
Solid State Lighting:
A Solid Investment?
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Agenda

- Lighting Terminology
- Different Types of Light Sources
- White Light
- Solid State Lighting
- Cost – Benefit Analysis
- When's the Right Time to Go LED
- The Bottom Line

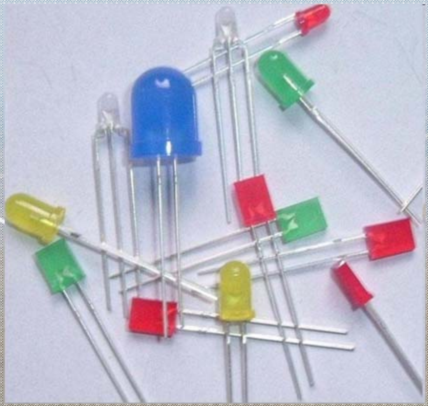
To Understand How LED Lighting IS Viable Today

- Get the Maximum Lumens Out of the Fixture at the lowest wattage possible

- Use Fewer Lumens to attain the desire light output for the appropriate application
  - LED povides ¼ to ½ the lumens of traditional sources
  - Take advantage of LED characteristics
    - Optical Control
    - Lumen Maintenance
    - Efficiency
    - Longevity
    - Brighter Appearance of Blue-White Light (Scotopic)

Lighting Terminology

- Solid State Lighting = LED
- LED stands for **L**ight **E**mitting **D**iode
- Uses different technology than current street lighting light sources
- LEDs used for street lighting are different from those that are used in traffic lights and automobile tail lights
  - Miniature vs. Chip-on-board LEDs



Lighting Terminology

- Measurement of Light
  - Candela
    - The amount of light emitted from a standard candle
  - Lumen
    - Unit of light leaving a one candela light source and falling uniformly on a one square foot surface that is one foot away
    - ~12.6 lumens in a 2' diameter sphere
  - Footcandle (fc)
    - How much light falls one square foot of the area inside a sphere one foot in distance from a standard candle.
    - 1 footcandle in a 2' diameter sphere
    - Typical roadway levels 0.4 -2.0 fc
  - Lux (metric)
    - 1 Footcandle = 10.764
  - Illuminance
    - How much light falls on the task plane
  - Luminance
    - How much light reaches the human eye from the task plane

Lighting Terminology

- Measurement of Light
  - Efficiency
    - How much of the light generated in a light fixture can escape
    - Bare light bulb is 100% efficient
  - Efficacy (system wattage)
    - Overall energy consumed to power the light source
    - Includes ballast/driver losses
    - e.g. 100w HPS = ~125w system
      - 100w HPS = 9500 lumens
      - 9500 lumens / 125w = 76 LPW

Lighting Terminology

- Correlated Color Temperature (K)
  - Based on a “Black body radiator”
  - Lower temps = more red color
  - Higher temps = more blue color
  - “White Light” typically between 2700k and 6500K

- Light Loss Factor (LLF)
  - Lamp Lumen Depreciation
  - Luminaire Dirt Depreciation
  - Ballast Factor
- Reflector
  - A surface that reflects light projected on it
- Refractor
  - A generally clear material that “bends” light by refraction (similar to a prism)

Lighting Terminology

- Color Rendering Index (CRI)
  - Measures the visibility of selected colors under a light source on a scale of 0-100
  - The sun and the incandescent lamp have a CRI of 100
  - Scale has recently come under attack as being too limited and may be changed in the future

Name	Appr. Munsell	Appearance under daylight	Swatch
TCS01	7,5 R 6/4	Light greyish red	
TCS02	5 Y 6/4	Dark greyish yellow	
TCS03	5 GY 6/8	Strong yellow green	
TCS04	2,5 G 6/6	Moderate yellowish green	
TCS05	10 BG 6/4	Light bluish green	
TCS06	5 PB 6/8	Light blue	
TCS07	2,5 P 6/8	Light violet	
TCS08	10 P 6/8	Light reddish purple	
TCS09	4,5 R 4/13	Strong red	
TCS10	5 Y 8/10	Strong yellow	
TCS11	4,5 G 5/8	Strong green	
TCS12	3 PB 3/11	Strong blue	
TCS13	5 YR 8/4	Light yellowish pink	
TCS14	5 GY 4/4	Moderate olive green (leaf)	

"New" Lighting Terminology

- LM79
  - Absolute photometry vs. relative
  - Fixtures must be tested as configured; no extrapolations allowed as with HID
- LM80
  - Department of Energy and Energy Star*
  - Diode run at two junction temperatures
    - 55 and 85 degrees C
  - Checked every 1000 hours
  - Runs a total of 6000 hours
    - If 91.8% of output remains, ok to claim 25,000 hours
    - If 94.1% of output remains, ok to claim 35,000 hours
- L70 (when light output reaches end of life)
  - LEDs @ 70% light output
  - LEDs don't usually "burn out;" steady decline similar to mercury vapor systems

White Light

- Professionals throughout the industry are researching differences in visibility under “white” light vs. “amber” light
  - Photopic
    - What’s right in front of you (foveal vision)
    - Mostly cones
  - Scotopic
    - “Night” vision (peripheral vision)
    - Mostly Rods
  - Mesopic
    - Vision under low light conditions (between Scotopic and Photopic light levels)
    - Mostly rods but some cones are activated
- Mesopic and Scotopic are NOT the same thing!

White Light

- Research indicates that in Mesopic light levels, one has better peripheral vision and an increased feeling of brightness under white light vs. amber
  - "White light" is considered being around 6000K
  - Current lighting measurement based on incandescent lamp at 2700k, doesn't take human eye into account
- IES: Standards are to be followed regardless of spectrum
- Groton, CT study (available online from LRC)
  - Search "Groton Mesopic Street Lighting"
    - Tested 55w 6500k induction; 70w 4000k CMH vs. 100w HPS
    - White light fared better overall

White Light

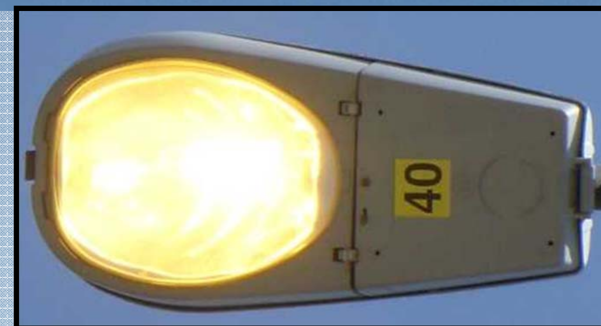
- Some LED companies may still be marketing with Mesopic Levels… Ask about it!
  - Failure to meet an established standard could lead to liability issues?
  - "White light" standard from the IES? Eventually?
    - CIE in Europe has a standard
  - Referred to as S/P Ratio (scotopic/photopic) ratio
  - Reputable companies may show both in their literature
  - Watch out for companies touting Mesopic levels only
- Perception
  - Perception tends to be that, even at lower levels, white light appears "brighter"

Historic Electric Light Sources

- Incandescent (8-20 LPW)
  - Street lighting service lamps rated in lumens
- Magnetic Ballast Linear Fluorescent (30-60 LPW)
  - Brief appearance in the '50s and '60s
  - Fluorescent making a comeback through Biax/CFL
- Mercury Vapor (30-60 LPW)
  - Compact Source
  - Similar output to Linear Fluorescent
  - Easier to control
  - Poor color rendering, Poor Light Loss factor
  - Available clear or phosphored
  - Federal EPACT legislation banned import or mfg of ballasts January 1, 2008

Current Electric Light Sources

- High Pressure Sodium (80-120 LPW)
  - Amber-gold color
  - Low color temperature
  - Low color rendering



- Low Pressure Sodium (100-200 LPW)
  - Distinctive amber color
  - Monochromatic light source with a CRI of zero or -44, depending on the literature

- Metal Halide (60-120 LPW)
  - Crisp white light of various color temperatures
  - High CRI
  - Shorter life than HPS
  - 140 LPW on the horizon

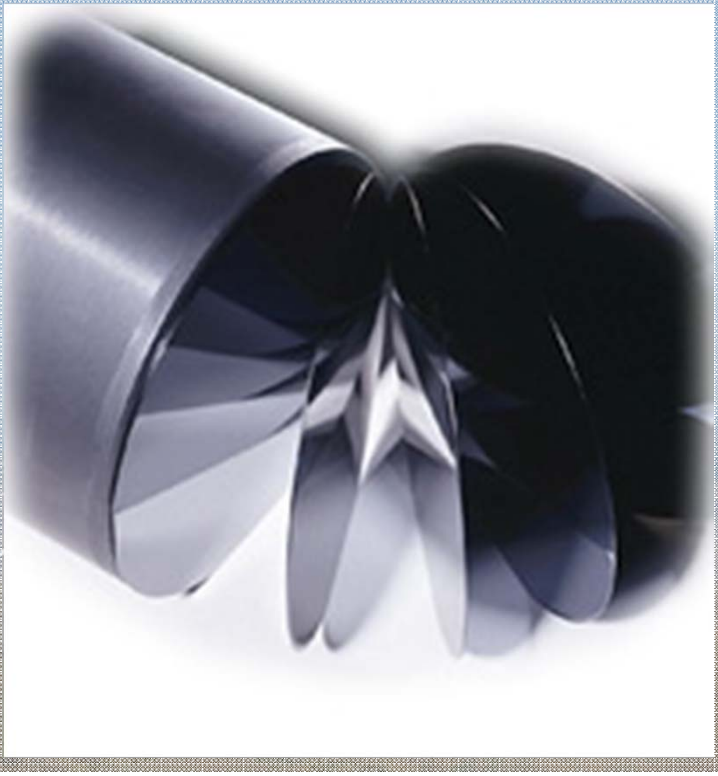
Current Light Sources

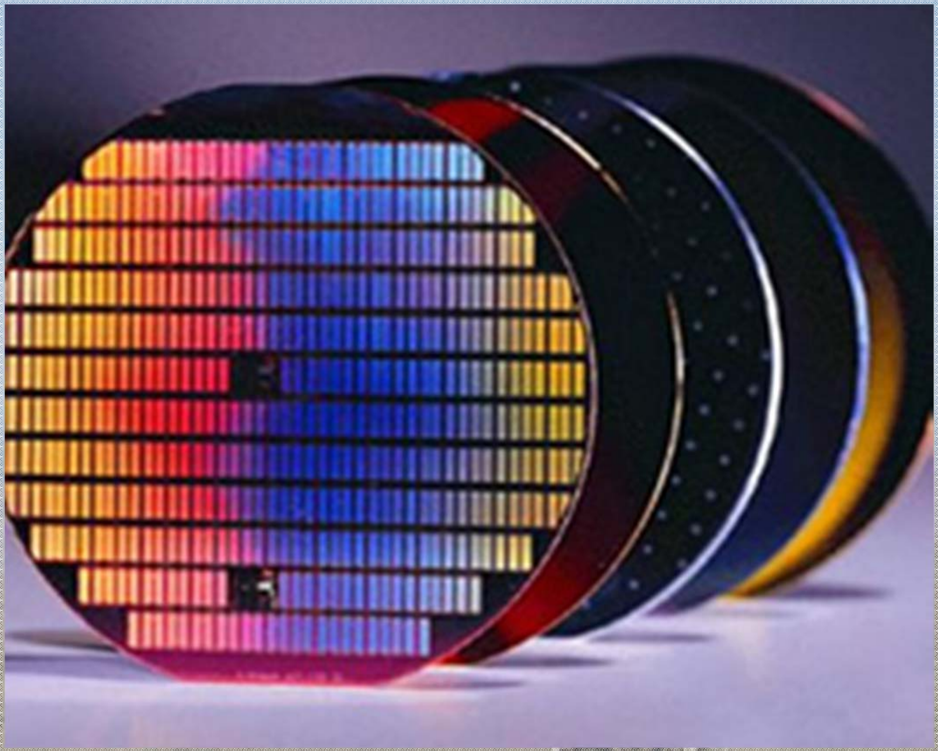
- Modern Electronic Ballast Fluorescent (70-100 LPW)
  - White light, available in multiple color temperatures
  - Instant-on instant-restrike
  - Phosphor-based; color temp 2700-6500k
  - Lamp life 10,000-40,000 hours
  - Large source, difficult to control

- Induction/electrodeless fluorescent (70-100 LPW)
  - White light, available in multiple color temperatures
  - Instant-on instant-restrike
  - Uses radio frequency to power the light source
  - 60,000-100,000 hour rated life
  - Phosphor-based; color temp 2700-6500k
  - Large source, difficult to control
  - Philips QL and Osram Icetron

Solid State Lighting
LED

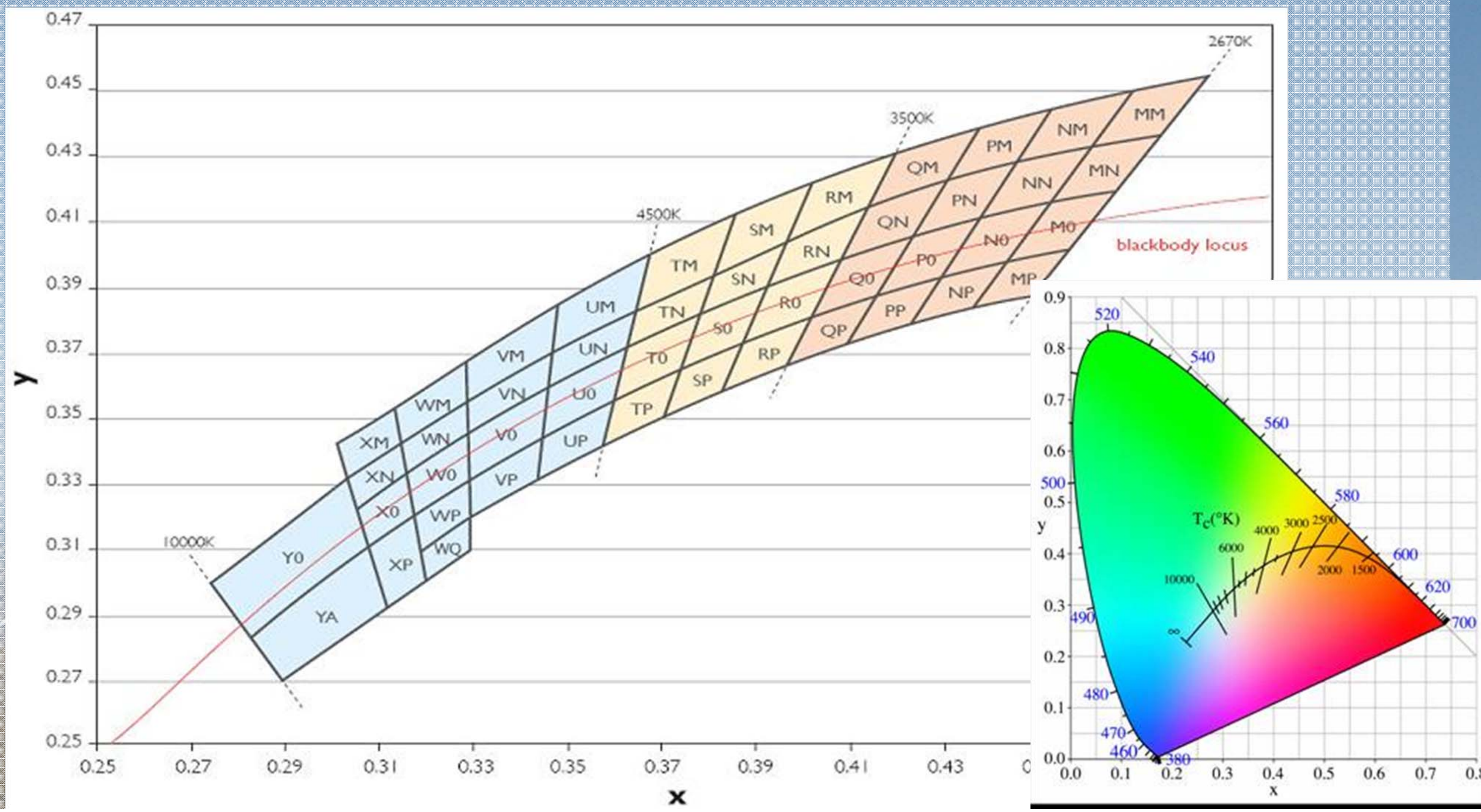
LED’s Are Fabricated Like Computer Chips





Solid State Lighting
LED

"Bins" Used to Control Variation



Solid State Lighting
LED

- LED
  - Capable of producing colored light with high efficiency
  - White LED (the workhorse of today's LED light fixture)
    - Currently bench testing in excess of 150 lpw
    - Theoretical maximum of ~240 lpw
    - Actually blue LEDs with a phosphor coating, which is why the light of the most efficient LEDs is blue-ish
    - Warm white available but at lower efficiency due to the need to add more phosphor to the LED to create a "warmer" light source
  - Fairly narrow beam of light when un-controlled
  - Requires heat dissipation to extend lamp life!

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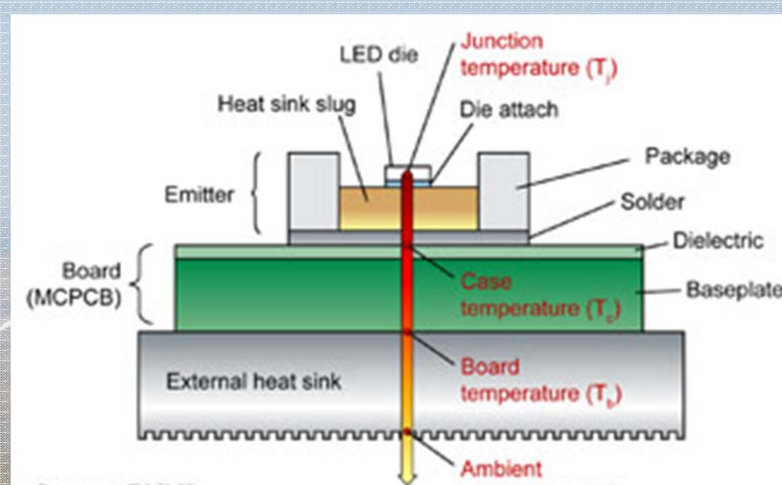
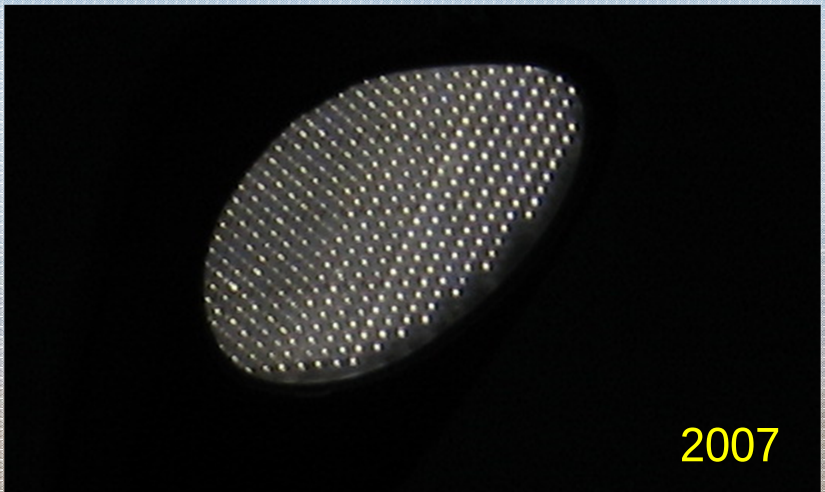
LED Heat Dissipation

- Different techniques, common goals
  - Fins
  - Direct exposure to air
  - Enclosed heat sink
- Junction Temperature (T_j)
  - Interior of LED
  - Critically important for LED life
  - Part of LM80



Solid State Lighting
In the Beginning

- First attempts at LED street lighting were feeble at best
- Used miniature LEDs
- Little optical control
- Attempted to direct LEDs to control distribution



Solid State Lighting

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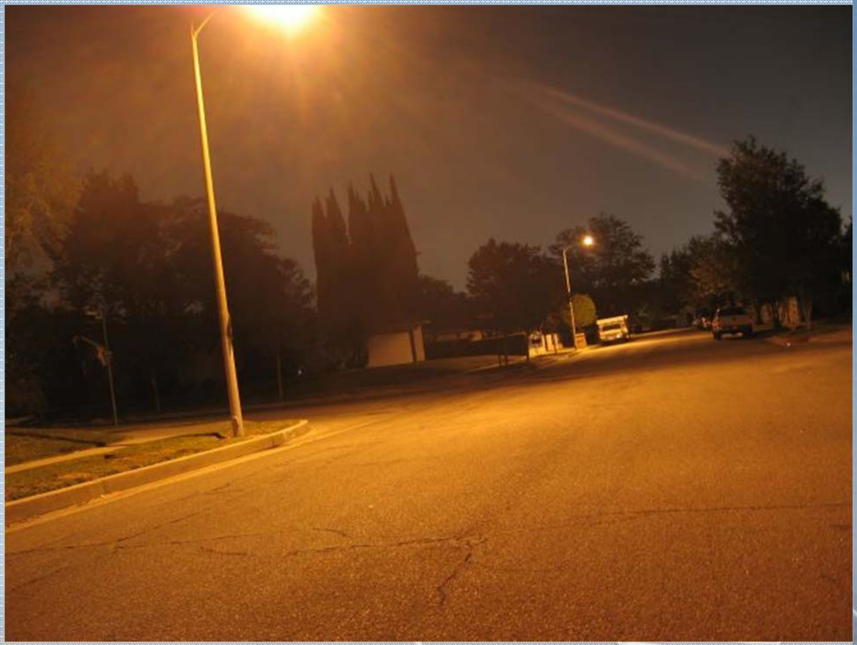
Solid State Lighting

Solid State Lighting – L.A. Test

- Control installation – HPS
- Exemplary of current street lighting technology
- Good light spread
- 100w rated ~130 actual watts drawn as estimated by city



Solid State Lighting – L.A. Test

- Design with high-brightness LEDs
- Little optical control
- 60w rated LED
- Result is intense pools of light and large areas of darkness
- Illustrates the need to mock up the technology you are using!
- Cars on this street tended to park in the “pool” of light!

Solid State Lighting – L.A. Test

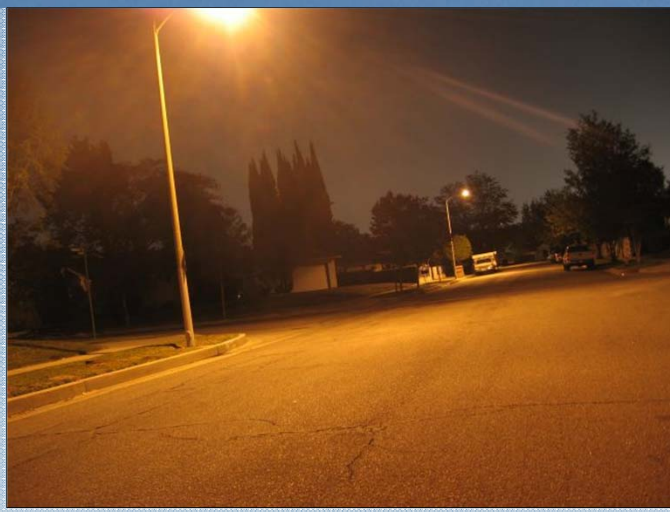
- 60w rated LED
- OK light spread
  - Note dark spot underneath fixture
- Slightly less glary
- Uses a combined reflective/refractive lens on each LED
- Good control on house-side

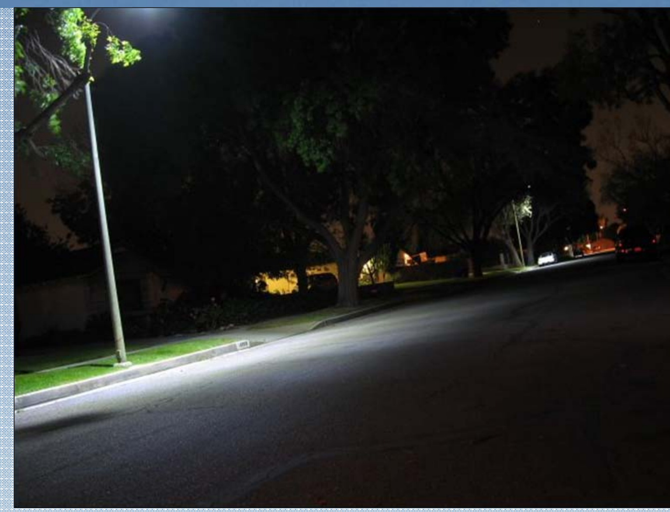
Solid State Lighting – L.A. Test

- 60w rated LED
- Optics more controlled
- Glare issues?
- Uses shaped lenses over each LED to bend light
- Good light spread
- Good control on house-side

Solid State Lighting – L.A. Test

(pictures all taken with the same camera using exactly the same settings)

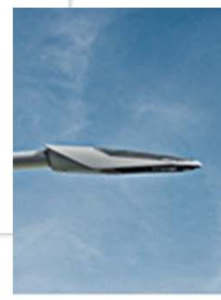




Luminaire Form Factor

- LEDs being a new light source bring new shape options to outdoor lighting

Luminaire Form Factor



Simple Cost-Benefit Analysis

Figure out annual Kwh usage

$$\frac{\text{system wattage x hours used (4160 hrs/year)}}{1000} \text{ X } \text{Power rate per kwh}$$

Add up accumulated parts and service costs during luminaire life

Divide by years of expected luminaire life and add the annual energy cost

Total will give an approximation of annual cost over the life cycle

Simple Cost-Benefit Analysis - HPS

- For example, smaller HPS fixture
  - 100w HPS fixture, less lamp - $100
    - Predicted 20 year luminaire life
  - Lamp cost - $20
  - Photocell cost - $10
  - Power cost $.10/kwh
  - Power usage ~120w
  - Total power cost: **$49.92/year**
  - Cost of a service visit at $150
  - Figure on lamp changes every 5 years, photocell change every 10 for a total of 4 service visits in 20 years
  - Overall cost to operate: **$90/year (20 year amortized)**
  - Failure Mode
    - Lamp failure
    - Ballast failure

Simple Cost-Benefit Analysis - LED

- For example, rough equivalent to 100 HPS
  - 60w LED - $500
    - Predicted 15 year life
  - Lamp cost – n/a
  - Photocell cost - $10
  - Power cost $.10/kwh
  - Power usage ~70w
  - Total power cost: **$29.12/year** ENERGY SAVINGS $21/year vs. HPS
  - Cost of a service visit at $150
  - Figure photocell change every 10 years; two service visits for life
  - Overall cost to operate: **$70/year - 20 year amortized**
    $93/year - 15 year amortized (predicted fixture life)
  - Failure Mode
    - Driver (50000-70000 hours)
    - Individual LED

www.lsi-crossover.com – “Energy Toolbox”

Energy & Maintenance Savings Analysis and Payback

Input Sheet

KWH Rate	$0.1000	
KWH Inflation Rate (percentage/year)	5.00%	
Crossover System		
ROI/Payback (Yrs)	3.53	
	Fixture Type 1	
Fixture Model	XPGHL-5-LED-68-CW-UE	175w MH
Fixture Wattage (Inc. Ballast Loss)	79	210
Fixture Quantity	100	100
Operating Hours / Day	24	24
Annual Operating Hours (365 days)	8760	8760
nitial Fixture Cost	$450.00	$0.00
*Per Fixture Rebate (All Available Rebates)		
nitial Average Install Cost / Fixture	$60.00	$0.00
Fixture Maintenance (HID/Fluorescent)		
Lamps / Fixture	1	
**Lamp Life (Hrs)	0	
Lamp Cost	$0.00	
Lamp Recycle Fee/Lamp	$0.00	
Spot/Group Re-lamp Labor Cost/Lamp	$0.00	
Ballasts / Fixture	1	
Ballast Life (Hrs)	50,000	

Crossover
SOLID-STATE LIGHTING

Energy & Maintenance Savings Analysis and Payback

Input Sheet

KWH Rate	**$0.1000**	
KWH Inflation Rate (percentage/year)	**5.00%**	
Crossover System		
ROI/Payback (Yrs)	**3.01**	
	Fixture Type 1	
Fixture Model	**XPGHL-5-LED-68-CW-UE**	**175w MH**
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Fixture Quantity	**100**	**100**
Operating Hours / Day	**24**	**24**
Annual Operating Hours (365 days)	**8760**	**8760**
Initial Fixture Cost	**$450.00**	**$0.00**
**Per Fixture Rebate (All Available Rebates)	**$75.00**	
Initial Average Install Cost / Fixture	**$60.00**	**$0.00**
Fixture Maintenance (HID/Fluorescent)		
#Lamps / Fixture	**1**	
**Lamp Life (Hrs)	**0**	
Lamp Cost	**$0.00**	
Lamp Recycle Fee/Lamp	**$0.00**	
Spot/Group Re-lamp Labor Cost/Lamp	**$0.00**	
#Ballasts / Fixture	**1**	
Ballast Life (Hrs)	**50,000**	

Crossover SOLID-STATE LIGHTING

Energy & Maintenance Savings Analysis and Payback

Input Sheet

KWH Rate	$0.1000	
KWH Inflation Rate (percentage/year)	5.00%	
Crossover System		
ROI/Payback (Yrs)	2.78	
	Fixture Type 1	
Fixture Model	XPGHL-5-LED-68-CW-UE	175w MH
*Fixture Wattage (Inc. Ballast Loss)	79	210
Fixture Quantity	100	100
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Initial Average Install Cost / Fixture	$60.00	$0.00
Fixture Maintenance (HID/Fluorescent)		
#Lamps / Fixture	1	
**Lamp Life (Hrs)	0	
Lamp Cost	$35.00	
Lamp Recycle Fee/Lamp	$1.00	
Spot/Group Re-lamp Labor Cost/Lamp	$30.00	
#Ballasts / Fixture	1	
Ballast Life (Hrs)	50,000	

The Good, The Bad and the Ugly

	HPS	LED
RI	Low ~22	Good ~ 70-80
CT	Low – 1900-2200k	Variable 3000-8000k
ervice nterval	Every 4-5 years	As long as 15 years
nd of fe	Cycles or rapid drop in output of lamps/blue color	Continuous depreciation
ailure node	Lamp or Ballast	Most likely electronic driver
[illegible]	Since the late 1960s	Since the early 2000s

LED End of Life

- Generally defined as when the luminaire reaches 70% of initial light output
- Official name is L70
- Individual LEDs generally not replaceable

When's the Right Time?

Possible complaints

- Color temperature (too "blue")
  - "It's different and I don't like it" argument
  - Circadian rhythm of animals
  - Warmer color temperatures less efficient; possibly less effective for human vision
- Glare
  - Glare is spread out over a larger area
  - Higher color temperatures appear more glary
  - Shielding?

When's the Right Time?

- There is no right answer for everyone
- Political implications
  - Cap and Trade?
- "Green" appearance
- Color temperature
- Energy efficiency
- More conventional luminaire designs
- Rebates / Incentives

The Bottom Line

- LEDs are likely the future of outdoor lighting
- Disruptive technologies exist
- Technology is changing rapidly
- Cost effectiveness varies by a number of factors
  - What's currently on your system
  - Buying power: quantity will affect the price!
- It may be years until the pace of changes in the industry slows down – is it worth waiting to see what comes next?

The Bottom Line

Many ways to implement

- Across-the-board change out
- $ Savings + Time = change out
  - Monitor energy savings of installed units and use cost savings to buy heads until the job is done
- Mandate all new or replacement luminaires be LED
- Offer “green option” to customers – HOAs? LIDs? at a premium? At a discount?

The Bottom Line

- There is no time like the present to test LEDs, crunch the numbers, and decide if it’s economically feasible
- The future is bright and getting brighter
- Stimulus dollars
  - Buy American requirement?
- Utility Incentives to come?

The Bottom Line

Research the Manufacturer

- What is their experience with LEDs
- Don’t be drawn to long warranties
  - Standard 5 years
  - Some companies providing warranties longer than their existence
- Where do they manufacture
- Price
- Availability
- Tools to Help
- Sample policy

The Bottom Line

Understand How they do It

- Whose LEDs
- Whose Driver
- Color Temps
- Heat Dissipation
- Optics
- Distributions
- Reflectors
- Life Expectancy

Reliability Starts With the Company

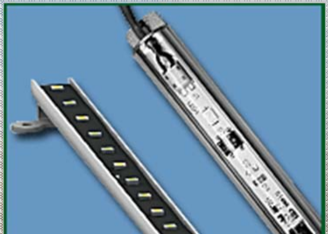
- 34 Years Experience in Lighting Fixtures
- Market-leading LED Technology
- Highest Level of Vertical Integration
- Adaptability to Changing Technologies

LSI Industries™

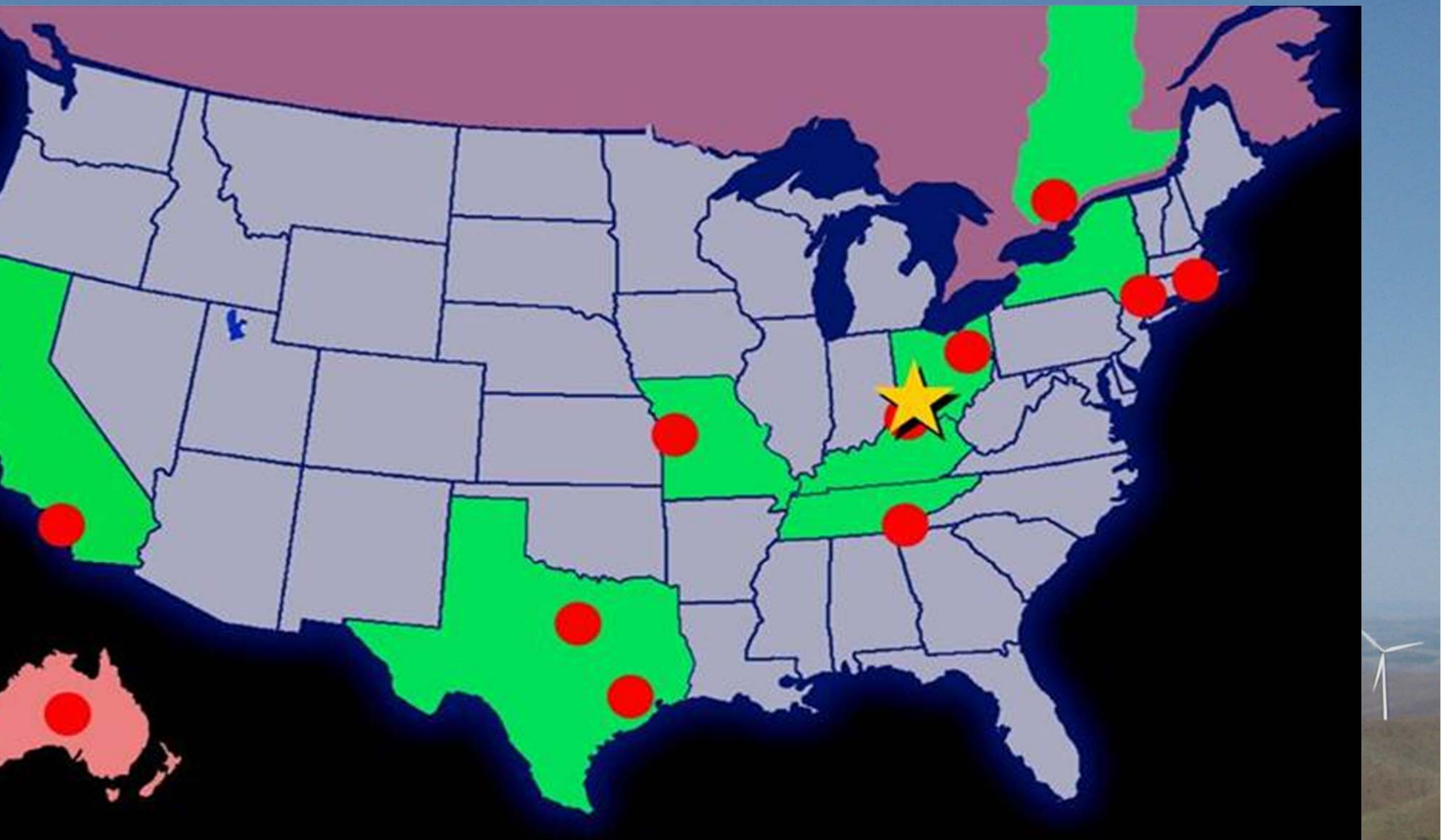
Crossover® SOLID-STATE LIGHTING

A Company with a Smart Vision



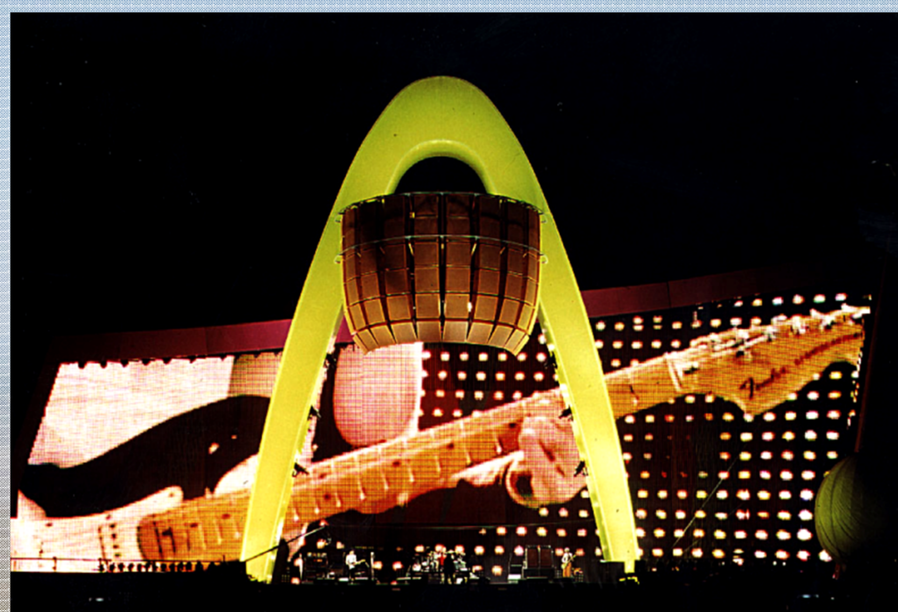



LSI operates nearly 1.5 million square feet of manufacturing & warehouse space in its 12 facilities and employs approximately 1400 people.



LSI SACO Technologies

- Leader in Large Scale Entertainment and Sports Displays
- Pioneered the Use of LEDs in Stadium Video Screens – 1988



LSI ADL Technology

- Circuit Board Production
- Electronic Design
- In-circuit Testing
- Quality Control


LSI LED

Crossover® SOLID-STATE LIGHTING

LSI Industries™

A Company with a Smart Vision

Thank you!
Any Questions?

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