# Cree Perspective on SSL

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# The LED Market

- Automotive

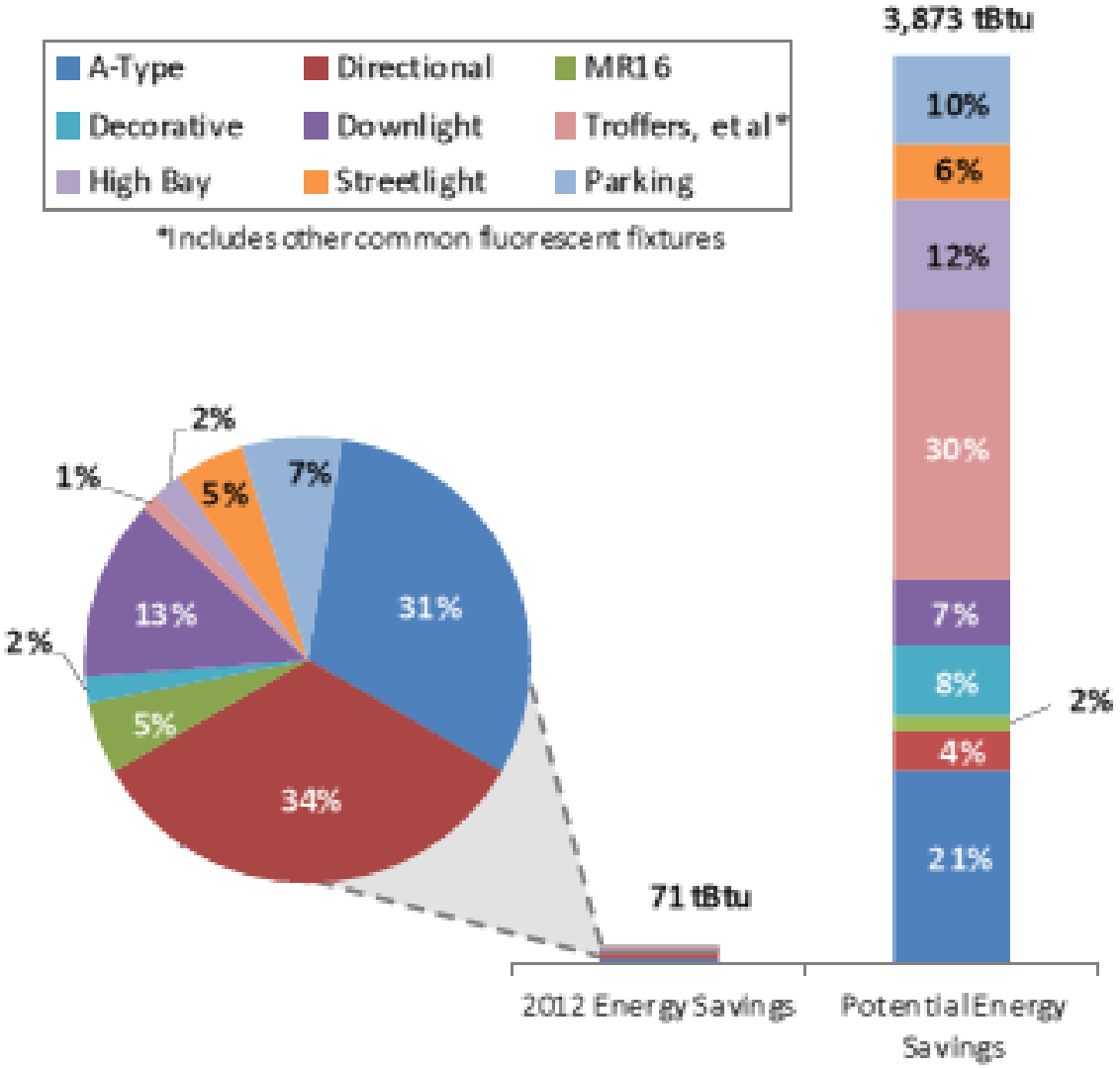
- Backlighting

- Consumer products

- Solid State Lighting

- Toys, tennis shoes & trinkets

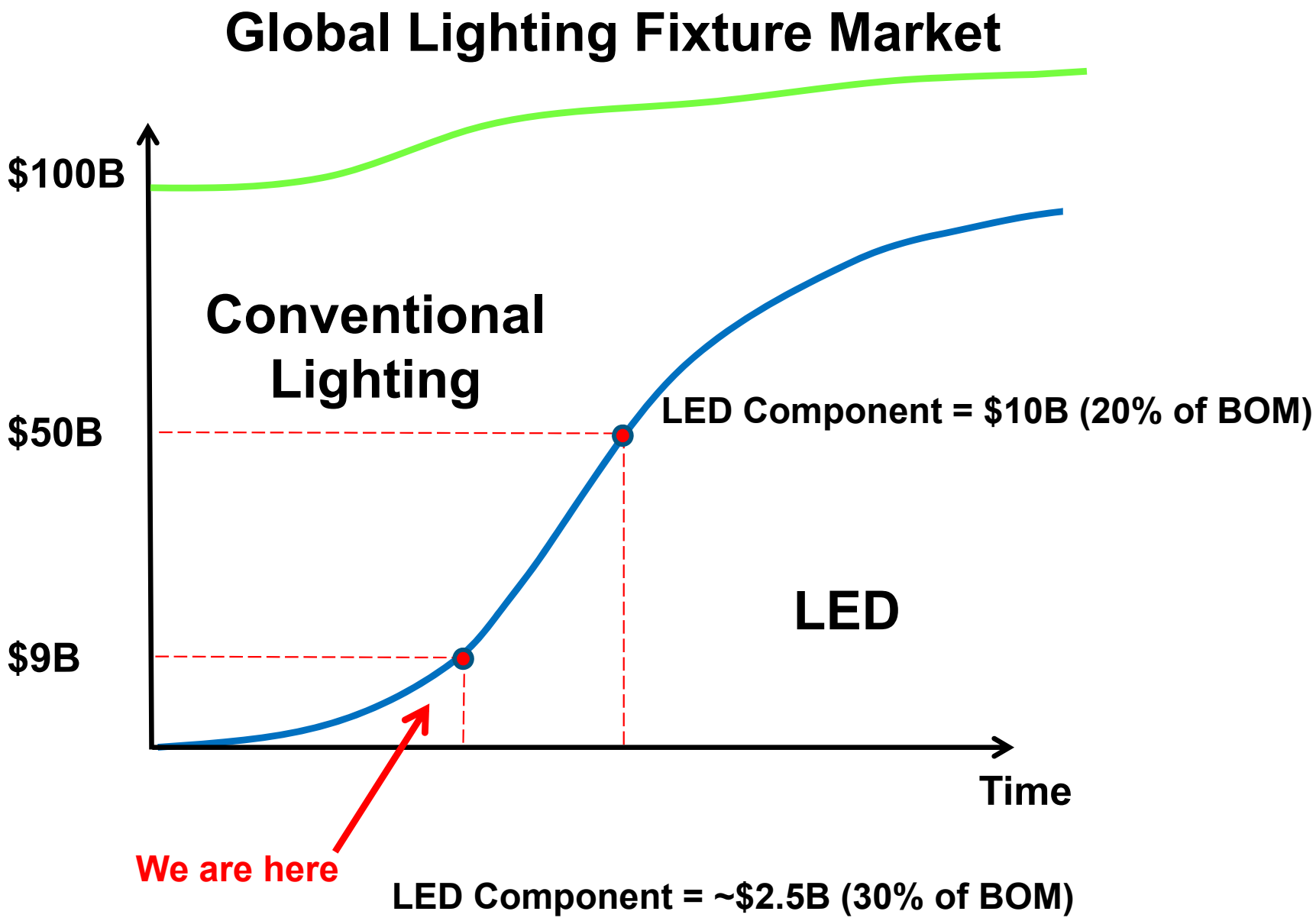
# Why SSL?



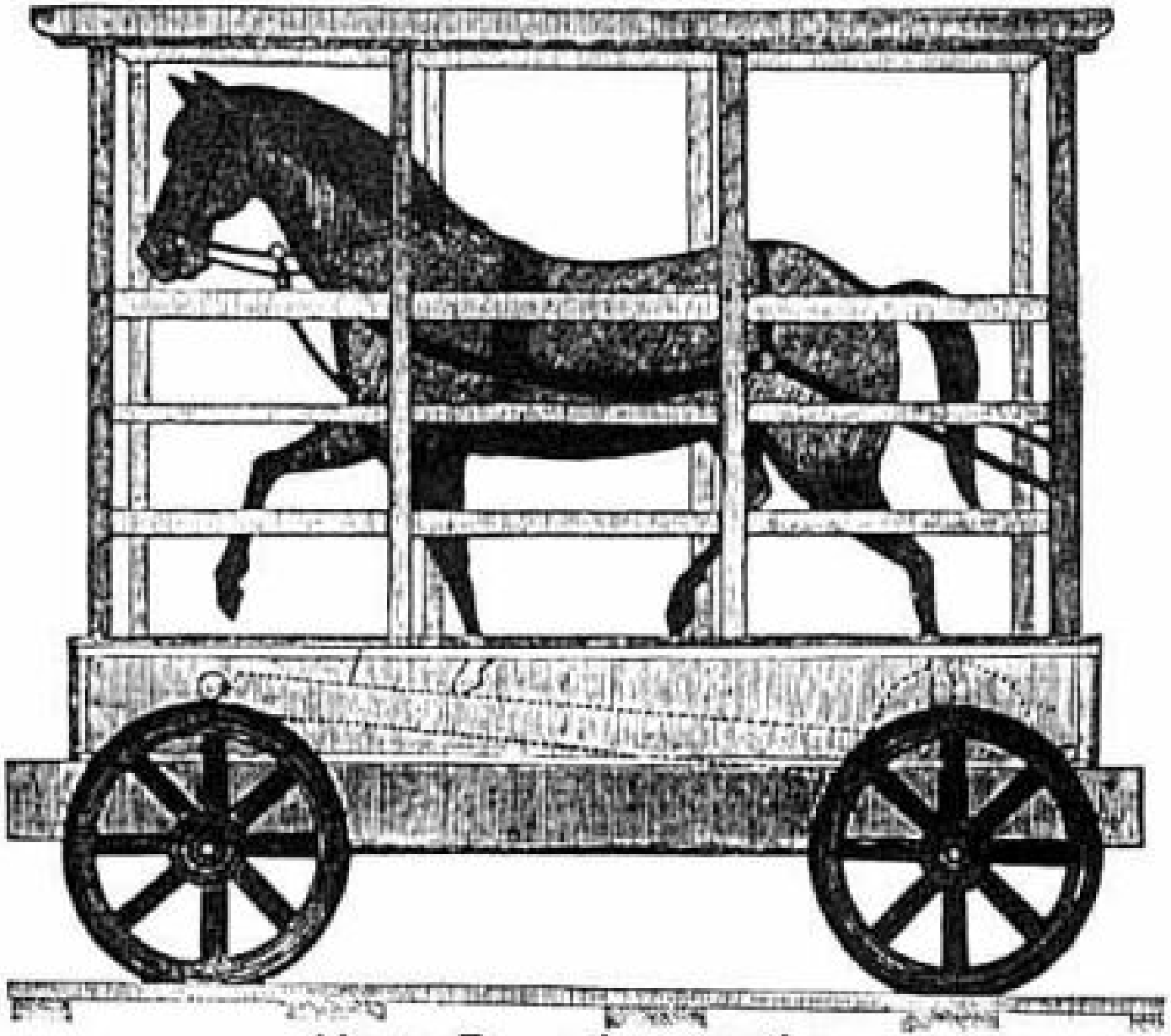

- It's big
- It's compelling
- The other markets are largely decided

*US Department of Energy, Adoption of Light-Emitting Diodes in Common Lighting Applications, April 2013, p.1*
http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led-adoption-report_2013.pdf

# How Big?

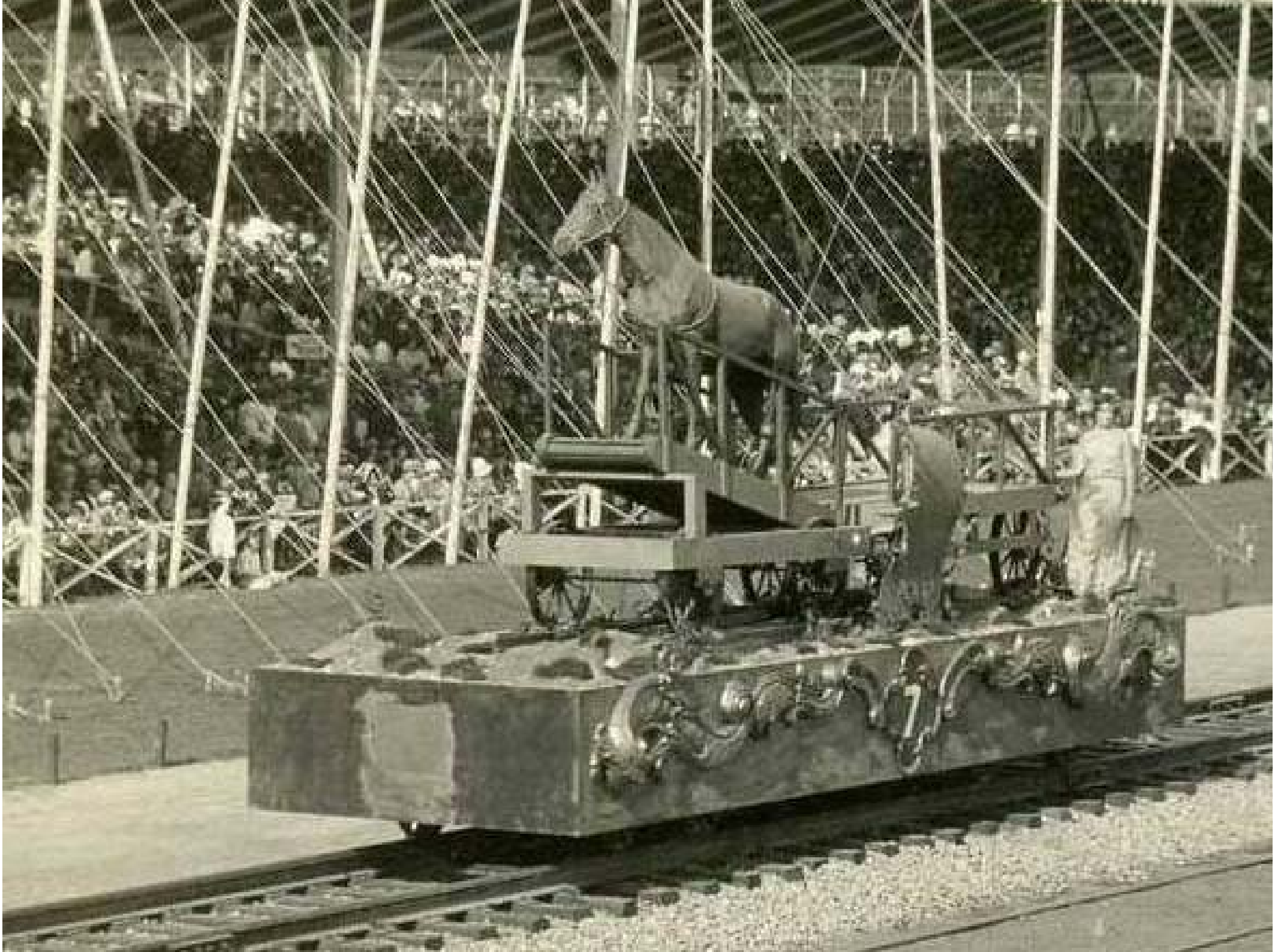

Global Lighting Fixture Market
$100B
$50B
$9B
Conventional Lighting
LED
LED Component = $10B (20% of BOM)
Time
We are here
LED Component = ~$2.5B (30% of BOM)

# People Will Try Almost Anything

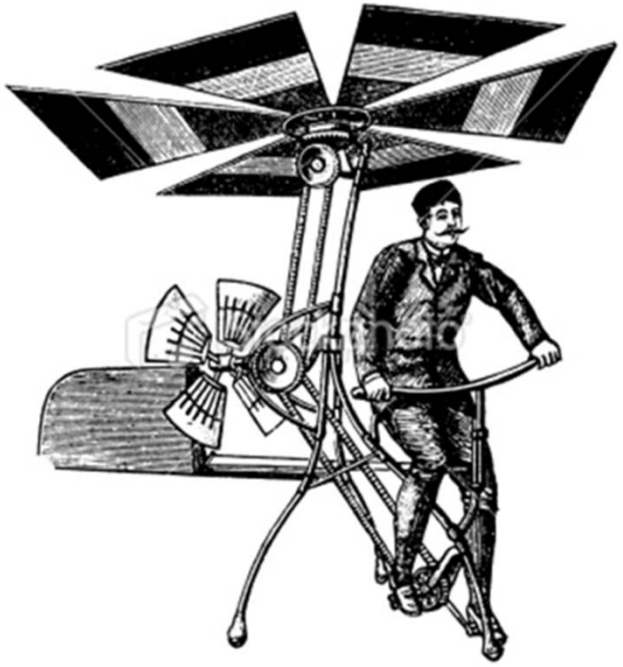


Horse-Power Locomotive

ca. 1818



# These Ideas Didn’t Work Out So Well



# SSL Ideas That Won't Work So Well Either…

- So-called 'AC' LEDs
- "Fixing" Droop
- GaN on GaN, GaN on Si
- Remote phosphor
- OLED (in lighting)
- "Fixing" Green Gap; RGB, RGBA, RGBAC… (in lighting)

# A Familiar Theme…

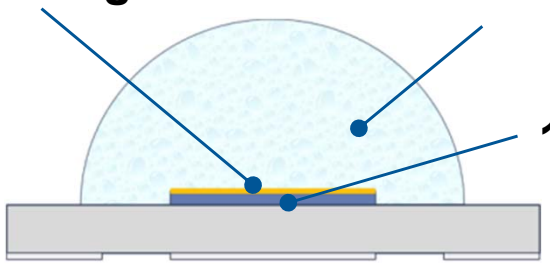
They don't **look**, **light**, or **function** the way consumers expect them to…

# Things Settle Out Eventually

- Non-weird shape
- Non-weird color
- Dimmable
- Affordable

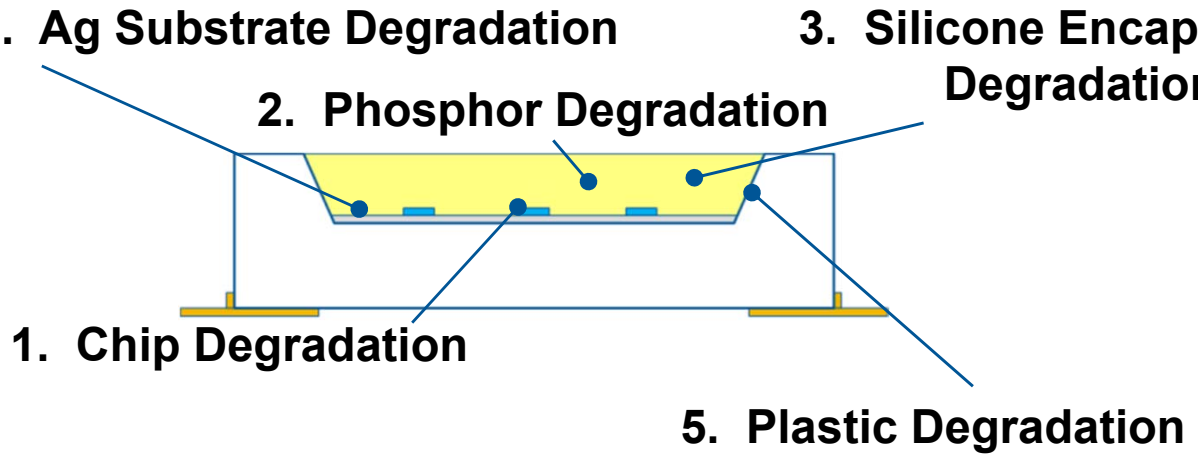
# Different LED Architectures, Sources of Light Degradation

## Ceramic Substrate LEDs



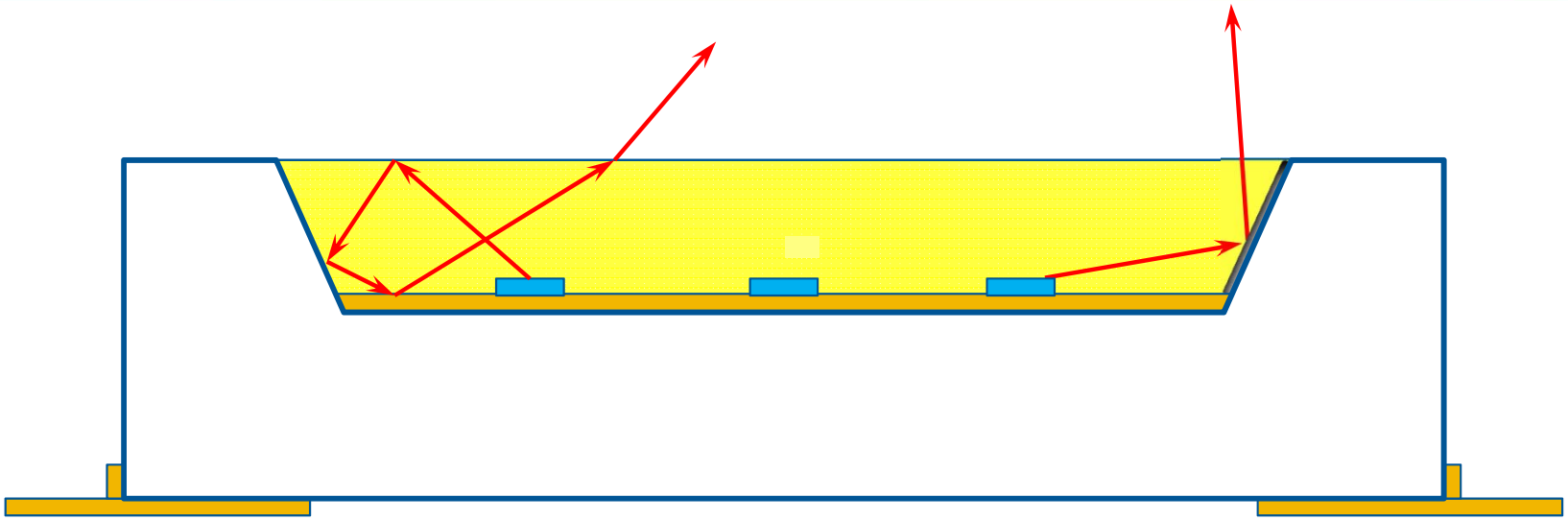

**3 Sources**

## Plastic Leadframe LEDs




**5 Sources**

# Plastic & Metal Degradation Mechanism



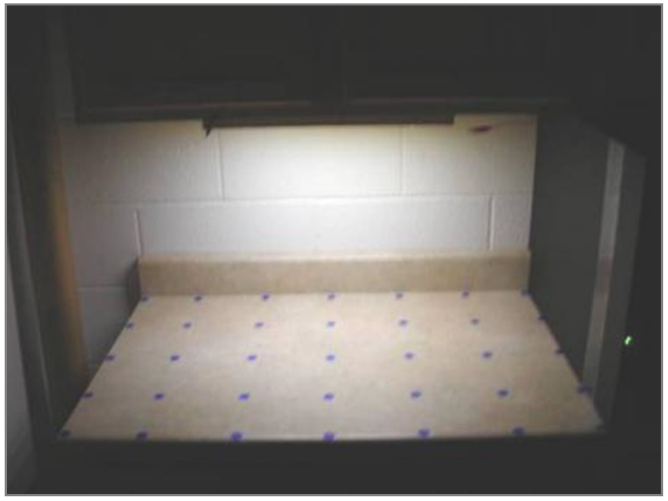
- Light extraction in this LED lamp architecture depends on substrate and sidewall reflectivity
- Plastic can degrade under photon bombardment and thermal stress
- Metal can tarnish due to application environmental conditions (moisture, sulfur, etc.)
- Both can reduce LED lamp light output…

# Light Degradation at the Application Level

## Time zero

## 1000 hours

Brightness



Color

This may be OK for some consumer applications
Brightness

Brightness

☼ Brightness

We don’t typically have this kind of control on our lights…
Brightness

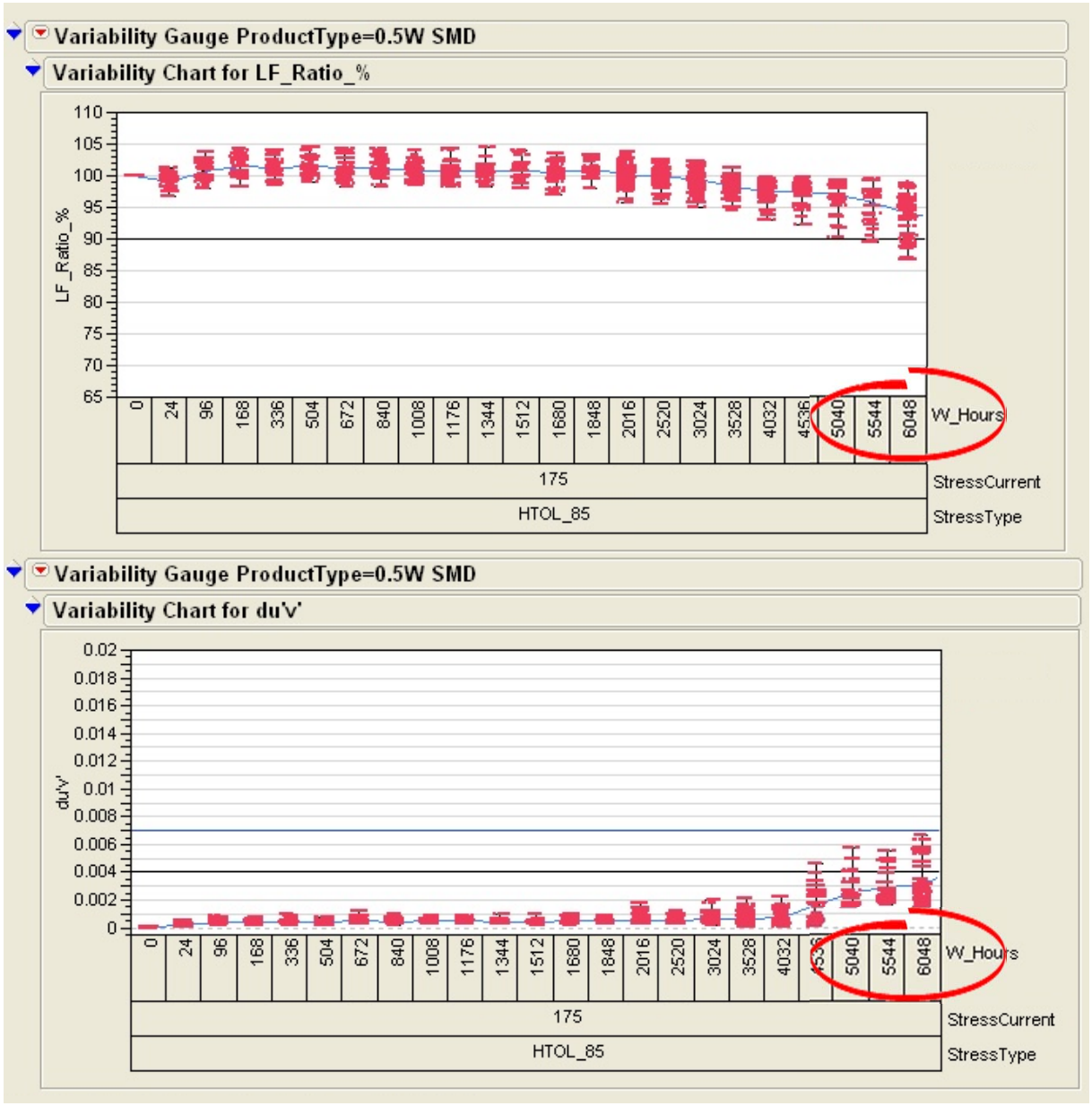
Hue

Hue

Hue

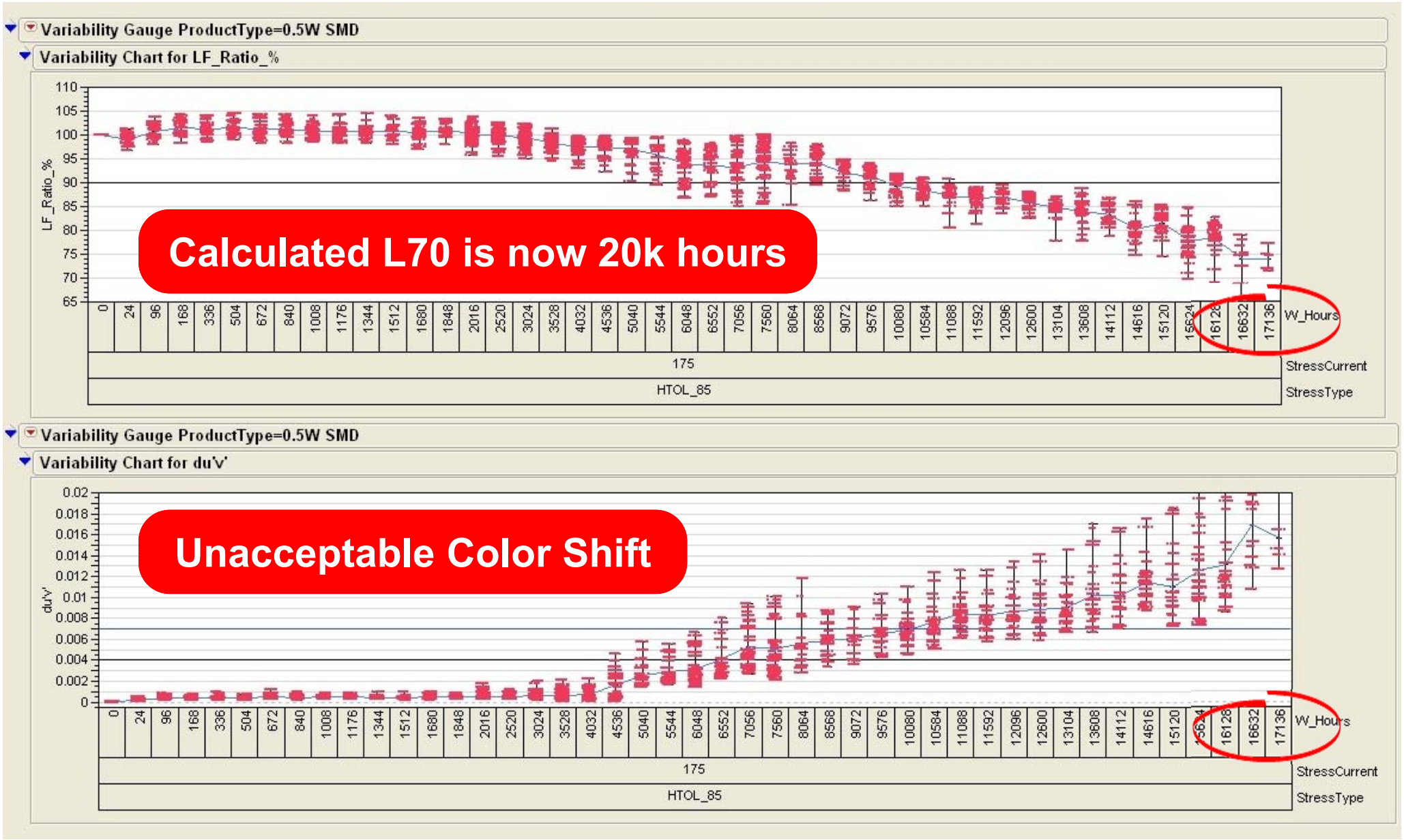
No remote control for this either…
Hue

# LM-80 Data with Plastic mid-power LEDs




- After 6,000 hours of LM-80 testing the calculated L70 for these LEDs is 43K hours
- Color shift (Δu'v') is within the Energy Star 7-step MacAdam Ellipse requirement

# Same Data Set After Additional LM-80 Testing



# LED Technology Drives Low Cost

## 2007

- 42 LEDs
- 650 lm
- 12W

>$100 Commercial
Wholesale (~$150)

## 2010

- 8 LEDs
- 650 lm
- 10.5W

$50 Retail

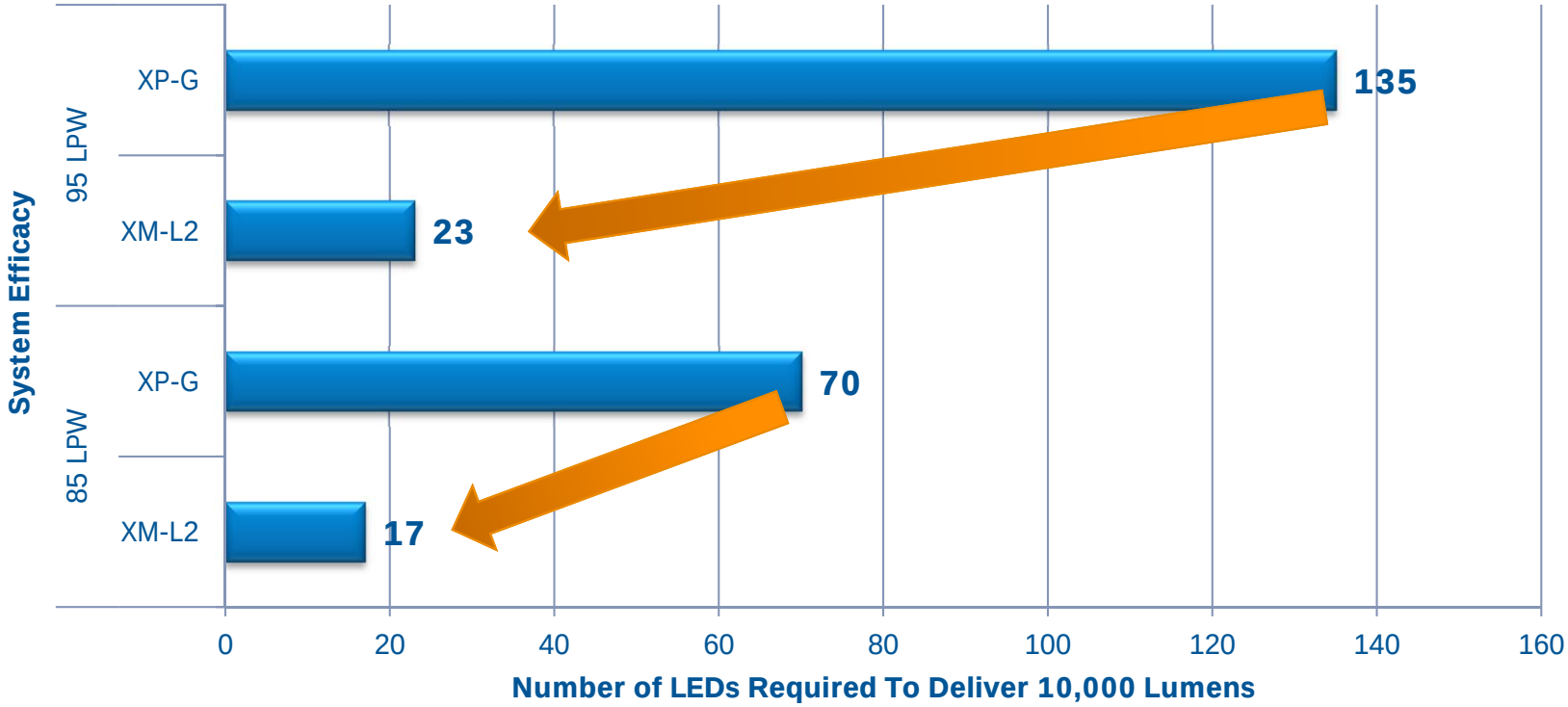
## 2012

- 5 LEDs
- 650 lm
- 9.5W

$25 Retail

# Because It Makes Systems Cheaper.  A Lot Cheaper.

## Fewer LEDs & optics for the same system



# The Next Big Opportunities in SSL

DIGITIMES

Taipei, Tuesday, May 21, 2013 19:2 (GMT+8)

## Revenues for drivers in LED general lighting applications to triple, says IMS Research

*Pres... Jessie Shen, DIGITIMES [Tuesday 21 May 2013]*

Global revenues for LED ... will more than triple from 2012 to 2015, as the market for solid-state illumination booms, according to IMS Research.

The market governing LED driver ICs for lighting will surge to US$666 million in 2015, up from US$214 million in 2012, said IMS. Growth will moderate somewhat during the following years, but revenues are expected to continue to expand, reaching US$810 million in 2018.

"Major advances and cost reductions in lamps, luminaires and automotive lighting are spurring the rapid growth of the market for LEDs in general lighting applications," said Stephanie Pruitt, lighting and LEDs analyst for IMS. "This in turn is generating major opportunities for LED driver ICs. Once dominated by the display backlighting business, the LED driver IC market now is being driven by the soaring market for general lighting."

**Daylight Harvesting**

**Internet of Things**

**Dimming & Control**

# Summary

- **This new LED market is upon us, but will consolidate like previous ones**
  - **People will try all kinds of wacky ideas in the mean time**

- **Making LED lamps is relatively easy**
- **Making Lighting-class LEDs is not**
- **LED performance and technology will drive lower SSL costs; not a race to the bottom on LED component quality**
- **The really interesting new semiconductor opportunities in Solid State Lighting will be in control:**
  - **Basic dimming and occupancy sensing**
  - **Daylight harvesting**
  - **Internet of things**

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