

LED Lighting: A clash of cultures

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On behalf of the U.S. Department of Energy
and NETL Morgantown





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LEARNING OBJECTIVES

LED LIGHTING: A CLASH OF CULTURES

- 1) Critical technical differences between LED and other lighting technologies
- 2) Differences in rate of product development with solid-state lighting
- 3) Understanding the effect of temperature on product lifetimes
- 4) How to distinguish good from poor SSL products and applications





- ➔ 1. LED Technology: Advantages; Differences; Limitations
2. LED Lifetimes: Not so simple anymore
3. Obsolescence and Equivalence: Source of major confusion
4. LED Applications: The good and not-so good
5. Architects & Lighting Designers: What's important
6. Rules of Thumb: Common sense helps



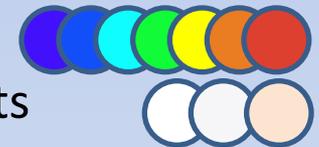
Why Should I Care About LEDs?

LEDs are like no other conventional lighting source

- + Potentially longest¹ life of any lighting sources
- + Very high energy efficiency
- + Small size and instant on allows new applications
- + Produces color light directly without filtering
- + Integrates will with other semiconductor electronic elements
- Thermal management requirements
- Cost
- New technology brings unfamiliar issues to architects, lighting designers, building owners and facilities managers



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¹Note: Some manufacturers have introduced products claiming long lifetimes: fluorescent tubes (40,000 hours); induction (100,000 hours)



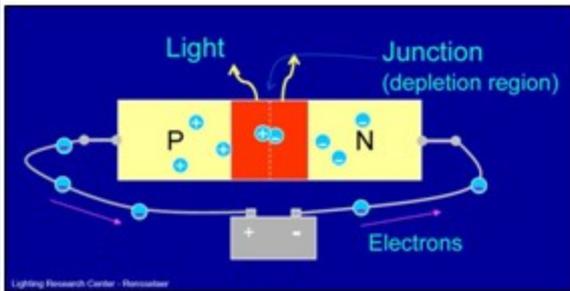
What have you heard about LEDs?

- They don't produce any heat
- They last forever
- LED products work well everywhere
- They don't work
- They are too expensive
- There is a conspiracy to limit the use of LEDs
- There is a conspiracy to force the use of LEDs

What is the truth about LEDs?

- They **do** produce heat – just not as much
- They **don't** last forever – just longer than other sources
- There are applications where LED technology is not appropriate at this time
- They don't work if misapplied
- They are expensive but costs continue to drop
- There is a conspiracy by physicists to force the metric system on everyone but that has nothing to do with LEDs

What is an LED?



An LED (**L**ight **E**mitting **D**iode) consists of a chip of semiconducting material treated to create a structure called a p-n (positive-negative) junction

The heatsink is what allows the high flux LED to generate much more light

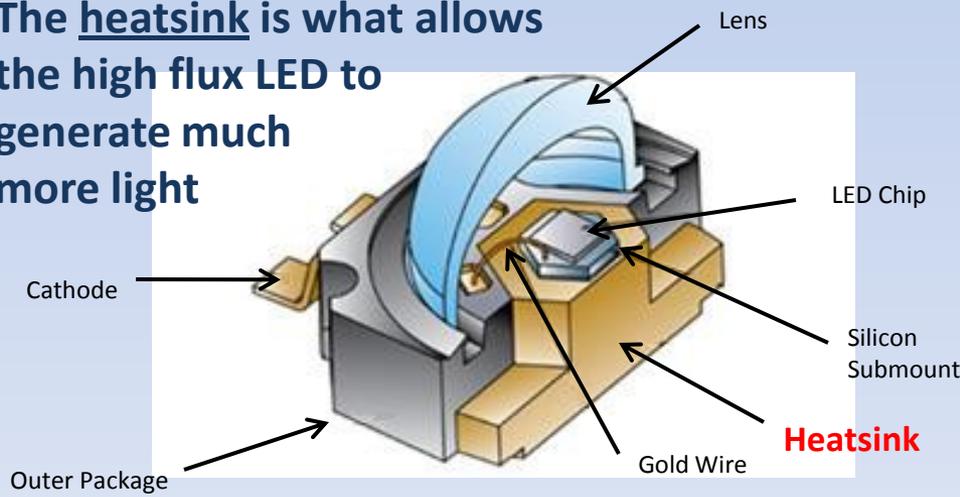


Diagram of a high flux LED

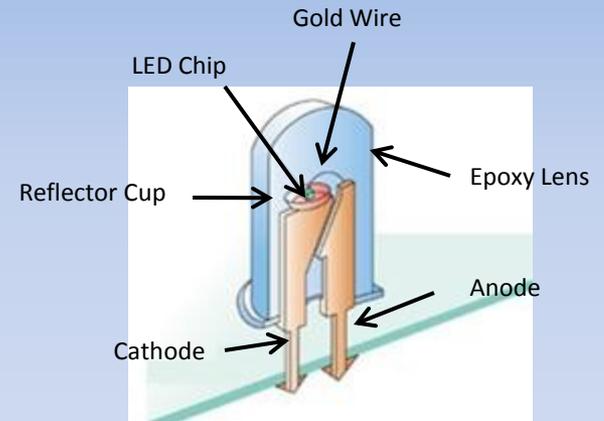
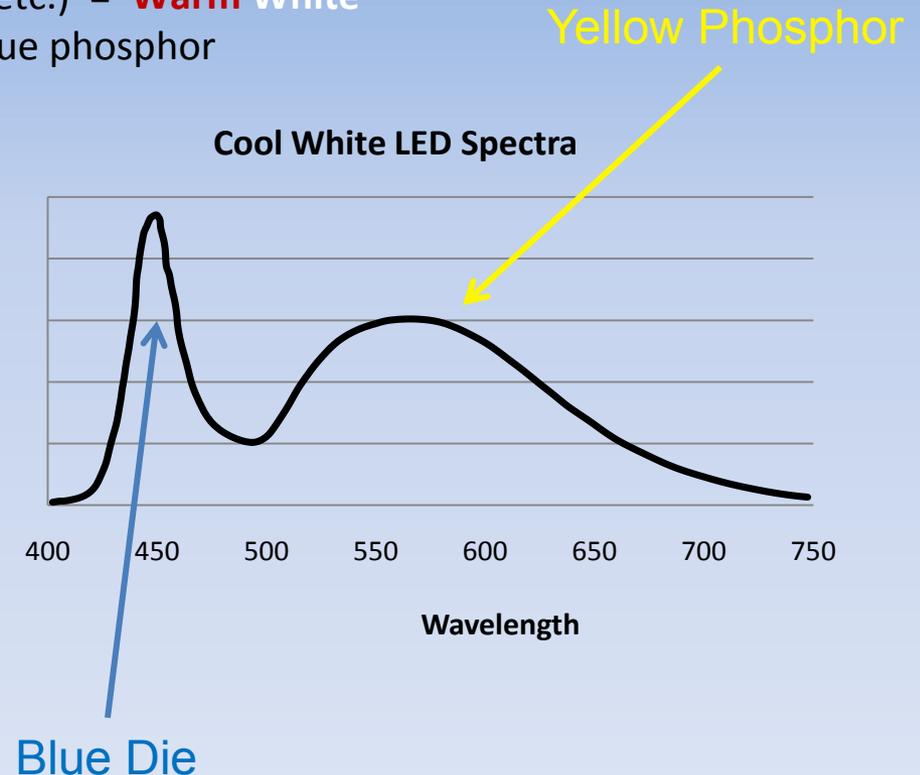
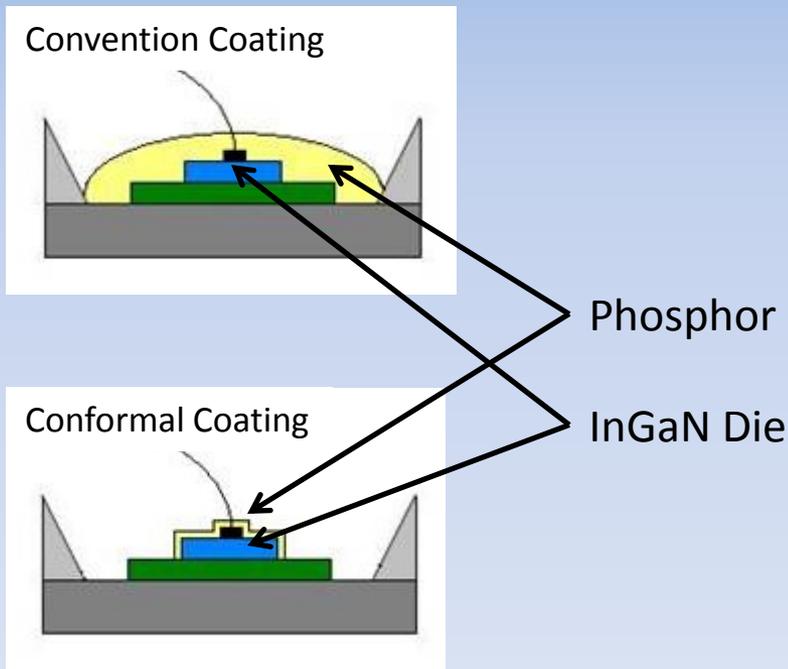


Diagram of a 5mm LED

How Do You Make a White LED?

Downconverting Phosphor

- Blue LED + YAG (Yttrium aluminium garnet) = **Cool White**
- Blue LED + YAG + Other phosphor (red, green, etc.) = **Warm White**
- UV LED + Red phosphor + Green phosphor + Blue phosphor



Small Size



T5 Fluorescent
1350 lumens

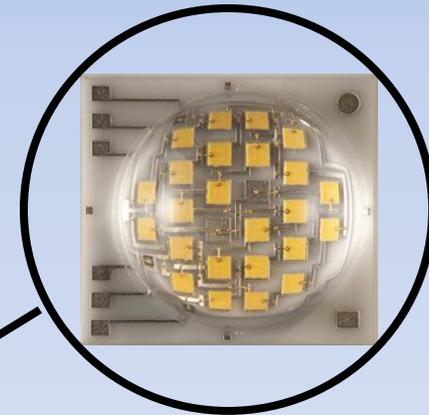
75W PAR 38 Halogen
1100 lumens



75W Incandescent
1200 lumens



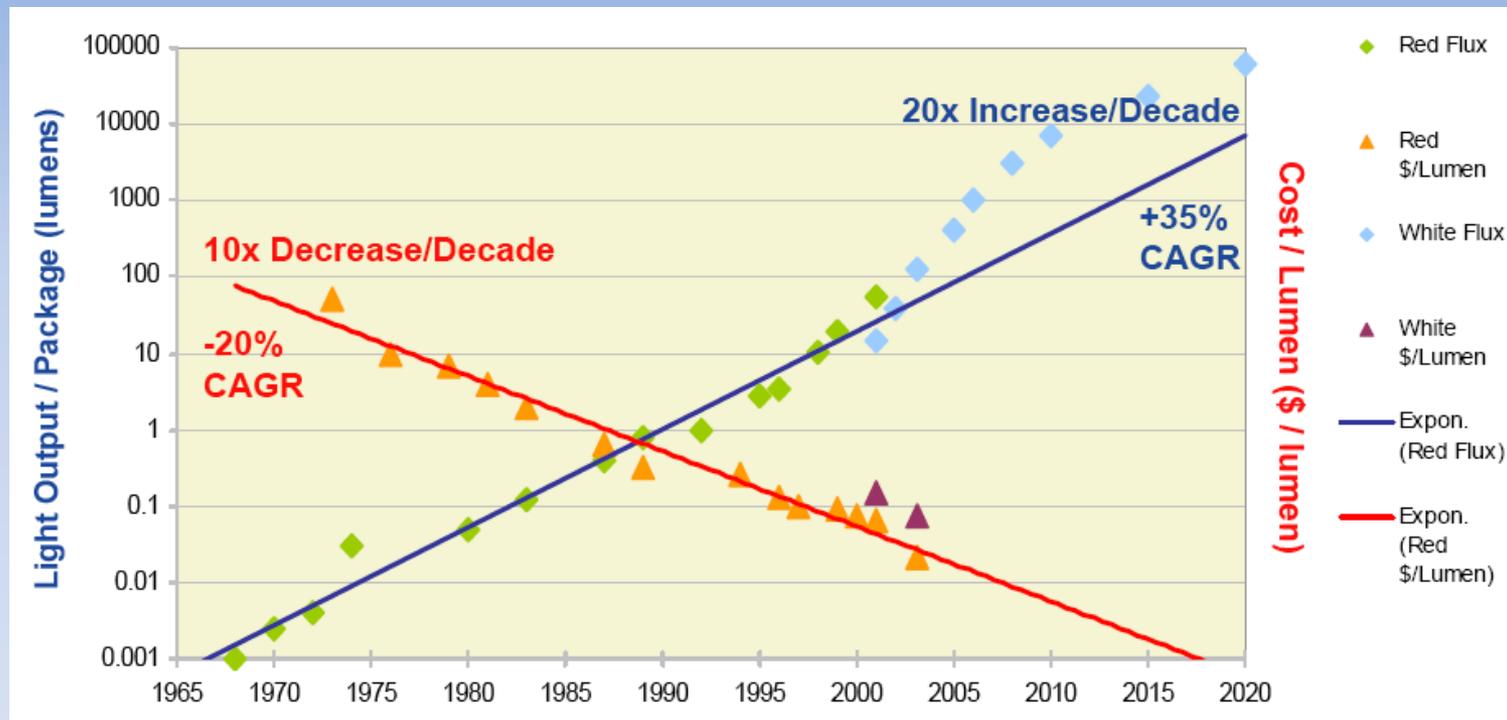
Cree MP-L LED
1200 lumens



Source: Cree

Rate of Development

LEDs follow a development rule known as Haitz's Law



Source: Roland Haitz & Lumileds

New Names & Shapes in Lighting

Traditional Lamp Suppliers

- Sylvania
- Philips
- GE



LED Suppliers

- Osram
- Lumileds
- Cree
- Bridgelux
- Nichia
- Seoul Semiconductor
- Toshiba
- Sharp
- Toyota Gosei
- Edison Opto
- and many more...



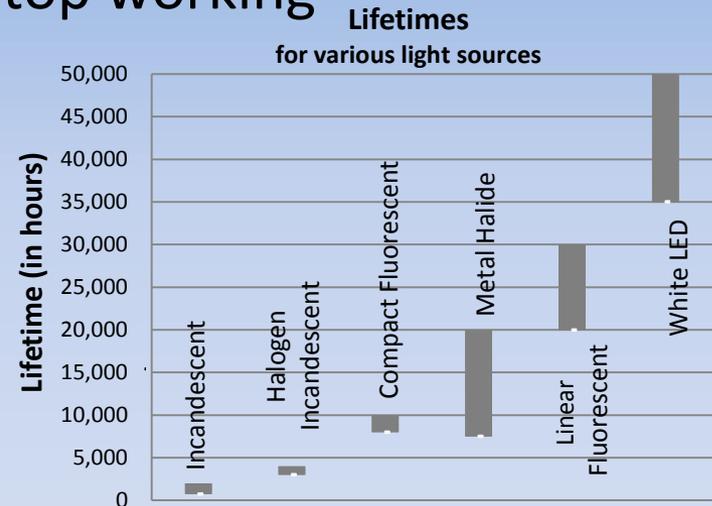
1. LED Technology: Advantages; Differences; Limitations
- ➔ 2. LED Lifetimes: Not so simple anymore
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Long Lifetimes

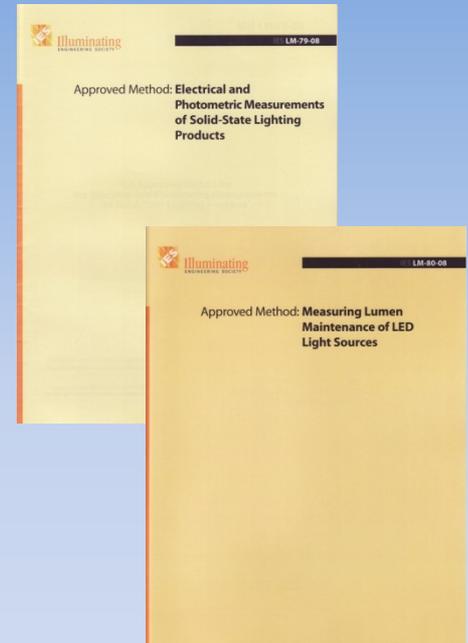
- Traditional light sources fail catastrophically due to electrodes which weaken or become contaminated and eventually fail, causing the lamp to stop working

- LEDs rarely fail catastrophically
 - Light output gradually decreases over operating time
 - End of life defined to be when light output reaches 70% of initial value
 - Raises issue for designers – how to warn users that product has exceeded end-of-life and is producing less light than the application may require
 - Lifetime highly dependent on temperature (ambient and device as well as operating current)



Standards – Help manage the risks

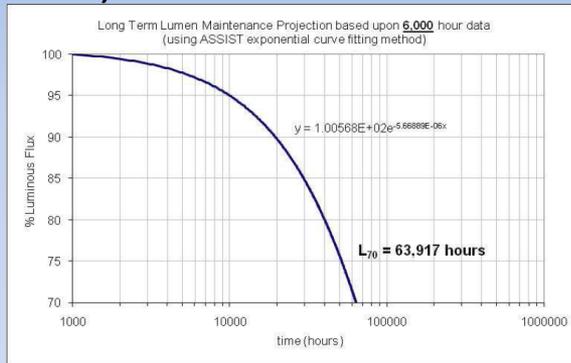
- LM-79-08 *Approved Method: Electrical and Photometric Measurements of Solid-State Lighting Products*
 - Describes testing procedure for measuring light output and distribution from LED-based luminaires
- LM-80-08 *Approved Method for Measuring Lumen Depreciation of LED Light Sources*
 - Describes testing procedure for measuring lumen depreciation of LED devices
 - Does not describe how to evaluate data taken
- ANSI C78.377-2008 Specifications for the Chromaticity of Solid-State Lighting Products for Electric Lamps



Long Lifetimes – A Measurement Issue

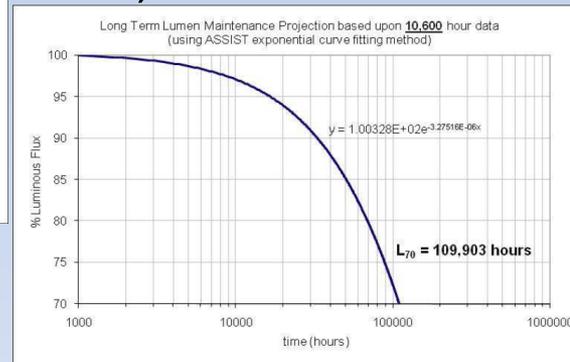
- It is difficult to predict the long term performance of a device with only early lifetime data

6,000 Hours of data

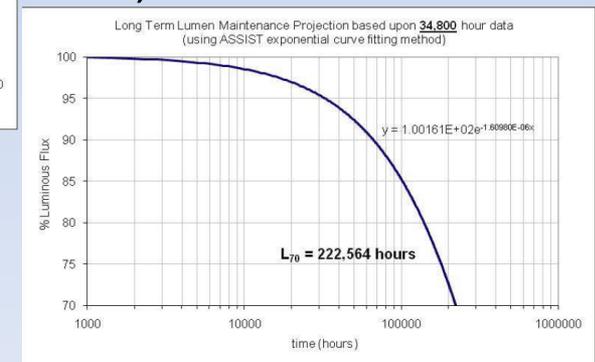


Source: Cree

10,600 Hours of data



34,800 Hours of data

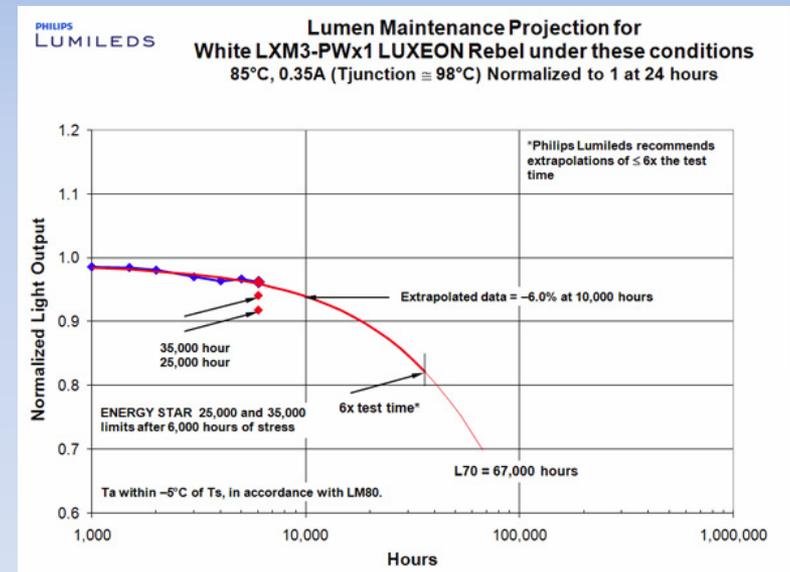
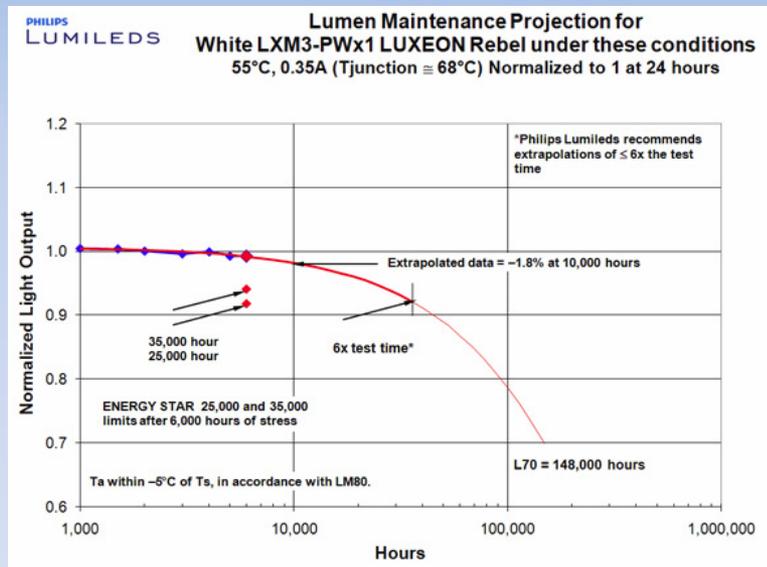


Almost 3.5 X's longer predicted lifetime than the 6,000 hour results

Effect of Heat on Lifetime

LED Lifetime with ambient temperature of 55°C is 148,000 hours

LED Lifetime with ambient temperature of 85°C is 67,000 hours

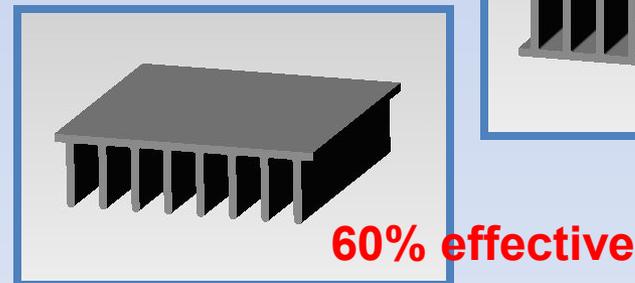
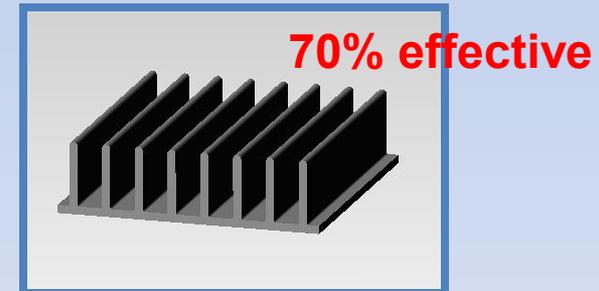
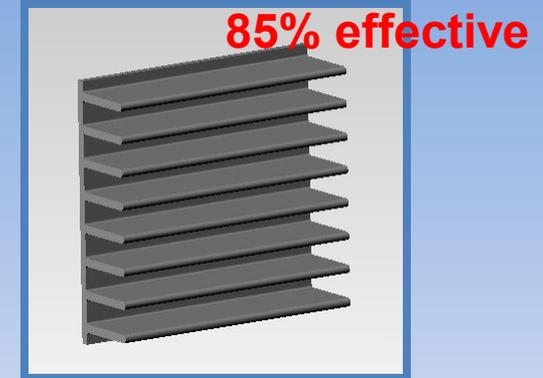


Source: Lumileds

Luminaire Orientation Can Effect Lifetime

Luminaire manufacturers must take desired orientations into account when designing thermal management system for products

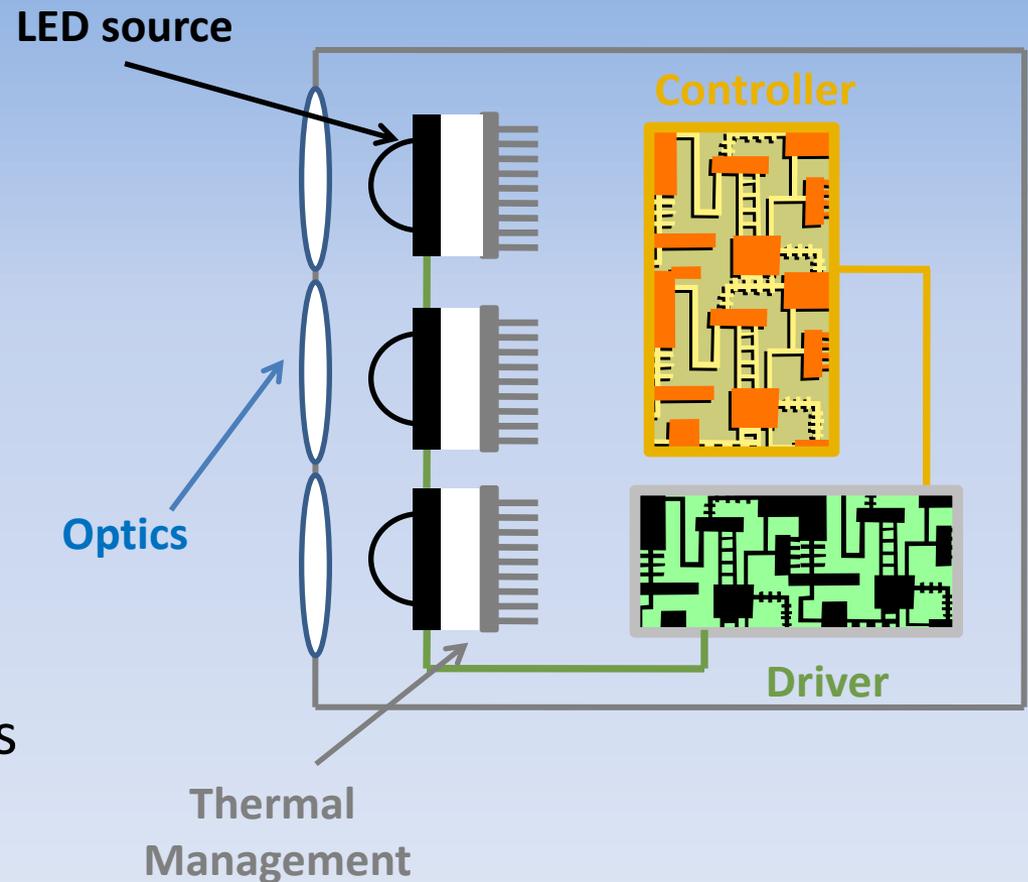
LM-79 testing standard requires the luminaire be tested in the orientation in which it will be mounted



Luminaire Lifetime – A Luminaire is a System

The failure of any one component can cause the entire system to stop functioning

Luminaire designers make trade-offs among the components, depending on the desired performance criteria – for example the number of LEDs (\$\$\$) versus drive current (lifetime)



Reliability – Depends on the driver as well

Two examples of failures caused by the driver



Stop & Shop, Raritan, NJ – 6 weeks



City Center, Las Vegas – 5 months

Not quite 50,000 hours!

Dimming – Another potential failure mode

- Because LED systems work differently from those of incandescent lamps, dimming is often an issue
- LED drivers must be designed to be compatible with line-voltage dimmers (of which there are many types)
 - Many line-voltage products not compatible (like CFLs) with certain dimmers
 - Many low voltage LED systems with certain step-down transformers are not compatible with certain dimmers
- One dimmer manufacturer provides a matrix showing compatibility and functionality with various manufacturers' luminaires/or drivers



LED PRODUCT COMPATIBILITY MATRIX				
Manufacturer	Model	Description	Dimming Range*	Compatible Product?
	Hi-kvme LED driver	Driver	100% - 1%	YES
	Xtanium	Current Driver	Not Specified	YES
	Xtanium	PWM Driver	100% - 0%	YES
	eW PowerCore	Strip Light	100% - 15%	YES
	eW Profile - 11"	Under Cabinet Light	100% - 15%	YES
	eW Profile - 41"	Under Cabinet Light	100% - 15%	YES
	eW Downlight	Downlight	100% - 15%	YES
	Downlight	6" Downlight	100% - 5%	YES
	LR4	4" Downlight	100% - 20%	YES
	LR8	6" Downlight	100% - 20%	YES
	LR8 - 230V	6" Downlight	100% - 20%	YES
	LR24	24" x 24"	100% - 5%	YES
	Tetra dimming module	Driver	Not Specified	YES
	LED Cove Light	Cove Light	100% - 3%	YES
	Downlight	Downlight	Not Specified	YES
	LED-18-350-120-D	Driver	100% - 0.1%	YES
	LED-36-700-120-D	Driver	100% - 0.1%	YES
	Calculla 10W	Downlight	N/A	YES
	Calculla 20W	Downlight	N/A	YES
	Par 30	Par 30 lamp	Not Specified	YES
	OT Dim	Driver	100% - 0%	YES

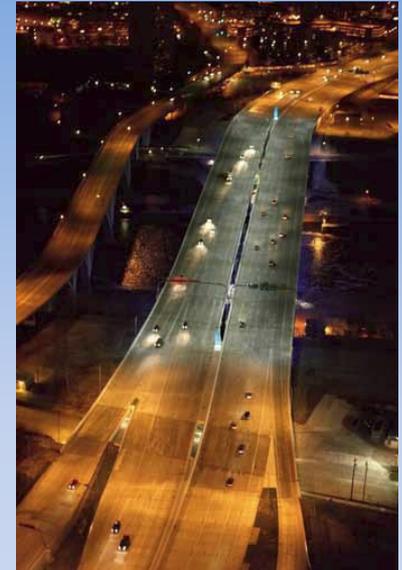
Measuring LED Lifetime – LED luminaires are systems

Original DOE Gateway Report: *At the prevailing average nighttime temperature in Minneapolis, the manufacturer projects that the luminaires would need to operate for several decades to reach this level of lumen depreciation [70% of original lumen output], estimating only about a 12% loss after 20 years.*

Recent interim DOE Report: *Continuing decrease detected in average illumination on the ground, roughly 12% from initial after a few [15] months.*

Reason #1: Earlier design used an optical gel to fill void between LED lens and proprietary *nano-optic*. Over time, a bubble forms in the gel that causes step change in both lumen distribution and output. The measured optical gel impact on these two samples corresponds to 6.6% and 7.4% reductions in total lumen output.

Reason #2: Dirt Depreciation



Site	Years of Operation	Lumen Output (Dirty Lens)	Lumen Output (Clean Lens)	Lumen Dirt Depreciation
I-35W	1.25	14520	15227	4.60%
I-35W	1.25	14670	15245	3.80%



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OBSOLESCENCE & EQUIVALENCE

The Word “Equivalent”

Definitions

- Corresponding or virtually identical, especially in effect or function
- A state of being essentially equal
- Like in signification or import
- A person or thing equal to another in value or measure or force or effect or significance etc.

Are these two balconies equivalent?

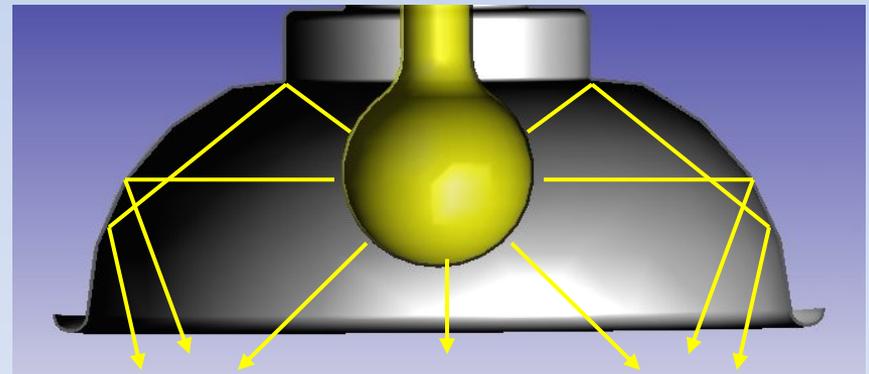
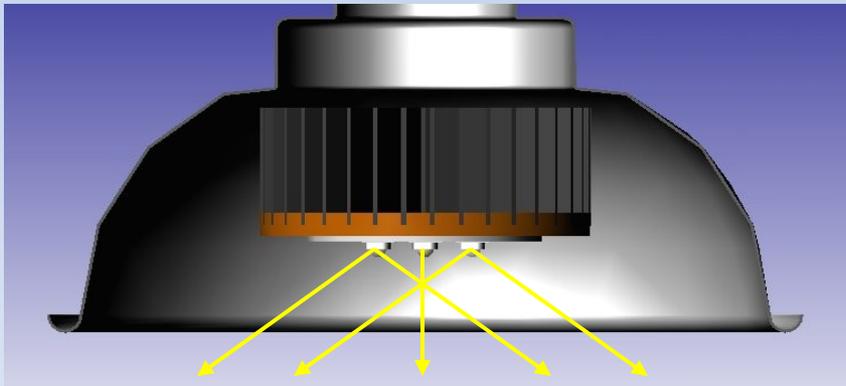
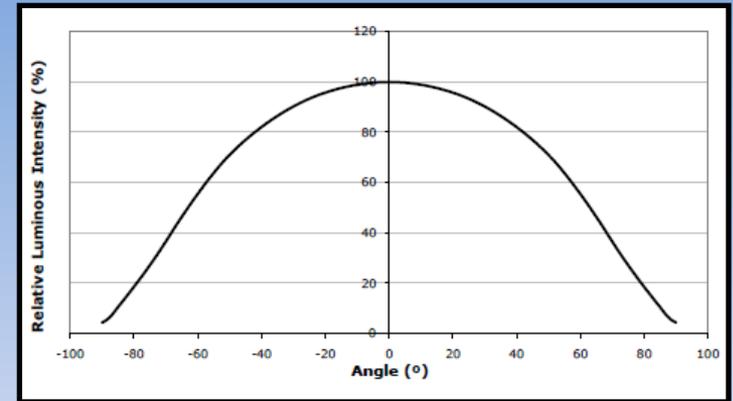
Maybe not



OBSOLESCENCE & EQUIVALENCE

LED Light Output – “Equivalent” to conventional sources?

- LED devices have highly directional light output unlike conventional light sources
- In directional fixtures such as downlights, this results in much less wasted light trapped in the fixture



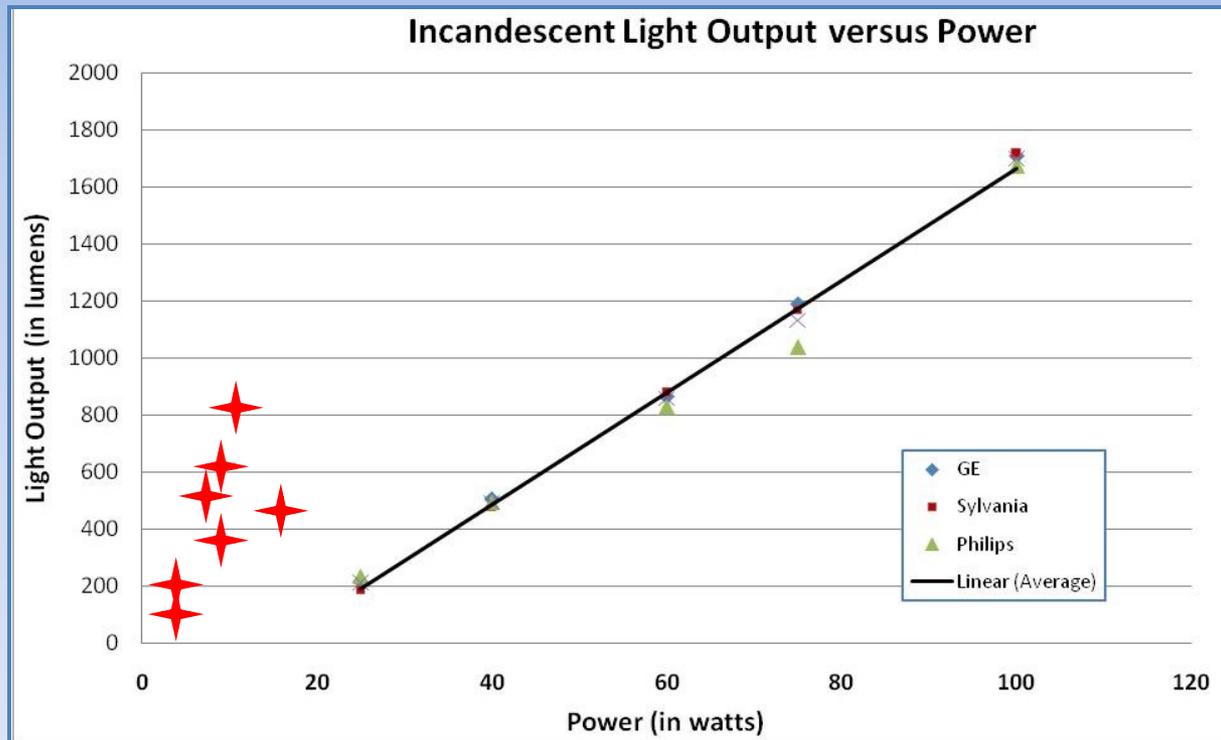
In properly designed fixtures, this might be a benefit

OBSOLESCENCE & EQUIVALENCE

The Word “Equivalent”

Incandescent lamp light output can be accurately conveyed by listing the lamp’s power (wattage)

LED-based lamps do not show the same linear relationship due to the differences in device efficacy

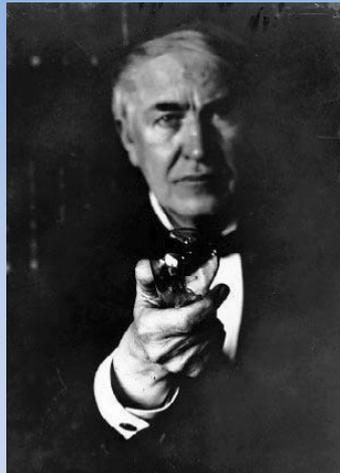


Source: LED Transformations

OBSOLESCENCE & EQUIVALENCE

Obsolescence – Part of the economic picture

- If Edison were alive today, he would certainly recognize his light bulb



- If you owned this fixture, you could still get lamps for it

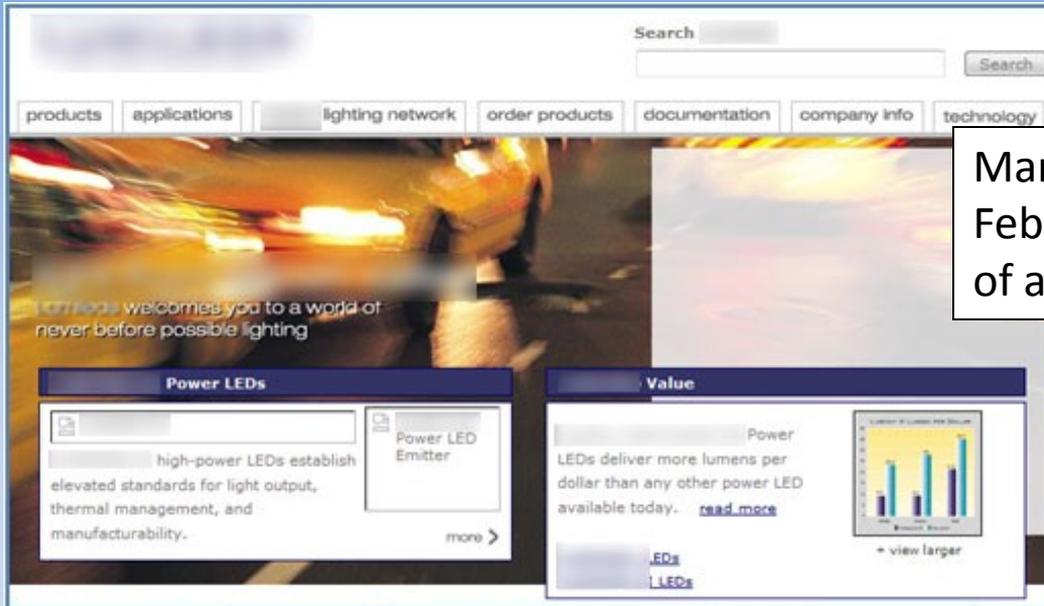


Early 20th century light fixture

Source: Scot Hinson, Modeliving

OBSOLESCENCE & EQUIVALENCE

Obsolescence – And some things do



Manufacturer's web site from February 2006 showing the addition of a new line of LED devices



The same manufacturer's web site from March 2010 discontinuing that same line of LED devices

OBSOLESCENCE & EQUIVALENCE

Obsolescence – Can have some unexpected results

It doesn't save energy if you can't get it

- Lighting is typically ordered late in the construction process. Backorder status because vendor builds in batches or ships quarterly from overseas does not help.
- Importance of spares when things do break or fail
 - As more LED-based products become available, this should be less of an issue
- Availability 5 years from now

Quantity	Catalog Number	Description	Ship Status	Unit Price	Total
5	DL - 2700-6-120	LED Downlight (2700K), 6" 120VAC	BACKORDERED	\$119.95	\$599.75
15	DL - 3000-8-120	LED Downlight (3000K), 8" 120VAC	BACKORDERED	\$139.95	\$2,099.25
50	CL - 3000-1-24	LED Cove Light (3000K), 1', 24VDC	BACKORDERED	\$45.00	\$2,250.00
10	WW - 3500-5-120	Wall Wash (3500K), 120VAC	BACKORDERED	\$279.00	\$2,790.00
15	DL - 3000-6-120	LED Downlight (3000K), 8" 120VAC	BACKORDERED	\$139.00	\$2,085.00
					\$0.00
					\$0.00
Total for this order					\$9,824.00

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Some Statistics — Presently LEDs represent a small portion

Area & Flood Lighting

Lamp Type	Percentage	Number of Lamps (000's)	Application
Incandescent	2.30%	1,200	Area Lighting
Halogen	19.00%	8,600	Area Lighting
Fluorescent	5.80%	3,600	Area Lighting
Induction	0.30%	200	Area Lighting
Mercury Vapor	12.70%	6,700	Area Lighting
High Pressure Sodium	22.10%	10,700	Area Lighting
Metal Halide	36.90%	18,900	Area Lighting
LED	0.90%	600	Area Lighting
Total	100%	50,500	Area Lighting
Incandescent	3.60%	1,600	Flood Lighting
Halogen	18.60%	8,000	Flood Lighting
Compact Fluorescent	0.20%	74	Flood Lighting
Fluorescent	7.90%	3,400	Flood Lighting
Mercury Vapor	8.40%	3,600	Flood Lighting
High Pressure Sodium	21.40%	9,200	Flood Lighting
Metal Halide	39.70%	17,100	Flood Lighting
LED	0.20%	74	Flood Lighting
Total	100%	43,048	Flood Lighting

Garage & Parking Lot Lighting

Lamp Type	Percentage	Number of Lights (000's)	Application
Incandescent	1.60%	600	Garage Lighting
Halogen	2.20%	800	Garage Lighting
Fluorescent	45.90%	16,600	Garage Lighting
Induction	7.40%	2,700	Garage Lighting
Mercury Vapor	0.10%	44	Garage Lighting
High Pressure Sodium	23.20%	8,500	Garage Lighting
Metal Halide	15.30%	5,600	Garage Lighting
LED	4.10%	1,500	Garage Lighting
Total	100%	36,344	Garage Lighting
Incandescent	2.60%	400	Lot Lighting
Halogen	0.10%	16	Lot Lighting
Mercury Vapor	2.40%	400	Lot Lighting
High Pressure Sodium	36.00%	5,700	Lot Lighting
Metal Halide	54.20%	8,600	Lot Lighting
LED	4.60%	700	Lot Lighting
Total	100%	15,816	Lot Lighting

Source: *Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications*, Navigant Consulting Inc, January 2011

Downlight – Good



Incandescent 5,135 W

Friendly's Restaurant
Westfield MA



LED 948W



Makes use of directionality

Source Cree

LED (2 Years Later)

Good Ones – Freezer/Refrigerator Cases



Albertson's San Diego, CA



Source: LED Transformations, LLC



Fluorescent

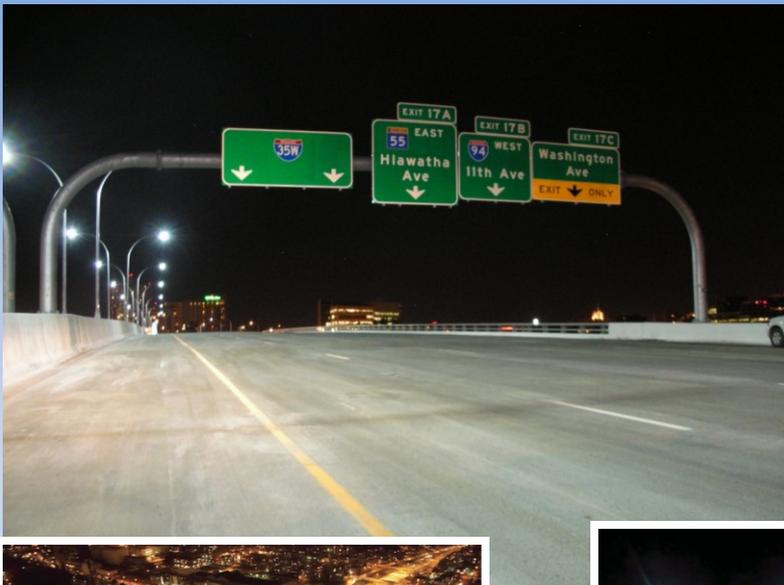
LED

Albertson's Grocery, Eugene OR

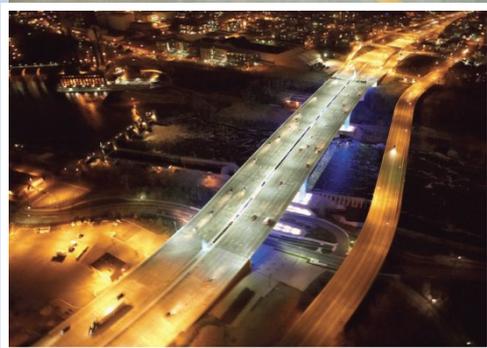
LEDs performance improves at lower temperatures

Albertson's (Eugene OR) results are part of a Gateway demonstration program available at: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/gateway_freezer-case.pdf

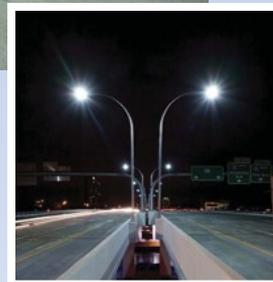
Street & Area Lighting – Good



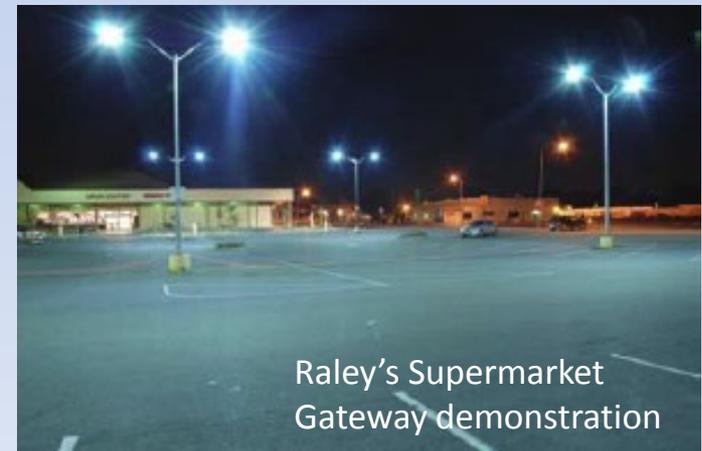
TJ Maxx Parking Lot
Gateway demonstration



Source: Eric Haugaard, Ruud Lighting



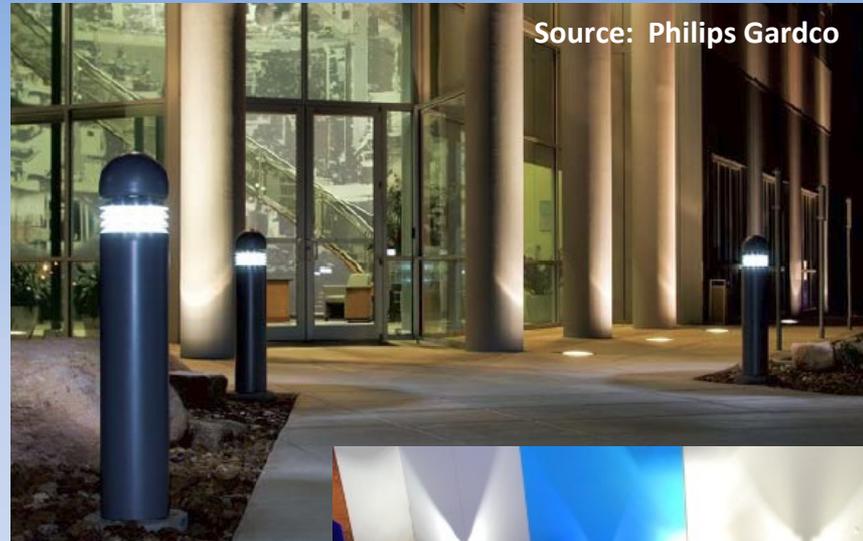
**Makes use of
directionality**



Raley's Supermarket
Gateway demonstration

Source: US DOE Gateway program

Task Lights / Bollards – Good



**Makes use of directionality
and small form factor**

LEDs for Residential Interiors – Undercounter



CSL - Creative Systems Lighting



Source: Kichler Lighting

Good Ones & Bad Ones – Low wattage MR-16s (<20W)

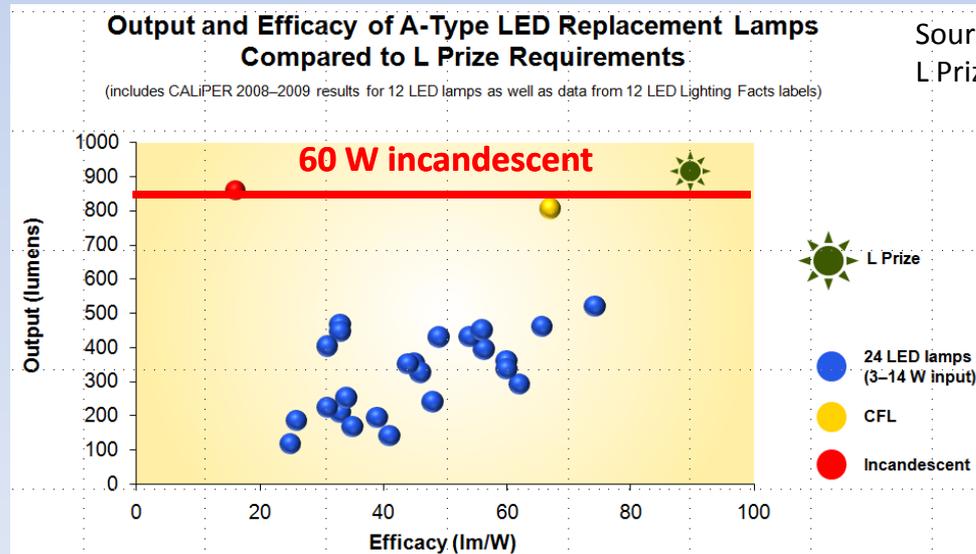


Hotel reception area
San Francisco CA

Source: LED Transformations

Good Ones & Bad Ones – Replacement lamps

Many LED replacement lamps on the market today don't match the lumen output of the incandescent lamps they are to replace

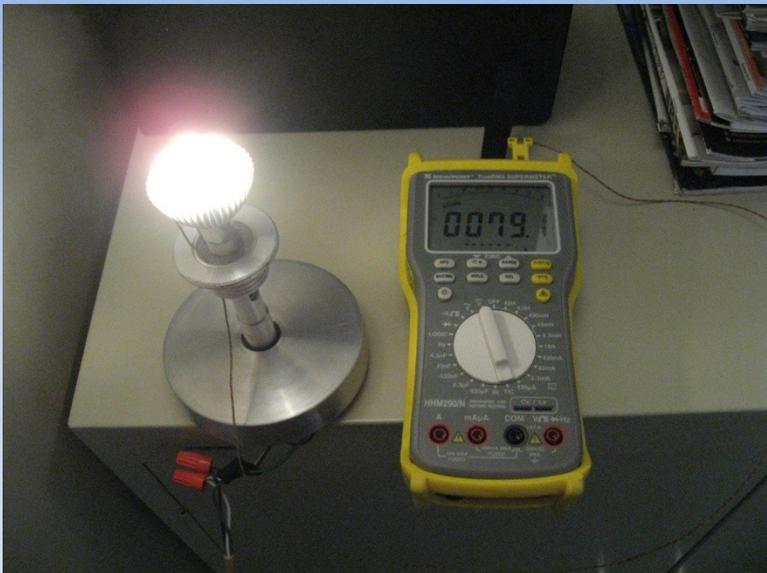


Source: Brodrick
L Prize Update Lightfair 2010

Lamp envelope limits the design of the LED system (i.e. heatsinks, optics, total output, etc.)

Good Ones & Bad Ones – Replacement lamps

Lamp performance highly dependent on application/environment



Open environment – $T_j = 79.1^{\circ}\text{C}$



Closed environment – $T_j = 97.4^{\circ}\text{C}$

Higher temperature results in lower light output and shorter life

Source: Michael Poplawski, PNNL

Good Ones & Bad Ones – Incandescent replacement lamps

And the winner is...

Wednesday, August 3, 2011 (for immediate release):

Washington, D.C. – The U.S. Department of Energy today announced that Philips Lighting North America has won the 60-watt replacement bulb category of the Bright Tomorrow Lighting Prize (L Prize) competition. The Department of Energy’s L Prize challenged the lighting industry to develop high performance, energy-saving replacements for conventional light bulbs that will save American consumers and businesses money.

Submitted in 2009, the Philips LED bulb successfully completed 18 months of intensive field, lab, and product testing to meet the rigorous requirements of the L Prize competition – ensuring that performance, quality, lifetime, cost, and availability meet expectations for widespread adoption and mass manufacturing. If every 60-watt incandescent bulb in the U.S. was replaced with the 10-watt L Prize winner, the nation would save about 35 terawatt-hours of electricity or \$3.9 billion in one year and avoid 20 million metric tons of carbon emissions.



Source: Philips web site

	L Prize Requirement	Philips Result (average for 200 units)
Luminous flux (lumens)	> 900 lm	910 lm
Wattage (W)	≤ 10 W	9.7 W
Efficacy (lm/W)	> 90 lm/W	93.4 lm/W
Correlated color temperature (CCT)	2700 – 3000 K	2727 K
Color rendering index (CRI)	> 90	93

Source: DOE Lprize FAQs

Good Ones & Bad Ones – L Prize real world assessments



Lodging



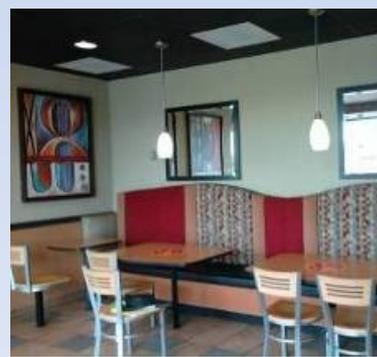
Retail



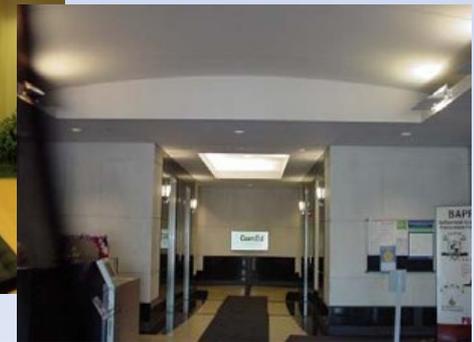
Residential



Restaurant

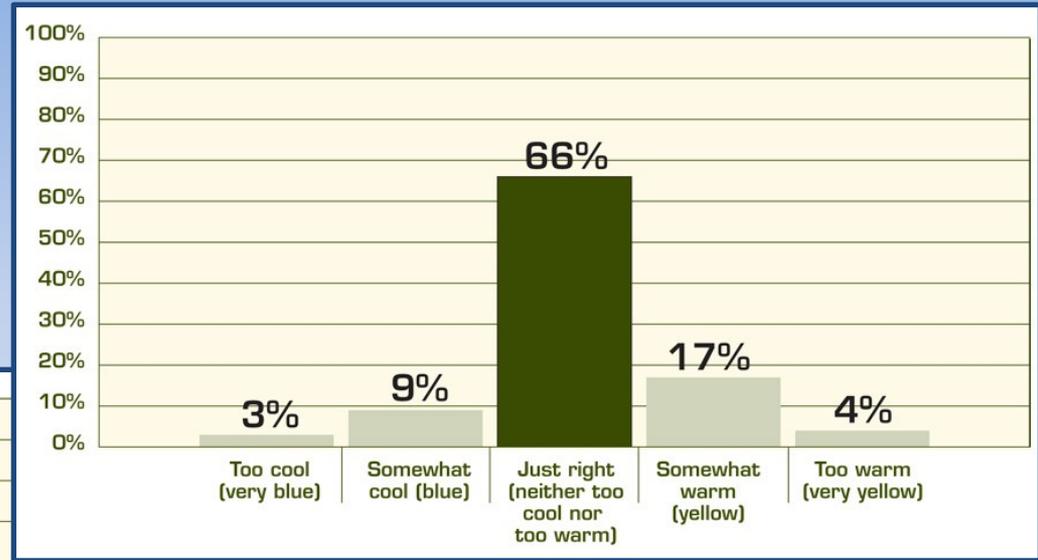


Office

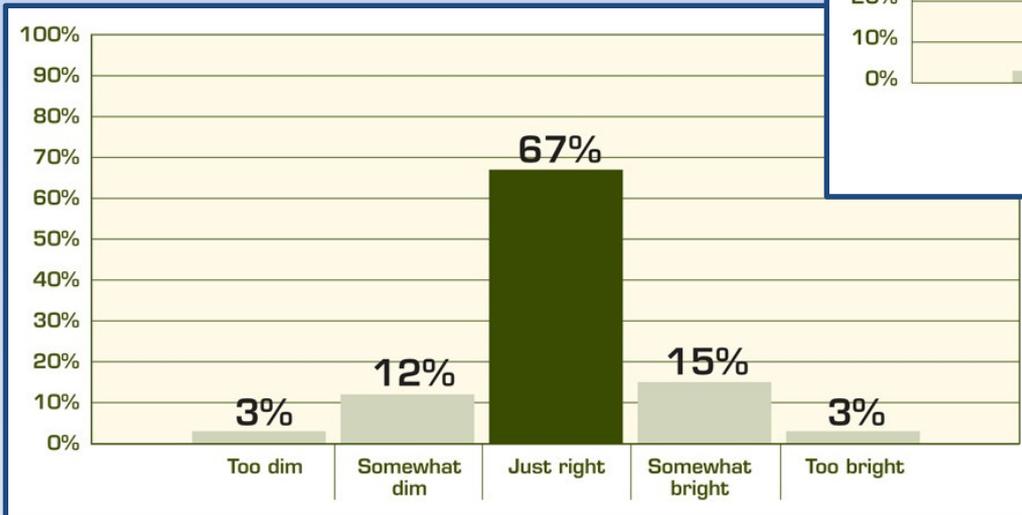


Good Ones & Bad Ones – L Prize real world assessments

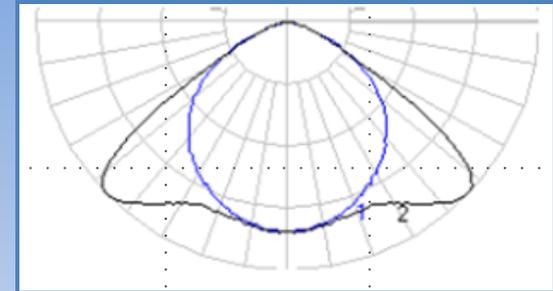
Is the color of the lighting too cool (blue) or too warm (yellow)?
1,237 responses



Is the lighting too dim? Too bright? Just right?
1,239 responses



Fluorescent Replacements – Depends



2x4 parabolic louver
Fluorescent T8

0.92 LLD

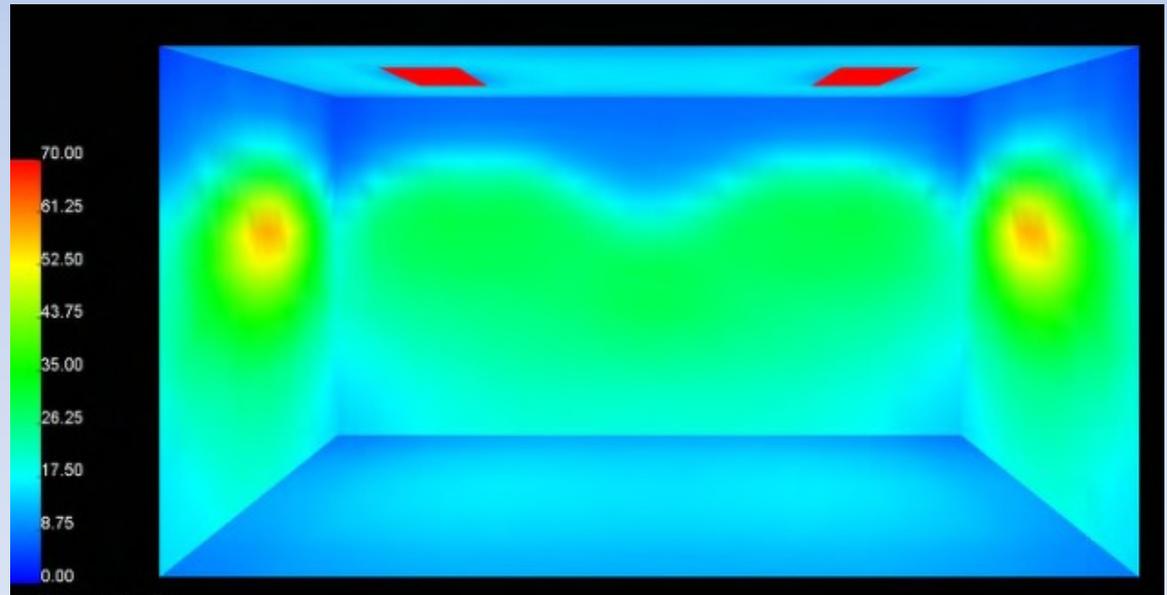
0.95 LDD

0.88 BF (n/a)

0.65 W/ft²

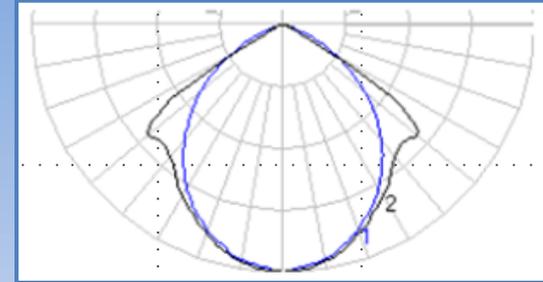
25 fc (average)

1.9 max/min



Source: Tuenge & Myer, DOE PNNL

Fluorescent Replacements – Depends



2x4 parabolic louver
LED Replacements

0.70 LLD

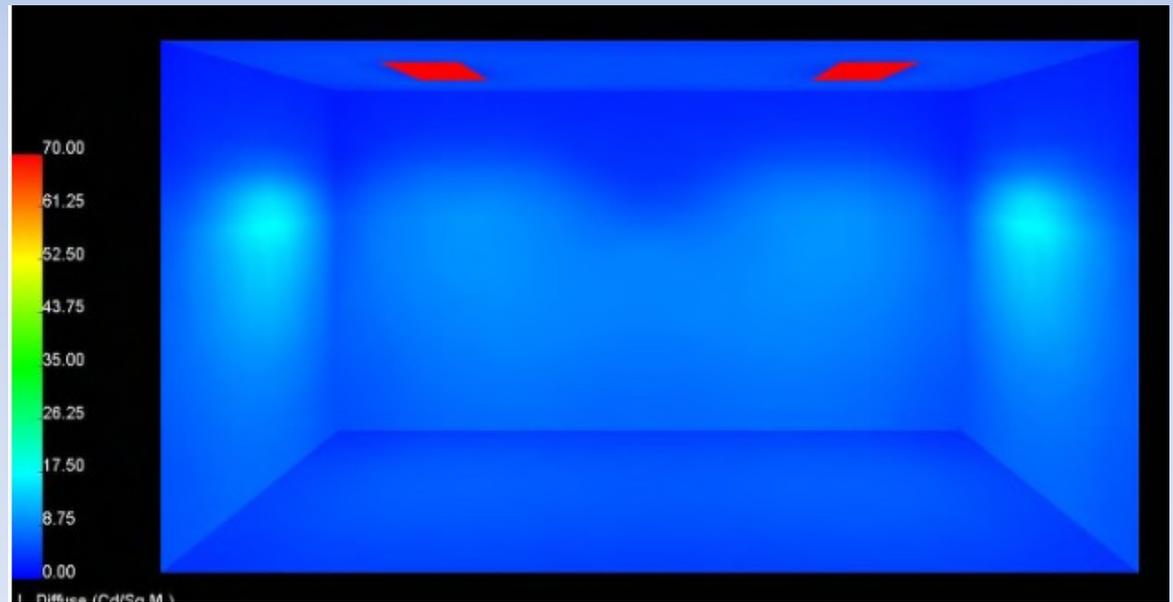
0.95 LDD

1.00 BF

0.44 W/ft²

10 fc (average)

2.3 max/min



Source: Tuenge & Myer, DOE PNNL



1. LED Technology: Advantages; Differences; Limitations
2. LED Lifetimes: Not so simple anymore
3. Obsolescence and Equivalence: Source of major confusion
4. LED Applications: The good and not-so good
- ➔ 5. Architects & Lighting Designers: What's important
6. Rules of Thumb: Common sense helps

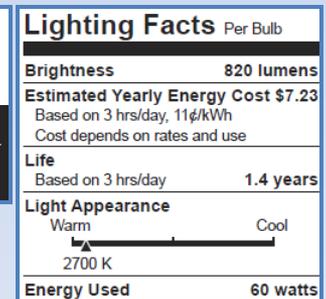
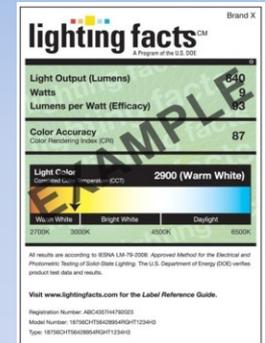


Another Way – Lighting Facts Labels

Don't trust a single data sheet without backup

- IES files match shipped product performance
 - If data is based on a “one of a kind” sample, lighting performance will most likely be deficient when facility is completed
- Lighting Facts™ Labels
 - Provide assurance that product will perform as specified
 - Required lamp label from Federal Trade Commission¹
 - Optional label from Dept. of Energy
- LM-79 luminaire third party test data
 - Acts as a double check even for high quality luminaire manufacturers

DOE Label
for luminaires



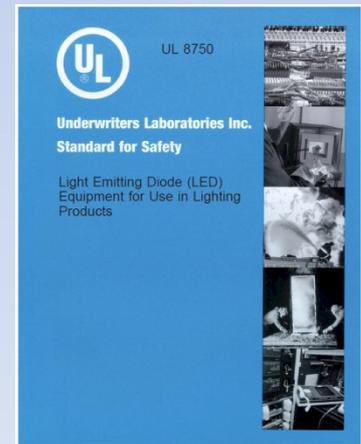
FTC Labels
for lamps
(front/back)

¹FTC Labeling takes effect January 2012

Standards – Agency Listings (US)

Underwriters Laboratories, one of the major safety listing agencies in the United States, has spent considerable effort trying to understand how to evaluate and list LED equipment and LED-based luminaires.

- Originally LED luminaires were tested under 1598 as incandescent lamps
- New 8750 Outline of Investigation “Light Emitting Diode (LED) Light Sources for Use in Lighting Products” was issued in January 2007
- Converted to Standard 8750 “Light Emitting Diode (LED) Equipment for Use in Lighting Products” was issued in November 2009
- LED drivers are covered by UL 8750, but can also be listed (as appropriate) under:
 - UL 1012 – Power units other than Class 2
 - UL 1310 – Class 2 Power units
 - UL 61950-1 – The Standard for Information Technology Equipment
Part 1: General Requirements, UL 60950-1
- UL 8750 requirements supplement existing end-product requirements

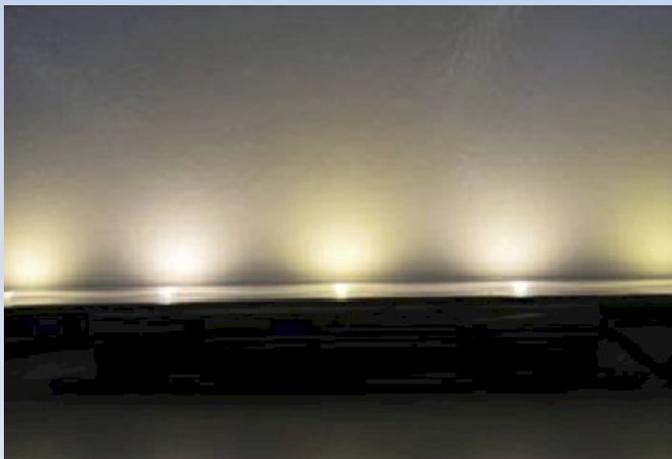


Items of Importance – Color consistency

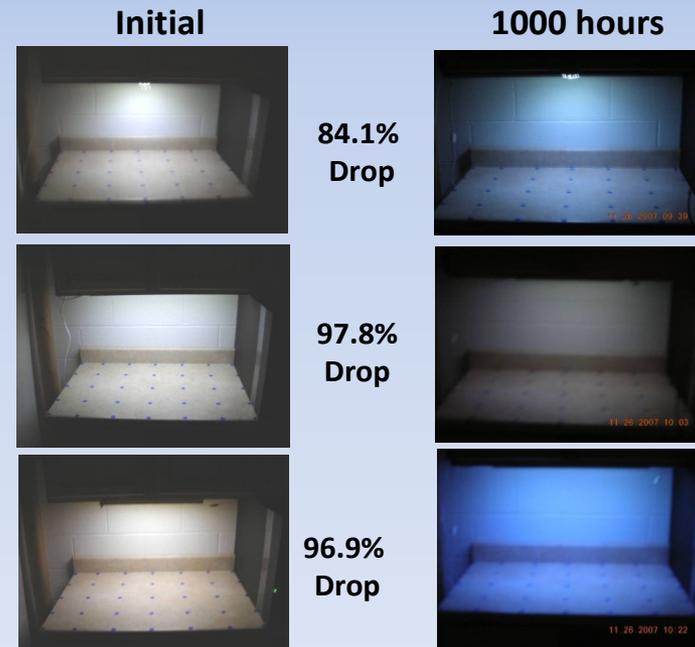
Color changes can be a major issue

Is an issue due to binning which occurs with LED production as well as color shift due to phosphor/die changes over time

- Unit to unit
- Purchase to purchase



Source: Cree



One Way to Determine What's Good - CALiPER

The DOE CALiPER program supports testing of a wide array of SSL products available for general illumination, using industry-approved test procedures. CALiPER test results:

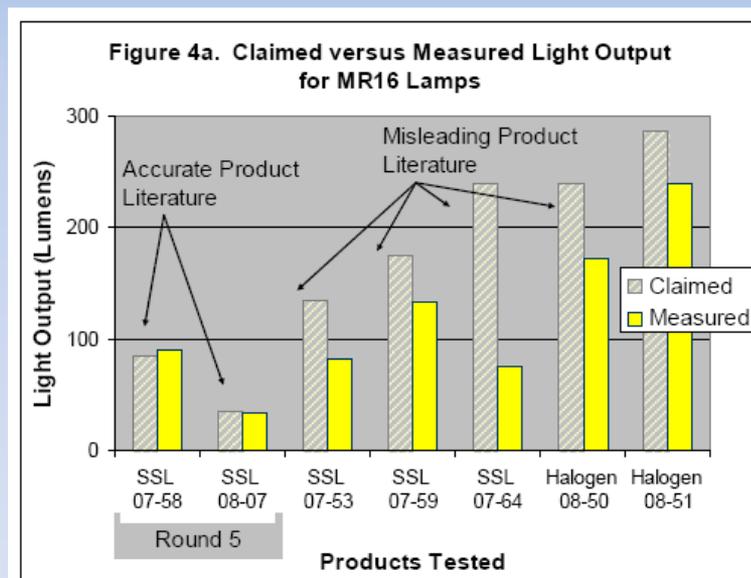
- Guide DOE planning for SSL R&D and market LED Technology activities, including ENERGY STAR[®] program planning
- Support DOE GATEWAY demonstrations and technology procurement activities
- Provide objective product performance information to the public in the early years, helping buyers and specifiers have confidence that new SSL products will perform as claimed
- Guide the development, refinement, and adoption of credible, standardized test procedures and measurements for SSL products

CALiPER – MR-16 Example

- Dozens of manufacturers are offering LED replacements for halogen MR-16 lamps.
- Many of these claim to be “equivalent” to 35W or 50W halogen lamps. However...

“In CALiPER testing to date, the performance of LED MR16 replacement lamps varied greatly. Power usage for the LED replacements is considerably lower than for halogen MR16 lamps. However, light output and intensity for the tested LED products falls significantly short of the halogen benchmark levels, limiting the usefulness of LED MR16 lamps as a one-for-one replacement in typical highlighting and accent applications.”

Source: CALiPER Benchmark Report Nov. 2008



CALiPER – Replacement Lamps

Results from Round 9 CALiPER testing (October 2009) show that a large number of LED product manufacturers are still not providing accurate performance data

Table 4. CALiPER ROUND 9 – Replacement Lamp Manufacturer Claims

Sample Type and CALiPER Reference	Manufacturer Claims	Actual Performance Level (e.g. Light Output, Efficacy, CBCP, Beam Angle)	Provides Accurate Product Reporting	
Replacement Lamp (MR16) 09-80	<i>180 lm, (54-69 lm/W) Eq. to 35W halogen</i>	165 lm, 50 lm/W 304 cd, 31° Less than average 20W halogen	NO	
Replacement Lamp (R20) 09-78	230 lm, (32 lm/W) 7W=35W	263 lm, 42 lm/W 944 cd, 25° Exceeds average 35W halogen	YES	
Replacement Lamp (R30) 09-64	<i>Replaces 45W (450 lm, 128 lm/W) CRI=84, 30° beam</i>	186 lm, 54 lm/W CRI=71, 695 cd, 20° Less than 20W eq.	NO	
Replacement Lamp (PAR30) 09-76	<i>Eq. to 75W Incand. 550 lm, 70 lm/W 60-70° beam</i>	468 lm, 59 lm/W 190 cd, 100° Eq. to 50W R30	NO	
Replacement Lamp (PAR38) 09-63	<i>Replaces 45W (450 lm, 90 lm/W)</i>	289 lm, 58 lm/W 902 cd, 22° Less than 25W eq.	NO	
Replacement Lamp (A-lamp) 09-60	260 lm, (34.6 lm/W) <i>Replaces 40W incandescent</i>	251 lm, 34 lm/W Eq. to 25W incandescent	NO	
Replacement Lamp (A-lamp) 09-77	155 lm, (22 lm/W) Eq. to 25W	208 lm, 33 lm/W Eq. to 25W incandescent	YES	
Replacement Lamp (Candelabra) 09-65	<i>Replaces 40W (320 lm, 220 lm/W)</i>	67 lm, 45 lm/W Less than average 15W incandescent	NO	
Replacement Lamp (Candelabra) 09-74	30 lm, (12 lm/W) "Uses less energy than a 15W candelabra"	31 lm, 17 lm/W Eq. to 7-15W night light	YES (possibly misleading)	

CALiPER results are available at:

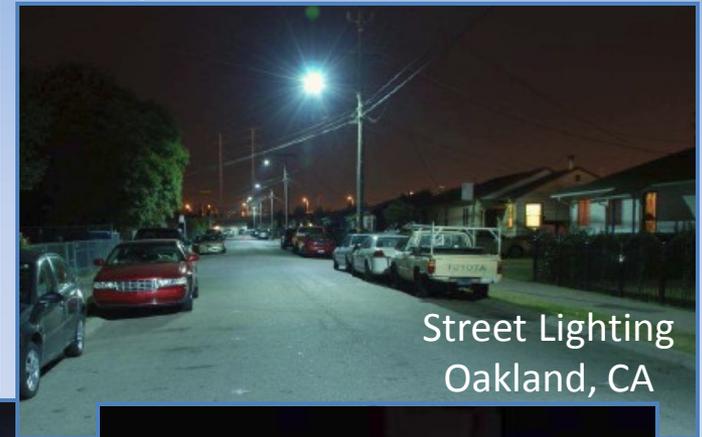
<http://www1.eere.energy.gov/buildings/ssl/caliper.html>

Gateway Program – Demonstrations in Various Applications

Demonstrations showcase high-performance LED products for general illumination in a variety of commercial and residential applications. Results provide real-world experience and data on state-of-the-art solid-state lighting (SSL) product performance and cost effectiveness.



Downlights Lane City Tour of Homes
Eugene, OR



Street Lighting
Oakland, CA



Freezer Case Lighting
Albertsons, Eugene OR



Raley's Supermarket
West Sacramento, CA



FAA Research Center
Atlantic City, NJ

Cost – Can upset traditional lighting distribution channels

A few mark-ups along the way

- ROI dependent of end user cost
 - Distribution chain markups can have a major effect on cost to building owners, particularly for higher cost LED-based products



- Utility rebates can make a major difference in ROI
 - Some utilities reluctant to provide rebates due to uncertainty in expected lifetime and luminaire efficiency performance
 - Energy Star ratings provide some assurance to utilities
 - Other review bodies such as Design Lights Consortium



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Questions You Should Ask Your Suppliers

1. Temperature range specification for operation
 - How does that compare with the maximum junction temperature for the LEDs used in the product?

2. Luminaire manufacturer
 - How long has the manufacturer been in business? What business?
 - Does the firm use brand name LEDs?
 - Were the LEDs tested to LM-80?

3. Warranty
 - Life expectancy of product (Energy Star requires at least a 3-year warranty)
 - What replacement costs are covered (e.g. installation labor, shipping, etc.)
 - What performance elements are warranted (e.g. CCT shift, lumen output, luminaire efficiency, etc.)



Questions You Should Ask Your Suppliers

4. Power Issues

- Power Factor
- Off-state power consumption (Energy Star requires $< 0.5W$)
- Is the unit dimmable? With what controllers?
- Step-down transformer compatibility for low-voltage retrofit products

5. Does it have a UL / ETL / CSA / applicable safety mark?

6. Chromaticity

- Shift over time/temperature
- Variation from fixture to fixture

7. Luminaire performance

- Fixture efficiency (in lumens/Watt)
- Delivered lumens (not just LED device performance)
- IES files
- LM-79 test results from approved third party laboratory
- Lumen maintenance

And Don't Forget...

Do not underestimate the use and practical application of simple
COMMON SENSE ¹

- If it seems too good to be true, it probably is
- If you can't understand how a product could do "that," there is a high likelihood that it probably "doesn't"
- If nobody else's product does "that" maybe this product does not do it either

¹ Requires ownership of at least a limited quantity

Which lamp would perform better? →



Where are LED-Based Products Appropriate?

- Outdoor area & street lighting
- Downlighting
- Task lighting
- Display lighting
- Cove lighting
- “Architainment” environments
- Other applications that make use of LED’s unique attributes
 - Small size
 - Directionality
 - Low temperature performance
 - Improved secondary optics performance due to die size



Source: Kelly Gordon, PNNL



A Lesson From History

- Think of how the microprocessor has changed the world over the last 30 years.



- The lighting world is about to undergo a change not seen since the invention of the incandescent lamp, and driven by that same semi-conductor industry.

Are you going to be ready for it?



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U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy



Questions?

Thank You

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