Energy Savings Impact of SSL

01/24/2017
Warren Weeks
Director, Innovation & Technology

Thanks to:
Chris Bailey
Scott Ziegenfus
The LED is the first commercially viable light source not based on a vacuum tube since the invention of the electric light in 1879.

The solid-state lighting revolution began in 2006.
Evolution of the LED

55 Year History

• 1962 First practical red LED invented on October 9 by Nick Holonyak (GE)
• 1971 “Blue” GaN MIS-LED demonstrated (Pankove)
• 1972 Yellow, red, and red-orange improved 10X by George Craford (HP)
• 1989 P-type GaN created by LEEBI (Nagoya University) – Akasaki, Amano, Hiramatsu
• 1991 High quality p-type GaN grown; first pn-junction GaN LED (Nichia)
• 1992 Short-lived ZnSe-CdZnSe blue laser developed (3M)
• 1993 Commercial “candela-class” blue GaN LEDs introduced by Shuji Nakamura (Nichia)
• 1995 Bright quantum-well blue and green LEDs introduced (Nichia)
• 1996 Room temperature nitride “blue” laser diode demonstrated (Nichia)
• 1997 US demonstrates room temperature “blue” laser diode (Cree)
• 2000 First large area LED chips (Lumileds)
• 2001 Surface roughening for improved light extraction (Taiwan)
• 2001 Patterned substrate technology for improved light extraction (Japan)
• 2004 SONY markets Blu-Ray (HD-DVD) players (23 GB/layer)
• 2005 Large area LED chips with roughened surfaced
• 2006 Solid-state lighting revolution begins
• 2016 Global SSL market nears $70B

2014 Nobel Prize
Hubbell Lighting

One Company, Distinct Brands
Lighting Brand Alignment

- Residential
  - Home Style Lighting
  - Progress Lighting
  - Loma Style Lighting

- Indoor Architectura
  - Alera
  - Prescolite

- Indoor Commercial
  - Columbia Lighting
  - Lintel

- Outdoor Architectura
  - Compass
  - Precision Paragon
  - Healthcare Solutions

- Outdoor Commercial
  - Hubbell Lighting
  - Norlux

- Controls / Components
  - Hubbell Control Solutions
  - Beacon
  - White Way
Operational Excellence

MANAGEMENT
3,900 Employees
10 States
United States, Canada, Mexico, Puerto Rico

MANUFACTURING
10 Plants
2.1 Million SF

DISTRIBUTION
8 Facilities
1.1 Million SF

- Corporate Headquarters
- Design & Service Center
- Regional Distribution Center
- Lighting Showroom
- Manufacturing
From Electrical to Electronics

Innovation
- Optical Design
- Electrical Design
- Thermal Design
- Source Technology

Applied Research
- Reliability
- Efficiency
- Durability
- Sustainability

Manufacturing
- Electronic Assembly
- Prototyping
- Quality Control
LED Sales Adoption

LED Sales %

- 2010: 0.0%
- 2011: 10.0%
- 2012: 20.0%
- 2013: 30.0%
- 2014: 40.0%
- 2015: 50.0%
- 2016: 60.0%
- YTD: 70.0%
- EST: 60.0%
Hubbell Adoption by Category

- Residential: 11%
- Troffer: 70%
- Industrial: 65%
- Outdoor: 69%
- Downlight: 83%
Conversion vs. Opportunity

Conversion of existing units

6% Conversion

94% Opportunity
### US LED Forecast Stock Results for SSL

**LED Installed Stock (million units)**

<table>
<thead>
<tr>
<th>Current SSL Path</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>424</td>
<td>2,740</td>
<td>5,500</td>
<td>7,040</td>
<td>7,860</td>
</tr>
<tr>
<td>Residential</td>
<td>136</td>
<td>436</td>
<td>826</td>
<td>1,080</td>
<td>1,220</td>
</tr>
<tr>
<td>Industrial</td>
<td>260</td>
<td>1,610</td>
<td>3,550</td>
<td>5,040</td>
<td>5,970</td>
</tr>
<tr>
<td>Outdoor</td>
<td>30</td>
<td>93</td>
<td>137</td>
<td>160</td>
<td>177</td>
</tr>
</tbody>
</table>

**LED Installed Stock Penetration (%)**

<table>
<thead>
<tr>
<th>Current SSL Path</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>6%</td>
<td>30%</td>
<td>59%</td>
<td>78%</td>
<td>86%</td>
</tr>
<tr>
<td>Residential</td>
<td>12%</td>
<td>36%</td>
<td>64%</td>
<td>80%</td>
<td>86%</td>
</tr>
<tr>
<td>Industrial</td>
<td>5%</td>
<td>28%</td>
<td>57%</td>
<td>77%</td>
<td>86%</td>
</tr>
<tr>
<td>Outdoor</td>
<td>8%</td>
<td>32%</td>
<td>65%</td>
<td>78%</td>
<td>83%</td>
</tr>
</tbody>
</table>

Source: US DOE EERE September 2016
Installed Projects for Lighting

Source: US DOE EERE September 2016
Current Energy Savings

Source: US DOE EERE July 2015
Why have energy codes?

- Reduce dependency on energy
- National Security
- Decrease pollution from energy production
- Increase wealth of the nation
- Overcome “split incentives”
  - *Builder does not pay energy bills*
  - *Landlord does not pay energy bills*
- Increase technological innovation
  - *Fuel injection, regenerative braking, CV transmission*
  - *High frequency ballasts, tri-phosphors, LEDs, controls…*
The Stakeholder Organizations

- EPAct 1992 / 2005
- ASHRAE 90.1
- EISA
- Energy Star
- DesignLights
- CEC Title 24
Emergency of a National Energy Policy

- All 50 U.S. States received funding through the American Recovery and Reinvestment Act of 2009.

- The terms for acceptance of these funds included agreement to put in place a commercial building energy code at least as stringent as ASHRAE 90.1-2010

- States are required to achieve at least 90 percent compliance with these codes by 2017.

Source: American Society of Heating, Refrigerating and Air-Conditioning Engineers
The United States Lighting Energy Policy is moving towards increased efficiency in order to lower greenhouse gas emissions and energy use.

- Lighting efficiency improvements in the United States can be seen through different standards and acts

- Tax incentive for energy efficient lighting (up to $0.60/ft²)
- For reductions 40% below ASHRAE/IESNA 90.1-2001 standards
- Expired on December 31st, 2013

**2007 Energy Independence & Security Act (EISA)**
- Phase out of incandescent lamps and standard MH lamps (>150W, <500W)

**2009 DOE Regulations**
- Phase out of 4-foot T12 lamps, some 4-foot T8 lamps and nearly all standard PAR38, PAR30 and PAR20 lamps
CA Title 24 2013 (Effective 2014)
- Outdoor lighting controls (clock & motion), glare & uplight, interior commercial dimming & controls, retrofit compliance triggers (50% down to 10%) and >40% lamp/ballast replacement
- In the 2008 standard, the word “control” occurs 594 times between the indoor and outdoor lighting manuals (200 pages)

Energy Star
- Minimum luminaire performance (electrical & photometric) and light quality (CRI, etc.). Varies by luminaire category
- Primarily residential consumer focus

Design Lights Consortium (DLC)+ Lighting Facts
- Minimum luminaire performance (electrical & photometric) and light quality (CRI, etc.). Varies by luminaire category
- Primarily commercial consumer (building owner & operator) focus
- In most cases, a requirement for utility incentives
## DLC Technical Requirements Table V4.1 (11/01/2016)

<table>
<thead>
<tr>
<th>#</th>
<th>Category</th>
<th>General</th>
<th>Minimum Light Output (lm)</th>
<th>DLC Standard</th>
<th>DLC Premium***</th>
<th>Requirements</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Application</td>
<td></td>
<td>Minimum Efficacy (lm/W)</td>
<td>Minimum Warranty (years)</td>
<td>Minimum Efficacy (lm/W)</td>
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<tr>
<td>10</td>
<td>Outdoor Retrofit Kit</td>
<td>Outdoor – Low Output</td>
<td>250-5,000</td>
<td>90</td>
<td></td>
<td>110</td>
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<tr>
<td>11</td>
<td>Outdoor Retrofit Kit</td>
<td>Outdoor – Mid Output</td>
<td>5,000-10,000</td>
<td>95</td>
<td>5</td>
<td>115</td>
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<tr>
<td>12</td>
<td>Outdoor Retrofit Kit</td>
<td>Outdoor – High Output</td>
<td>≥10,000</td>
<td>100</td>
<td>5</td>
<td>120</td>
</tr>
<tr>
<td>13</td>
<td>Outdoor Retrofit Kit</td>
<td>Outdoor – Very High Output*</td>
<td>≥30,000</td>
<td>100</td>
<td>5</td>
<td>120</td>
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<tr>
<td>14</td>
<td>Indoor Retrofit Kit</td>
<td>Troffer</td>
<td>≥21,500</td>
<td>100</td>
<td>5</td>
<td>125</td>
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<tr>
<td>15</td>
<td>Indoor Retrofit Kit</td>
<td>Linear Ambient</td>
<td>≥375 lm/ft</td>
<td>105</td>
<td>5</td>
<td>130</td>
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<tr>
<td>16</td>
<td></td>
<td>High-Bay</td>
<td>≥25,000</td>
<td>105</td>
<td>5</td>
<td>130</td>
</tr>
</tbody>
</table>

* Retrofit Kits for Fuel Pump Canopy Luminaires

** Retrofit Kits for Outdoor Full-Cutoff Wall-Mounted Area Luminaires

*** Retrofit Kits for Parking Garage Luminaires

**** Retrofit Kits for Fuel Pump Canopy Luminaires

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The Lighting Solutions Center

Hubbell Lighting
Rising Cost of Energy

Retail Price of Electricity in Commercial Sector, U.S. Average

U.S. Electricity Summary

<table>
<thead>
<tr>
<th>Sector</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
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<tbody>
<tr>
<td>Residential</td>
<td>11.72</td>
<td>11.88</td>
<td>12.02</td>
<td>12.25</td>
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<tr>
<td>Commercial</td>
<td>10.23</td>
<td>10.12</td>
<td>10.30</td>
<td>10.45</td>
</tr>
<tr>
<td>Industrial</td>
<td>6.82</td>
<td>6.70</td>
<td>6.82</td>
<td>6.93</td>
</tr>
</tbody>
</table>

Source: Short-Term Energy Outlook
Population Growth

313.9 million (2012)
United States of America, Population

- United States of America: 313.9 million
- Russia: 143.5 million

Source: World Bank

Since 1950

+206%
Electrical Energy Production by Source

- Fossil Fuel: 68%
- Nuclear: 19%
- Hydro: 7%
- Other: 5%

Source: U.S. Energy Information Administration
40% of primary energy
71% of electrical energy
Lighting uses more energy in commercial buildings than any other appliance (U.S. DOE)
32.6% site energy savings
energy cost savings
# Lumen Power Density Requirements (W/ft²)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>1.26</td>
<td>1.3</td>
<td>1.0</td>
<td>0.90</td>
<td>0.82</td>
<td>-18%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>0.96</td>
<td>2.2</td>
<td>1.3</td>
<td>1.11</td>
<td>1.17</td>
<td>-10%</td>
</tr>
<tr>
<td>School/University</td>
<td>1.29</td>
<td>1.5</td>
<td>1.2</td>
<td>0.99</td>
<td>0.87</td>
<td>-27.5%</td>
</tr>
<tr>
<td>Retail</td>
<td>2.25</td>
<td>1.9</td>
<td>1.5</td>
<td>1.4</td>
<td>1.26</td>
<td>-16%</td>
</tr>
<tr>
<td>Warehouse</td>
<td>1.03</td>
<td>1.2</td>
<td>0.80</td>
<td>0.66</td>
<td>0.66</td>
<td>-25%</td>
</tr>
<tr>
<td>Parking Garage</td>
<td>1.03</td>
<td>0.30</td>
<td>0.30</td>
<td>0.25</td>
<td>0.21</td>
<td>-30%</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>1.44</td>
<td>1.6</td>
<td>1.0</td>
<td>0.87</td>
<td>0.90</td>
<td>-10%</td>
</tr>
</tbody>
</table>

Lighting Power Densities Using the Building Area Method
Lumen Power Density Requirements (W/ft²)

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>1.3</td>
<td>0.82</td>
<td>-37%</td>
<td>0.79</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>2.2</td>
<td>1.17</td>
<td>-47%</td>
<td>0.9</td>
</tr>
<tr>
<td>School/University</td>
<td>1.5</td>
<td>0.87</td>
<td>-42%</td>
<td>0.81</td>
</tr>
<tr>
<td>Retail</td>
<td>1.9</td>
<td>1.26</td>
<td>-34%</td>
<td>1.06</td>
</tr>
<tr>
<td>Warehouse</td>
<td>1.2</td>
<td>0.66</td>
<td>-45%</td>
<td>0.48</td>
</tr>
<tr>
<td>Parking Garage</td>
<td>0.30</td>
<td>0.21</td>
<td>-30%</td>
<td>0.15</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>1.6</td>
<td>0.90</td>
<td>-44%</td>
<td>0.82</td>
</tr>
</tbody>
</table>

Lighting Power Densities
Using the Building Area Method
Current State Adoption

Commercial Buildings

The Lighting Solutions Center
HUBBELL Lighting
Receptacle (wall plug) Control
Requires that 50% of receptacles (in a space have automatic shutoff control)

- Applies to 125 volt 15 and 20 Amp receptacles in private offices, open offices, computer classrooms
- Requires automatic control using:
  - Time of day schedule
  - Occupancy Sensor
  - Other auto control based on occupancy
- Exceptions:
  - Spaces where automatic shutoff would be a safety/security issue
  - Spaces where all loads require 24 hour operation

ASHRAE requirements for projects designed after December 20, 2013
“Bi-level” Space Lighting Control

Requires that manually controlled lighting have at least one control step between 30% and 70% of full lighting power, in addition to off (0%)

- Exceptions:
  - Lights in corridors, Electrical/mechanical rooms
  - Public Lobbies, Restrooms,
  - Stairways, Storage Rooms
  - Spaces with only one luminaire with rated input power less than 100W
  - Space types with a lighting power allowance of less than 0.6W/ft²

- Could include Bi-level switching or dimming

ASHRAE requirements for projects designed after December 20, 2013
Complying with ASHRAE/IES 90.1-2013

Automatic Lighting Shutoff
Automatic shutoff of all building lighting when not needed

- Intended to mean EVERYTHING including “night lights” considered part of egress lighting
- Compliance by one of three methods:
  - Time of day schedule
  - Occupancy Sensor
  - “a signal from another control or alarm system…”

ASHRAE requirements for projects designed after December 20, 2013
Manual-on Requirement

Automatic control devices shall not be set to Automatically turn the lighting on

- Manual “ON” or auto-ON-to-50%
- Exemptions:
  - Public Corridors
  - Stairwells
  - Restrooms
  - Others…
- Automatic exemption removed for buildings less than 5,000ft²

ASHRAE requirements for projects designed after December 20, 2013
Vacancy Sensor Control
Sensor control in specific spaces

- Conference/meeting rooms and training rooms
- Classrooms and lecture halls
- Employee and lecture halls
- Storage/supply rooms between 50ft² and 1000ft²
- Rooms used for document copying and printing
- Dressing/locker rooms and Fitting room
- Office spaces up to 250ft²
- Restrooms

ASHRAE requirements for projects designed after December 20, 2013
Mandatory Lighting Control Requirements

Automatic Bi-level Switching or Dimming Required

Stairwell  Outdoor Area  Parking Garage

Source: Lighting Controls Association
Stairwell 50% Reduction

Stairwell lighting must have automatic shutoff control

- Applies to lighting enclosed stairwells
- Must have control to automatically reduce lighting power in any control zone by at least 50% within 30min of all occupants leaving zone

ASHRAE requirements for projects designed after December 20, 2013
Parking Garage Control

Parking garage lighting must be automatically controlled including daylighting

- Reduce lighting power by 30% or more when no occupancy is detected in lighting zone
  - Lighting zone must be ≤3,600ft²
- Daylight transition zone lighting (66ft wide by 50ft) must be separately controlled for eye adaption
- Daylight control required for lights within 30ft of perimeter wall with net opening to wall ratio of 40%
- There are some exemptions

ASHRAE requirements for projects designed after December 20, 2013
Advanced Exterior Lighting Control
Requires specific daylight and building operation lighting controls for exterior

- Lighting must be off during daylight conditions
- Building façade/landscape lighting must be off from closing or midnight (whichever comes first)
  - Remain off until 6am or opening
- Other lighting including advertising signage, shall be automatically reduced by at least 30% either afterhours or when area is unoccupied

ASHRAE requirements for projects designed after December 20, 2013
Complying with CA Title 24 2013 Efficiency Standards
Complying with CA Title 24 2013 Efficiency Standards

**DAYLIGHT STATE**
- FIXTURE OFF
- Controlled by a photocontrol or outdoor astronomical time-switch control that automatically turns OFF the outdoor lighting when daylight is available.

**NIGHT STATE (UNOCCUPIED)**
- FIXTURE ON; Reduced State
- Shall be capable of automatically reducing the lighting power of each luminaire by at least 40 percent but not exceeding 80 percent.

**NIGHT STATE (OCCUPIED)**
- Motion sensors or other lighting control systems that automatically controls lighting.
- Shall employ auto-ON functionality when the area becomes occupied.
The Emergence of Daylighting
Complying with ASHRAE/IES 90.1-2013

• Require the automatic control of electric lighting when sidelighting is available
• Applied based on “primary sided lighted area” exceeding 250 ft²
• Control is required for the general lighting over these areas
• Control must be multi-level photocontrol with two output levels
  • 0-35%
  • 50-70%
  • Continuous Dimming

Complying with ASHRAE/IES 90.1-2013
Daylighting Control

Several addenda that:
Comparing Lighting Upgrades

The scope can vary:

- Installing lighting controls & replacing lamps
- System-wide conversion to LED
According to UCLA’s survey of 129 commercial buildings ranging in size.

HVAC retrofit cost is 69% greater than lighting.
First-year Average Savings

According to UCLA’s survey of 129 commercial buildings ranging in size.

Year-1 HVAC savings is 50% greater than lighting.
Simple Payback

According to UCLA’s survey of 129 commercial buildings ranging in size.

HVAC payback is 66-250% longer than lighting.
According to UCLA’s survey of 129 commercial buildings ranging in size, lighting provides a 50-250% greater return on investment compared to HVAC.
Types of Lighting Solutions (New & Retrofit)

1. **Lowest Initial Cost (cheap, cheap, cheap)**
   - Typically shortest payback
   - Typically not the lowest wattage or most efficient
   - May suffer from near-sightedness
   - Short-term play
   - You get what you pay for…

2. **Greatest potential initial savings/earnings**
   - Could possibly be the lowest initial cost (energy & maintenance)
   - May not be optimized for lifetime expectations

3. **Best technical fit**
   - *Probably not the least expensive*
   - *May be the specified product*
   - *May include “off balance sheet” benefit*
SSL Lighting Revolution Continues

- Energy supply vs. demand
- Widespread expansion of energy policy
- Green Building and shift to Retrofit & Relight
- Rationalization of artificial lighting
- Advancement of daylighting
- Integration of high-level controls, automation and DR
- Emergence of new light sources
- Unlimited flexibility
- New questions posed regarding light and human health
Thank you! – Questions?

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