LED Lighting ...
What you need to know!

A webinar sponsored by: GE Lighting
LED Lighting ... What you need to know!

Today’s Presenters

Derek Publicover
GE Lumination
General Manager
PM and Marketing

Jim Benson
GE Lighting
Marketing Manager
Agenda

- LED basics and lingo
- Benefits and challenges of LED systems
- GE LED quality and reliability
- Questions you should ask
- Best applications - evolution
- GE LED solutions
- A look at the future ...
LED basics and Lingo

• A solid state light source (semiconductor diode)

• When an electrical charge is applied, light is generated from electronic transitions and released as a photon
## Benefits of LED systems

<table>
<thead>
<tr>
<th>Potential Benefits</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy savings</td>
<td>High efficiency 30-65+ LPW</td>
</tr>
<tr>
<td>Maintenance savings</td>
<td>Long life 20K-50K+</td>
</tr>
<tr>
<td></td>
<td>Robust – vibration resistant</td>
</tr>
<tr>
<td></td>
<td>Cool burning</td>
</tr>
<tr>
<td></td>
<td>Great operation in cold temperatures</td>
</tr>
<tr>
<td>Environment</td>
<td>High efficiency – low energy consumption</td>
</tr>
<tr>
<td></td>
<td>RoHS compliant, no heavy metals (Hg and Pb)</td>
</tr>
<tr>
<td>Improved lighting design</td>
<td>Controllability, flexible small packages</td>
</tr>
<tr>
<td></td>
<td>Point light source, optical precision</td>
</tr>
<tr>
<td>Reduced fading / spoilage of</td>
<td>Instant on, no warm up time</td>
</tr>
<tr>
<td>displayed merchandise/art</td>
<td>No UV / IR, low heat</td>
</tr>
</tbody>
</table>
Challenges of LED systems

- Many new lighting LED startups
- High variability from system to system
- Color consistency
- Cost of light vs. some of today’s efficient light sources ... inadequate paybacks
- High cost of white light
- Thermal management, heat sinks required
- Confusion over evolving standards
- Performance Claims
Standardization Activities ... US SSL

- DOE
  - “CALiPER”
  - Workshops
- EPA
  - NGLIA
  - “ASSIST”
- Energy Star Requirements
  - NGLIA
  - DOE
  - EPA
- ANSI/IESNA WG
  - Standards
    - C78.377
    - Other
  - Measurements
    - LM-79
    - LM-80
- UL
  - Safety
    - TM-21
    - Other
- UL
  - Safety
    - TM-21
    - Other

Other

DOE
EPA
NGLIA
“ASSIST”
Workshops
Energy Star Requirements
Standards
Measurements
Safety
C78.377
LM-79
LM-80
TM-21
Other
Life Claims

**Poor quality LED systems**

- Uses LED manufacturers life claim qualification without consideration of system losses
- Does not perform proper testing
- Uses B50 for Life rating

**High Quality LED systems**

- Independently test LEDs for long term at multiple temperatures and currents
- Performs accelerated life testing at 85C/85% RH and rack testing up to several thousand hours
- Uses LEDs that were tested to the LM80 requirements and bases final rating on L70 or L50 (application dependant)

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**B₅₀ - 50% Mortality**

- Life rated when 50% of a population has failed

**L₅₀ - 50% Lumen Maintenance**

- Life defined as point at which lumen depreciation reaches 50%

**L₇₀ - 70% Lumen Maintenance**

- Life defined as point at which lumen depreciation reaches 30%
Performance Claims

LED Ratings vs. “System” Ratings

System De-rating RTY ~ 25%

- LED Lab: 6500K, 70 CRI, 135 LPW
- Commercially Available LED: LPW 90-100
- Thermal Derating: 8-10% loss
- Optical Efficiency: 10-15% Loss
- Driver Efficiency: 10-15% Loss
- Delivered LPW: 75
US Dept. of Energy ... taking action

- **Standards**
  - LM-79: LED system photometric testing methodology
  - LM-80: LED package life/maintenance rating methodology

- **Quality Advocates / Lighting Facts Label**
  - Voluntary pledge program to assure that LED lighting ratings are represented accurately

- **CALiPER testing program**

- **Next Generation Luminaries Awards**
  - Recognizes excellence in the design of energy-efficient LED commercial lighting
  - Sponsored by DOE, the IES, and IALD

- **ENERGY STAR®**
  - Establishing the industry-wide SSL criteria
GE LED quality and reliability
... leading the way

<table>
<thead>
<tr>
<th>Experience Global System Leader</th>
<th>System Design Leader</th>
<th>Six Sigma Reliability Protocol</th>
</tr>
</thead>
</table>
| • Invented first visible LED (1962) | • Minimize system losses:  
- Thermal  
- Optical  
- Electronic | • Design for reliability |
| • 10+ years: traffic, signage, architecture and retail | • Maximize ease of installation / use | • Design for manufacturability |
| • Largest installed base of white LED systems (US) | • Provide low maintenance design | • Robust reliability protocol exceeds industry standards |
  - 500,000+ LED refrigerated light bars |
  - 5 million+ LED signal modules |
  - 19 million+ feet Tetra® LED signage and architectural |
**Experience ... A Global Systems Leader**

<table>
<thead>
<tr>
<th>Market Segments</th>
<th>Products</th>
<th>Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td><img src="image1.png" alt="Traffic Light" /></td>
<td>City, County, State Municipalities, Traffic Distributors and OEM's</td>
</tr>
<tr>
<td>Signage</td>
<td><img src="image2.png" alt="Hilton" /></td>
<td>Retail, Hospitality, Other Corporate Identity, Architectural</td>
</tr>
<tr>
<td>Specialty</td>
<td><img src="image3.png" alt="Retail" /></td>
<td>“Big Box” Retailers, National and Regional Grocery Chains, Equipment OEMs</td>
</tr>
<tr>
<td>General Illumination</td>
<td><img src="image4.png" alt="Traditional GE Lighting" /></td>
<td>Traditional GE Lighting Customer, Retail, Distributors, OEMs, End Users</td>
</tr>
</tbody>
</table>

**A Global Leader in White LED**

- **Vio™**
  - High power LED focused on general illumination grade quality white light

- **Commercial Refrigeration**
  - Largest installation of white LEDs to replace fluorescent

- **Big investments, Relationships**
  - $100MM investment and Strategic Alliance with Nichia

- **White LED Systems Leader**
  - > 45% of 2007 sales are white LED systems
GE System Design Leader

Three major technical levers to pull in order to optimize system efficiency:

- Optical Design
- Thermal Management
- Electrical Design

Fig E.2 Relative Luminosity vs. Drive Current
GE System Design Leader

Provide a strong customer value proposition: superior luminance and light quality...

AEP Beta Site – Columbus, OH

400W HID Area Light

- Smoother gradient demonstrates improved uniformity

GE LED Area Light

- Improved light control provides for less light trespass – more light where desired
GE System Design Leader

Reduced energy and improved maintenance drive the customer ROI
GE System Design Leader

Designing in ease of installation as a customer benefit can drive value versus traditional systems

- 600,000 bars installed
- Fast retrofit on large locations
- Simple replacement of light and PSU

**200 fixtures per junction box**

Advanced thermal management design optimizes efficiency, performance and life

System design delivers uniform light and eliminates shadows

Integrated technology eliminates the need for remote mounting power supplies

Hard usage 16-gauge wire with quick-connect plugs eliminates complex wiring and enables long runs

Cut-to-fit mounting tracks available in 0°, 15° or 30° angles securely lock fixtures into place to provide straight and accurate illumination in the cove
GE System Design Leader

System serviceability is a critical component of design

Design Excellence

- Robust Design
  - 10 year service life

- Replaceable light module

- Maintenance Friendly
  - Access to electronics
Six Sigma Reliability Protocol

**What we do**

- System testing under extreme environmental conditions: Heat, humidity, cold, shock, vibration
- LED qualification process for each new system
- Field validation and beta testing
- 5000 hour life test for system and LED prior to launch
- LM79 photometry measurements where applicable
- LM80 for Vio LED
- 3rd party certification for UL and CE
- GE vendor manufacturing qualification

**Why we do it**

- Simulate worst case operating conditions and identify failure modes
- Confidently predict life and lumen maintenance
- Demonstrate robustness of design
- Optimize and validate efficiency
- Validate performance
- Deliver the highest quality products for our customers
Six Sigma Reliability Protocol

**Failures desirable**
- Reliability Specifications

**Failures OK**
- System/Rel Modeling
- Design Freeze
- Design Validation Testing
- Meet Goals
- Field Surveillance

**Failures undesirable**
- Production Qualification - Validation Testing
- Meet Goals

- At minimum meet Life Claim
- Application of DFR Tools
  - Modeling, Simulation, DFMEA, Benchmarking, Life Studies
- Robustness (DME, HALT), HTHH, HTOL, Thermal Shock, Thermal Imaging, Life Testing
- System Level, HTHH, DME, Thermal Cycling, PPAP

- Product Launched
  - With Reliability Designed In

- Failures desirable
- Failures OK
- Failures undesirable

(Time and $$)
GE LED quality and reliability ... leading the way

The Results: Award winning products

GE received a “best in class” distinction from the LED Next Generation Luminaries™ Solid State Lighting Design Competition for the Immersion® LED Display Case Lighting and a “special recognition” from the same awarding body for the GE LED Cove Lighting System as a market-ready luminaire.

GE also earned the top prize for “light sources and controls” at the Lighting Design Awards 2009 for GE’s Vio® High-Power White LED technology.
GE LED quality and reliability ... leading the way

The Results: Independent Rating Confirmation

Overall only 22% of LED products meet claim in DOE CALiPER testing but GE has 100% conformance

<table>
<thead>
<tr>
<th>Industry - CALiPER Testing Results:</th>
<th>GE: CALiPER Testing Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Round</td>
<td>Date</td>
</tr>
<tr>
<td>-----------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>Mar-07</td>
</tr>
<tr>
<td>2</td>
<td>Aug-07</td>
</tr>
<tr>
<td>3</td>
<td>Oct-07</td>
</tr>
<tr>
<td>4</td>
<td>Jan-08</td>
</tr>
<tr>
<td>5</td>
<td>May-08</td>
</tr>
<tr>
<td>6</td>
<td>Aug-08</td>
</tr>
<tr>
<td>Total</td>
<td>101</td>
</tr>
</tbody>
</table>

GE Six Sigma and NPI process drive conformance to claims... Reliability Protocol key differentiator in dynamic environment.
GE LED quality and reliability ... leading the way

The Results: Towering Reliability!

Over 80MM LEDs equal to 19MM feet of Tetra signage and architectural products have been installed since 2001

Tetra has a warranty return rate of 0.05%
GE LED quality and reliability ... leading the way

The Results: An LED leader trusted by early adopters

<table>
<thead>
<tr>
<th>LED Refrigeration</th>
<th>LED Signage</th>
<th>LED General</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walmart</td>
<td>AT&amp;T</td>
<td>Starbucks</td>
</tr>
<tr>
<td>United Supermarkets</td>
<td>Holiday Inn</td>
<td>Red Robin</td>
</tr>
<tr>
<td>Walgreens</td>
<td>Woolworth's</td>
<td>The Venetian</td>
</tr>
<tr>
<td>Target</td>
<td>Tesco</td>
<td></td>
</tr>
<tr>
<td>Seiyu (Walmart Japan)</td>
<td>FedEx Office</td>
<td></td>
</tr>
<tr>
<td>Woolworth’s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tesco</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aldi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Couche-Tard (Circle K)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We have sold LED lighting in 56 countries
### Top 10 - Supplier Screening Questions

1) **Is your company registered as a DOE Quality Advocate? This includes taking the Quality Pledge for Solid State Lighting Products?**

   GE is registered as a Quality Advocate. The CEO of our company has taken the quality pledge. You will find the listing of our company at [www.lighting-facts.com](http://www.lighting-facts.com)

2) **Who’s LED chips do you use? Has the product gone through an IP (Intellectual Property) clearance?**

   Our products go through an extensive patent clearing process.

3) **What is the LED chip manufacturers rating and what is the rating of your product?**

   GE does not base product ratings on LED chip manufacturing ratings, but instead ratings are inclusive of thermal losses, optical losses, and driver losses.

4) **What precautions do you take to ensure the appropriate LED is selected for your product? Can you share your data showing the LED selection process for your product?**

   Prior to selecting a LED for our product, we perform long-term qualification testing at multiple temperatures and operating currents. We trend data for color shift, light output depreciation, and power consumption. Having this data we compare to the LED supplier data. If data is found equivalent, we release the LED for use in the product. Yes, upon request we can share the data.
### Top 10 - Supplier Screening Questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>5) Does your product use LEDs that been LM80 tested to demonstrate L70 life after 6000hrs of test? If yes, can you share your LM80 data and life model used to demonstrate the L70 life?</td>
<td>For our products we try to use LEDs that were tested to the LM80 requirements. Having the LM 80 life data complements our in house testing of the LEDs. The combination of the two tests significantly increases the confidence level in LED life. Yes, upon request we can share the LM80 data. At this time not all LED suppliers provide LEDs that have been LM80 tested.</td>
</tr>
<tr>
<td>6) Does your product meet the LM79 requirements? If yes, can you provide the LM79 test report from an accredited NVLAP test lab?</td>
<td>Where possible, we will test our product to LM79 and provide the NVLAP report upon request.</td>
</tr>
<tr>
<td>7) Do you ‘design in reliability’ or do you ‘test for reliability’ to demonstrate the long-term performance of your product? Can you share your reliability product development process?</td>
<td>We ‘design in’ reliability for our products. When you ‘design in’ reliability you design the product to take into consideration various stress conditions the product will see over its lifetime. We follow a 10step Design For Reliability (DFR) process to ensure the product is designed and validated to the product specification. It has been shown just testing the product to demonstrate reliability will not adequately precipitate all failure modes that will be observed over the lifetime of the product. Yes, upon request we can share our process to show the steps taken to demonstrate our product life claim and overall product performance.</td>
</tr>
<tr>
<td>Question</td>
<td>Response</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>8. What type of testing do you perform to validate your product life and safe operation? Can you share the test results?</td>
<td>Our product validation protocol includes accelerated life testing at 85°C / 85%RH and rack testing up to several thousand hours to show the product meets or exceeds our life claims. In addition, we perform robustness testing to precipitate failures to understand how the lamp fails and to ensure it fails in a safe manner.</td>
</tr>
<tr>
<td>9. What actions take place in the factory to ensure the product properly works when installed by the customer?</td>
<td>During the assembly process, inline checks take place to properly ensure the product is assembled in accordance with the assembly instructions. Once fully assembled, the product is operated for at least 24 hrs to screen out any failures. After burn in, the product’s light output and power is measured to ensure it meets the specification. Lastly, the product is packaged and shipped to the customer.</td>
</tr>
<tr>
<td>10. How do you ensure the product will continue to meet the specification?</td>
<td>At predefined intervals we send samples of the lamp to our NVLAP for LM79 testing. This is in addition to the 100% light up test and power measurement in the factory.</td>
</tr>
</tbody>
</table>
GE LED Solutions

<table>
<thead>
<tr>
<th>Application</th>
<th>GE Brand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signage</td>
<td>Tetra® Signage Series</td>
</tr>
<tr>
<td></td>
<td>• Listed under UL879 for use in sign enclosures and limited access interior applications</td>
</tr>
<tr>
<td></td>
<td>• Available in WW, CW and colors only</td>
</tr>
<tr>
<td></td>
<td>• Available from GE Lumination signage distributors</td>
</tr>
<tr>
<td>Architectural</td>
<td>Tetra® Architectural Series</td>
</tr>
<tr>
<td></td>
<td>• Listed under UL2108 as a low-voltage lighting system</td>
</tr>
<tr>
<td></td>
<td>• Available in multiple WW ANSI colors (2700K-6500K)</td>
</tr>
<tr>
<td></td>
<td>• Available from GE Lighting distributors</td>
</tr>
<tr>
<td>Display Case</td>
<td>Immersion®</td>
</tr>
<tr>
<td>Lamps</td>
<td>GE ENERGY SMART®</td>
</tr>
<tr>
<td>Outdoor Lighting</td>
<td>Evolve™</td>
</tr>
<tr>
<td>High Power White LEDs</td>
<td>Vio®</td>
</tr>
</tbody>
</table>
GE LED Solutions
Tetra® miniMAX - LED Architectural Series

Applications
Tetra miniMAX is ideal for cove, indirect lighting and accent lighting applications.

Features and Benefits
- Up to 40% more energy efficient than neon
- Low voltage 12VDC system is compatible with GE LED Drivers 74914, 74601 and 74913
- Contains no lead, mercury or glass. RoHS compliant
- Long rated life of 50,000 hours
- Colors: white and warm white
GE LED Solutions
Tetra® Contour - LED Architectural Series

Applications
Tetra Contour is ideal for border lighting, interior art, cove and accent lighting.

Features and Benefits
• Up to 40% more energy efficient than neon
• Low voltage 24VDC system is compatible with GE LED Drivers 74917, 74915 and 74916
• Contains no lead, mercury or glass. RoHS compliant
• Long rated life of 50,000 hours
• LED light engine colors: red, red-orange, amber, green, blue, white and warm white
• Light guide colors: red, orange, yellow, lime green, green, blue and white

ecomagination™
a GE commitment
imagination at work
GE LED Solutions

Tetra® PowerGrid - LED Architectural Series

Applications

Tetra PowerGrid is ideal for backlighting walls, ceilings and under cabinets.

Features and Benefits

- Up to 64% more energy efficient than fluorescent
- Low voltage 24VDC system is compatible with GE LED Drivers 74917, 74915 and 74916
- Contains no lead, mercury or glass. RoHS compliant
- Long rated life of 50,000 hours
- Colors: white and warm white
GE LED Solutions
LED Cove Lighting System - LED Architectural Series

Applications
LED Cove Lighting System is ideal for cove, backlighting walls, and under cabinets.

Features and Benefits
• Up to 7X more energy efficient than xenon
• Contains no lead, mercury or glass. RoHS compliant
• Long rated life of 50,000 hours
• Improved brand image
• Reduced installation costs
• Colors: white and warm white

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imagination at work
GE LED Solutions
Vio® High Power White LED

Applications
• Under shelf
• Step/marker
• Down light
• Accent

Features and Benefits
• Outstanding light quality and stability
• Incandescent look and feel
• Less than 75K color shift over life
• Easy to integrate module format
GE LED Solutions
GE Energy Smart® LED Replacement Lamps

Applications
GE Energy Smart® lamps are ideal for applications where directional, high quality light is required.

Features and Benefits
- Outstanding energy efficiency
- Long Life
- Excellent color rendering CRI >80
- Low heat, no UV or IR
- High power factor of 90%

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GE LED Solutions
Immersion® LED Display Case Lighting

**Applications**
Immersion® LED Display Case Lighting is ideal for case applications in Museums, Jewelers, Gift Shops, Department Stores.

**Features and Benefits**
- Sparkle – Quality of Light
- Design flexibility
- Energy efficient
- Long life = labor savings

**Light Distribution (Lux)**

<table>
<thead>
<tr>
<th>Immersion LED Display Case Lighting</th>
<th>Fluorescent T8 in Typical Extrusion</th>
</tr>
</thead>
</table>

Measurements taken from a typical 5-foot display case appropriately outfitted with a 62-inch Immersion LED light (E72T8) and 42-inch fluorescent tube (FL48T12), as seen from an overhead view of the case.
GE LED Solutions
Evolve™ LED Outdoor Lighting

<table>
<thead>
<tr>
<th>Applications</th>
<th>Features and Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking lots</td>
<td>Reduced energy consumption</td>
</tr>
<tr>
<td>Public areas</td>
<td>Improved uniformity and light quality</td>
</tr>
<tr>
<td>Roadway and Street</td>
<td>Long service life and reduced maintenance costs</td>
</tr>
<tr>
<td>Parking garage</td>
<td>Reduced trespass light</td>
</tr>
</tbody>
</table>

Relevant images depict outdoor lighting solutions, showcasing a variety of applications and features.
A look into the future...

Dynamic, evolving market segment...

GE committed to deliver value across platforms
A look into the future ... Bringing OLEDs to Life

• Looking at market needs, current technical weaknesses and OLED capabilities

• Achieved roll-to-roll manufacturing capability
  - Enables low-cost manufacturing
  - Allows design flexibility vs. stiff glass panel

• Tapping GE’s ultra-high barrier coatings experience
  - Allows use of low-cost flexible substrate that protects OLED material throughout its life

• Validating attributes: flexible and thin
A look into the future ...
Envisioning OLEDs applications

Illuminated Safety Outerwear
Advertising Signage
Concealed Under-Shelf
Decorative Wall Peel
Illuminated Stairs
Portable and Flexible Lamp

These images were created to illustrate concepts of potential future applications

Working with The Cleveland Institute of Art, Case Western Reserve University, Architects, Lighting Designers and Others...
Thank You!
Questions?

For more information, visit these websites:

www.gelighting.com/led
www.led.com
www1.eere.energy.gov/buildings/ssl

Or contact me by e-mail:

james.benson@ge.com

Contact GE For a FREE Lighting Analysis / Energy Audit!

www.gelighting.com/LEDwebinar