lamps that have passed a quality check. LED technology trends make reaching these levels easier to achieve than was the case only 1-2 years ago. (Supporting information is provided in the Appendix.) Evidence from focus groups in Asia indicates that people's expectations for light levels are similar to those in Africa-based focus groups. (Supporting information is provided in the Appendix)	A number of products that pass now, particularly those that "design to the Target" will not pass. However, there will be time to redesign in anticipation of the new Targets and technology will be one year better by the time the updated Targets go into effect.

[4] Note that the previous framework allowed 4 hours of solar run time OR 8 hours of full battery run time. The proposed revisions involve shifting to an "AND" requirement so that any product that includes a solar module must meet the solar run time Target.

Supporting Information 1:
“Legacy” Lighting Global Standards and Targets – previous version

***Table 3: Version 3.1 (Sept.** 2012) Lighting Global Standards and Targets*

Category	Specification Sheet Field	Quality Standards	Performance Targets (beyond the Standards)
Information	Manufacturer	Accurately Specified	
	Product Name & Model #	Accurately Specified	
	Warranty	Accurately Specified, Minimum coverage 6 months on manuf. defects under normal use, including battery.	
Illumination	Light output	Accurately specified at each available level (lumens).	At least one level, which defines the “specified light output” in subsequent testing, must meet one of the following criteria: • ≥ 20 lumens • Illuminates a 0.1 m² surface at ≥25 lux under conditions defined by QTM
	Lamp Type	Accurately Specified	
Energy System Performance	Run Times	Accurately specified for each light setting.	Autonomous Run Time (full battery): ≥ 8 hours @ ≥ specified light output *AND/OR* Lighting hours per solar day (PV only): ≥ 4 hours @ ≥ specified light output
Lumen Maintenance	Lumen Maintenance at 2000 Hours	≥ 70% of specified light output at 2000 hours (depreciated at highest setting)	
Charger	Charger Rating	Charger Power Rating Accurately Specified (e.g. PV power or mechanical charge time)	
	AC-DC Charger Safety	Any *included* AC-DC charger carries approval from a recognized consumer electronics safety regulator[5]	
Storage	Battery Capacity	Accurately Specified	
	Battery Protection	Protected by an appropriate charge controller that prolongs battery life and protects the safety of the user	

[5] Approved marks: UL or similar

Category	Specification Sheet Field		standards Quality Standards	targets Performance Targets *(beyond the Standards)*
Quality and Durability	Physical Ingress Protection	Fixed Outdoor	IP 5x	
		Others	IP 2x	
	Water Protection[6]	Fixed Indoor	no requirement	
		Portable Separate	Occasional rain: *IP x1 OR technical equivalent OR with warning label*	
		Portable Integrated	Frequent rain: *IP x3 OR technical equivalent OR IP x1/equivalent + warning label*	
		Fixed Outdoor	Permanent outdoor exposure: *IP x3 AND circuit protection*	
	Drop Test	Fixed Indoor	None result in dangerous failures[7]	
		Others	5 out of 6 samples are functional after drop test (1m onto concrete); none result in dangerous failures	
	Soldering and Electronics Quality		Pass Soldering and Electronics Inspection (without endemic bad joints, pinched wires, etc.)	
	Switch, Gooseneck, and Connector Durability		5 out of 6 samples are functional after 1000 cycles; none result in dangerous failures[7]	

[6] There are two alternative Water Protection compliance pathways allowed by Lighting Africa (i.e. these are alternatives to meeting the IP class requirements). In one alternative ("technical equivalent"), the whole system of protection (ingress protection + electronic circuit protection + manufacturing QC) is evaluated to determine if the protection level is equivalent to that of a product with the required level of ingress protection. In another alternative ("warning label") there are clear messages to the consumer about the degree of protection from water. The warning level messages must meet Lighting Global program guidelines. The pathways and associated guidelines are described in greater detail in a document titled "Integrated Water Protection Assessment."

[7] Dangerous failures are defined as those which may expose the user to physical harm, such as harmful chemicals, heat (e.g., from an electrical short or fire), or sharp materials (e.g. broken glass).

Supporting Information 2:
Benchmarks for Brightness and Run Time

The purpose of this section is to provide documentation and rationale for choosing brightness and run time Performance Targets. It includes a combination of large-scale survey analysis, focus groups, and an understanding of technology performance and trends.

Contents

- **Context – guiding goals and constraints**
- **Brightness Targets**
- **Run Time Targets**
- **Policy Discussion**

Context

The goal of the Performance Targets policy is to help buyers identify products that meet the brightness and run time expectations of most off-grid end-users.

The broad policy drivers for the Targets are listed in the table below. The Targets are driven by consumer expectations (which are summarized separately for brightness and run time) and are tempered by constraints related to affordability and the state of current technology.

***Table 4**: Drivers for overall Targets policy*

Policy Driver	Key Sources	Summary
Affordability	Income data	$20 is a useful benchmark price; products at this price level are likely to be affordable to somewhere between 50% and 75% of the off-grid population.
Technology trends	Market trend information and projections, market monitoring, internal Lighting Global analysis	Rapidly improving LED efficacy drives the market to higher performance-to-price ratios.
Market expectations and needs	Depends on context, various for brightness and run time	Most rural end-users would be satisfied with 25 lumens for ambient lighting and 50 lux for task lighting. People use about 4-5 hours of lighting per day in the surveyed African countries and about 6 hrs/day in India.

Affordability
The income distribution data shown below indicate that a $20 product is likely to be affordable for approximately 50% to 75% of the off-grid population, since it represents between 10 to 20 days of income. Lower cost products will reach greater numbers of people. These financial constraints tend to put downward pressure on Performance Targets. The goal is to set Targets that are relevant for products that are affordable by a majority of potential buyers. See Figures 2a and 2b.

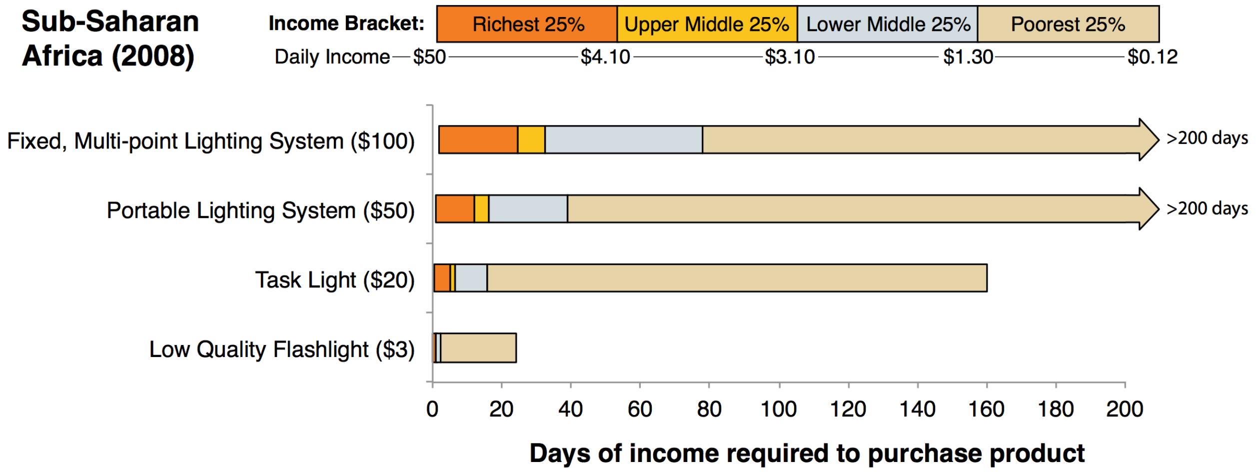


Figure 2a: *Days of income required to purchase various, hypothetical lighting products. Adapted from Expanding Women's Role in Africa's Modern Off-grid Lighting Market and based on aggregate five-country survey data from Research International (2008; Kenya, Ghana, Tanzania, Zambia, Ethiopia; n=1,000/country).*

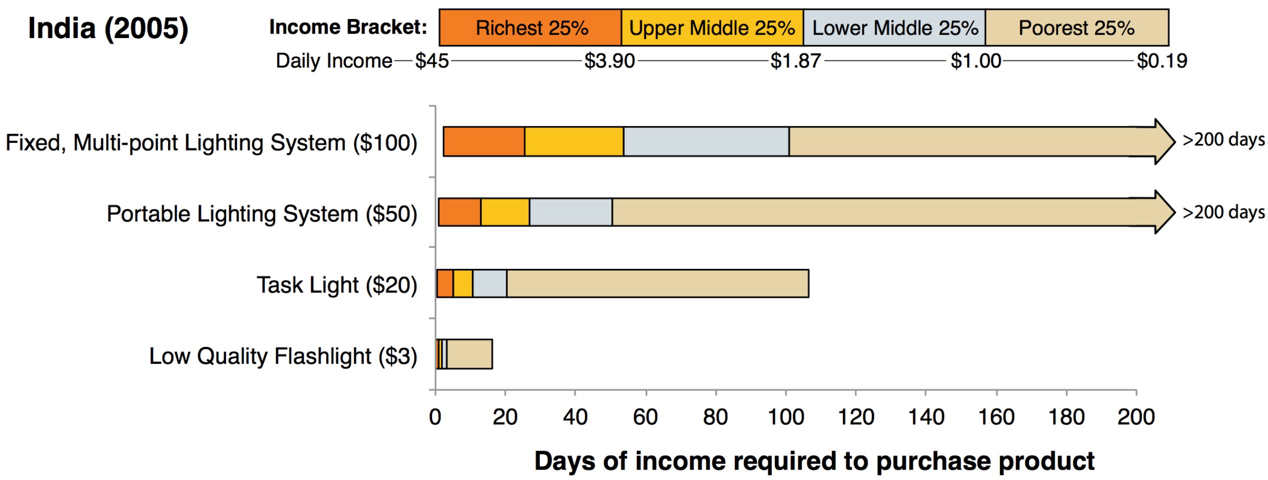


Figure 2b: *A similar plot as above with data for India from a 2005 survey of approximately 45,000 households[8]. All households (on and off grid) are included in this data, which is justifiable given the very low reliability of the Indian grid (only ~15% of households in the survey reported 24 hour/day electricity; about 2/3 are electrified). This figure shows a pattern similar to the one in the Africa data in Figure 2a..*

Technology Trends

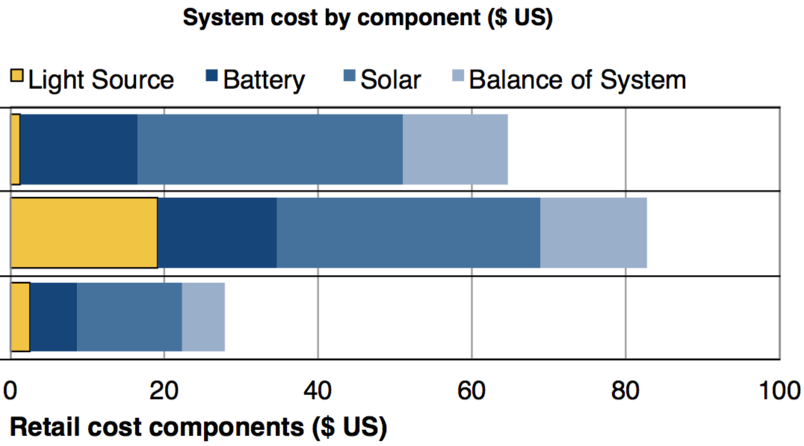
The trends in LED price and efficacy that have played out over the last several years have resulted in lower costs for the light source (less expensive LEDs) and lower power (and cost) requirements for the battery and solar charging system. Figure 3, below, shows how decreasing LED cost and increasing performance has driven the cost of LED lighting products to less than half that of comparable products using compact fluorescent lamps (CFLs). These trends continue. In this context, for Performance Targets to remain relevant, they must be revised upward every few years. Changes to

[8] Desai, Sonalde, Reeve Vanneman, and National Council of Applied Economic Research, New Delhi. India Human Development Survey (IHDS), 2005. ICPSR22626-v8. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2010-06-29. doi:10.3886/ICPSR22626.v8

Performance Targets should also be driven by consumer expectations, which may rise as technology improves and modern lighting becomes more pervasive.

Estimated system cost for a 120 lumen product that provides 4 hours of light from one day of solar charging

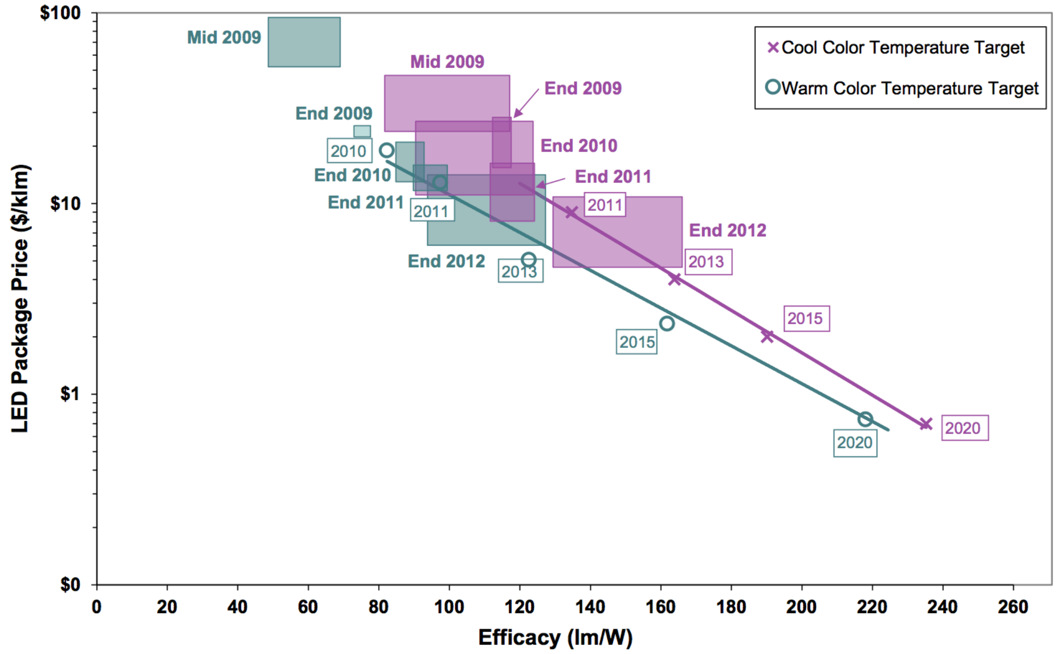
Source	Efficacy (lm/W)	Unit Cost ($/klm)	Power Req. (W)
CFL	40	5	3
LED (2009)	40	80	3
LED (2012)	100	10	1.2



Assumptions: 120 lumens for 4 hours each day, solar cost $5/W, solar resource 5 kWh/m2, battery cost $0.3/Wh, balance of system cost $2/W, 70% derating factor for solar and electricity losses

***Figure 3:** Estimated cost for generic, high performance LED and CFL products. The energy side performance and cost for each system is fixed so the model shows the relationship between light source cost and performance and assembled system cost.*

The United States DOE *Multi-year program plan for Solid State Lighting R&D* (2013 version) indicates that the cost and efficacy of LED lighting is indeed improving rapidly and continued progress is anticipated. Figure 4 below shows the historical values and projections for LED packages, which do not include losses from optics or driver assemblies. The mid-2012 estimates from this report indicate we should expect several products to have LED efficacy greater than 130 lm/W on the package level; assuming combined driver and optical losses of 20%, this efficacy corresponds to about 100 lm/W on a system level. Indeed, several products have surpassed the 100 lm/W benchmark and we see continued progress in efficacy in the Lighting Global testing program.



PRICE-EFFICACY TRADEOFF FOR LED PACKAGES AT 35 A/CM^2 AND 25 °C

Notes:

1. Cool-white packages assume CCT=4746-7040 K and CRI >70; warm-white packages assume CCT=2580-3710 K and CRI >80.
2. Rectangles represent region mapped by maximum efficacy and lowest price for each time period.
3. The MYPP projections have been included to demonstrate anticipated future trends.

Figure 4: *Historical and projected LED package efficacy and price. Copied with superficial edits from 2013 USDOE Multi-year program plan for Solid State Lighting (http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_mypp2013_web.pdf)*

Brightness Targets

Recommendation: 25 lumens for ambient lighting and 50 lux over a 0.1 m^2 area for task lighting.[9]

Drivers for the brightness Targets include multiple sources of information ranging from end-user feedback to the scientific literature. In the context of technology and affordability criteria, the key supporting information for brightness policy development is summarized in Table 5. When drawing from focus group results, our approach is to select values that would satisfy most of the participants (e.g. at least 90%). This is appropriate for a consumer-oriented Performance Target that is intended to ensure widespread consumer satisfaction.

Table 5: *Drivers for Brightness Targets policy*

Policy Driver	Key Sources	Summary
Consumer expectations	Lighting Africa / Asia focus groups	Most rural end-users would be satisfied with 25 lumens for ambient lighting and 50 lux for task lighting.
Health	Scientific literature, summarized in Lighting Global Eco-Design Note Number 2: "LED Lights and Eye Safety"	There is a range of "low light" recommendations. Our target light levels are below typical industrial and occupational standards, but represent an improvement relative to existing lighting conditions for many off-grid households.

[9] See the supporting information for a discussion on the applicability and relationship between ambient targets ("lumens") and task lighting targets ("lux").

Evidence from Africa Focus Groups: 2011

Results Summary: Focus groups find that 25 lumens and 50 lux will meet most peoples' expectations for ambient and task lighting for a quality assured product (Figures 5 and 6).

During fiscal year 2011 Lighting Africa (LA) supported fieldwork across five African countries, including three West African countries (Senegal, Mali and Ghana) and two East African countries (Tanzania and Kenya). Within each country the fieldwork was conducted in towns in areas where early adopters of solar portable lamps (SPLs) were likely to reside. The fieldwork was conducted during 34 focus group sessions involving 284 people across all five countries.

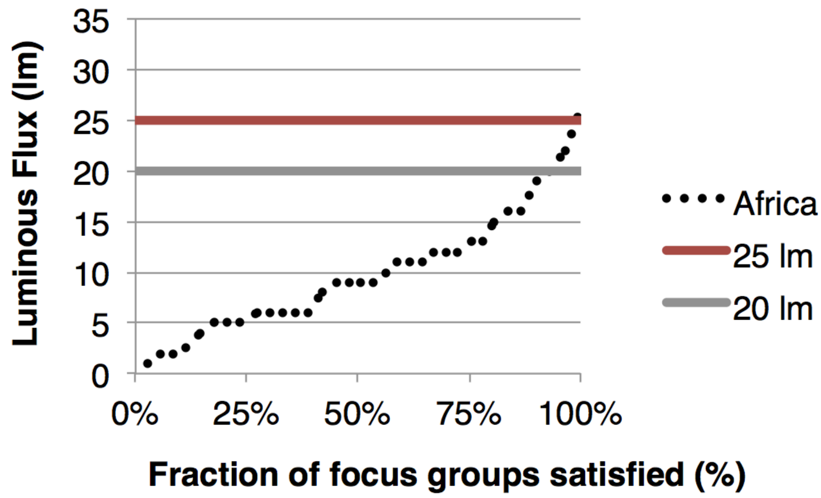


Figure 5: *Fraction of focus groups whose group expectation is exceeded for ambient lighting from a product that has passed a quality check. 50% of group responses were below 10 lumens, 75% below 12 lumens, etc. The current (20 lumen) and proposed (25 lumen) Targets are included. Aggregated from five countries in Sub-Saharan Africa in 2011-12 and weighted by the focus group size.*

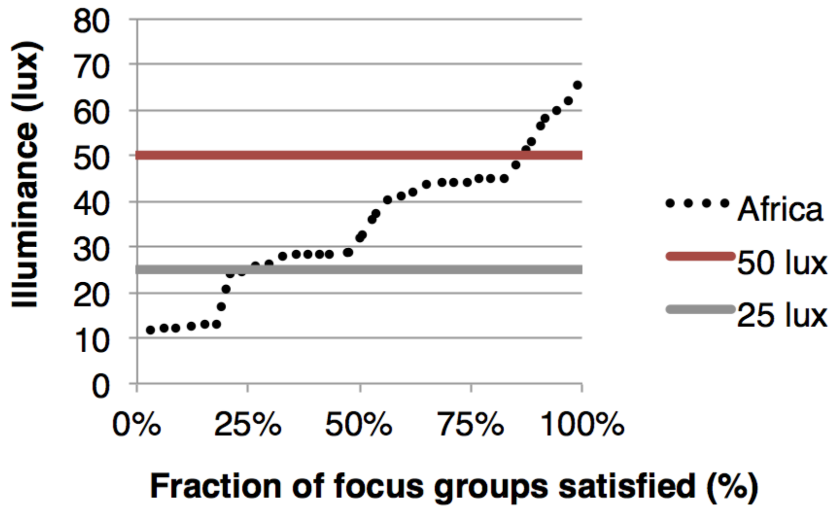


Figure 6: *Fraction of focus groups whose group expectation is exceeded for task lighting from a product that has passed a quality check. 50% of group responses were below 30 lux, 75% below 45 lux, etc. The current (25 lux) and proposed (50 lux) Targets are included. Aggregated from five countries in Sub-Saharan Africa in 2011-12 and weighted by the focus group size.*

Brief Details on Field Methods

The fieldwork in Africa took place between September 2010 and May 2011 in Senegal, Mali, Ghana, Kenya, and Tanzania. Data were collected by means of focus group sessions in each country. The sessions focused on three main topics: 1) quality label design preferences, 2) minimum lighting levels for quality assured products, and 3) identification of priority information for consumers at the point of purchase of modern off-grid lamps. The sessions emphasized receiving input from each participating individual in the context of a collaborative discussion that often led to a group decision. The sessions took place in the evening, with each lasting approximately two to three hours. This enabled the final part of the focus group to occur after sunset so that the minimum lighting level thresholds could be measured in the dark. Similar research was carried out in two Indian states (Bihar and Odisha) in February 2013. More details on the methods and results from these focus groups will be available in a separate forthcoming report.

The focus group research centered on brightness expectations and was conducted using a battery-powered device specifically designed for the field study. The device consisted of two LED lamps; one was designed to deliver light for a task lighting application and the other was design to deliver light for ambient room lighting. The lamps were controlled using a custom power supply that allowed the light output to be adjusted is small increments. The voltage levels at each step were displayed on an LCD screen. Each voltage level corresponded to a particular lumen level as determined by prior laboratory calibration.

The lamps were set up in a room, generally a sitting room in a local house. The task lamp was hung 75 centimeters above a tabletop surface. The ambient lamp was hung 2.25 meters above the ground. The participants were gathered in the room and provided the details about the test, why the test was being administered, and the difference between the task light and the ambient light. These details were provided in complete darkness to enable the participants' eyes to adjust to the very low light levels. The general message communicated by the enumerator went something like this (translated into an appropriate language and with currency converted to local currency):

> We will be doing two separate tests. We want you to tell us what amount of light you would be satisfied with if you just bought an off-grid lamp for approximately $12 USD and knew it had passed a quality check. Remember that this price includes the solar panel. We want to know: if you were to bring home this light and turn it on, would you be satisfied with the level of light – or would you be dissatisfied with your purchase of this low-cost quality assured solar lamp because it is not as bright as you think it should be. The light we are using in this test can get very bright, but we do not want to know what level you like the best. We first want to know the minimum light level in which you would feel satisfied with your purchase. The first test will be with a light we call the task light. This light is designed to be used for things such as reading, studying, selling goods, etc. Let us know the minimum level of light you are satisfied with for using for such tasks for a relatively low cost product that has passed a quality check.

After the participants were informed about the test and understood their role the test began. The task lamp was connected to the power supply and switched to the lowest setting. With pauses of 20 seconds or more the voltage was increased until the participants indicated that the minimum threshold had been reached. Once there was general agreement the voltage measurement was noted and an illuminance meter was placed on the tabletop to record the maximum illuminance provided by the setting. A similar consensus-based approach was used to determine the minimum acceptable ambient light output levels. For the ambient test the table was removed, the participants received an explanation related to ambient lighting applications, and once the participants agreed on a minimum level an illuminance measurement was taken with the illuminance meter on the ground and the drive voltage was noted.

Evidence from India Focus Groups: 2013

Results Summary: Focus groups find that 25 lumens and 50 lux will meet most peoples' expectations for ambient and task lighting for a quality assured product (Figures 7 and 8).

Following up on and replicating the methods from the Africa 2011 fieldwork, in February and March 2013 consumer oriented field research was carried out with the objective of informing the development of Lighting Asia (India) Quality Assurance framework. The research study was conducted in the states of Bihar and Odisha, each of which has a large potential for clean off-grid lighting solutions.[10]

The light output results below show that the proposed Targets of 25 lumens and 50 lux are likely to meet the expectations of nearly all the focus group participants.

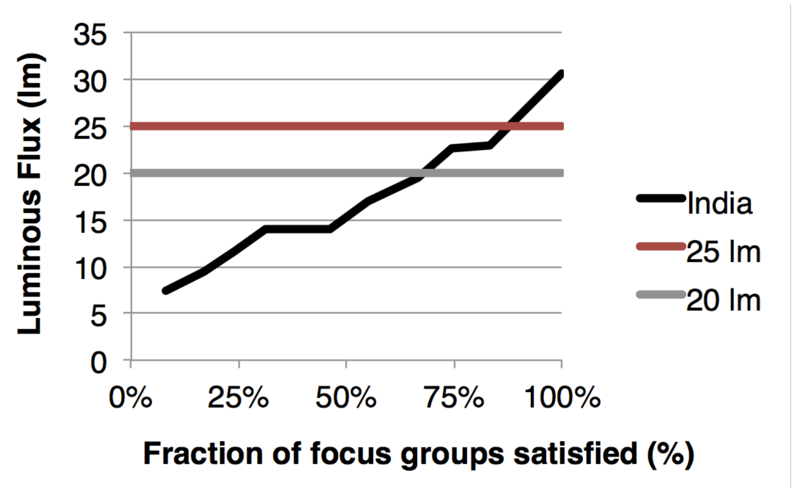


Figure 7: *Fraction of focus groups whose group expectation is exceeded for ambient lighting from a product that has passed a quality check. 50% of group responses were below 15 lumens, 75% below 20 lumens, etc. Aggregated across all of the 2013 India focus groups and weighted by the focus group size.*

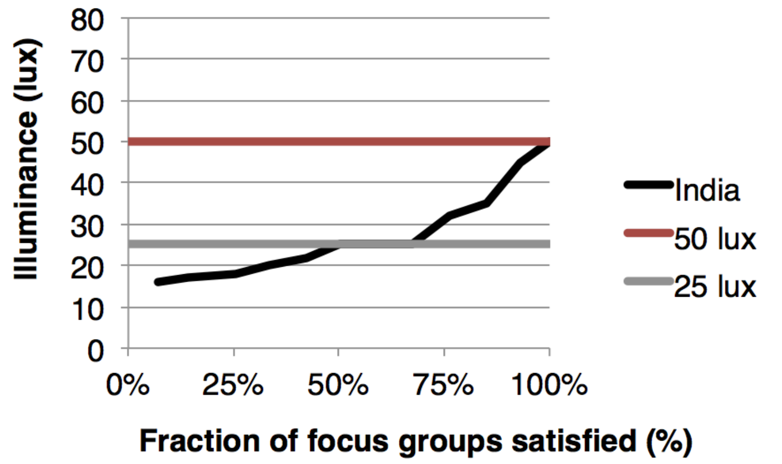


Figure 8: *Fraction of focus groups whose group expectation is exceeded for task lighting from a product that has passed a quality check. 50% of group responses were below 25 lux, 75% below 30 lux, etc. Aggregated across all of the 2013 India focus groups and weighted by the focus group size.*

[10] Details on the methods and results from these focus groups will be available in a separate report that is forthcoming. The outline of methods in the previous section describing Africa focus groups is representative of the methods used in the India focus groups.

Run Time Targets

Recommendation: 5 hours per day from solar charging; two days of autonomy (i.e., 10 hours) for non-solar products.

The available run time data include broad surveys of the market and responses from focus group participants. The common thread is that these data describe the baseline use of lighting technology whether it is fuel-based (most common) or otherwise. These results are somewhat less directly comparable to consumer expectations than the brightness data presented above since they do not directly pertain to expectations but rather are "revealed expectations" based on current practices in the context of the cost and utility of baseline technology.

Table 5: *Drivers for Run Time Targets policy*

Policy Driver	**Key Sources**	**Summary**
Consumer baseline use	Lighting Africa / Asia surveys; other surveys	People use about 4-5 hours of lighting per day in the surveyed African countries and about 6 hrs/day in India.

Evidence from Africa Survey 2008

Results Summary: 4 to 4.5 hours is a reasonable estimate for daily baseline use.

In 2008, Research International (contracted by Lighting Africa) surveyed 1,000 people in each of five countries in Sub-Saharan Africa. One of the questions on the survey dealt with their baseline use of lighting.

A key finding shown in Figure 9, below, is that about 3.5 to 4 hours is a typical nightly use rate for fuel-based lighting. Very few people have baseline evening needs over five hours when using fuel-based lighting. The data in Figure 9 do not include morning use. While we do not have comparable data for morning use, numerous field observations indicate that 0.5 to 1 hour of morning use is common for many households. These observations indicate that 4 to 4.5 hours is a reasonable estimate for the duration of daily use if one takes the baseline use rates as indicative of needs. However, it would also be possible to justify higher use levels on the order of 4.5 to 5 hours.

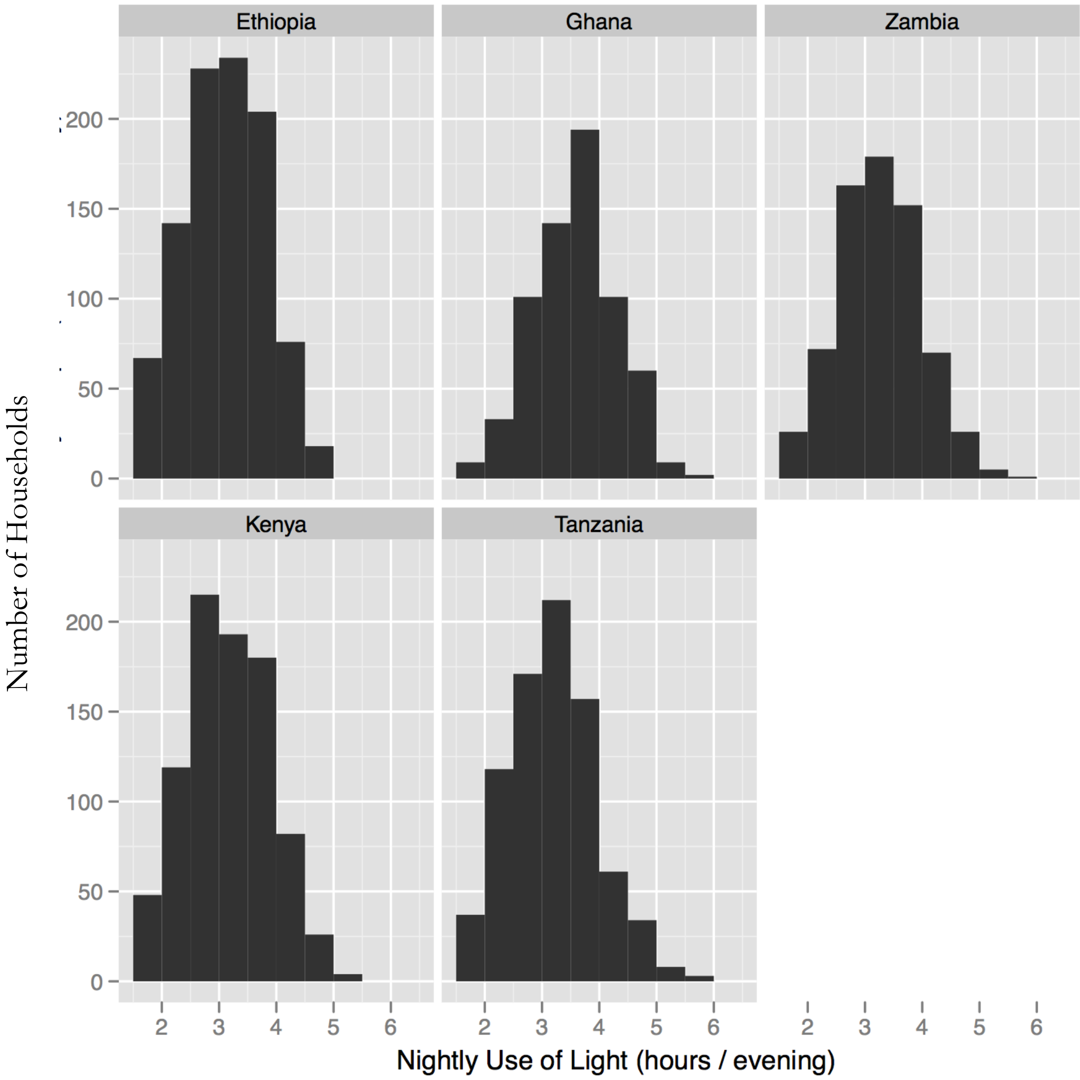


Figure 9: *Histograms of self-reported nightly use for fuel-based lighting in five countries (indicated on top of each histogram) from 2008. The histograms show the distribution in responses for people who could recall the typical time they begin and end the use of artificial light in the evening (this does not include any use in the mornings). The household survey sample size was 1,000 in each country.*

Evidence from Africa Focus Groups: 2010

Results Summary: People tend to require 4-6 hours of light each night from fuel-based lighting.

The table below summarizes the self-reported daily run time for a range of technologies in use in the five countries where the 2010 Africa focus groups were held. In total, 284 people participated in the focus group sessions. An important outcome is that use rates are relatively uniform at four hours per night across the countries with some notable outliers: in Ghana people report using LED flashlights for eight hours a day and in Tanzania people report using hurricane and simple wick lamps for six and seven hours respectively. Note that the sample size for these data is substantially smaller and has somewhat less geographic diversity (i.e., fewer towns in each country) than the country-level data presented above.

Table 6: *Summary of lighting technology and baseline run time based on focus group participant surveys (2011, n=284). Each percentage is the proportion of people in the focus groups who use the technology and each run time is the mean of those who use it.*

Product Popularity	**Senegal**	**Mali**	**Ghana**	**Tanzania**	**Kenya**
Most common Prevalance (%) – Use (hr.)	Low cost LED lamp (dry cell) 88% – 4 hr.	Low cost LED lamp (dry cell) 91% – 4 hr.	Low cost LED lamp (dry cell) 94% – 8 hr.	Hurricane lamp 60% – 6 hr.	Simple wick lamp (tin can) 57% – 4 hr.
Second-most common Prevalence – Use	Candle 66% – 3 hr.	Hurricane lamp 29% – 5 hr.	Hurricane lamp 59% – 5 hr.	Simple wick lamp (tin can) 36% – 7 hr.	Hurricane lamp 54% – 4 hr.
Third-most common Prevalence – Use	Local repurposed LED 51% – 6 hr.	Local repurposed LED 20% – 4 hr.	Simple wick lamp (tin can) 47% – 5 hr.	Low cost LED lamp (dry cell) 19% – 2 hr.	Low cost LED lamp (dry cell) 46% – 2 hr.

Evidence from India Focus Groups: 2013

Results Summary: People tend to require approximately 6 to 8 hours of light each night from fuel-based lighting.

The India focus group results, which involved participation by 116 people in the states of Bihar and Orissa, indicate that a range of products are in use, but hurricane and wick lamps are the key baseline technology. People report using these for five to six hours a day, and many people use an auxiliary light source as well (i.e., a secondary light that is used less often, such as another fuel-based light or a flashlight/torch); the average total daily run time for all sources was about 8 hours. It is important to point out that there is anecdotal evidence of long duration, low level lighting for bed-lamps as a common use in India.

Table 7: *Summary of lighting devices and typical run time for India focus groups. The device reported to be used for the longest number of hours is the primary device. Secondary, tertiary, and other devices are grouped in "other". For the primary device, the mean daily run time is reported. (n=116)*

Lamp Type	Primary Use (%)	Other Use (%)	Run time for Primary Users (hr/day)
Wick Lamp	52%	10%	5.2
Hurricane	46%	6%	6.6
Solar Lamp	2%	2%	6.5
Pressure Lamp	1%	3%	6.0
Dry Cell Torch	0%	25%	N/A
Rechargeable Torch	0%	1%	N/A
Candle	0%	3%	N/A

Synthesis of Africa and India Policy

Policy summary: Harmonized Targets between the Lighting Africa and Lighting Asia are desirable and achievable. We suggest a harmonized brightness Target of 25 lumens (ambient) / 50 lux (task) and a harmonized run time Target of 5 hours solar run time and 10 hours full battery run time.

Brightness Harmonization

There are not wide variations between the regional markets for brightness preferences, supporting the proposal for harmonization. Figures 10 and 11 below combine responses from the 2011 Africa and

2013 India focus groups with respect to expectations for lighting service in ambient and task applications. Focus groups in both areas targeted the same population (off-grid potential end-users) and used the same techniques and equipment to investigate expectations. The results indicate slightly lower expectations for ambient lighting (on the order of 5 lumens lower) and slightly higher expectations for task lighting (on the order of 10 lux higher) in Africa compared to India.

The proposed Targets of 25 lumens for ambient lighting would satisfy the expectations of essentially all the focus groups across both geographies. The proposed 50 lux Performance Target would satisfy nearly all the India focus groups and approximately 90% of the Africa focus groups. This analysis suggests a harmonized approach to lighting level Targets is appropriate.

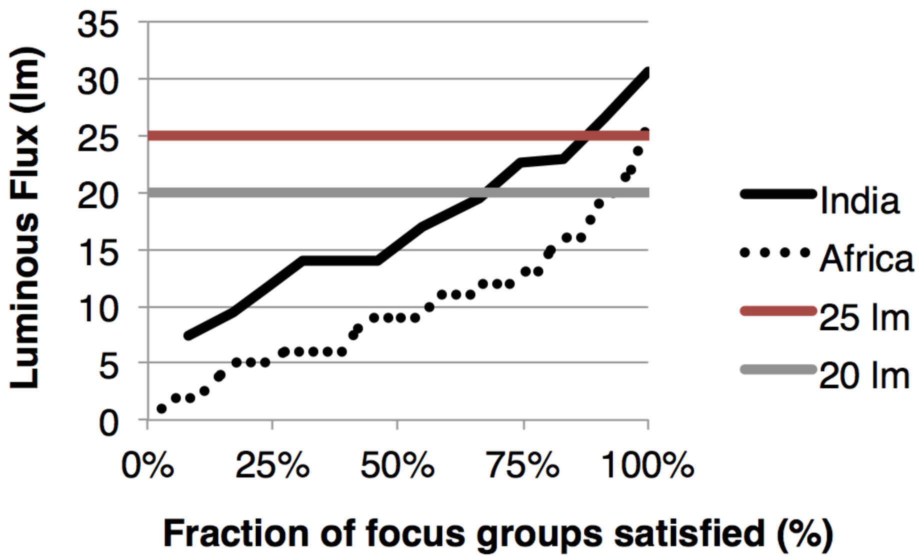


Figure 10: *Fraction of focus groups whose group expectation is exceeded for ambient lighting from a product that has passed a quality check, aggregated across all of the 2011 Africa and 2013 India focus groups and weighted by the focus group size.*

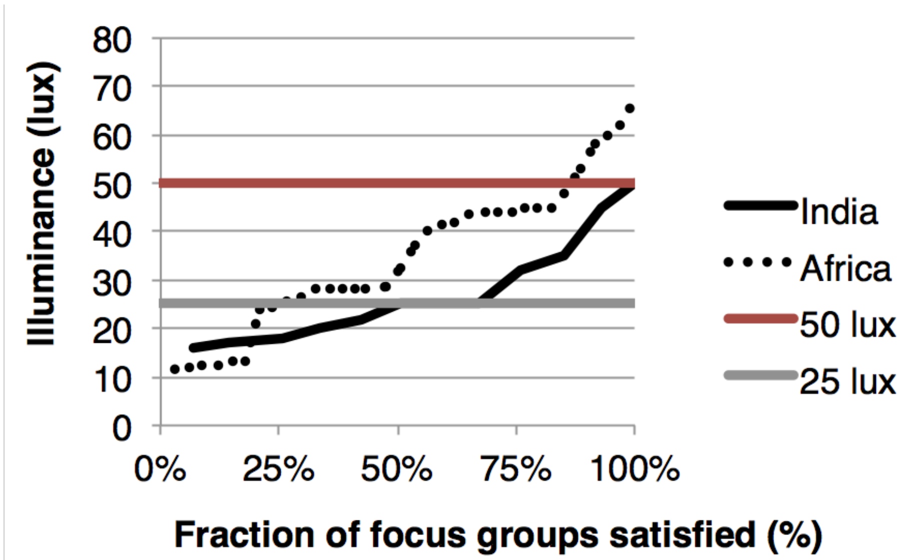


Figure 11: *Fraction of focus groups whose group expectation is exceeded for task lighting from a product that has passed a quality check, aggregated across all of the 2011 Africa and 2013 India focus groups and weighted by the focus group size.*

Run Time Harmonization

There appear to be modest differences between the baseline use of "traditional" lighting in each place. The best estimates we have from Africa data are approximately 4 to 5 hours of use per day and from India approximately 6 to 8 hours. It is important to note that these are not apples-to-apples comparisons because the Africa data are for a single light source and the India data are for multiple sources (e.g., many people use both kerosene lamps and LED flashlights). Additionally, there is strong anecdotal evidence in the two Indian states that were studied that there is a cultural preference for long run-time, low output light in the evenings. The variation in expected light output over the course of a day is not captured in these data.

An additional, more important source of variation is the run time available from a given product throughout the year and from place to place. Figure 12 below shows the variation in daily solar radiation (which is directly related to run time) for three years in three Kenyan towns. When a product is reported to have "4 hours of solar run time" under the Lighting Global QA framework, this number is based on an incident solar resource of 5 kWh/m^2-day. It is evident that in a given location there can be wide day-to-day variation, in this case between close to zero and over 7.5 kWh/m^2-day. While the battery can be used in some cases to "smooth" some of those peaks and valleys, there will certainly be seasonal and day-to-day variations in service. Similarly, there is variation from location to location and even from house to house depending on the surroundings; shading or a poorly placed solar module can drastically reduce its performance.

The key take-home message is that while brightness is a parameter that is relatively uniform for a given product type, run time is highly contextual. This strengthens the argument for harmonization, since, in practice, there will be much larger differences in run time for a given product that is used in different places (or in the same place at different times of year) than the differences that manifest between two products with relatively similar laboratory performance. In other words, the benefits of harmonization outweigh the value of distinguishing between modest regional differences in consumer preference.

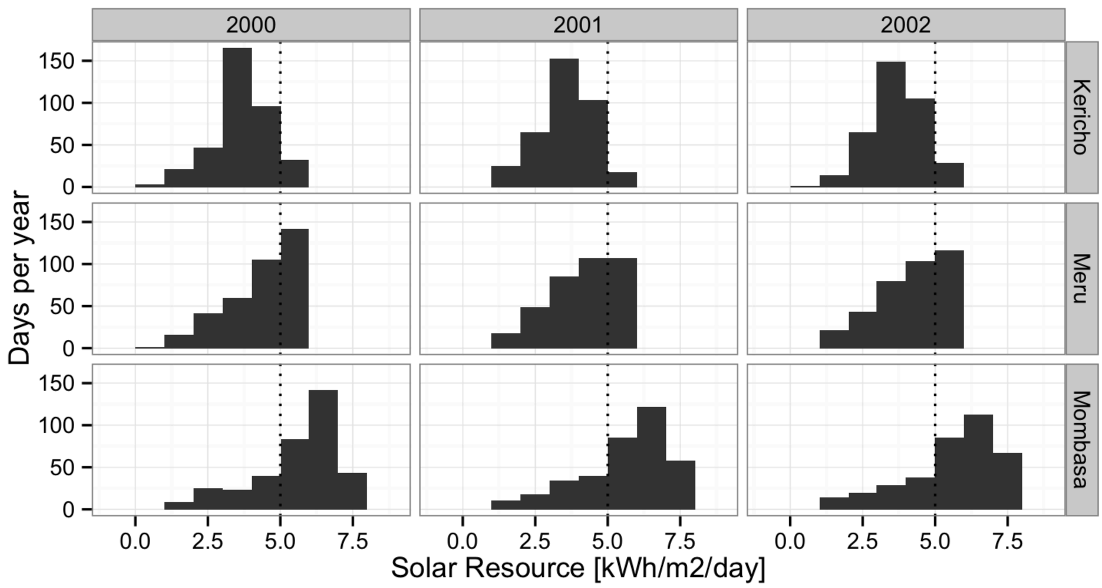


Figure 12: *A matrix of histograms that shows the variation in solar resource, which is directly proportional to the predicted daily lighting service provided by pico solar systems, in three Kenyan locations over three years. The "typical" solar resource of 5 kWh/m^2-day is indicated with dotted lines. The mean daily solar resource in each town is: 3.6 (Kericho), 4.2 (Meru), and 5.6 (Mombasa). The data are from the Deutsches Zentrum für Luft- und Raumfahrt and were accessed through http://en.openei.org/datasets/node/529.*

Supporting Information: Applying and Relating Lumens and Lux

There are two options for meeting the lighting service targets, an **ambient lighting** requirement and a **task lighting** requirement. General ambient lighting applications are concerned with general purpose lighting of some area (e.g., a sitting room), while task lighting is intended to illuminate a surface (e.g., a schoolchild's notebook or a cutting board in the kitchen). The Targets are structured to address each situation with appropriate photometric ("light measuring") units.[11]

Background on Units

The **ambient targets** are in terms of luminous flux, the total visible light emanating from a product (with units of lumens). Because general-purpose lighting is concerned with illuminating a room, there are no specific requirements for how this light is distributed. LED lighting generally has a "cone" of light with a minimum distribution angle of about 120° (for a single LED) and a maximum of 360° (for an array of several LEDs or products that use optical distribution). General-purpose lighting devices like "traditional" light bulbs and fluorescent tubes are typically rated in terms of lumens.

The **task lighting targets** are in terms of illuminance, the "density" of light that is projected on a surface (with units of lux, equivalent to lumens/m^2). The total luminous flux from a product must be distributed in such a way that the light on a target surface meets minimum requirements, which depends both on the shape of the distribution and the position of the lamp with respect to the surface. Details on how this is measured in a laboratory setting are available in the test methods document (IEC/TS 62257-9-5). Industrial standards or design targets for lighting in workplace settings are specified in terms of illuminance.

Relating Lumens to Lux

It is helpful to relate luminous flux and illuminance to understand how much light needs to be "made" to sufficiently illuminate an area for a particular activity (i.e., how many lumens do you need to achieve a particular level of illuminance [lux] over some area). The Lighting Global Performance Target for task lights is 50 lux over a 0.1 m^2 area. By definition based on the units, the theoretical minimum level of luminous flux to meet the Targets is $50\ lumens/m^2 \times 0.1\ m^2 = 5\ lumens$. In practice, however, the distribution of light is not perfect. Some light falls outside the target area and there is not perfectly even light within the target area.

Lighting Global tested a representative set of products with "typical" distributions for single, wide-angle LEDs and found that approximately four times the theoretical minimum is required to meet illuminance targets. For a 50-lux target over 0.1 m^2, a luminous flux of approximately 20 lumens is required from the light source. Using the best available optics, the minimum luminous flux is about three times the theoretical minimum.

The approximate 4:1 relationship between luminous flux and task lighting illuminance for typical LED sources indicates a general agreement in magnitude between the proposed ambient lighting target (25 lumens) and task lighting target (50 lux over 0.1 m^2).

Why not have a unified target? Since there is a general equivalence between the ambient and task lighting targets, one could argue for eliminating one or the other. The issue with this approach would be that while a "typical" wide angle LED achieves the task lighting target with 25 lumens, this would not be universally true because of differences in the distribution of light with optics and various types of LEDs. Having split targets ensures that the correct incentives are in place to produce task lights with distributions that maximize the useful area for end-users.

[11] The content in this part of the supporting information is covered in more depth in a Lighting Global Technical Briefing Note called *Light Emitting Diode (LED) Lighting Basics*, available at: http://www.lightingafrica.org/technical-notes.html

Supporting Information: Change in Lumen Maintenance Targets

The previous lumen maintenance Standard specifies that after 2,000 hours a product must maintain at least 70% of its initial output ("L70 at 2,000 hours"). This level of decrease—L70—is associated with the threshold for perception of a change in light; i.e., people can generally tell if light output is reduced to 70% of an initial value. To speed the results of the test, we also allowed products that met L95 at 1,000 hours to pass, which meant many products with clearly good lumen maintenance did not need to undergo a full 2,000 hour test (about 3 months).

The proposed change is that we would require L85 at 2,000 hours, a 50% reduction in the tolerance for degradation over the test period. The 1,000 hour "short cut" at L95 would remain in place. Since products are expected to last several years and will be used about 4 hours a day, the 2,000 hour run time is only expected to last through about 1.5 years of product life. An L85 Standard means that products are likely to be 2-3 years old before the decrease in light output is perceptible to users.

The plots in Figure 13 below show the implications of the more stringent 2,000-hour Standard on false positives and negatives for the 1,000-hour L95 check as a predictor of 2,000-hour performance. Using an L70 at 2,000 hour standard did not lead to any false positives from 1,000-hour checks for L95. The false negatives that occurred are corrected (i.e. converted to true positives at 2,000 hours) by continuing the test.

Under a hypothetical L85 at 2,000 hour standard there is not as much "tolerance" between the 1,000-hour check for L95 and L85 at 2,000 hours. This leads to a ~3% false positive rate—products that meet L95 at 1,000 hours but drop below L85 at 2,000 hours. Note that none of these false positives dropped below L70 at 2,000 hours (since there were no false positives in the previous L70 at 2,000 hour framework).

Statistical Note:
The following definitions are helpful for interpreting the plots below. False positives and negatives come from checks at 1,000 hours that do not correctly predict the 2,000-hour performance.

Table 8: *Statistical definitions for positive and negative results in the context of lumen maintenance test results*

Situation	**Predicted Result** at 2,000 hours based on X,000-hour check for LXX	**Actual Result** at 2,000 hours (pass or fail at LXX level)
True Negative	Fail (i.e., below L95)	Fail (i.e., below LXX)
True Positive	Pass (i.e., above L95)	Pass (i.e., above LXX)
False Negative	Fail	Pass
False Positive	Pass	Fail

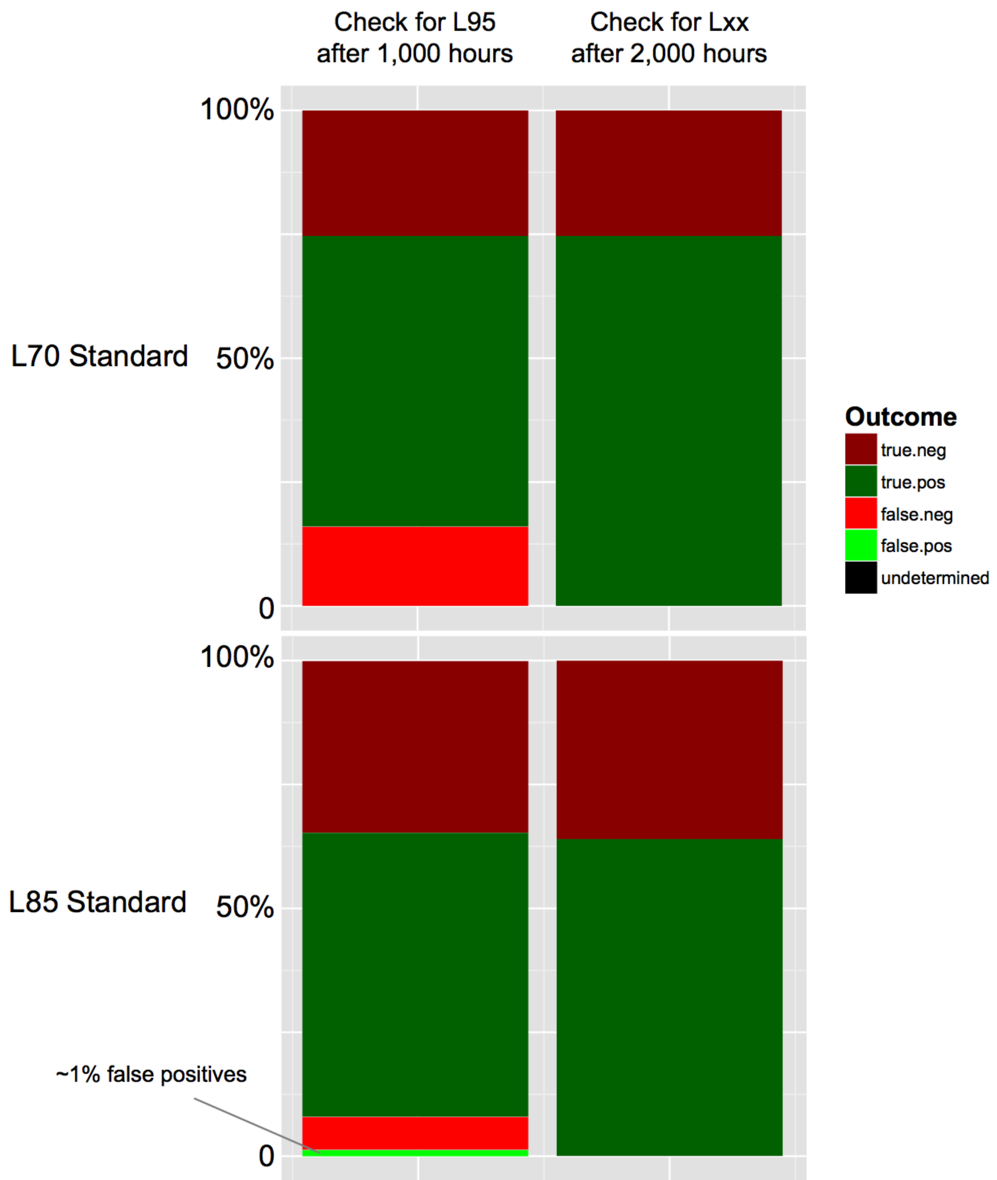


Figure 13: *Synthesis of alternative lumen maintenance Standards based on running alternatives with the existing Lighting Africa testing dataset. The top plot is the status quo and shows how a check for L95 at 1,000 hours will correctly identify many positive results and have some false negatives that require the full 2,000 hour test to verify they meet the Standard (L70 at 2,000 hours). If the final Standard is increased to L85 at 2,000 hours, we expect on the order of 1% false positives at the 1,000 hour check for L95. This results from the more stringent threshold. The products that are false positive do not fail altogether and would have met the existing L70 Standard.*

Supporting Information: Battery Quality and Storage Durability

The Battery Durability Standards that are proposed address issues of batteries that fail quickly due to poor design and manufacture or damage that was incurred in the supply chain.

There is a Lighting Africa Briefing Note that describes issues of damage from supply chain mismanagement for lead-acid batteries (see *Shipping and Storage of Sealed Lead-Acid Batteries* - Technical Note Issue 9 at http://www.lightingafrica.org/resources/briefing-notes.html). A brief synopsis of the key issue is as follows:

One disadvantage of SLA batteries is that they can be permanently damaged if stored in a discharged state. Like all batteries, lead-acid batteries slowly self- discharge even when not connected to a load. This self-discharge occurs during shipping and warehousing and while products are sitting on store shelves. If care is not taken to limit a product's time in the supply chain, the battery may have suffered permanent capacity loss by the time the product is purchased. This damage will result in decreased run time or, in severe cases, an unusable product.

LIGHTING GLOBAL Minimum Quality Standards

Scope

These **Quality Standards** and **Warranty Requirements** are the minimum requirements for participation in Lighting Global program activities.

The aim of these Quality Standards is to protect end-users from early failure and ensure that advertised information is valid. The warranty requirements provide a baseline of support and protection from early failure.

All test methods, aspects, and definitions in this standard are based on technical specification IEC/TS 62257-9-5, Edition 2.0.

Test Requirements

Initial qualification under these Standards and Targets requires Quality Test Method (QTM) test results with a sample size of 6. On-going qualification is subject to successful market checks according to the market check method. Full re-testing with QTM is required after two years.

The Aspects listed in the tables below refer to definitions in Section 4 of IEC/TS 62257-9-5.

Product Category Requirements

This document applies to *fixed separate (indoor), portable separate, portable integrated* and *fixed integrated (outdoor)* products. It is generally applicable only to products with an FOB wholesale price of 100 $USD or lower but may also be applied to higher-cost products that fit the general scope.

Qualification as a "separate" PV module—required for solar products to be categorized as *fixed separate or portable separate* —requires meeting the criteria listed in Table 1:

Table 1 – Qualification as separate PV module

Criterion	Aspect(s)	Required value
PV module cable length	4.2.6.2 Solar module cable length	≥ 3 m to qualify as a "separate" PV module with 10 % tolerance

Quality Standards

The product must meet each of the criteria listed in Tables 2 and 3 to meet the Quality Standards:

Table 2 – Truth-in-advertising tolerance

Truth-in-advertising criterion	Aspect(s) considered in assessment	Requirement
System performance tolerance – numeric ratings	4.2.7 Run time aspects 4.2.8 Light output aspects Others, if applicable	≤ 15 % deviation from ratings (always ok if actual performance is better than advertised).
System components tolerance – numeric ratings	4.2.6 Solar module aspects 4.2.5 Battery performance aspects Others, if applicable	≤ 15 % deviation from ratings (always ok if actual performance is better than advertised).
Other numeric ratings tolerance	Multiple	≤ 15 % deviation from ratings (always ok if actual performance is better than advertised).
Overall truth-in-advertising statement	Multiple	Any description of the product that appears on the packaging, inside the package, and in any other media should be truthful and accurate. No statements should mislead buyers or end users about the features or utility of the product.

Table 3 – Safety and durability Standards

Safety or durability criterion	Aspect(s) considered in assessment	Product category	Requirement
Overall water exposure protection	4.2.11 Water protection integrated assessment 4.2.3.1 Water protection – enclosure 4.2.3.2 Water protection – circuit protection and drainage 4.2.10.1 Product and manufacturer information 4.2.2.7 Packaging and user's manual information	Fixed separate (indoor)	No protection required.
		Portable separate	Protection from occasional exposure to rain.
		Portable integrated	Protection from frequent exposure to rain.
		Fixed integrated (outdoor) AND External PV modules (typically paired with "Portable Separate" and "Fixed Indoor" products).	Protection from permanent outdoor exposure.
Physical ingress protection	4.2.3.3 Physical ingress protection	All except below	Minimum of IP 2x protection.
		Fixed integrated (outdoor)	Minimum of IP 5x protection
Mechanical durability – drop test	4.2.3.4 Drop resistance	Fixed separate (indoor) and fixed integrated (outdoor)	None result in safety hazards. There is no requirement that the lighting kits are still functional after a drop.
		Portable separate	Maximum failure rate for functionality is 1/6; none result in safety hazards.
		Portable integrated	Maximum failure rate for functionality is 1/6; none result in safety hazards.
Mechanical durability – goosenecks	4.2.3.5 Gooseneck durability	Any with gooseneck	Maximum failure rate for functionality is 1/6; none result in safety hazards.
Mechanical durability – connectors	4.2.3.6 Connector durability	All products	Maximum failure rate for functionality is 1/6; none result in safety hazards.
Mechanical durability – strain relief	4.2.3.8 Strain relief durability	All products	Maximum failure rate for functionality is 1/6; none result in safety hazards.
Mechanical durability – switches	4.2.3.7 Switch durability	All products	Maximum failure rate for functionality is 1/6; none result in safety hazards.
Workmanship	4.2.3.9 Wiring quality	All products	Maximum prevalence of bad solder joints is 1/6 samples; maximum prevalence of poor wiring is 1/6 samples; maximum prevalence of overall workmanship failure is 1/6
Battery protection	4.2.3.10 Battery protection strategy	All products	An appropriate battery protection strategy is used that will protect batteries from early failure and end-users from harm.
Battery Durability	4.2.5.3 Battery durability parameters	All products	Maximum failure rate for the Battery Storage test is 1/6 with a passing threshold of maintaining at least 80% of the initial capacity during the tests.
Lumen maintenance	4.2.4.2 2 000 hour lumen maintenance	All products	L_{85} time is greater than 2 000 h for the average sample. No more than 1/6 samples fails (defined as being more than 10 % below L_{85} at 2 000 h). *OR* L_{95} time is greater than 1 000 h for the average sample. No more than 1/6 samples fails (defined as being more than 10 % below L_{95} at 1 000 h).
Fluorescent light durability	4.2.4.3 Fluorescent light durability	Products with fluorescent lights	Maximum failure rate for functionality is 1/6.
AC-DC charger safety	4.2.2 Product design, manufacture, and marketing aspects	Products that include an AC-DC grid charger	Any included AC-DC charger carries approval from a recognized consumer electronics safety certification organization such as UL or similar.

Safety or durability criterion	Aspect(s) considered in assessment	Product category	Requirement
Hazardous Substances	4.2.10.1 Product and manufacturer information	All products	Cadmium and Mercury shall not be present in batteries at levels greater than those established in the European Union Batteries Directive (directive 2006/66/EC of the European Parliament).

Warranty requirements

The product must meet each of the criteria listed in Table 4 to meet the warranty requirements:

Table 1 – End-user support requirements

Support type	Aspect(s)	Requirement
Maintenance and warranty terms	4.2.2.8 Warranty information 4.2.10.2 Warranty coverage	End-users are provided at least one year of warranty coverage from the time of purchase; it should cover manufacturing defects that impede operation under normal use and protection from early component failure, including coverage on the battery.

