U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

LED Technology Basics: What makes it go and some myth busting



"Uses virtually no energy!"

"Never replace another bulb!"

"100,000 lifetime!"

"LED's last forever!"



"Super Efficient"

"Will replace any other bulb!"

GreenBuild 2010

November 17-18, 2010

Eric Richman, LC

Pacific Northwest National Laboratory

Eric.Richman@pnl.gov

What makes LEDs go…….

You've heard that LEDs are different than other lighting technology. So what's the difference?



- Incandescent/Halogen --- a glowing wire or filament



- Fluorescent --- an electric arc that excites a gas that causes phosphors to glow

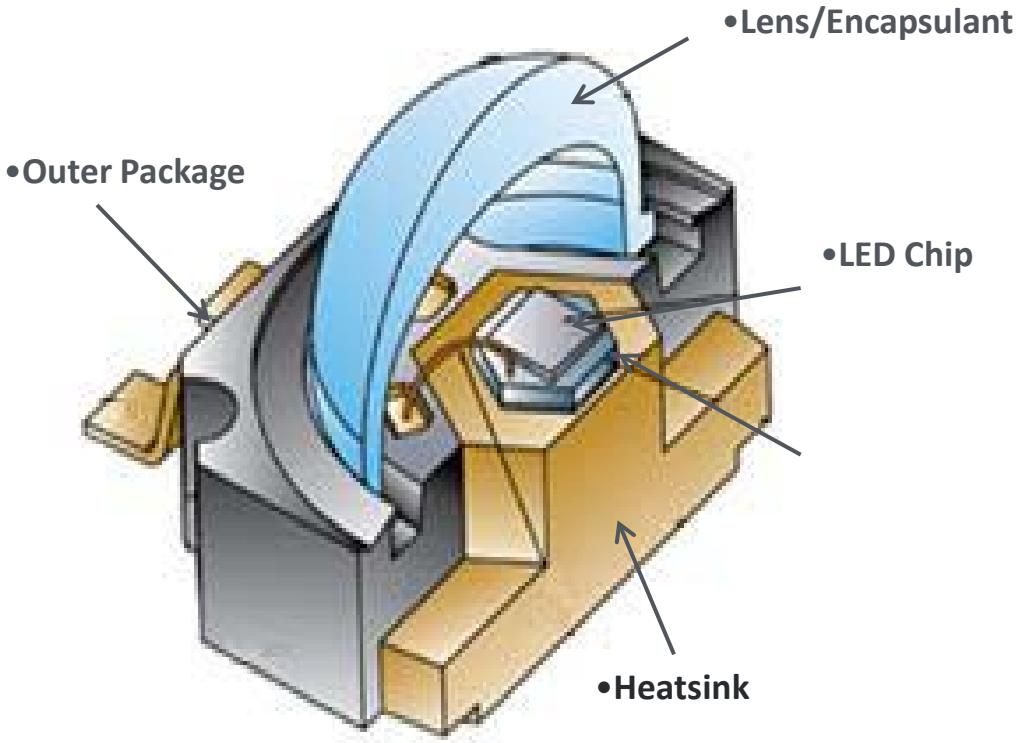


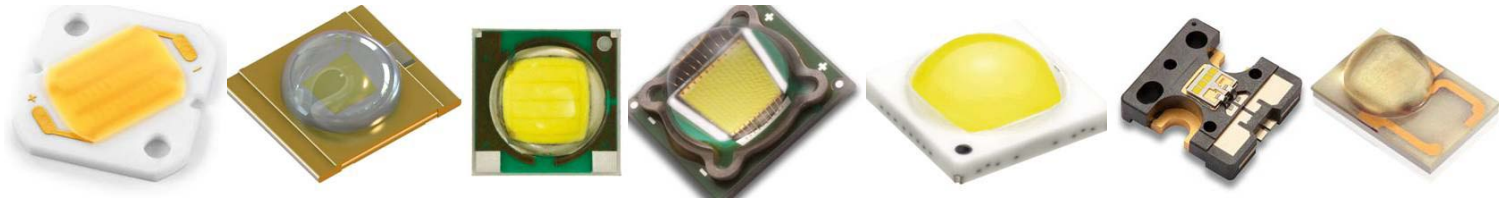
- HID (metal halide, high pressure sodium) --- an electric arc that vaporizes material that emits light

- **LED --- an electronic semiconductor diode (chip) that emits photons (light) when current is applied…..**



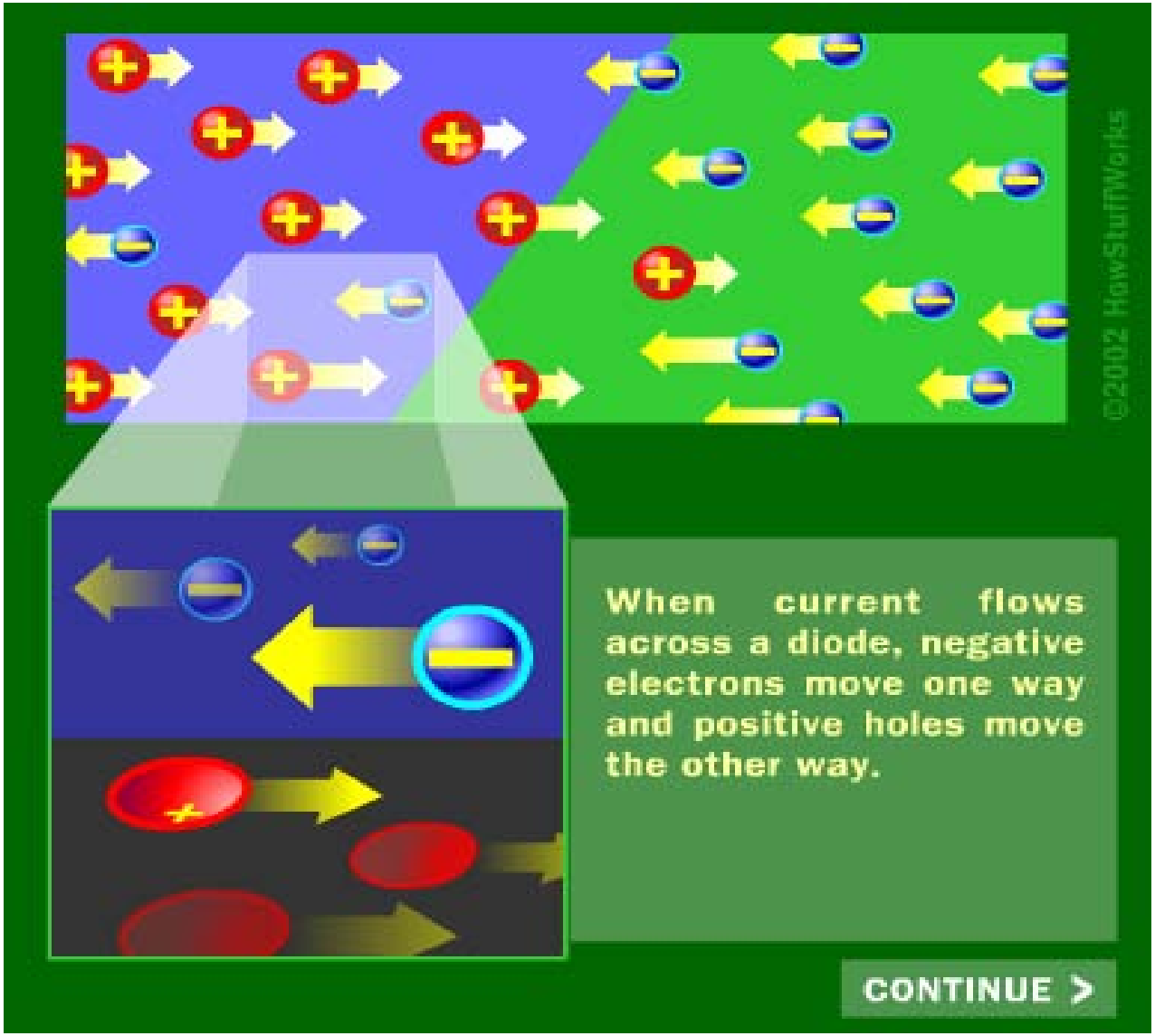
Basic anatomy of a typical LED



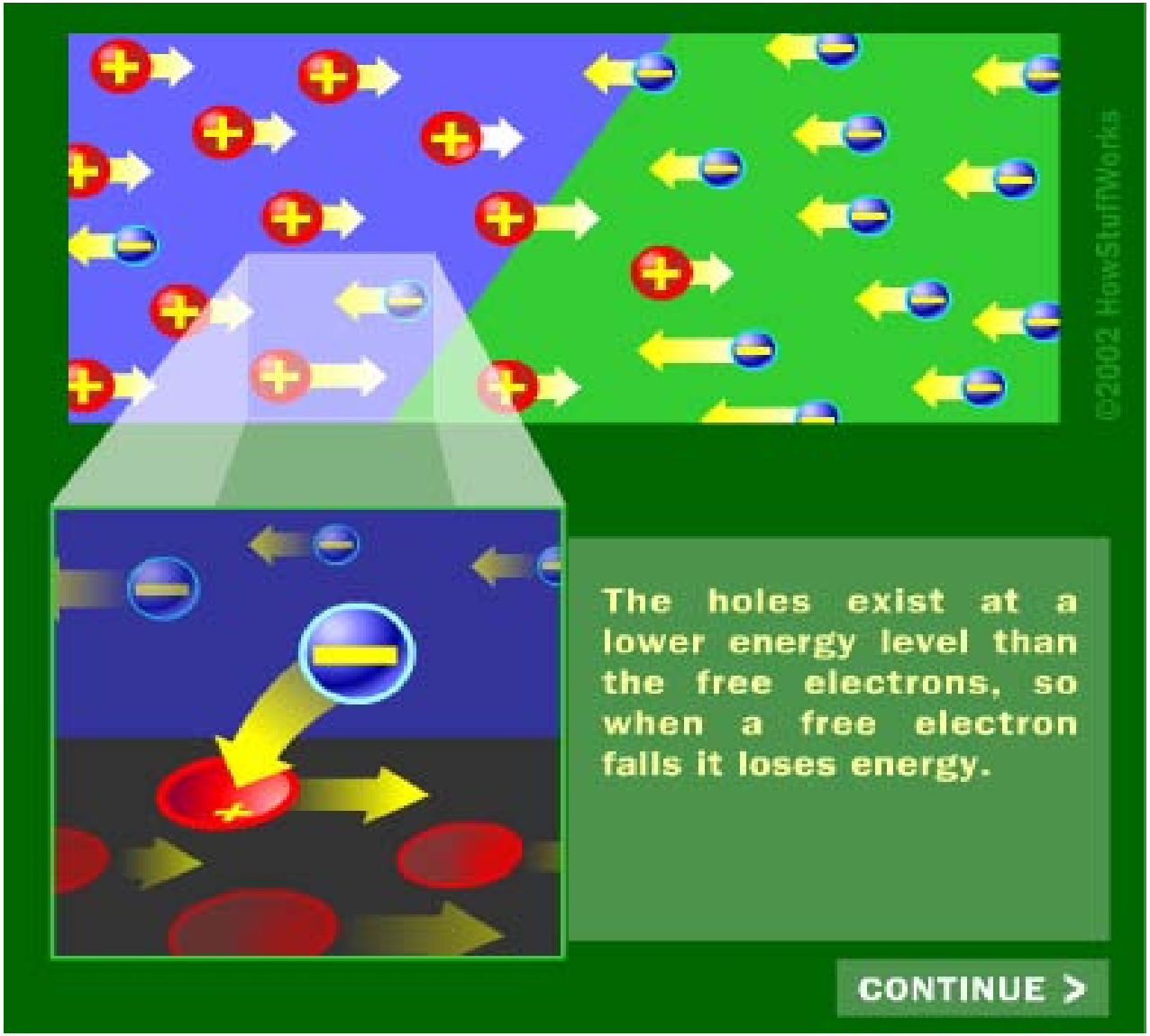


Back to a diode that emits photons....

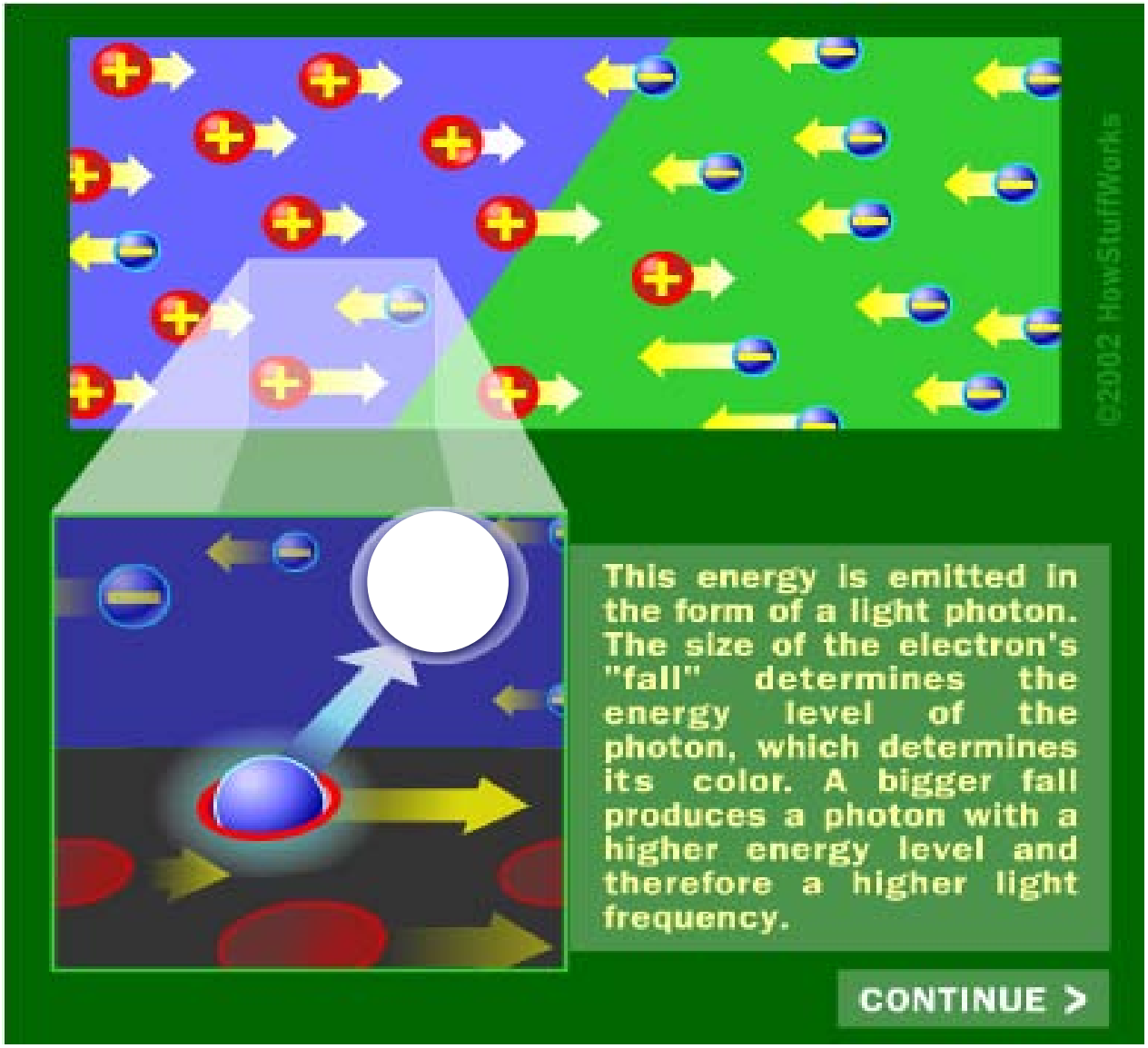
- ***Diode***: a device with a semiconductor junction that restricts current flow to one direction



A diode that emits photons....



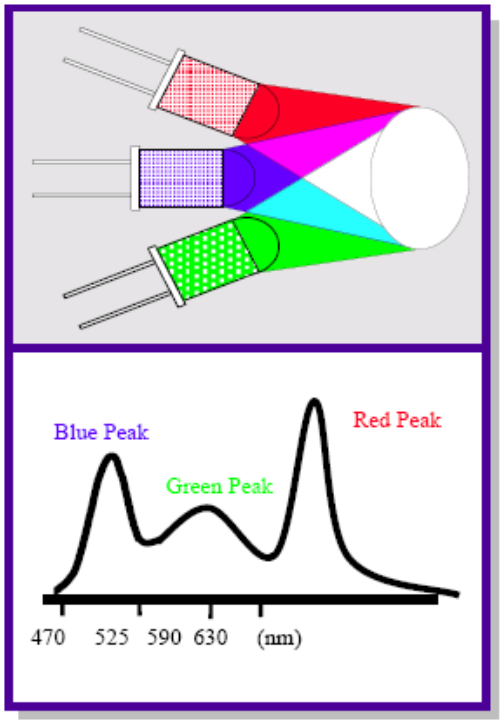
A diode that emits photons....



- Color of light depends on energy level of photon

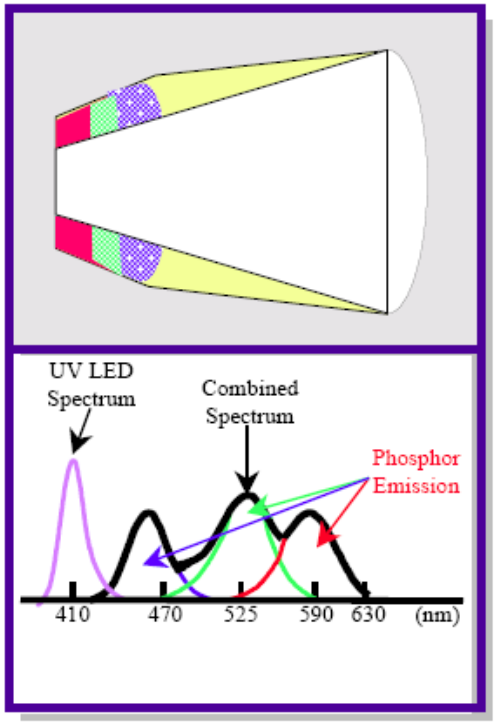
So How Do We Get White Light?

Red + Green + Blue LEDs



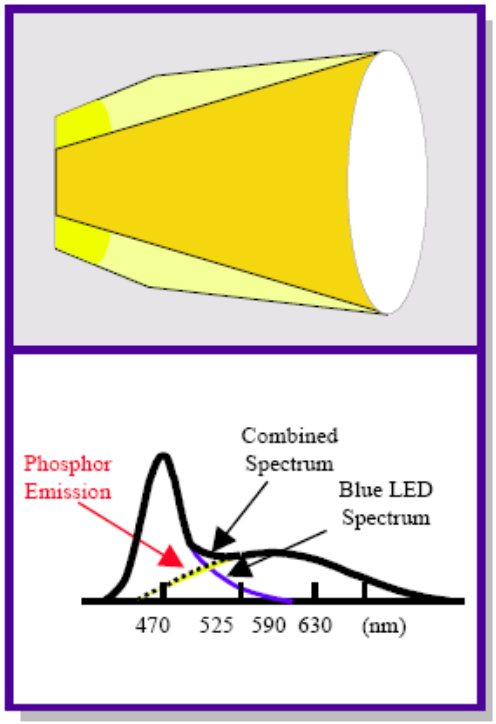
- Dynamic color tuning
- Excellent color rendering
- Large color gamut

UV LED + RGB Phosphor



- White point tunable by phosphors
- Excellent color rendering
- Simple to create white

Blue LED + Yellow Phosphor

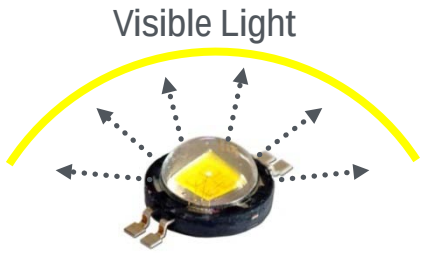


- Simple to create white
- Good color rendering

Courtesy: Lumileds

Good stuff about LEDs

- Small format
  - Provides for more flexibility in luminaire design
  - Great fit for hidden applications (i.e. showcases, equipment, architecture lighting)
- Directional – radiate in 180 degrees
  - Can improve application effectiveness
  - Helps put light where its needed
- Robust and sturdy
  - No fragile filament to break
  - No large glass enclosure to break
- Potentially small environmental footprint
  - Relatively small material component
  - Heat sinks are large but typically of easily recyclable aluminum
  - Current study underway to characterize cradle-to-cradle affect



More good stuff…..with caveats!

- Do not *radiate* waste heat
  - Good for fragile artifacts and organics (i.e paintings, food)

    …..but they do produce heat - more later
- Potential long life
  - Could reduce replacement costs
  - Could reduce maintenance costs

    ….but this is not simple – more later
- Potential high efficacy – low energy
  - Promising efficacy that can surpass other technologies
  - Could be important part of near zero-energy strategies
  - Low energy a perfect “green” component

    ….but efficacy characterization is not simple – more later

Busting Some Popular Myths…..

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

….or at least clarifying the reality

- Three of the biggest miss-statements….
  - "*LEDs produce no heat*"
  - "*LEDs are extremely efficient….more so than any other light source*"
  - "*LEDs last 50,000 hours - 100,000 hours - forever!*"



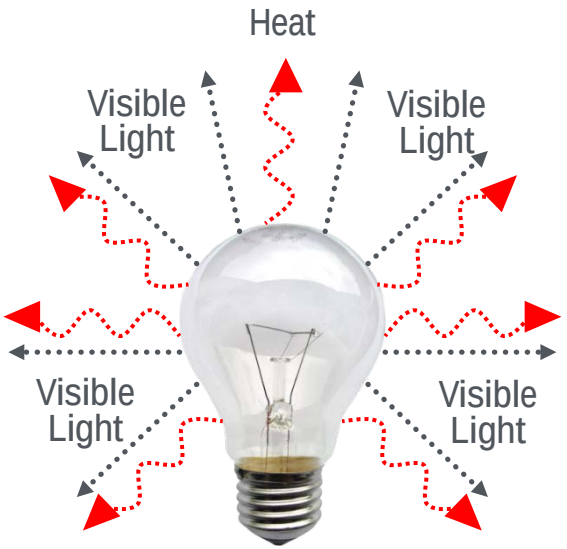
“LEDs produce no heat”

They DO, but prefer to keep it to themselves

Incandescent source

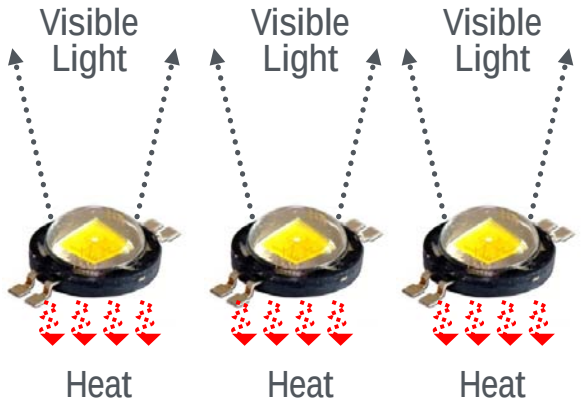
(also typical for FL, HID)

- Some generated heat is radiated away (IR)



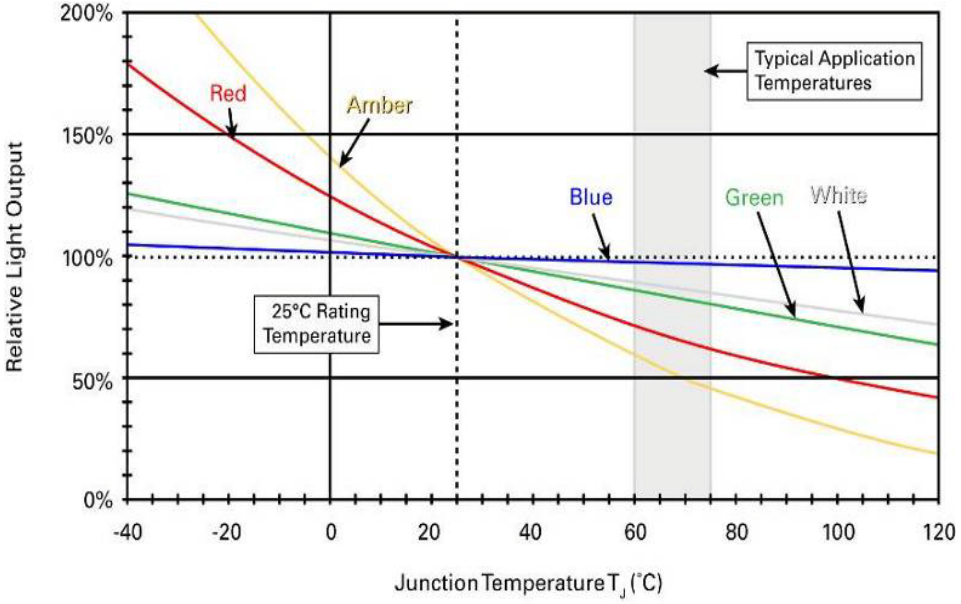
LED source

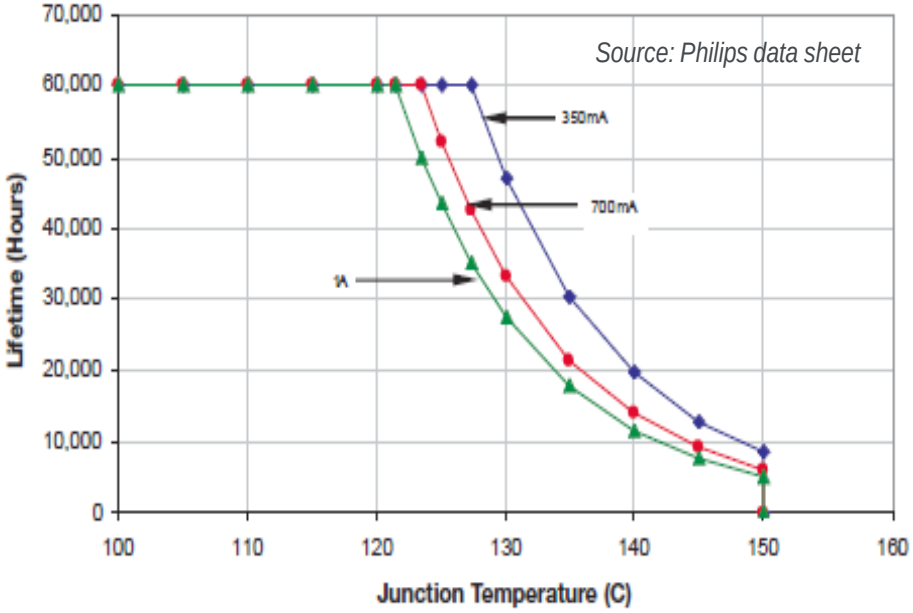
- Generated heat does not radiate. It must be conducted (primary) or convected away



Heat effects on LED performance

- Higher junction temperature (at the LED diode) degrades light output and life
- Heat can also degrade other components
  - Lens or encapsulant
  - Substrate connection materials
  - On-board electronics

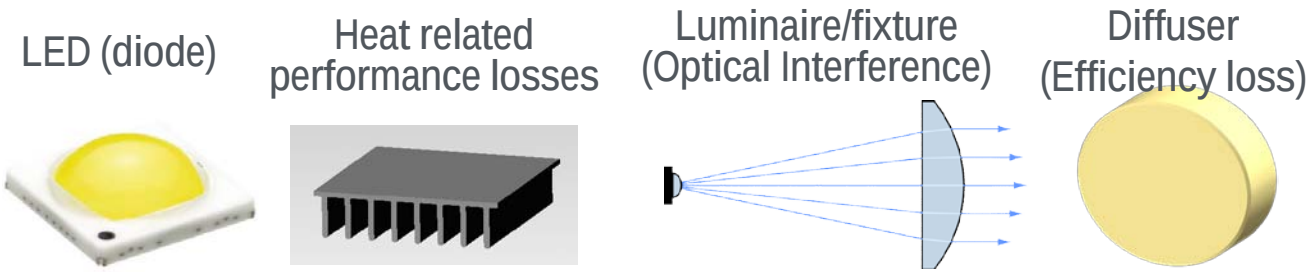




“LEDs are extremely efficient….”

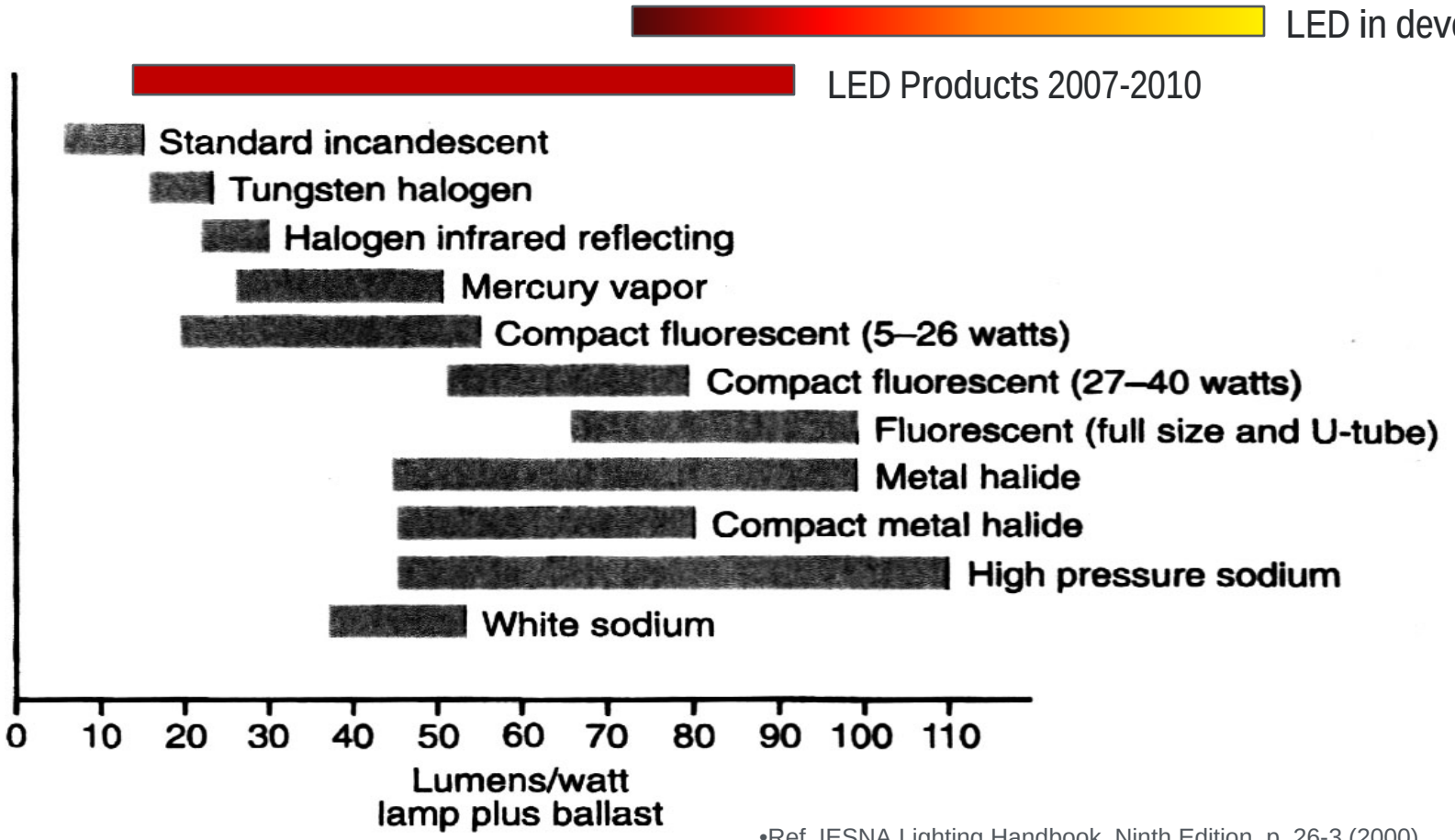
Well….some are and some aren’t (yet)

- Claims of diode efficacies (ideal conditions) exceed 100 lumen/watt – higher than any “white” light source
- However, an LED luminaire (fixture) is a **system** and all components and their specific combination effect efficacy



- LED luminaire efficacies are more modest and variable. (CALiPER has tested from 10 lm/Watt to 108 lm/Watt)

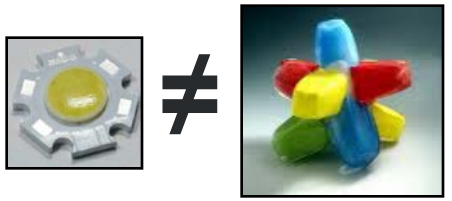
LED system efficacy



•Ref. IESNA Lighting Handbook, Ninth Edition, p. 26-3 (2000).

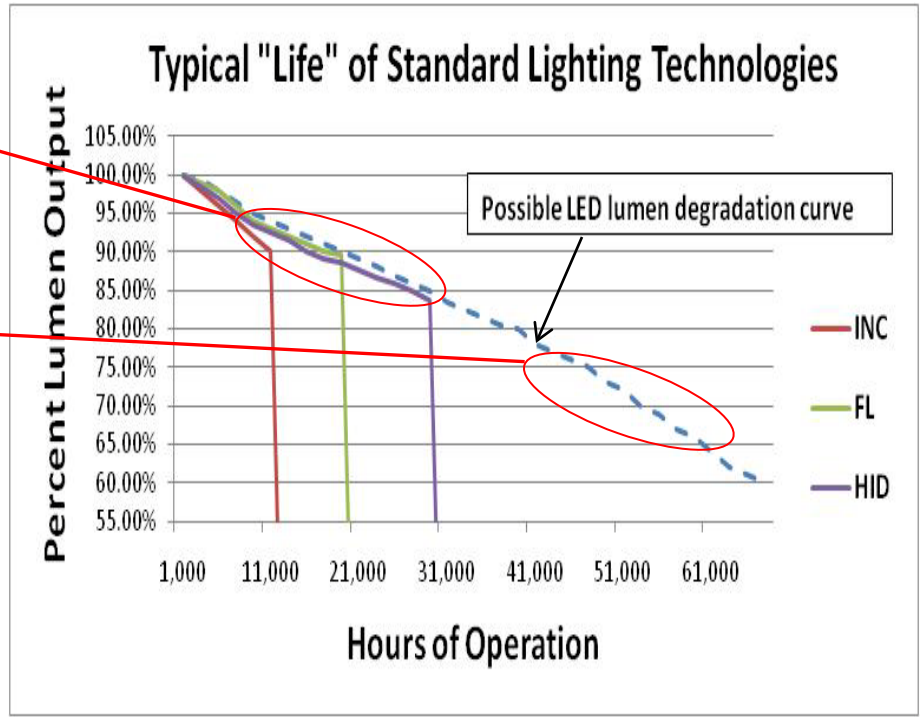
"LEDs last……*forever*!"

LEDs are not "Everlasting Gobstoppers"



- **All** light sources degrade - most fail before critical light output is exceeded
- LED diodes can survive but also degrade well beyond useful light level
- Industry is considering lumen output as a measure of the **useful** life of an LED diode:

  L_{70} = the point where 70% of initial lumen output remains and can be considered the end of **useful** life.

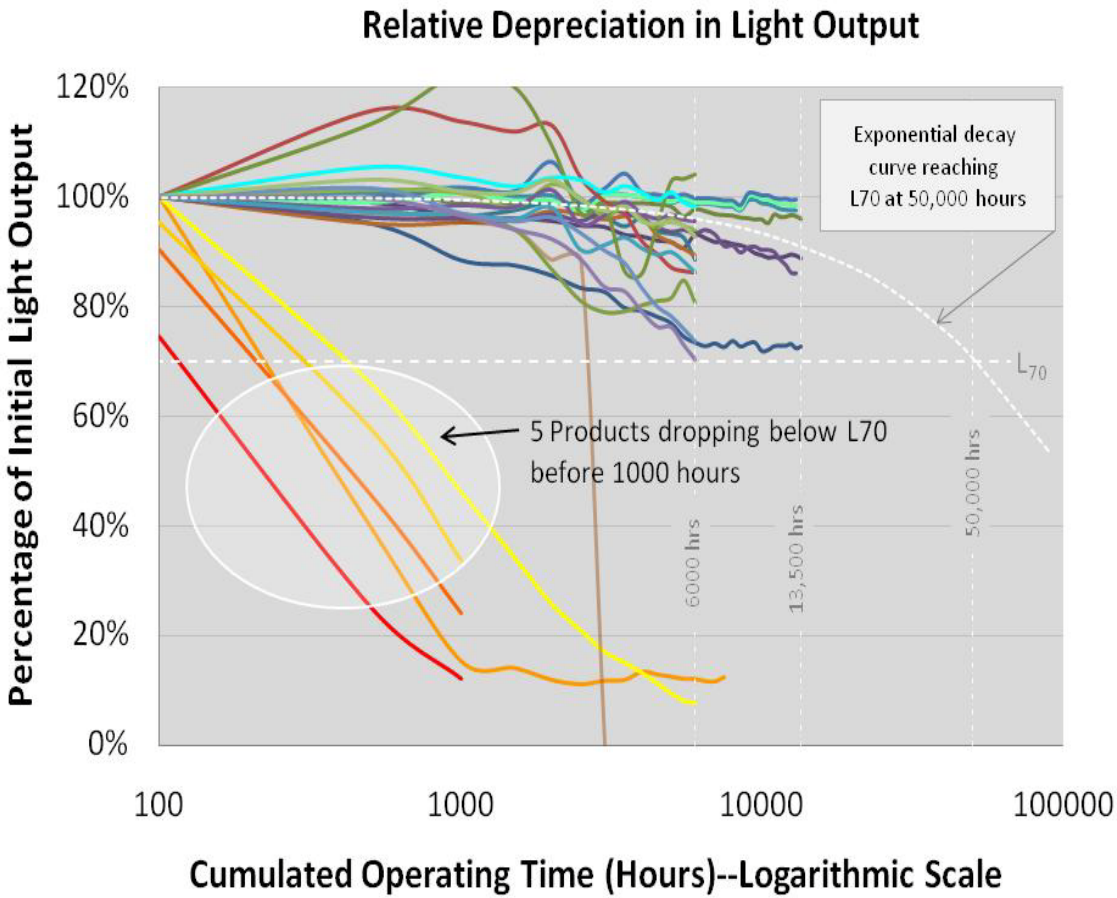


LED life characteristics

- However, “Life” for the LED **system** has multiple elements:

  LED diode, encapsulant , array architecture, driver electronics

- LED system Test data shows success and caution…



So How Do I Characterize Good LED Products?

- Ask for the data! – Well-meaning manufacturer's literature may not have what you need!
- LEDs require specific test procedures
  - LM-79 provides lumen output and efficacy data
  - LM-80 will provide lumen degradation data for at least 6,000 hours
- Look for LM-79 data for accurate capability data
  - Does the capability compare favorably with other options?
  - Does the capability provide what is needed (output, distribution)
- Look for LM-80 data (if available) to provide a reasonable idea of potential life/reliability of the diodes used in the product
- Look for a Lighting Facts Label

Want to Know More?.....

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Fact Sheets… behind you!

Main DOE website: www.ssl.energy.gov

Questions?