Solid-State Lighting
The New Basics

2013 DOE Solid-State Lighting Market Introduction Workshop

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On behalf of the U.S. Department of Energy
and NETL Morgantown
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The five stages of Solid-State Lighting

• Introducing LEDs – What do you mean they get hot?
• How to use LEDs – Where can I stick ‘em?
• Lighting Controls – Just when you thought things couldn’t get any more confusing
• OLEDs – Is that a typo?
• Wow! – Unimagined uses for solid-state lighting technology
TECHNOLOGY EVOLUTION

LEDs Lighting Market Share – Growing in all segments

LEDs continue to follow Haitz’s Law

Haitz’s Law

Red Output (in lumens/device)
White Output (in lumens/device)
Red Cost (in $/lumen)
White Cost (in $/lumen)
Output Trend
Cost Trend

Source: Roland Haitz & Lumileds

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The Culture Wars – Something new to the lighting industry

LEDs grew up in the semi-conductor world, where change is king; Lighting practices have slowly evolved over time

- Testing Standards
- Obsolescence
- Rapid Evolution of Products

Versus

- Limited Testing
- Long Product Cycles
- Slow Style Changes
There is much discussion on light trespass, light pollution, etc.

The typical view is that light cut-off is desirable for many applications.

LEDs allow cut-offs that are not possible with other light sources.

Sometimes, that exact cut-off is not what people really want.
Critical to Remember — A Luminaire is a System

The failure of any one component can cause the entire system to stop functioning.
Why do We Care – Longer life = greater payback

Where are the savings for LED lighting?

The longer the life difference, the greater the savings for the LED light source

LED Savings

Total Cost

5 X’s longer life

4 X’s longer life

Breakeven¹ (3X’s longer life)

Initial Fixture Cost
Energy Costs
Replacement and maintenance costs (source + labor)

Operating Time

Traditional Source
LED Source

¹Note: breakeven is a function of a number of parameters
Temperature vs. ROI? – Warmer ambient $\Rightarrow$ shorter lifetime

The higher the junction temperature, the shorter the lifetime, resulting in a lower ROI

<table>
<thead>
<tr>
<th>Temp</th>
<th>L70 Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>55°C</td>
<td>130,416</td>
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<tr>
<td>85°C</td>
<td>84,703</td>
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<tr>
<td>105°C</td>
<td>57,004</td>
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</table>

Source: Lumileds (Rebel)
Standards – Help manage the risks

- **LM-79-08**  *Approved Method: Electrical and Photometric Measurements of Solid-State Lighting Products*
  - Describes testing procedure for evaluating light 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

- **TM-21-11**  *Projecting Long Term Lumen Maintenance of LED Light Sources*
  - Provides the method for determining when the “useful lifetime” of an LED is reached

- **ANSI C78.377-2011**  *Specifications for the Chromaticity of Solid-State Lighting Products*
  - Describes binning structure to specify LED colors
The defined color bins with a range of 7 MacAdam ellipses for each bin are too large, in many people’s opinion, and need to be tightened.
Color Shifts – Can change in many directions

Results of DOE CALiPER testing from 2008 thru 2010 shows color shifts after 6000 hours of operation (black) and 12,000 hours (red)

Shift to blue

Shift to yellow
Timeline for a new LED-based product

LM-80 Testing (To claim 50k hours) → LDL

LM-80 Testing (minimum) → Design → Tooling → Pilot → LF → LDL

Agency

LF = Lighting Facts
LDL = Lighting Design Lab, Energy Star or Design Lights Consortium
★ = Market Release

LED Mfg Introduces new LED

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Testing Time/Temperature – Can have a drastically different effect

When you speed things up

21 days at 37.5°C

3 minutes at 70°C
How about this one?

Source: Philips-Gardco
Luminaire Evolution – Which tube is the LED version?

Something completely different

Source: GE Lighting
Replacing the lightbulb – Makes sense in some cases

Replacing 2 billion sockets in a short period of time might not make economic sense for now
Number of LightingFacts Products Listed by Quarter

- Replacement Lamp – Other
- Replacement lamp - Omnidirectional (A Lamp)
- Replacement lamp - Linear T8/T5/T12 tube
- Replacement Lamp - Directional (R38, PAR38)
- Replacement Lamp - Directional (R30, PAR30)
- Replacement Lamp - Directional (R20, PAR20)
- Replacement Lamp - Directional (Other)
- Replacement Lamp - Directional (MR16)
- Replacement lamp - Decorative
Lighting Evolves

Luminaire Evolution – Replacing the LED

A new lamp that uses OLDS rather than LEDs
Lighting Evolves

OLEDs in Niche Products — New form factors but high cost

Sources:
- Osram
- Blackbody (Astrom FIAMM)
- Philips Lumiblade
- Universal Display Corporation

Photo Credit:
©John Sutton Photography 2011
Lighting Controls – Are Light Switches destined for museums?

Turn off the light

From Wikipedia, the free encyclopedia

Turn off the light was a phrase used by previous generations to request that an electromechanical device known as a light switch (see Light Switch) was moved to a position that disrupted the flow of current to the types of light sources in use at that time. One of the most popular sources used during that period was the incandescent light bulb. An incandescent light bulb was a light source that produced illumination with a filament wire heated by a current passing through it until it glows (see Incandescence). Another was the fluorescent lamp which was a tube coated with a mixture of phosphors that were excited by photons given off by a gas which contained mercury (see Fluorescent Lamp). All of the light sources in use at that time offered poor efficiency as compared to the solid-state devices in use today.

During that period of human existence, building inhabitants were required to start and stop the sources of illumination for the spaces they entered or exited. They did this by moving the position of a switch (see Light Switch), often located on a wall near the entrance to a space. The switches were bipolar having only on and off states. Often these light sources were left on independent of the presence of occupants. The phrase Turn off the light was an admonition to an occupant to remember to move the switch to the off position when exiting the space. It was a particularly popular suggestion by parents to their children.

Early in the twenty-first century, a few states began to regulate their use, as the movement toward energy saving began to spread. The lack of lighting control was another major market driver that helped eliminate the light switch. Eventually the Federal Government placed severe performance restrictions on their use with the passage of Pub. L. 99-514. Today these light switches can only be seen in museums and some private collections. With the phasing out of these light switches, the use of the phrase Turn off the light has fallen out of the popular vernacular.

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3 Efficiency and environmental impact
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   3.2 Measures to ban its use
   3.3 Efforts to improve efficiency
4 Construction
5 Manufacturing
A demonstration of outdoor LED lighting was conducted at Nike’s corporate offices also under the DOE’s Gateway program.

Since LEDs have no restrike time and are easy to turn on/off motion sensors were incorporated into the testing.

During months of testing the outdoor fixtures would turn on and off unexpectedly. This issue seemed to increase on windy days.

Finally someone traced the problem to leaves on the trees moving in the wind in front of the motion sensors.
Sensors – Typical sensor ranges for IR/ultrasonic types

Source: Efficiency Maine
Lighting Controls – Off saves more than on

Annual Energy Usage
(in kWh/yr/fixture)

- Original HPS (w/ballast)
- LED Product (no controls)
- LED Product 10 minute turn-off delay
- LED Product 2.5 minute turn-off delay

Source: Gateway Report, “Use of Occupancy Sensors in LED Parking Lot and Garage Applications: Early Experiences” 10/12
Trustwave Holdings, an e-security firm, published an advisory notice last week warning Satis smart toilet owners that their toilets could potentially get hacked.

“Attackers could cause the unit to unexpectedly open/close the lid, activate bidet or air-dry functions, causing discomfort or distress to user,” Trustwave Holdings said in its notice.
Lighting For Activities – An example from the aviation industry

Lighting Scenes from the Boeing 787 Dreamliner

- Boarding
- Cruise
- Relaxation
- Meal Service
- Sleep
- Prelanding

Source: Boeing
Imagine an office system that recognizes what tasks its occupant is performing, the time of day, the ambient lighting environment, what his/her lighting preferences are, what type of mood to set, etc.

Or imagine light bulbs that light a home based on what its occupants are wearing.
A 50% reduction in energy usage due to lighting changes represents a 0.6% decrease in lifecycle operating costs, while a 1% decrease in office worker performance represents a 0.9% increase in lifecycle operating costs. Do the math!
Lifecycle Operating Costs — An example

Reno Nevada Main Post Office

A $300,000 renovation in the facility’s lighting system, produced a little over $50,000 annual savings ($22,400 in direct energy savings and $30,000 in reduced maintenance)

That same renovation resulted in major reductions in operator errors (to 0.1%) as well as a 6% improvement in employee productivity which was worth an additional $400,000 annual savings
Thank You

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