Varying Perspectives and Approaches in Developing QA for Off-Grid Lighting

Presented at the World Bank Group's
Lighting Africa - Product Quality Assurance Workshop
Airlie Center, Warrenton Virginia
October 14-16, 2007

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The Lumina Project • http://light.lbl.gov

Acknowledgments

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  - United Nations Industrial Development Organization

Perspectives

Audiences

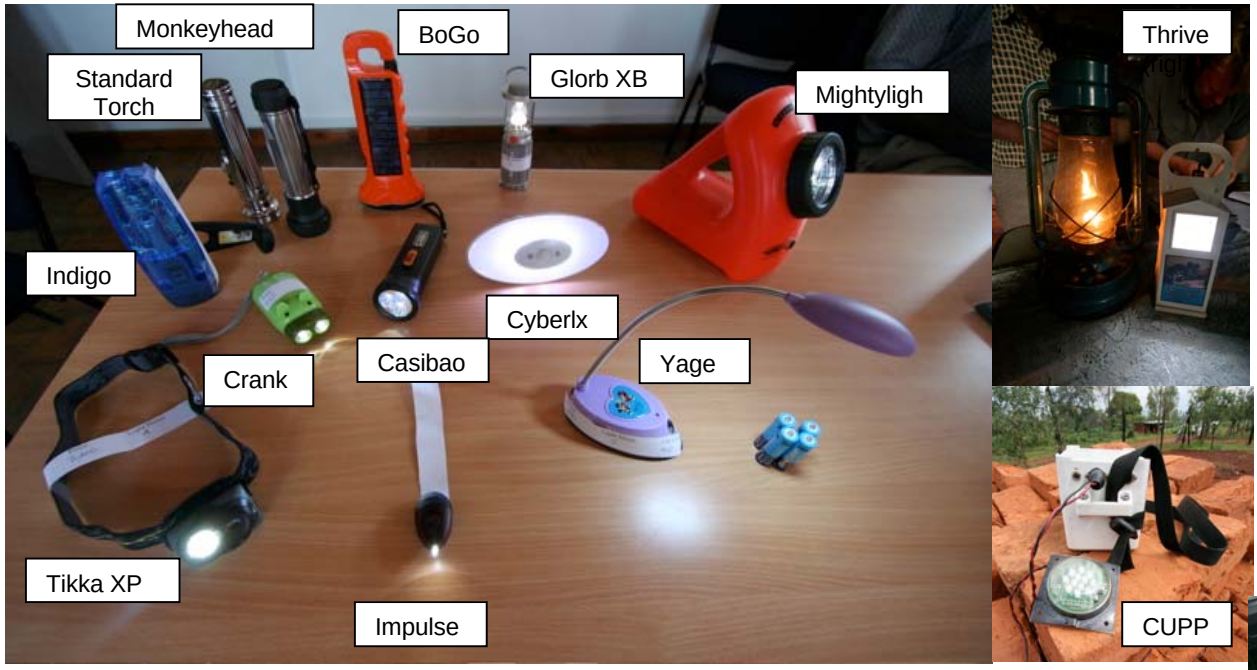
- End users
  - many types
  - cultural context
  - gender; age; literacy
- Intermediary purchasers
  - wholesalers
  - donors
  - refugee camp operators
- Product developers
- Investors
- Carbon traders
- Standards bodies
- Program designers
- Program evaluators

Many Uses

(Modest expansion on list from Kate Conway)

- Accurately illuminating retail items
- Attracting customers to retail items
- Giving a sense of increased security
- Having conversations
- Highlighting goods for sale
- Identifying and manipulating small objects
- Identifying persons, animals and objects
- Locating pathways
- Making handicrafts, processing food, etc.
- Making the home appear occupied (from outside view)
- Moving around and locating passages inside the home
- Moving around outdoors
- Personal grooming
- Preparing food
- Reading and writing
- Signaling to other viewers
- Religious purposes
- Increasing hen laying
- Attracting fish

Consumers' Assessment of Products Kenya: June 2007



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

LED flashlights for sale in Luanda market (Western Kenya).

Kenya Focus Groups: June 2007 (N~90)

Kenya Night Markets - 1

Kisumu, Kenya

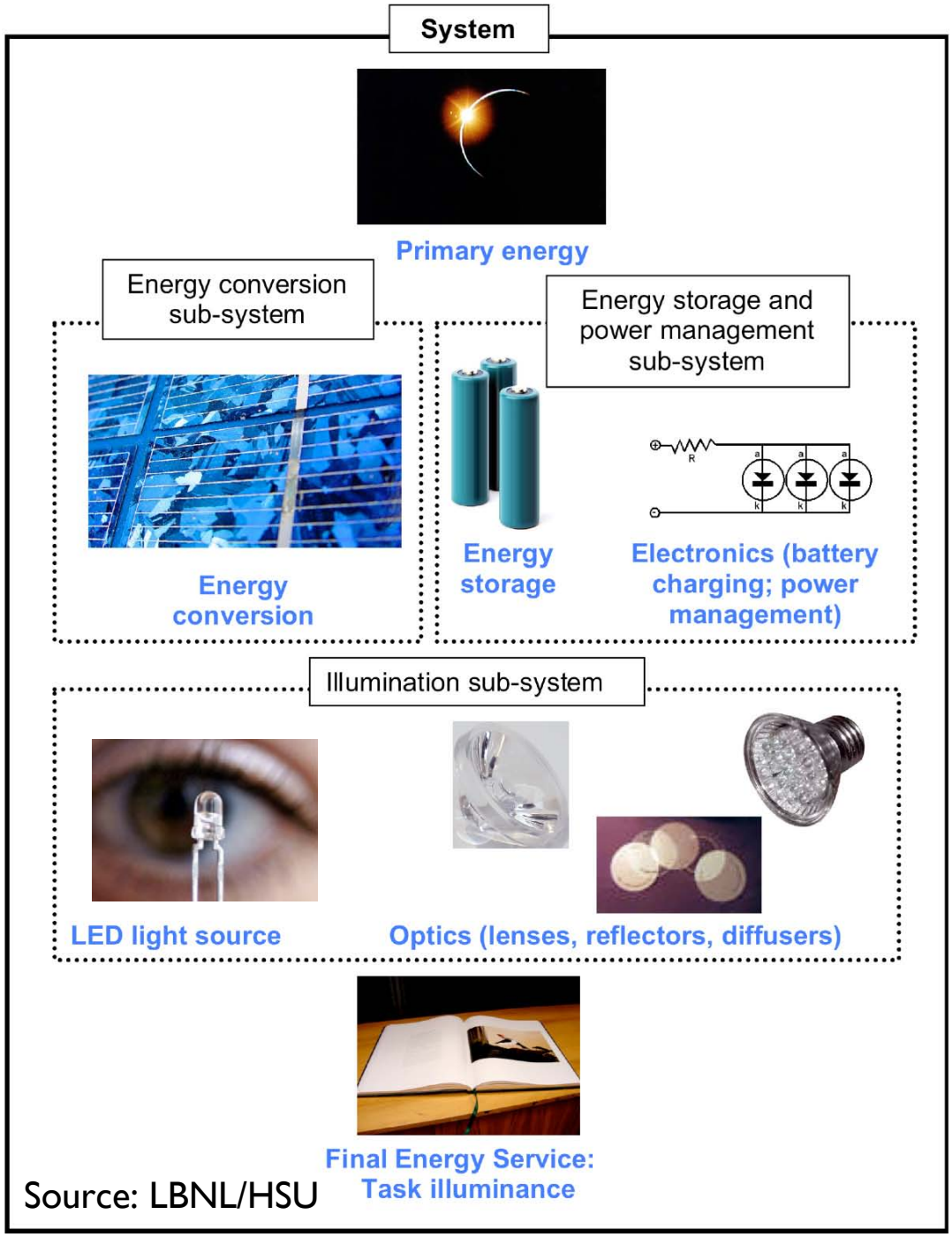
Kenya Night Market - 2

Kenya Night Market - 3

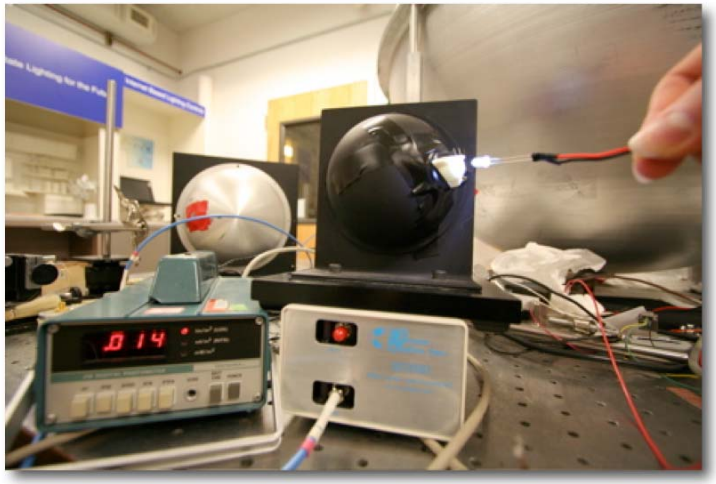
Kisumu, Kenya

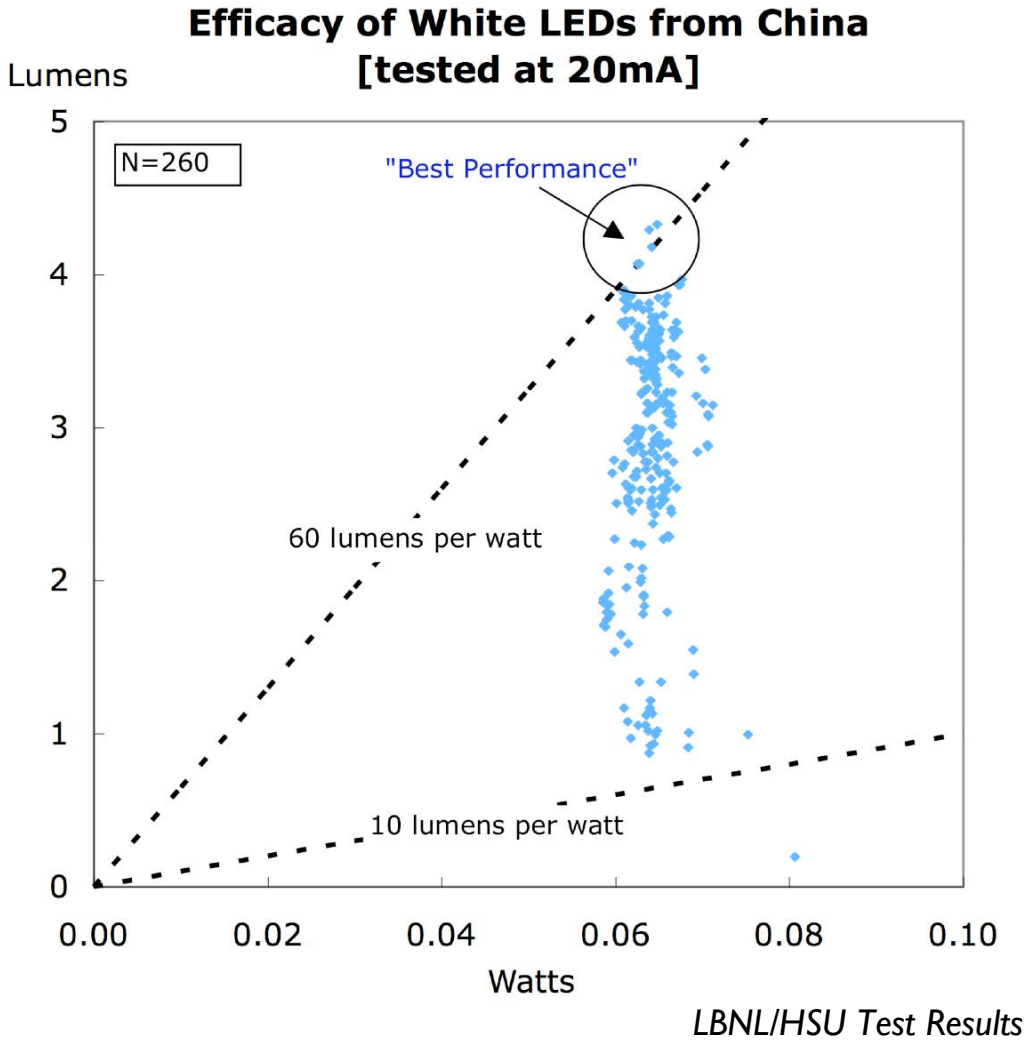
Kenya Night Market - 4

Kisumu, Kenya


System
Primary energy
Energy conversion sub-system
Energy storage and power management sub-system
Energy conversion
Energy storage
Electronics (battery charging; power management)
Illumination sub-system
LED light source
Optics (lenses, reflectors, diffusers)
Final Energy Service: Task illuminance
Source: LBNL/HSU

LED Performance

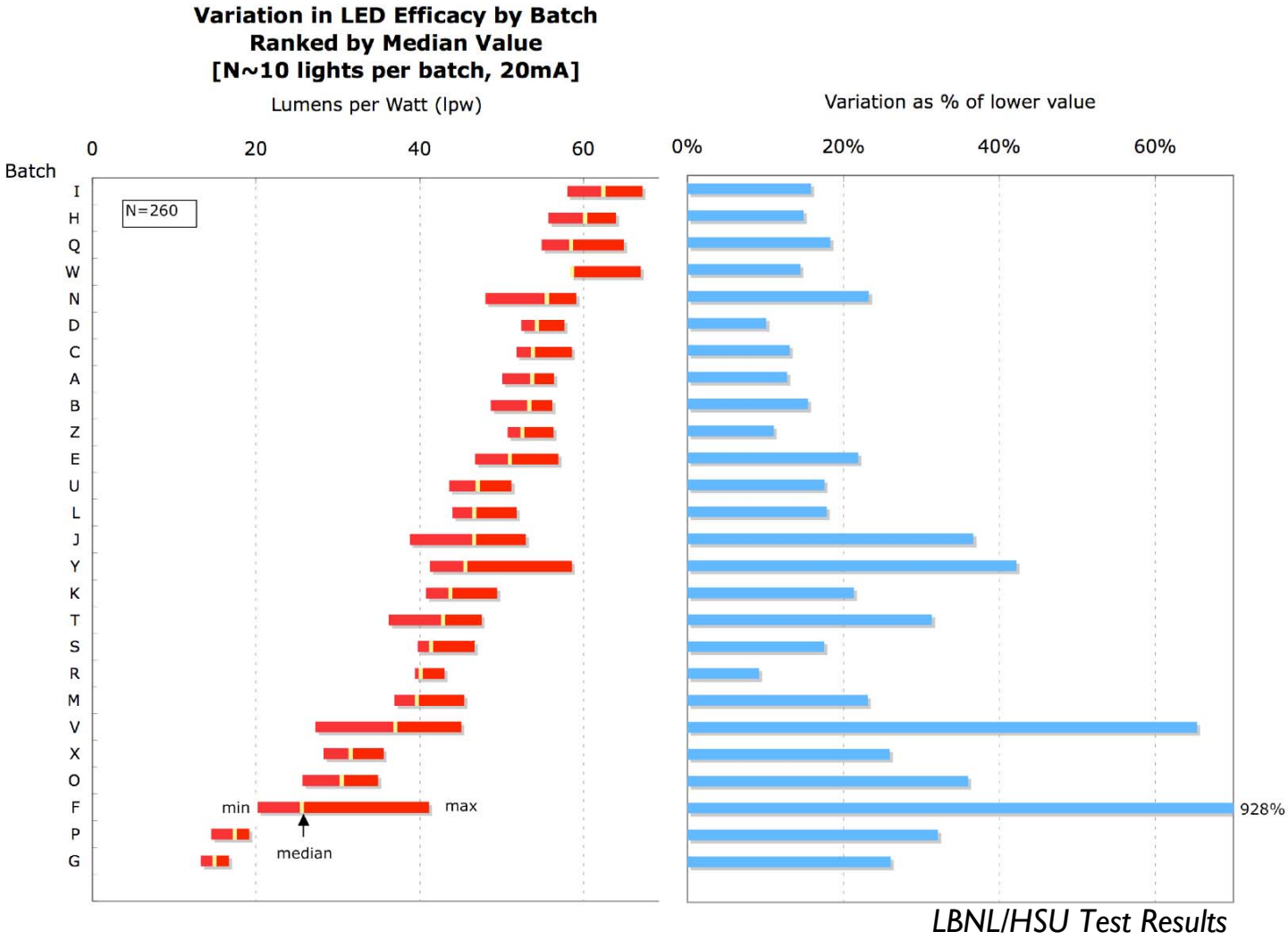




LBNL/HSU Test Results

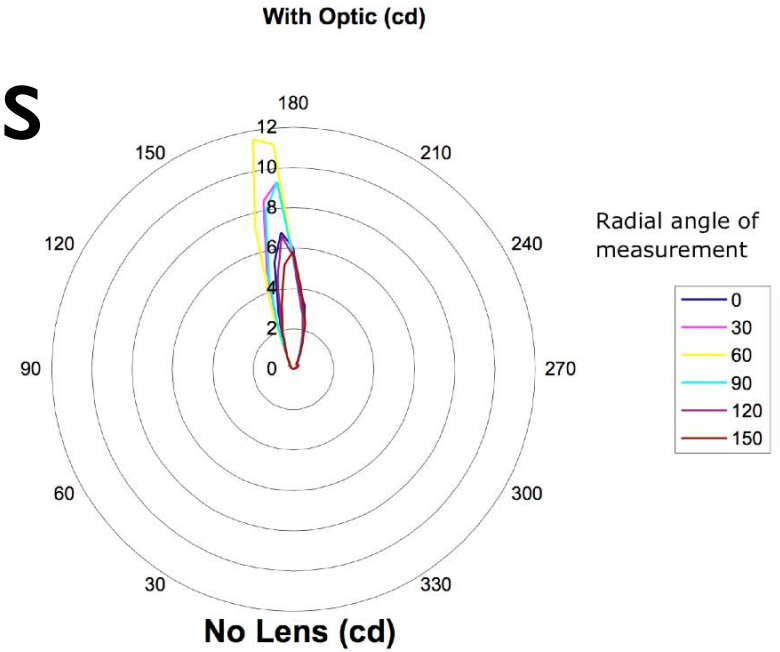
Luminous Efficacy for 26 Batches of White LEDs (260 individual Units, All in the 5mm Size Class)

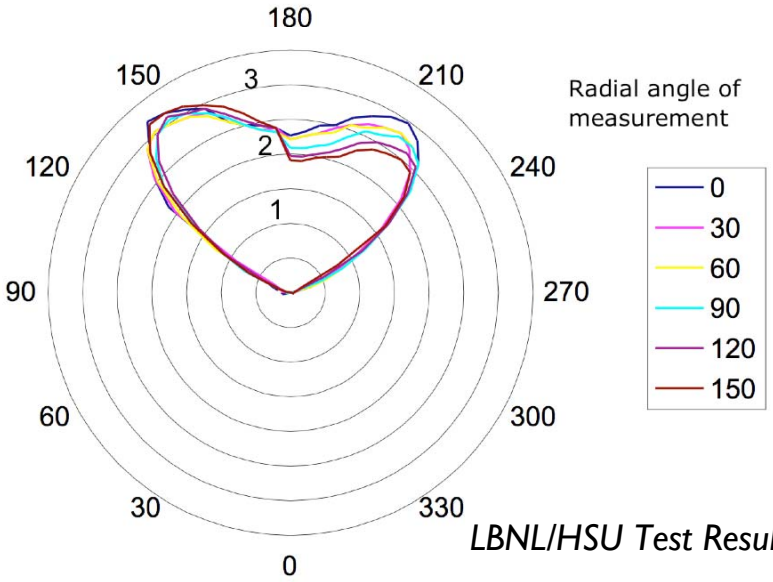
High Variance in LPW



Variation of Luminous Efficacy within 26 Batches of WLEDs

Optics

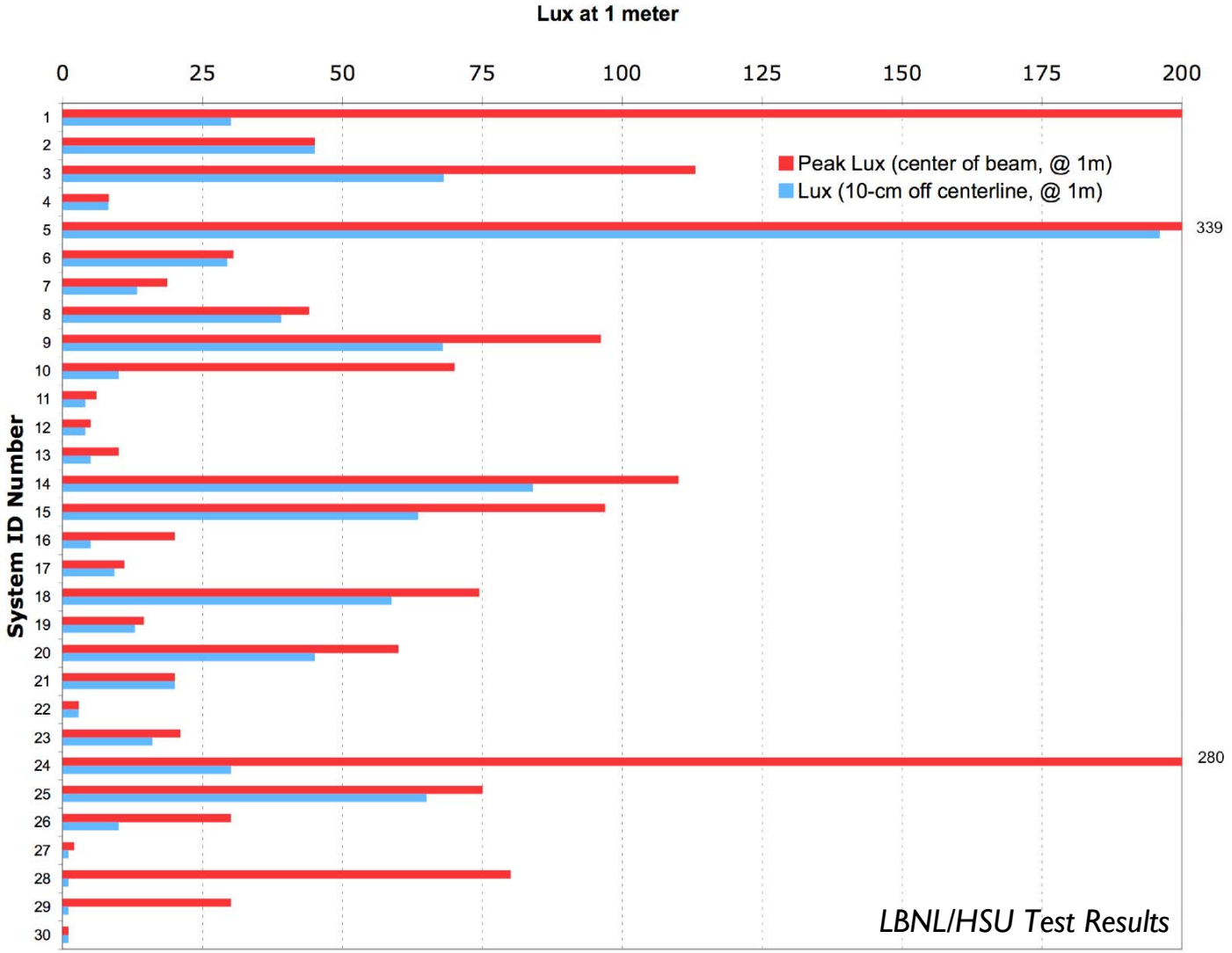




LBNL/HSU Test Results

Performance of an WLED Lamp with Optics (System 3, top) and without Optics (System 4, bottom), candelas

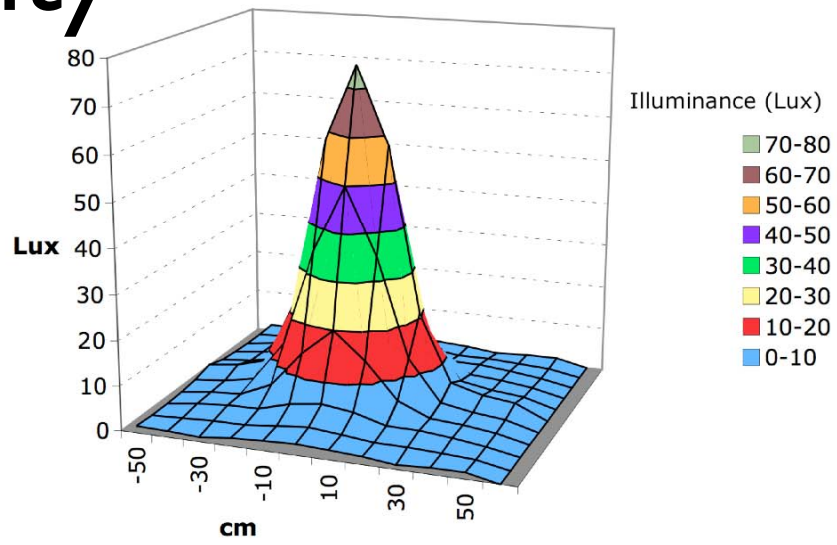
Illuminance Across 30 Products

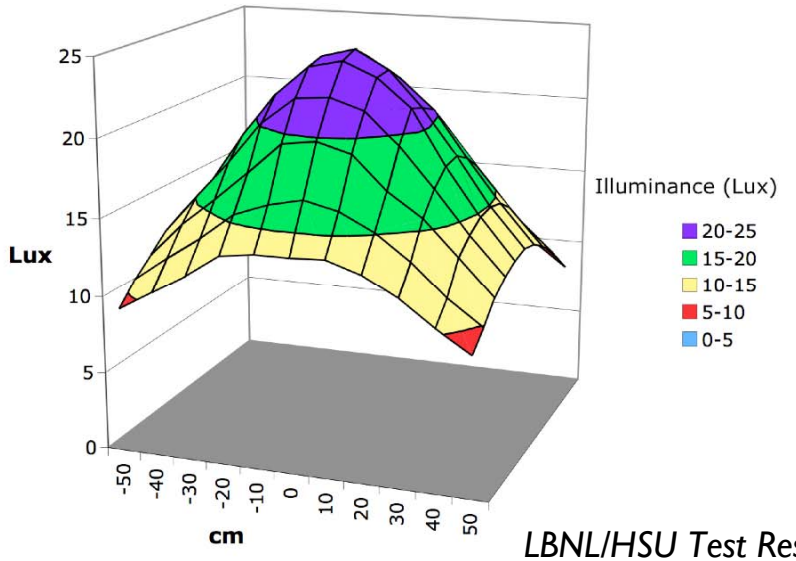


Point Illuminance at a Distance of One Meter for White-LED Systems

Illuminance Uniformity

Stephen Kullmann and Ranjit Deshmukh, Humboldt State University

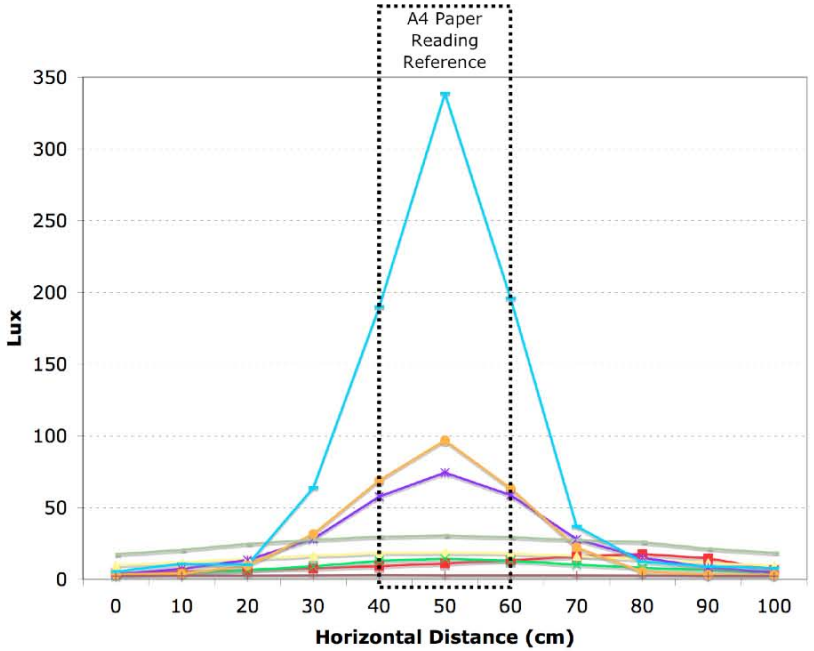




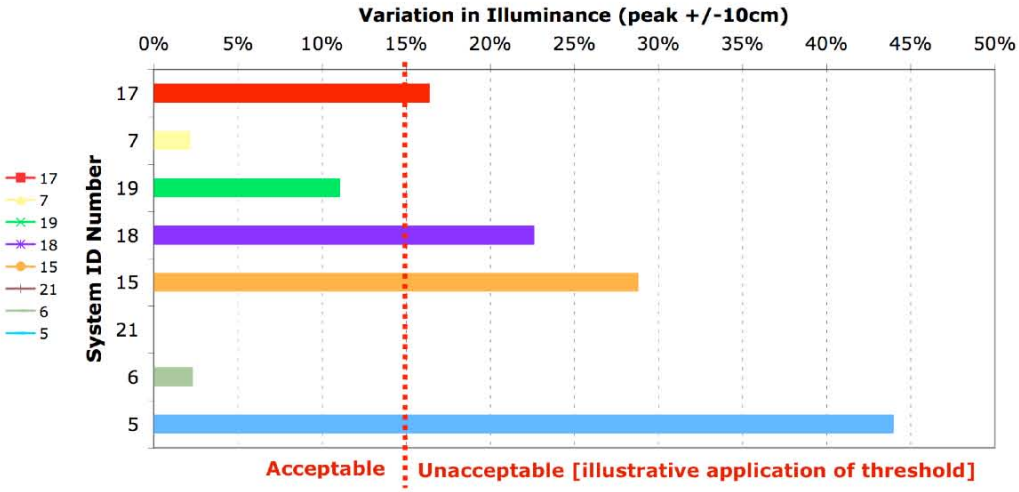
LBNL/HSU Test Results

Illuminance Distribution at a Distance of One Meter for Two White-LED Lighting Systems (System 7, top; System 15, bottom)

Illuminance Benchmarking



Benchmarked Illuminance Distribution for 8 LED Systems

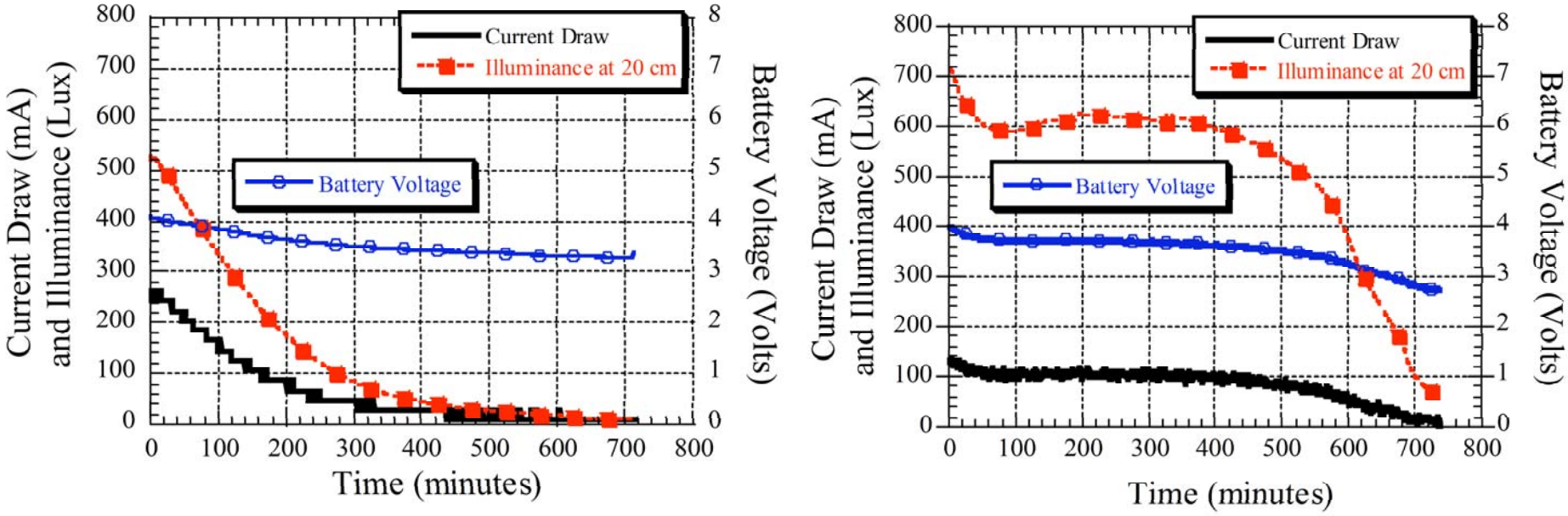


Illuminance Ratios for 8 LED Systems

LBNL/HSU Test Results

Performance Over Time

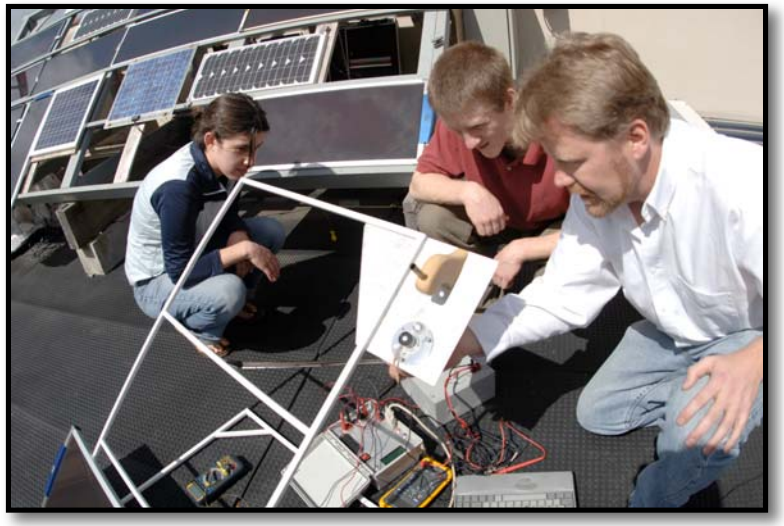
System on left (SLA): light level is not maintained



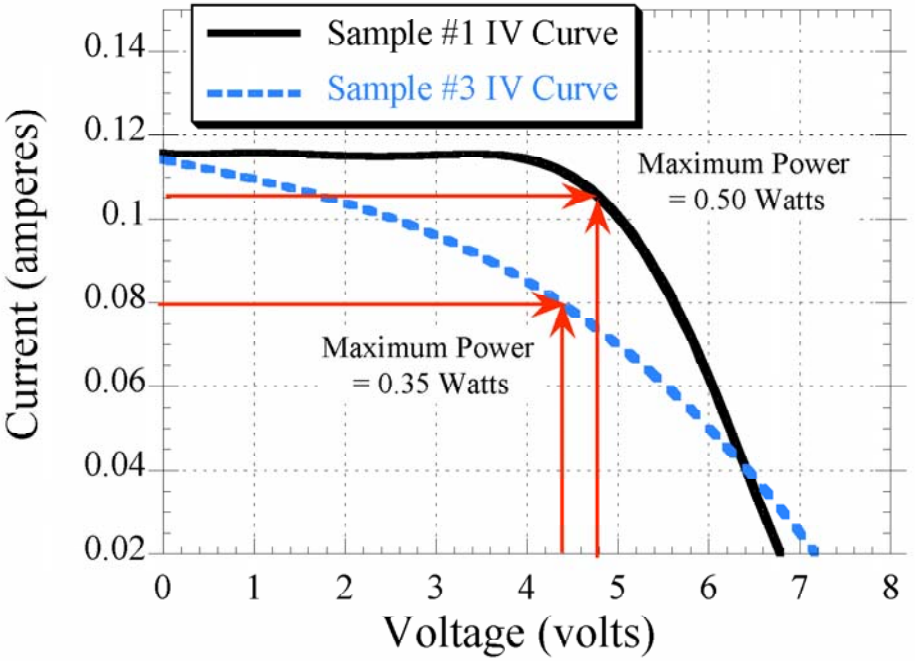
LBNL/HSU Test Results

Performance Data for Two Off-Grid White LED Products During Normal Operation (System 7, left; System 15, right)

Variance in PV Power Output



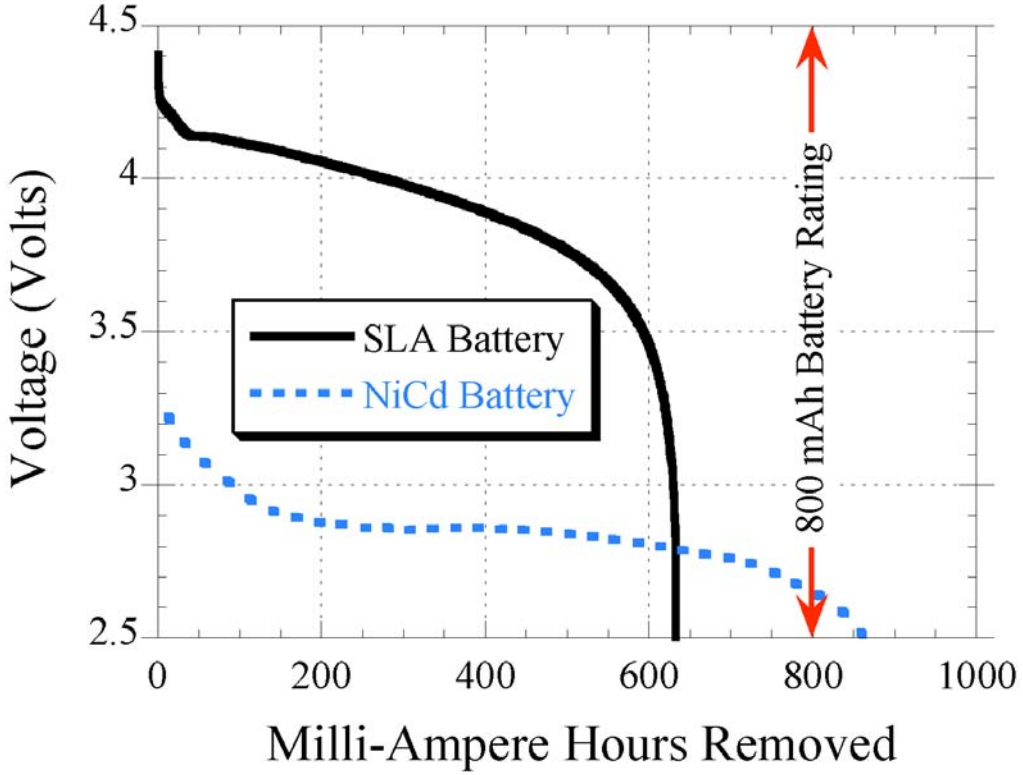
PV cells from two "identical" products



LBNL/HSU Test Results

Current-Voltage (IV) Curves for Solar PV Modules Used in a Single Off-Grid WLED Product Line (System 15)

Battery Capacity Can Fall Short of Rated Level



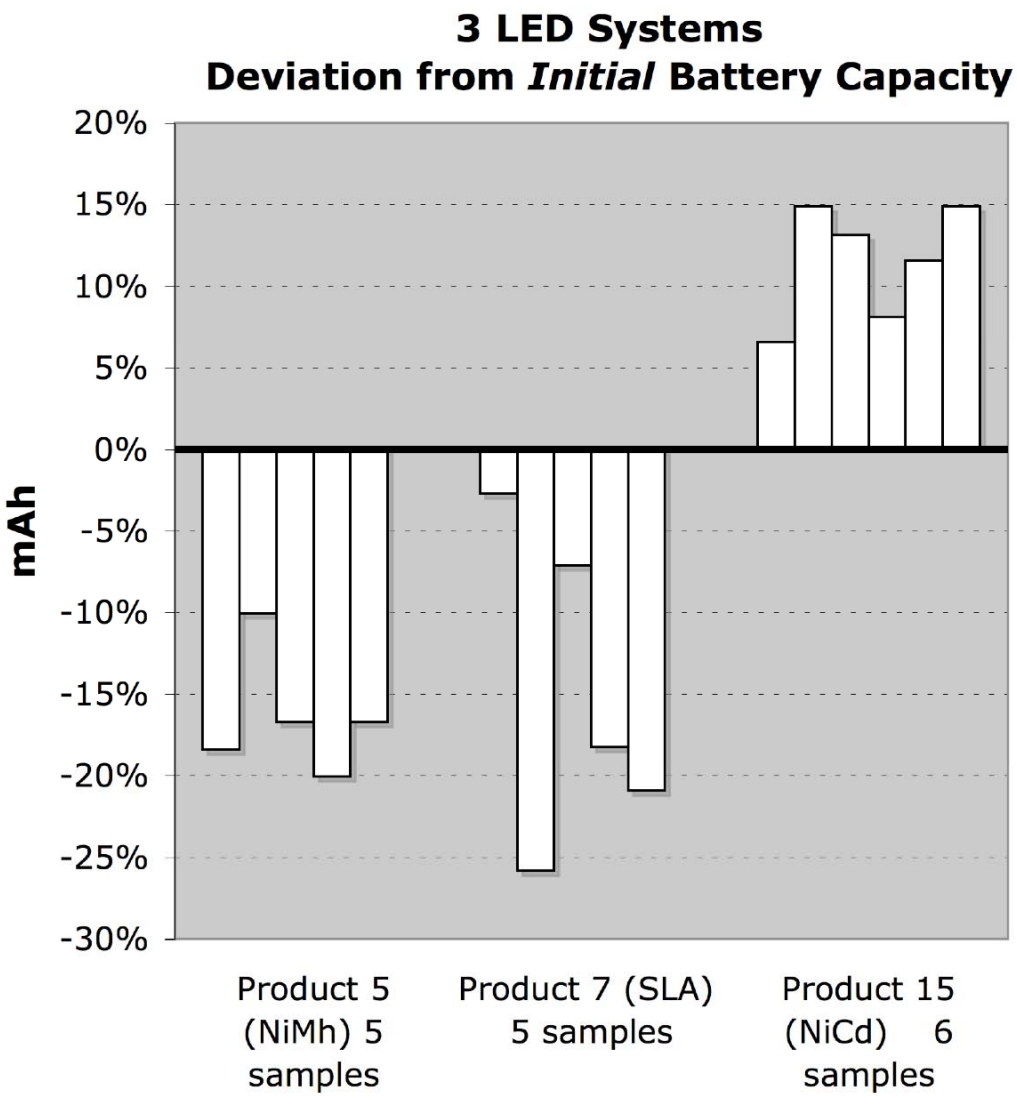
LBNL/HSU Test Results

Discharge Curves for an 800 mAh-Rated Sealed Lead Acid (SLA) Battery and an 800 mAh-Rated Nickel Cadmium (NiCd) Battery Pack (System 7 and 15, respectively).

Variation in Battery Capacity

Better than rated

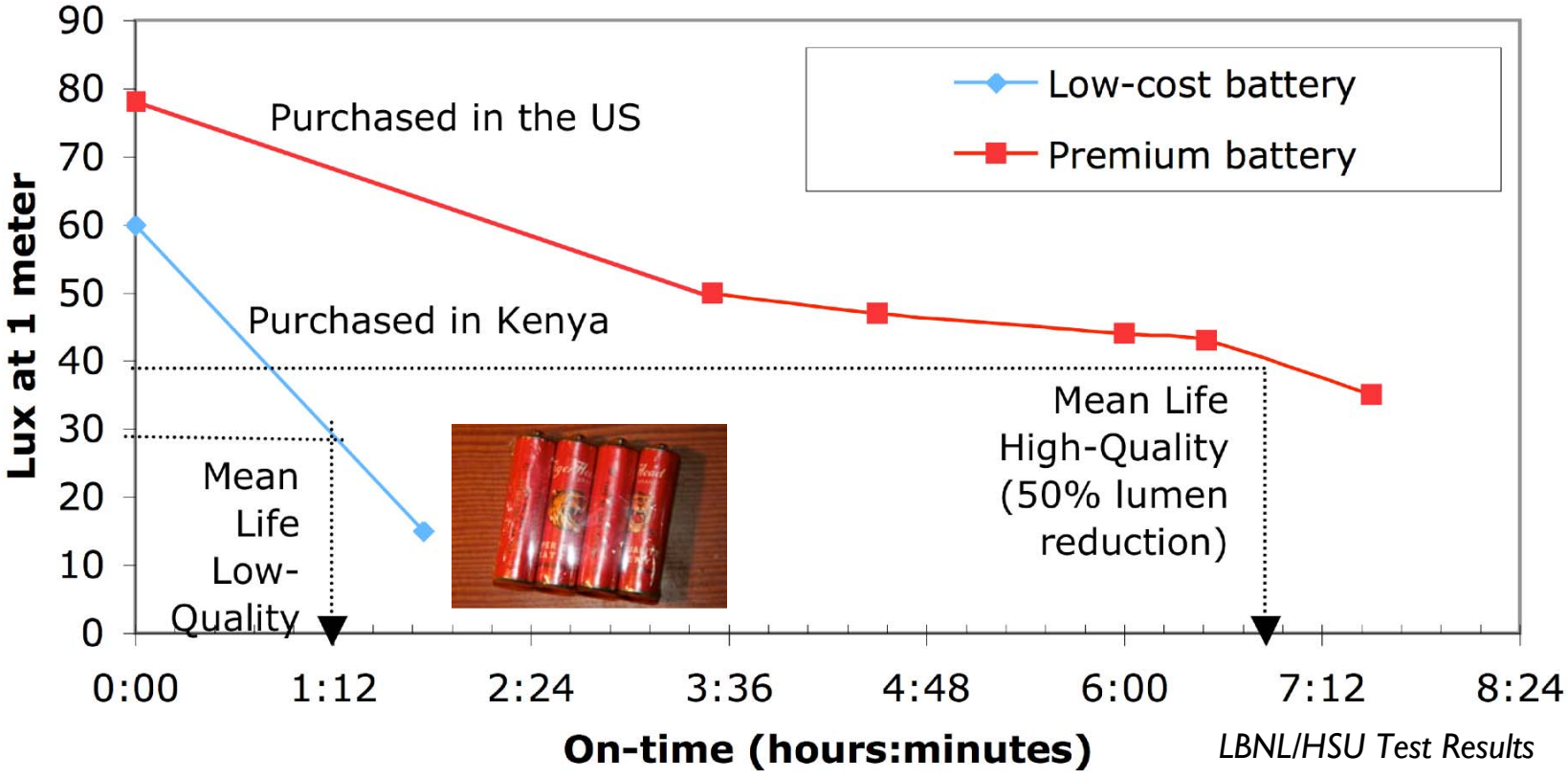
Poorer than rated



LBNL/HSU Test Results

Disposable Battery Life

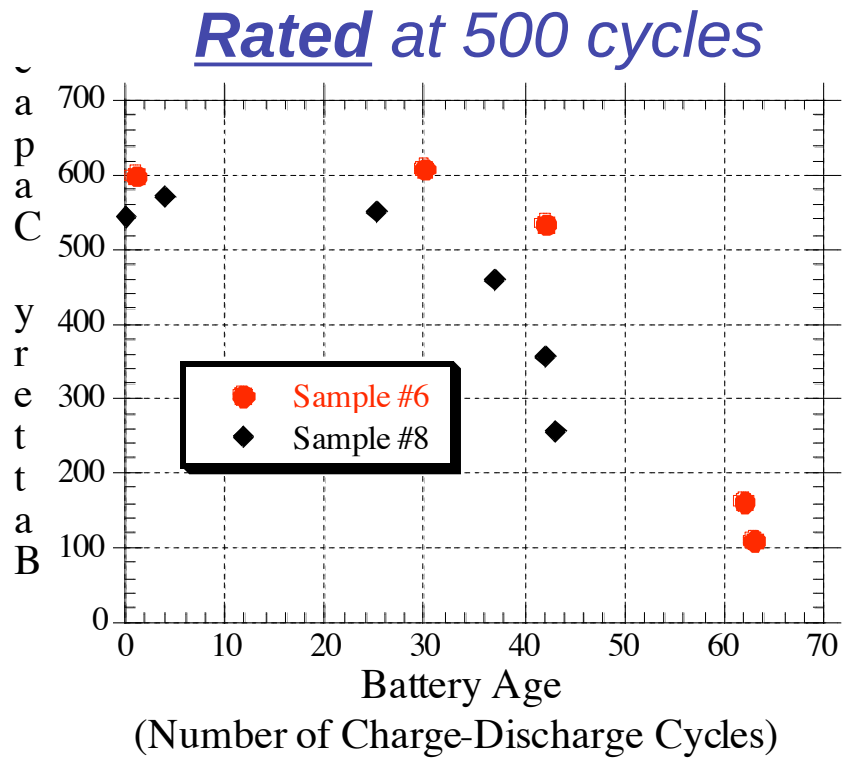
(especially important where user pays for grid-based recharging)



Variability in Alkaline Battery Service Life (System 1, trials with two types of batteries)

Rechargable Battery Life Time

- Worst-case scenario (nearly 100% discharge), yielded ~40-60 cycle life (versus claimed life of 500)
- Likely performance ~100-200 cycles (4-6 months)

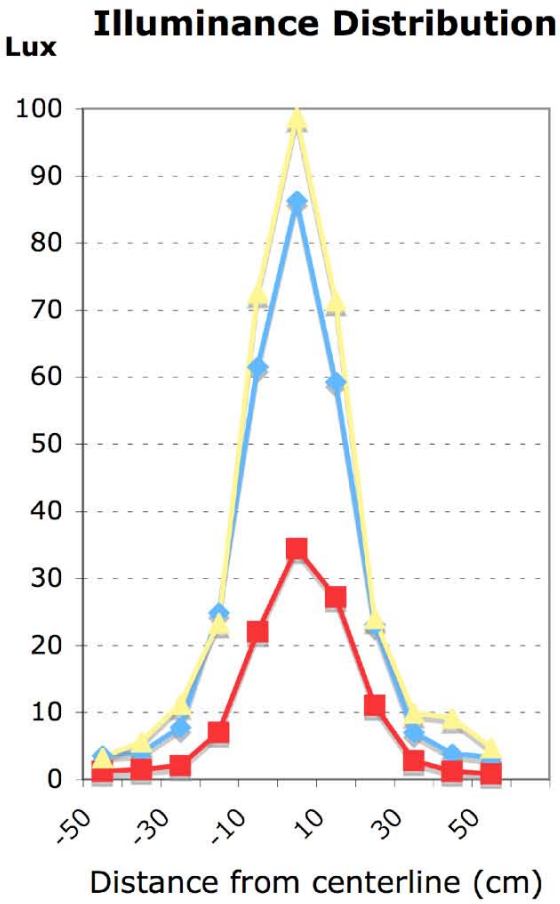


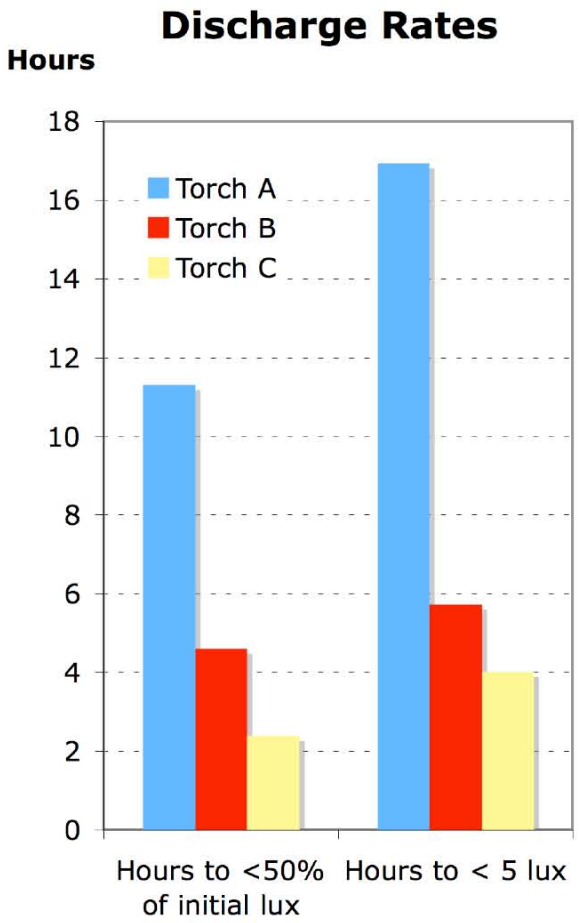
LBNL/HSU Test Results

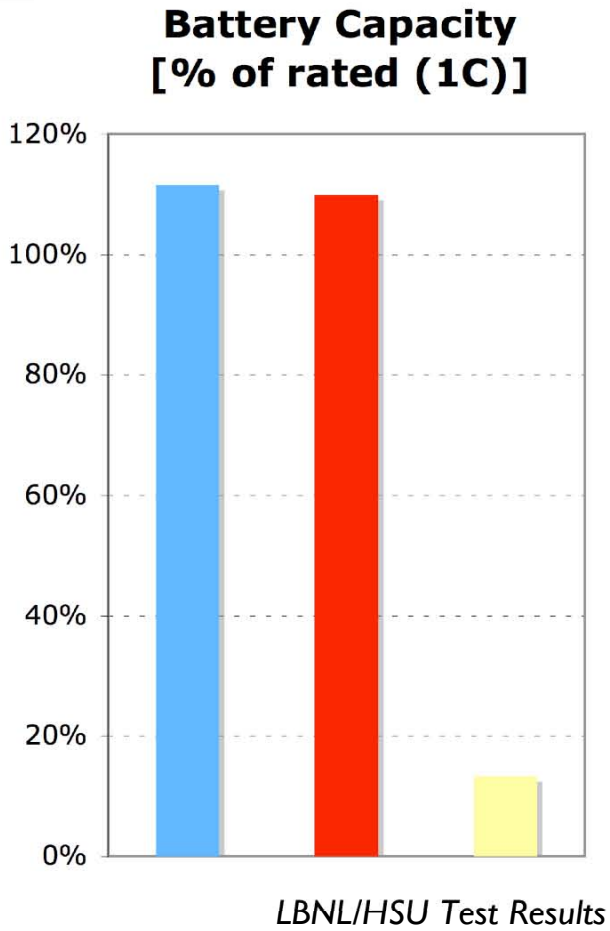
Battery Capacity as a Function of Lifetime Charge-Discharge Cycles. The results are for two 600 mAh rated sealed lead acid (SLA) batteries used in a white LED product. The results indicate that the batteries lost one-half of their original rated capacity after approximately 42 and 55 cycles, respectively.

Tale of Three Torches

Torch A (0.27 Wp)= $10-$12
Torch B (0.23 Wp): ~$6
Torch C (0.05 Wp): $12-$14

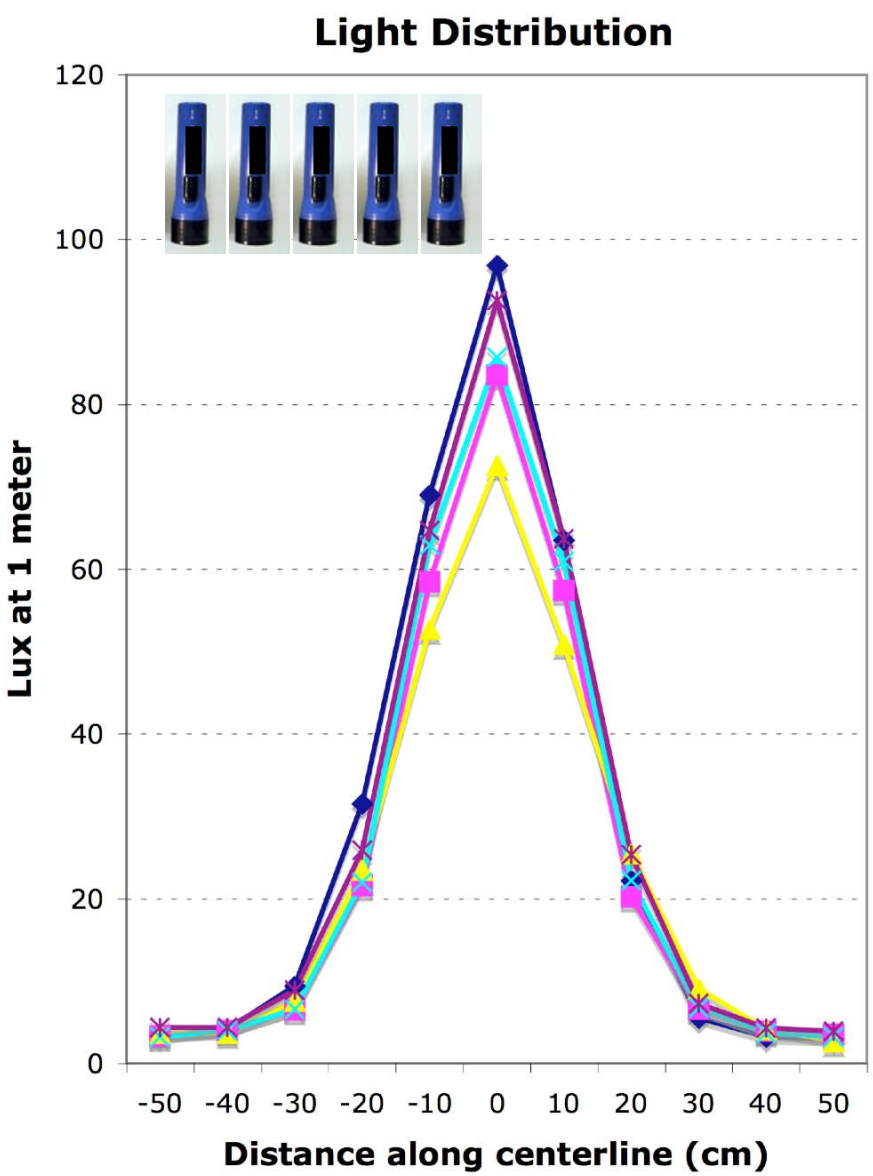


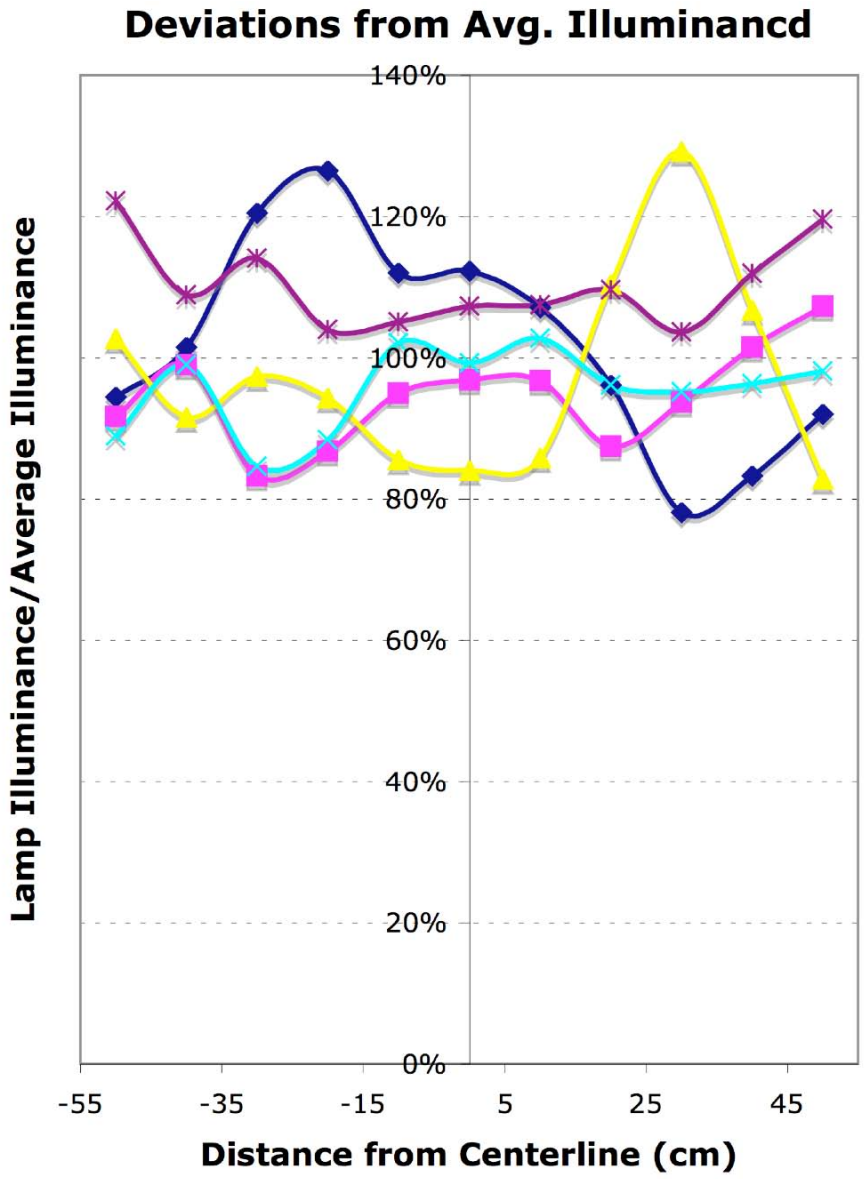




Note: A - waterproof; B & C not

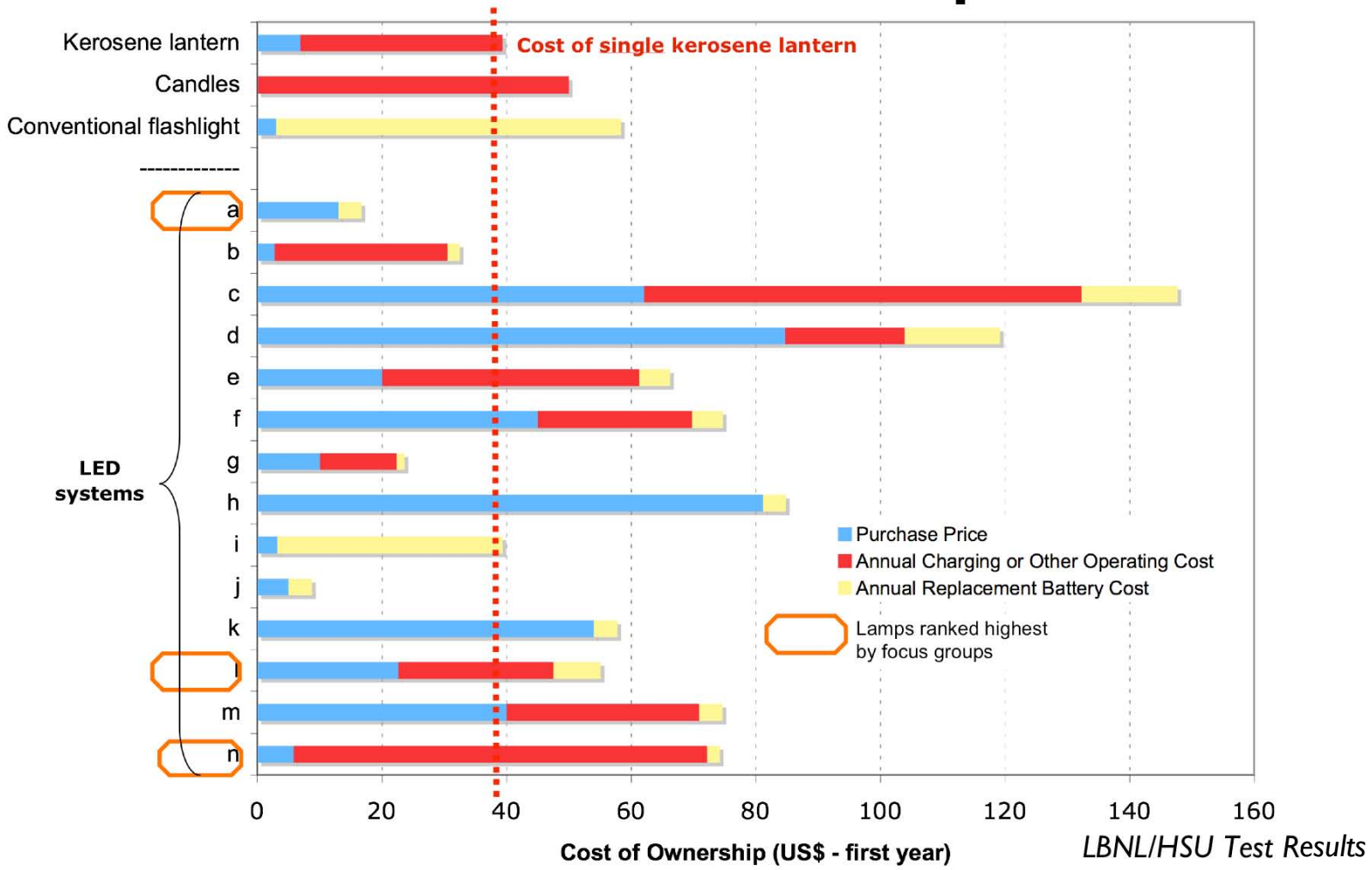
5 “Identical” Torches





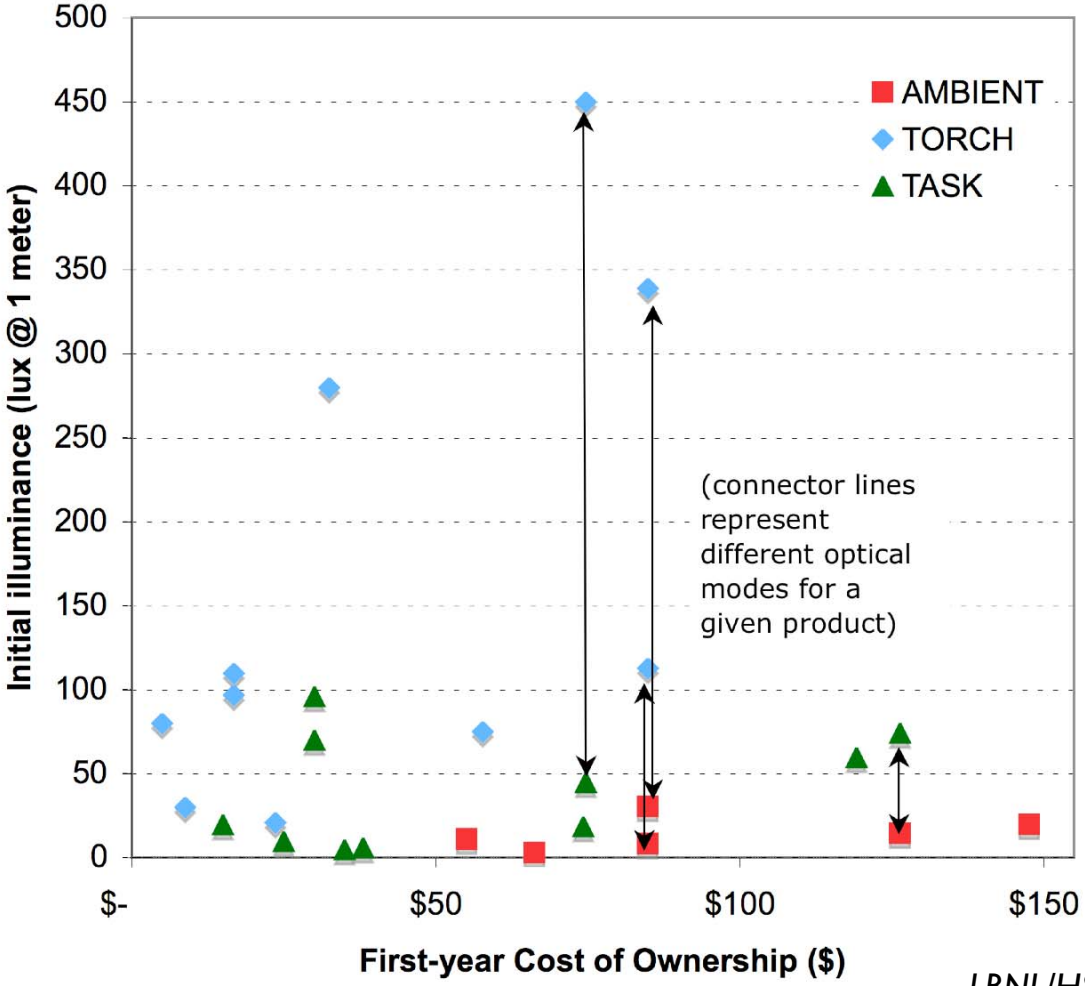
LBNL/HSU Test Results

Annual Cost of Ownership: 16 Prod's



Total yearly cost of ownership for various LED lighting products, with comparison to kerosene lighting and conventional flashlights with disposable batteries

Cost-quality correlation?



LBNL/HSU Test Results

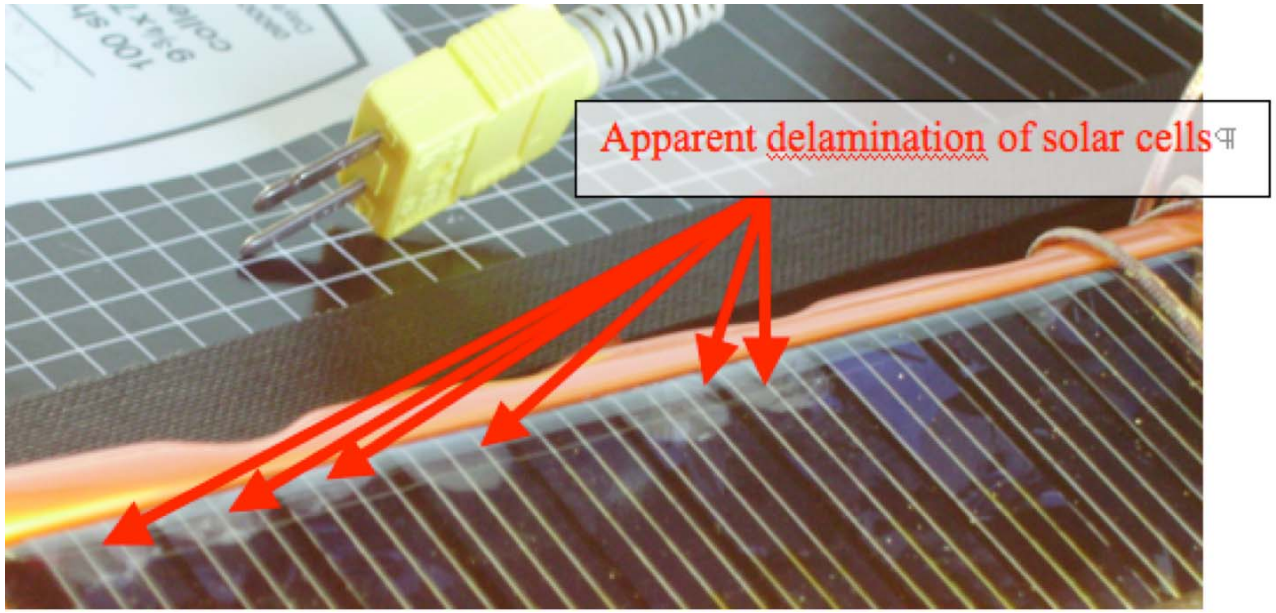
LED system cost of ownership versus lighting service level

Non-Energy/Illumination Issues

- Safety
- Vulnerability to over/under charging
- Durability
  - rough treatment
  - PV delamination
  - water-proofness
  - sensitivity to humidity
  - battery temperatures
  - battery leaking
  - fouling (insects; dirt)
- Usability
  - intuitiveness
  - ergonomics (form, weight, bulk)
  - battery replacement frequency and *availability*
- Lifecycle considerations - solid waste; batteries

Photo credit: J. Apte, A. Gopal, K. Lindgren, M. Fuller

Durability Example: PV Delamination



- De-lamination can lead to charging performance degradation or failure.
- The damage shown in the photo occurred after only 10 days of charging, probably due to thermal cycling (repetitive heating-cooling). Observed in 2 out of 2 products tested from one mfr.

Deceptive Products

Deployment Strategies
(not all may be in IFC's domain)

- Published quality/performance information
  - advertisements
  - consumer education; point-of-sale
  - product catalogs
  - trade literature
- Labeling
- Defined thresholds for procurement; incentives; duties
- Guidelines (voluntary); Standards (mandatory)
- Feedback to manufacturers & component suppliers
- Design tool for manufacturers

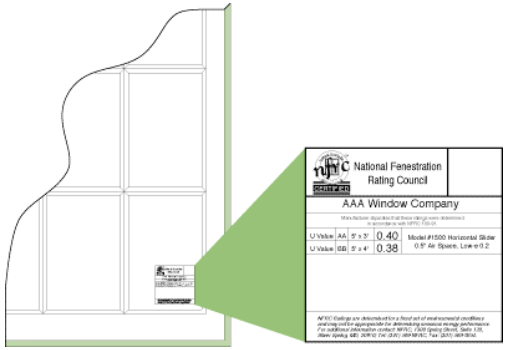
Inspire Manufacturers

"I spent much of the weekend on the phone with the engineers at my factory and we will heavily depend on using your report on the new model. We are going to totally redo our light and your report will be invaluable."

- Anonymous manufacturer

Success Story Analogy: *NFRC*

- Windows in the1980s: wide range in quality of energy-efficiency, no standard for reporting performance; poor consumer info environment
  - National Fenestration Rating Council (NFRC)
    - WINDOW Software
    - On-line product catalog (1.67 million products; 500 mfrs)
    - Industry-wide labeling to avoid "outlandish claims"
  - Basis for incentives, codes, and EnergyStar rating



Consider similar strategy for Lighting Africa ...

Issues & Potential Pitfalls - Technical

- Inadvertently disadvantaging useful products (e.g. security light)
- Lab versus as-used (position, temperature, battery charging behavior)
- Defining “adequate” illuminance
- Defining acceptable variability
- What is adequate amount of sampling?
- Total cost of ownership varies wildly depending on performance, duties, and taxes (and value chain)

Issues & Potential Pitfalls - Conceptual

- "Low quality": fact or value judgment?
  - Market spoiling vs market priming & consumer choice
- Market is not monolithic
  - Must isolate product classes; not always a tidy distinction; some products have multiple modes
- Scope: scale-of-influence • audiences • integrated products *vs.* components
- Measuring "everything" without clear purpose
- The perfect as enemy of good (cost of testing)
  - Equipment cost for results show in this talk: $15,000
- Being adaptive to technology change
- Where should QA be done, by whom, and why?
- Avoid standards patchwork
- Factory inspection; after-market service; warranty

Summary

- Need is acute
- "Quality" is somewhat subjective
- Audiences are many (need different approaches)
- QA process and strategy should be guided by a combination of testing and user-preferences
  - Energy
  - Illumination
  - Other attributes
- QA *process* must affordable to be scalable
- Standards shouldn't make *products* unaffordable
- Strategies must reflect our goals for QA

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Extra Slides

Forms & Uses of QA

- Methods
  - Performance testing
  - Quality assessment
  - Field observation, user feedback
- Uses
  - Inform consumers and intermediaries
    - Failure or defect rates
    - Counterfeit detection
    - Copycat evaluation (price/performance)
    - Carbon offset estimation
  - Motivate/assist product improvement
  - Track market development

Measuring current draw for LED lights in Kenya

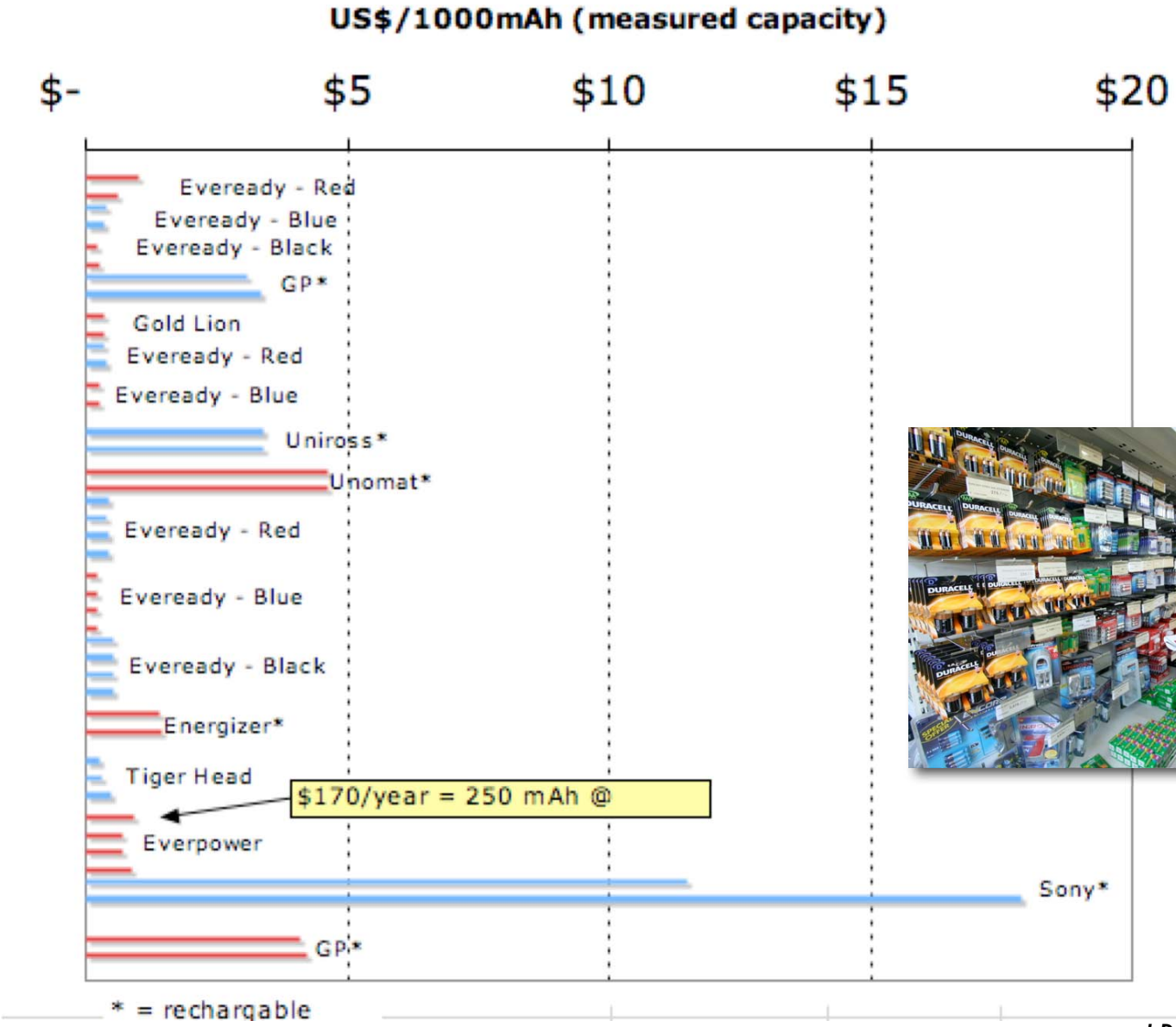
Bottom-Line Metrics

(absolute levels as well as variance)

- Lighting Services
  - Service level (peak; uniformity)
  - Hours of useful illumination delivered per charge
  - Lighting quality (glare, color, uniformity)
- Usability
  - Time to charge the battery
  - Frequency of charging for given rate of use
- Cost of Ownership
  - Total cost to purchase and operate the system
  - Cost per unit of service

Metrics must be meaningful to intended target audience(s)

Normalized Battery Operating Costs (New Batteries)



LBNL/HSU Test Results