



LED Technology Progress

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Who is Cree?



- Semiconductor company, headquarters in Durham NC, USA
- Revenue of \$394 million in FY 2007
- 12 locations worldwide, 2600 employees
- Technology leader with 827 U.S. and 1,800 foreign patents
- Leader of the LED Lighting Revolution

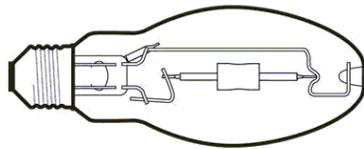
Traditional Lighting Technologies

Incandescent



Pros: Very cheap, great color
Cons: **Very short lifetime,**
poor energy efficiency

High Intensity Discharge



Pros: Cheap, efficient
Cons: **Poor color,**
long restart, Hg

Fluorescent



Pros: Cheap, efficient
Cons: **Can not run in cold temp;**
difficult/costly to dim,
control, Hg

Compact Fluorescent



Pros: Energy efficient
Cons: **Hg, Cold temp operation,**
High cost vs. Incand

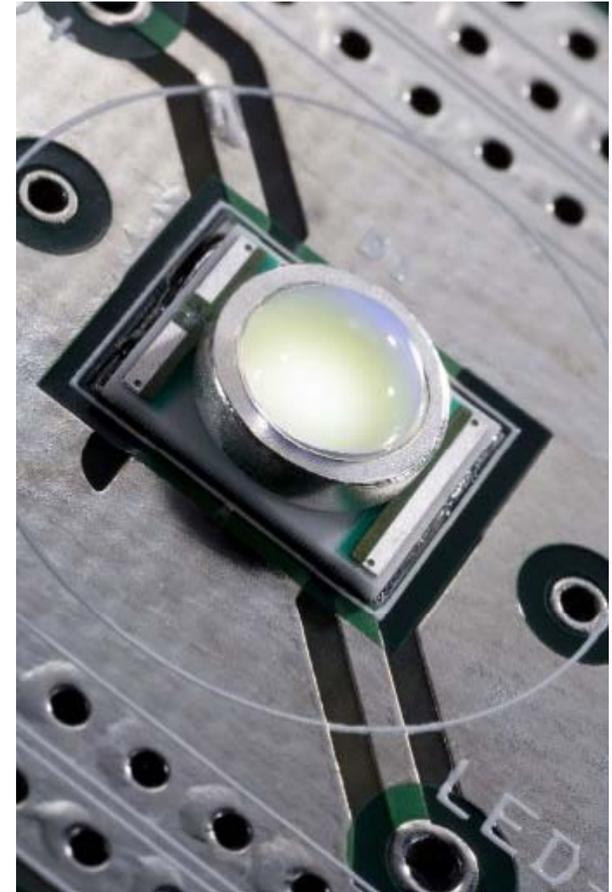
Halogen



Pros: Great color, focused light
Cons: **Very short lifetime,**
poor energy efficiency

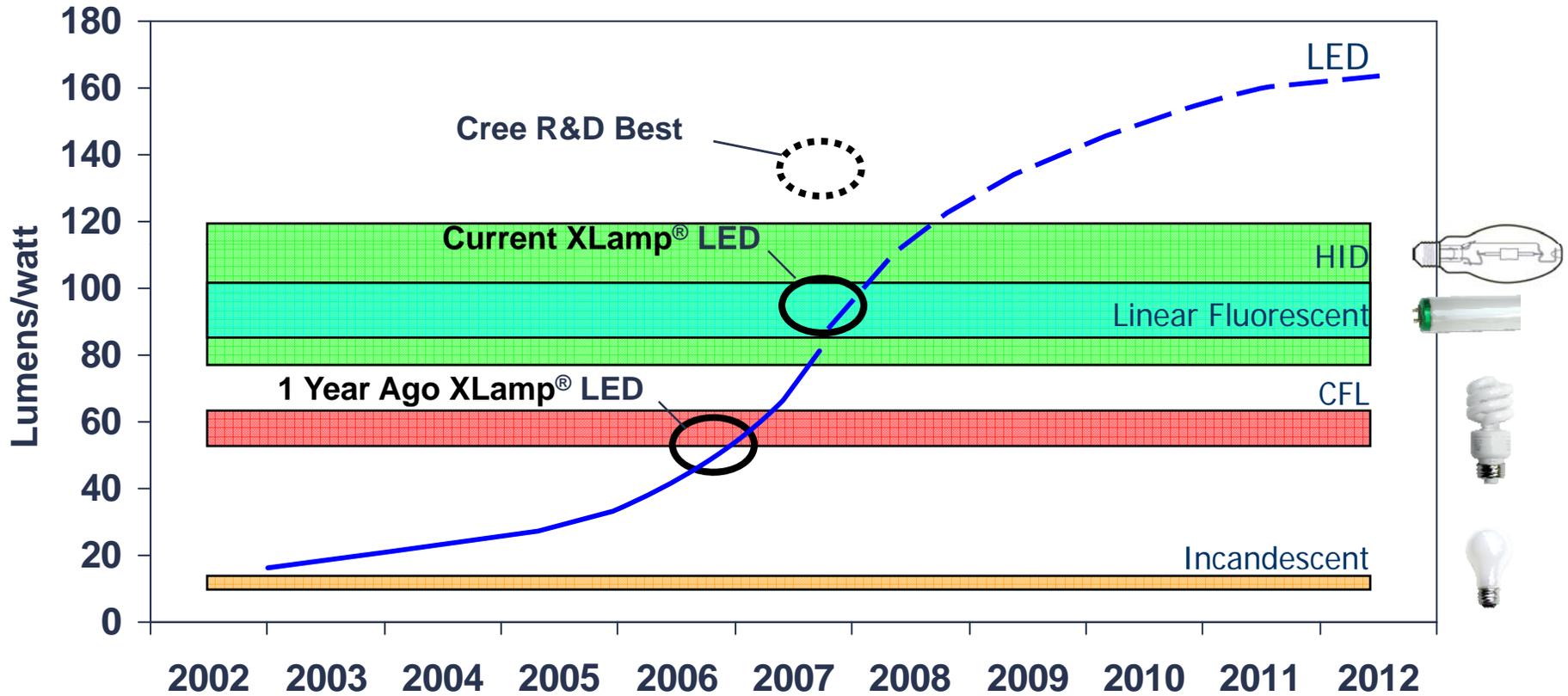
Basic Advantages of LED Light

- LEDs are...very **energy efficient** → >90LPW (near-term roadmap to >150LPW...)
- Are **directional** → No wasted light, any pattern possible
- Have very **long lifetime** → >50,000 hours to 70% Lumen Maintenance (L₇₀)
- Are inherently **rugged** → No filament to break
- **Start instantly** → nanoseconds vs. > 10 min re-strike (HID)
- Are **environmentally sound** → no Hg, Pb, heavy metals
- Are **infinitely dimmable, controllable** → New lighting features, power savings
- Love cold temperatures → **No cold starting or performance issues**



LED Performance Continues To Increase

Light Source Efficiency Trends



100% Improvement in last 18 months

Oakland, CA



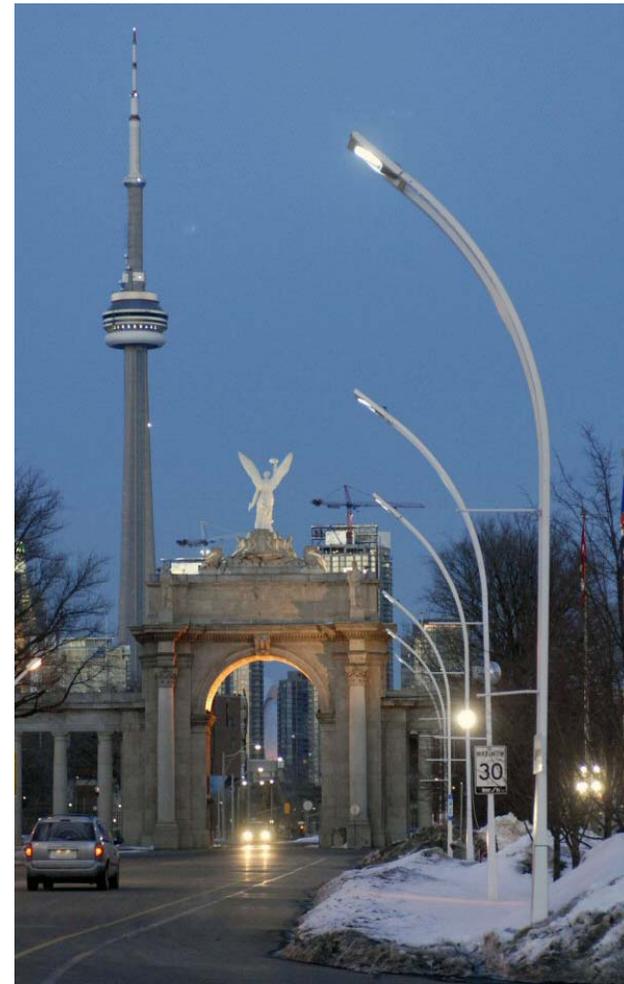
Courtesy of BetaLED

Jackson Hole, WY



Courtesy of Relume

Toronto, Canada



Courtesy of Leotek

Durham, NC

Cree Headquarters



Courtesy of BetaLED

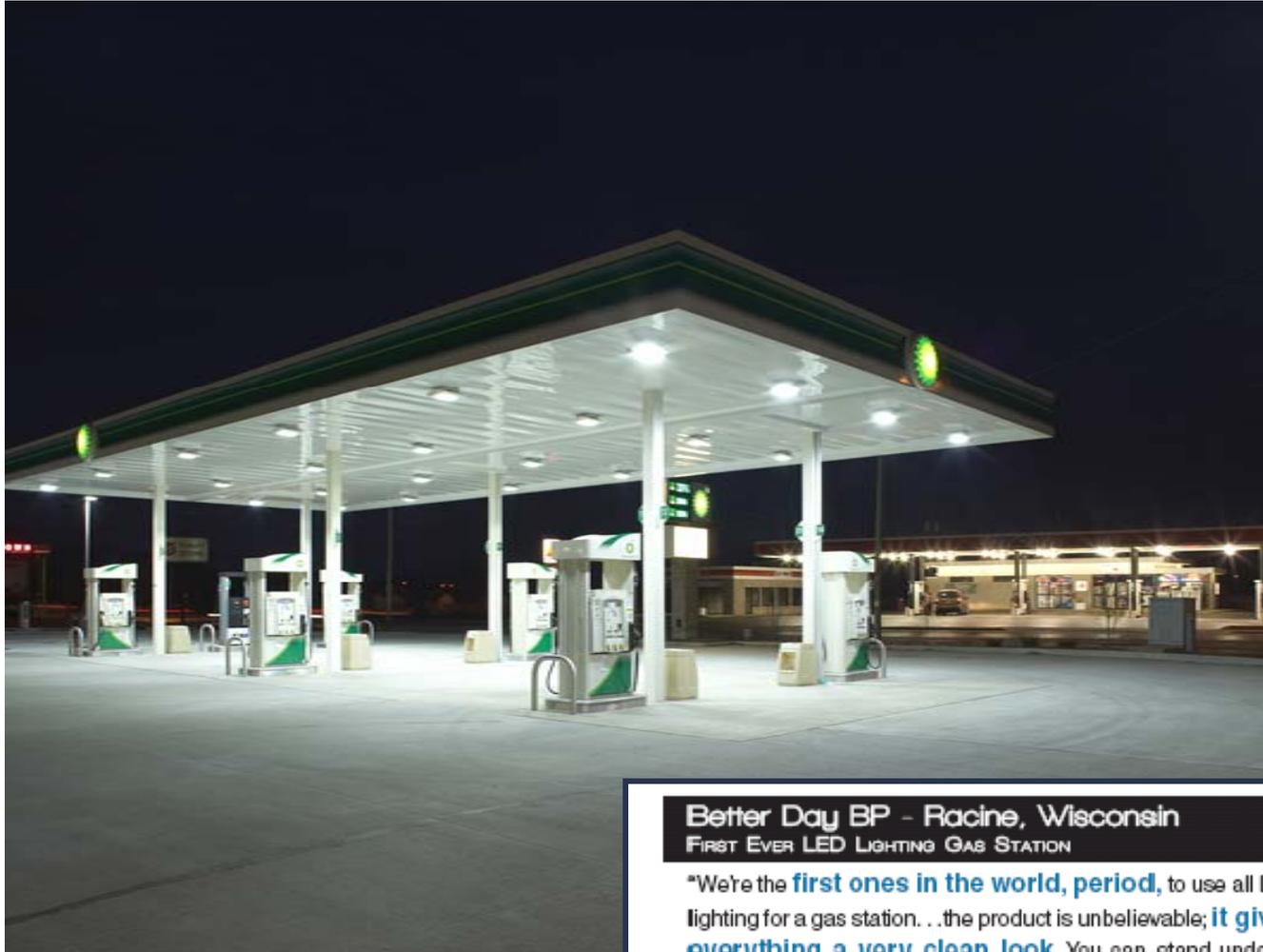
Guangzhou, China



Courtesy of Multi-Cell Semiconductor Lighting Technology Co., Ltd.

Hybrid Solar/Grid Powered Street Lamps

Better Day BP, Racine, WI



Courtesy of BetaLED

Better Day BP - Racine, Wisconsin
FIRST EVER LED LIGHTING GAS STATION

"We're the **first ones in the world, period**, to use all LED lighting for a gas station. . .the product is unbelievable; **it gives everything a very clean look**. You can stand under it, your car looks clean, your shoes look clean."

Hastings, UK Town Centre



Courtesy of Advanced LED

Racine, WI



Courtesy of BetaLED

140W LED vs. 300W HPS Comparison

Split, Croatia



Courtesy of Schröder

Warm White Street Lamps

Waukesha, Wisconsin



Courtesy of BetaLED

Sentry Equipment Corp., Oconomowoc, WI



Courtesy of BetaLED

Torraca, Italy



Courtesy of Elettronica Gelbison, SRL

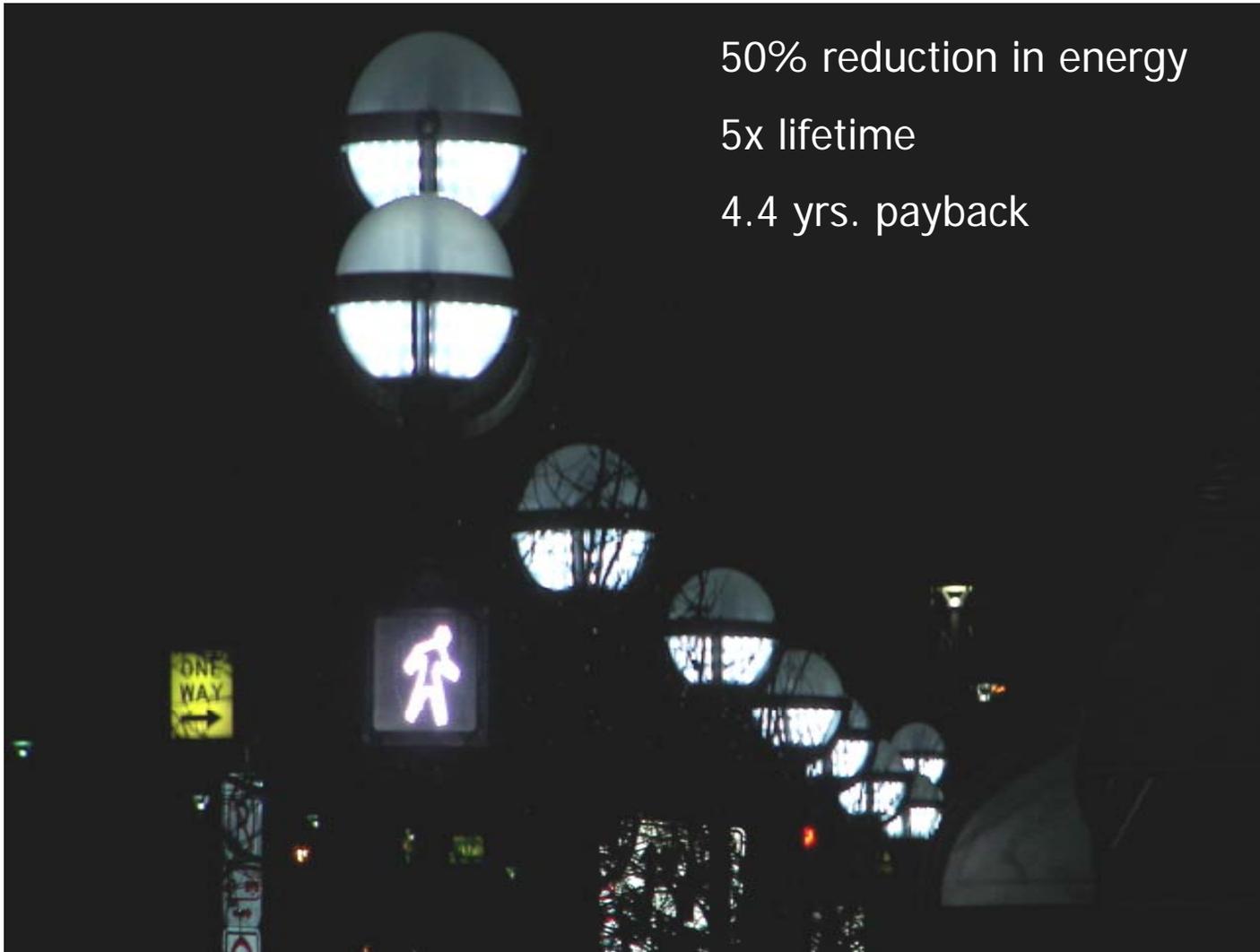
- **530 Luminaires Installed**
- **75% Power Savings**
- **9 month payback**

Crocina Tunnel, Arezzo, Italy



Courtesy of BetaLED

Ann Arbor Streetlight Retrofit



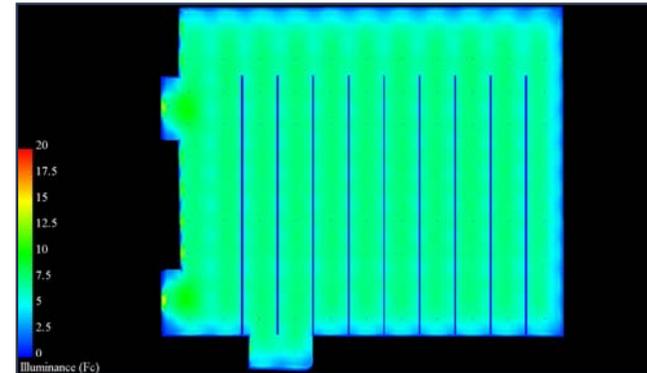
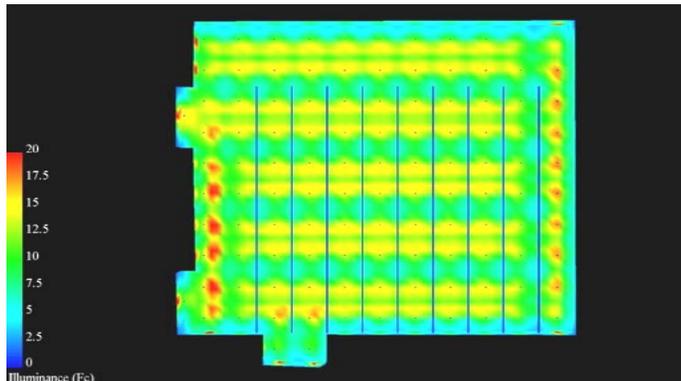
50% reduction in energy

5x lifetime

4.4 yrs. payback

Courtesy of Relume

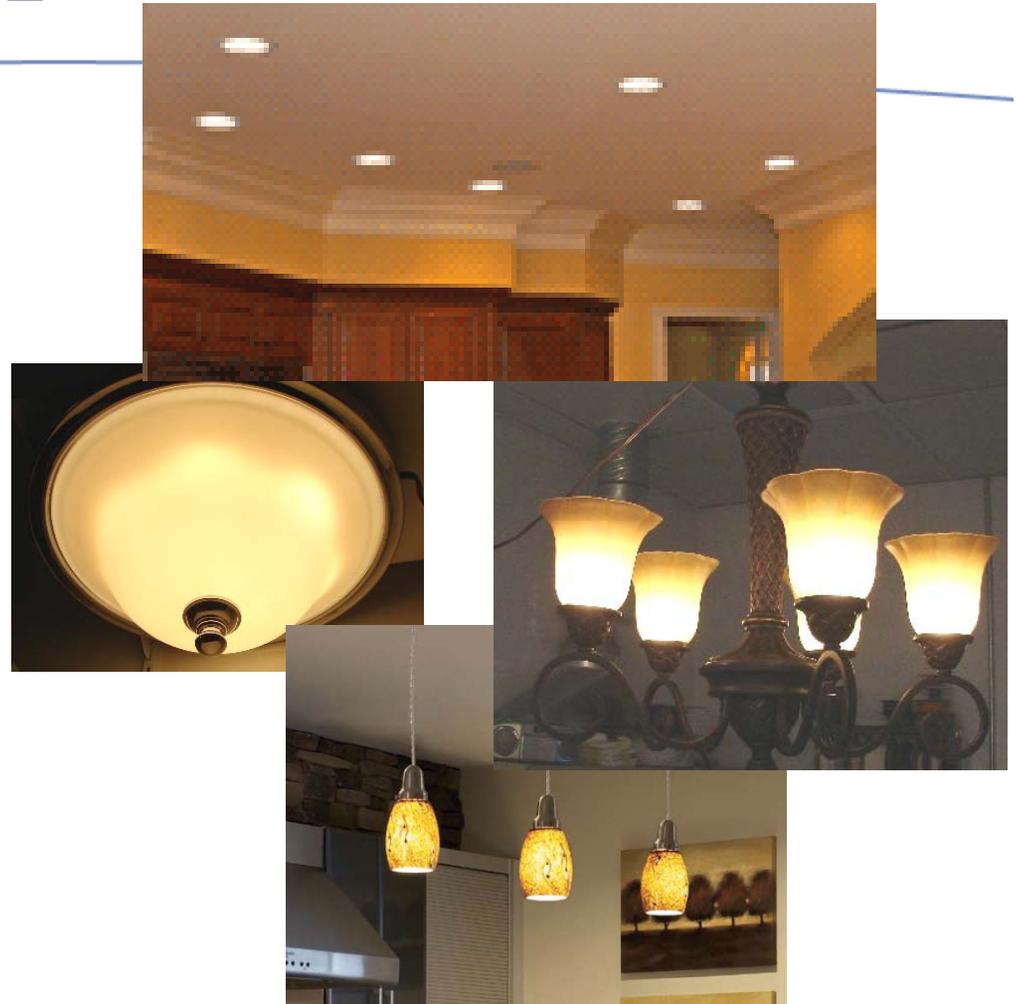
Austin, TX



Courtesy of BetaLED

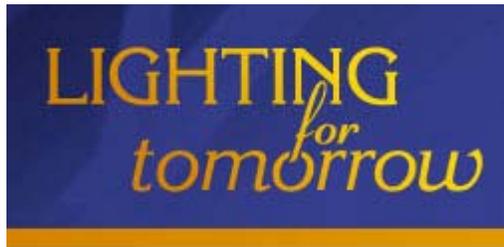
Next Wave: Indoor SSL

- **Different requirements than outdoor**
 - Warm White Color Temperature (~3000K) required
 - High CRI (>80)
 - Lamp maintenance not a driving factor
 - High style content
 - Focus on energy, green
 - Different market channels, cost expectations (consumer product)



Yes, these are LED!

Excellent Results Indoor



**Grand Prize Winner:
LED Lighting Fixtures, Inc.
2007 Lighting For Tomorrow Design
Competition**



- **600 lumens @ 2950K, 11W total power**
- **55 LPW wall-plug (verified independently)**
- **CRI 95**



BEFORE

Incandescent 65W BR30 - Total Power = 5,135W



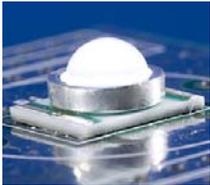


AFTER

LR6 - Total Power = 948W

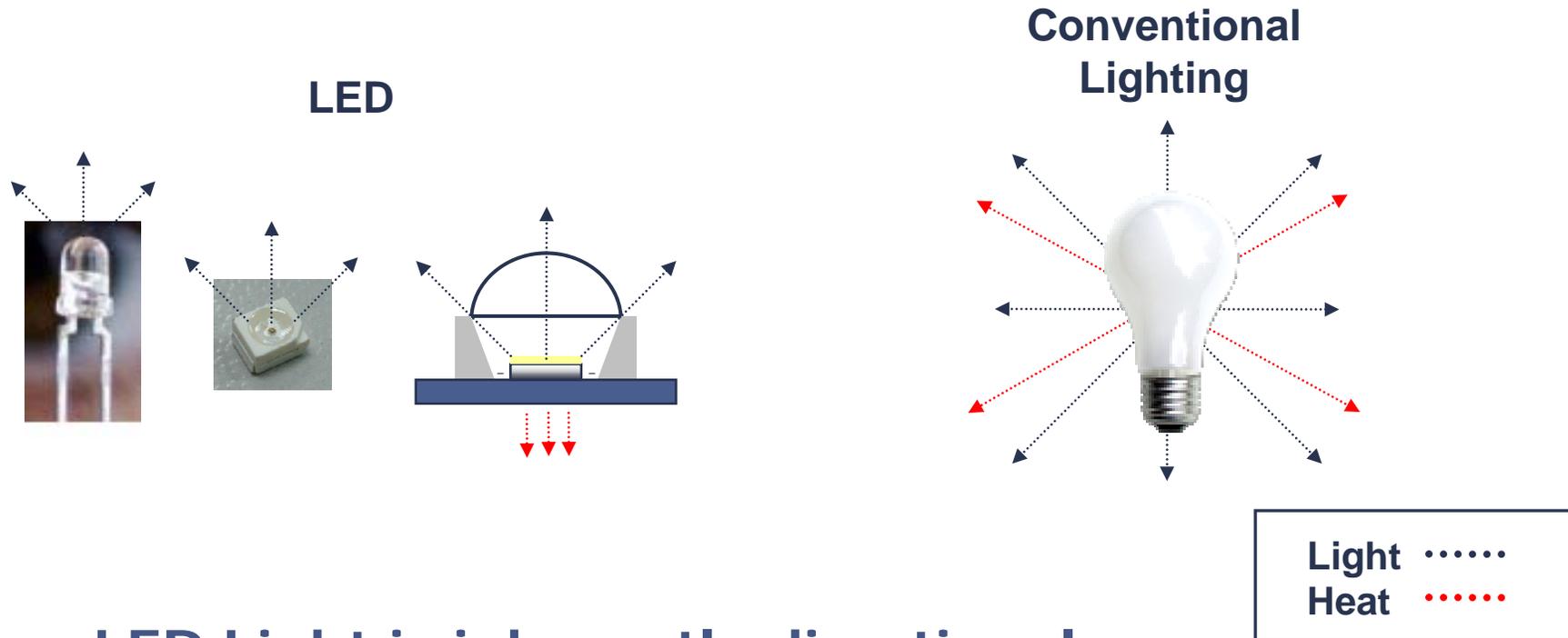


Packaged LED Classes

Lamp Type	Drive Current	Light Output	Brands	Applications
 <p>T1-type (3 – 7 mm)</p>	5 – 20 mA	<1 – 4 lm	<i>(Commodity product)</i>	<ul style="list-style-type: none"> • Indicators • Votive lights • Rope lights • Traffic signals
 <p>Surface mount</p>	20 – 100 mA	1 – 30 lm	<i>(Commodity product)</i>	<ul style="list-style-type: none"> • Cell phone backlighting • Automotive • Channel sign lighting
 <p>High power (Lighting-Class)</p>	> 300 mA	> 80 lm	<ul style="list-style-type: none"> • XLamp® • Luxeon/Rebel • NS6XXXX • Ostar 	<ul style="list-style-type: none"> • General illumination

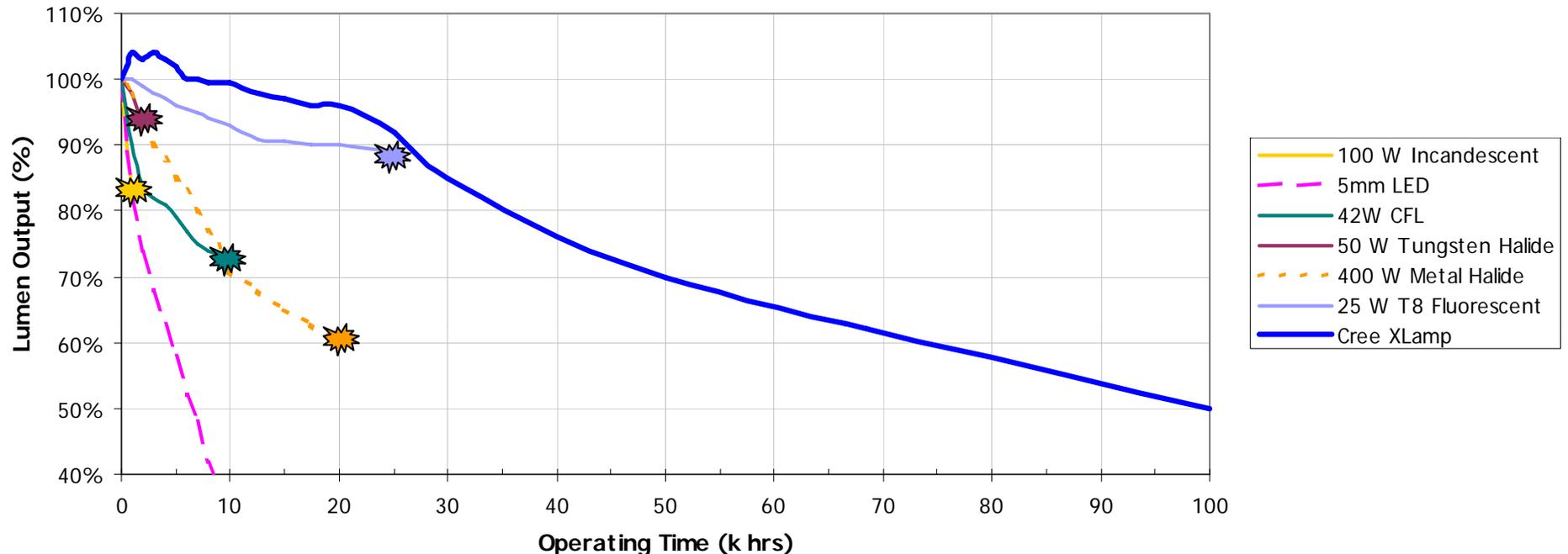
NOTE: T1 and surface mount LEDs are usually rated in microcandela (mcd) for light output instead of lumens (lm). For the purposes of explanation, we converted mcd to lm to measure total light output.

Good LED Luminaire Design Will Be Different...



- LED Light is inherently directional
- LED thermal path accomplished by conduction
 - No IR, no UV in the light beam
- Power LEDs provide conductive thermal path; 5mm and SMD LED lamps normally do not

50,000hrs & Other LED Fairy Tales*



Source: Adapted from Bullough, JD. 2003. *Lighting Answers: LED Lighting Systems*. Troy, NY. National Lighting Product Information Program, Lighting Research Center, Rensselaer Polytechnic Institute.

- 5mm LEDs are not recommended for lighting applications
- Risk: 5mm LEDs are cheap, readily available. Who will have the discipline NOT to use them? Impact on the public perception of SSL?

* ref: John Curran, Dialight

The 5mm LED Risk Realized

Time zero

1000 hours



LED Puck
84.1% Drop



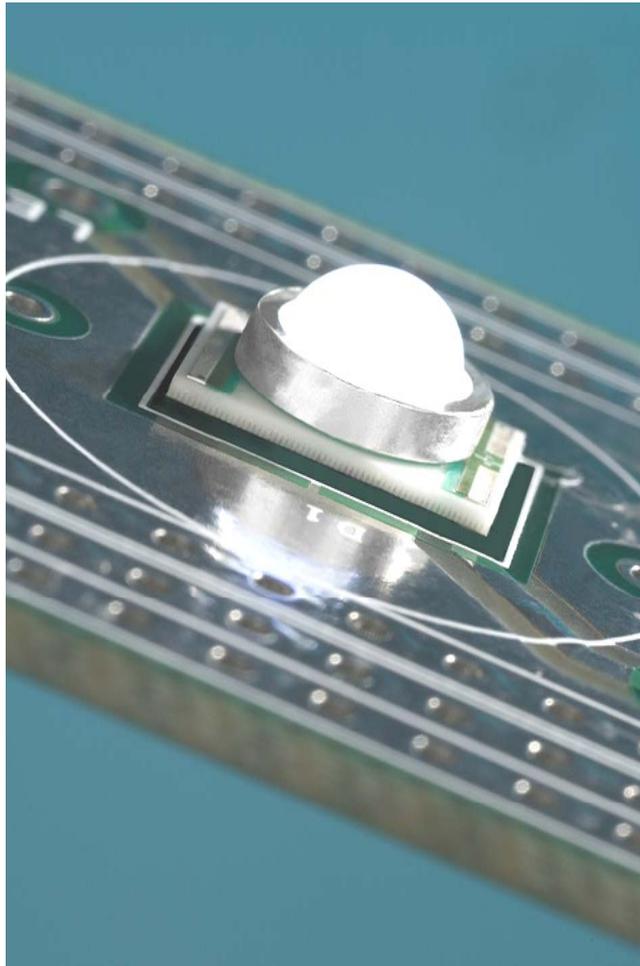
16.5" Linear
97.8% Drop



22" Linear
96.9% Drop



Lighting-Class LEDs



Lighting-Class LEDs	
High Output	>80 lm @ 350mA
High Efficacy	> 75 LPW
Stable Color Point	No bin change over lifetime
Long Lifetime	>40k hrs per IESNA LM-80
Isolated Thermal Path	Designed for lighting apps
High Color Rendering Index	>75
Avail in full range of CCT	7000K - 2700K
Binning	Per ANSI 78.377A

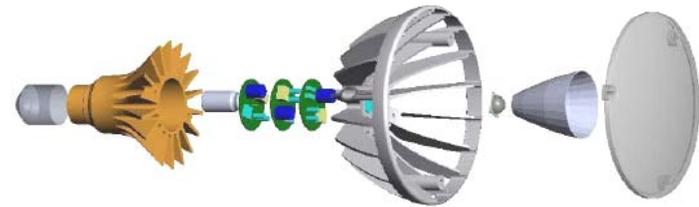
- New in the last 12-18 months
- Stable, High-output, Warm & Cool White
- CRI 75-85 typical
- Thermal path & optics designed for lighting applications

LED Technology Better For Fixtures Than Bulbs

Some Early Attempts



More Recently



- Philips & Cree DOE PAR38 R&D results: 56 LPW, CRI >90
- LLF PAR38 R&D results: 113 LPW, 2760K, CRI 91
- New Energy Bill awards for A-lamp & others

Summary

- LEDs have made unprecedented technological advances in the last 12-16 months
 - Light Output
 - Lumens per watt
 - Color, CRI, and color point stability
- First installations beginning to appear; fixtures designed for LED
- LED Bulb replacements are more challenging, but we'll get there
- LEDs and the SSL market runs a risk of poor quality
 - Not all LEDs are Lighting-class

