LED Chip & Package Manufacturing - Development for Application Impact

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LED Chip and Package Mfg. – Relevant DOE Tasks

- **M.L4 - Tools for Epitaxial Growth**
  - *Tools, processes and precursors to lower cost of ownership and improve uniformity.*
- **M.L5 - Wafer Processing Equipment**
  - *Tailored tools for improvements in LED wafer processing.*
- **M.L6 - LED Packaging**
  - *Back-end processes for packaged LEDs and improved processes and/or equipment to optimize quality and consistency and reduce costs.*
- **M.L7 - Phosphor Manufacturing and Application**
  - *Efficient manufacturing and improved application of phosphors (including alternative down converters)*

LED Cost Contribution to Luminaire BOM

- **A moving target with respect to overall BOM**

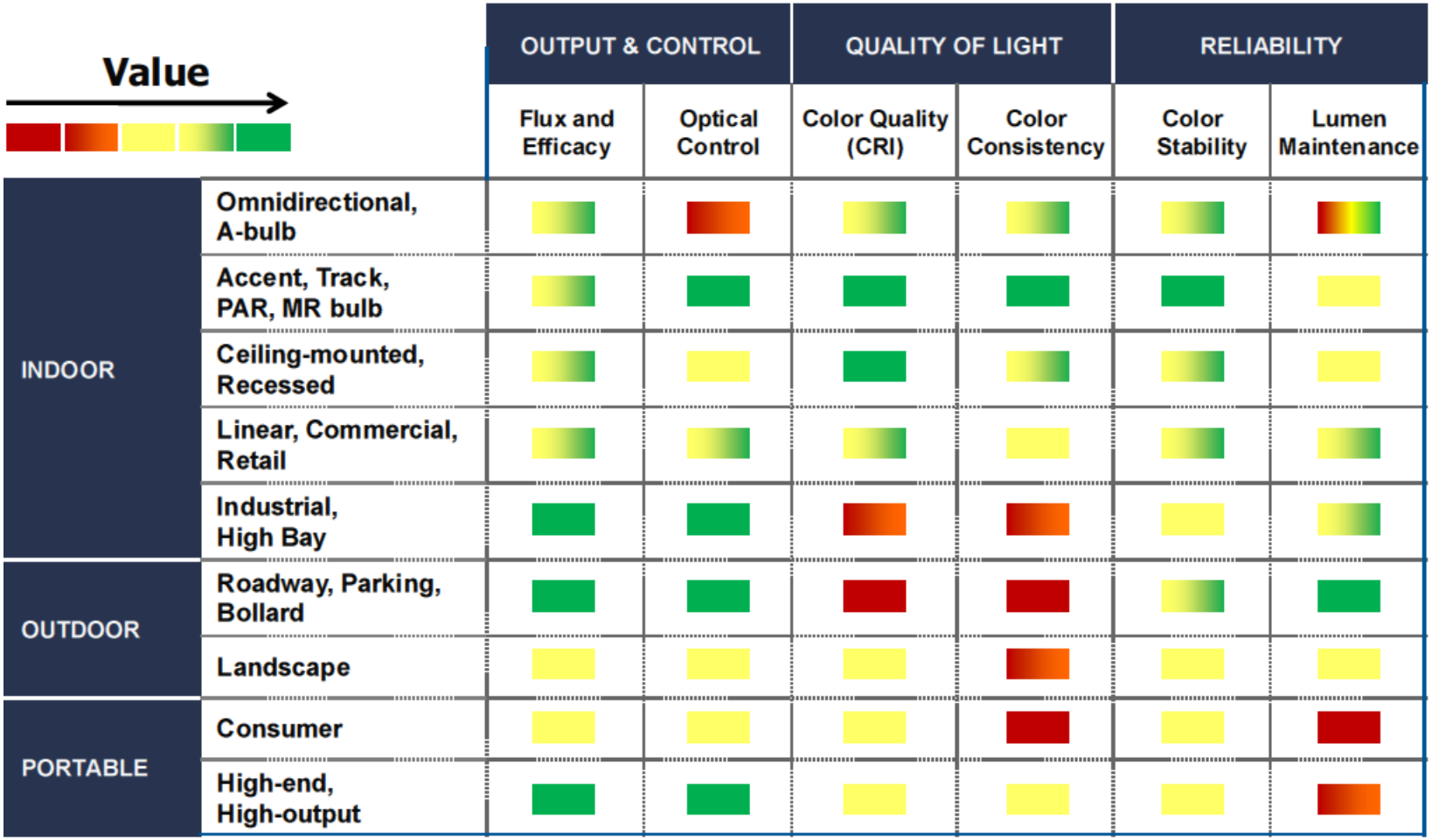
	Drive Current	BOM Cost (%)
2008	350mA	
2009	525mA	
2010	700mA	
2011	1000mA	

LED Optic Driver Housing

- **4,000 lm LED Area Light**
- **Includes optics, LED cost, reduction of LED count, driver, housing**
- ***Can we assume that LED % of BOM will continue to fall?***

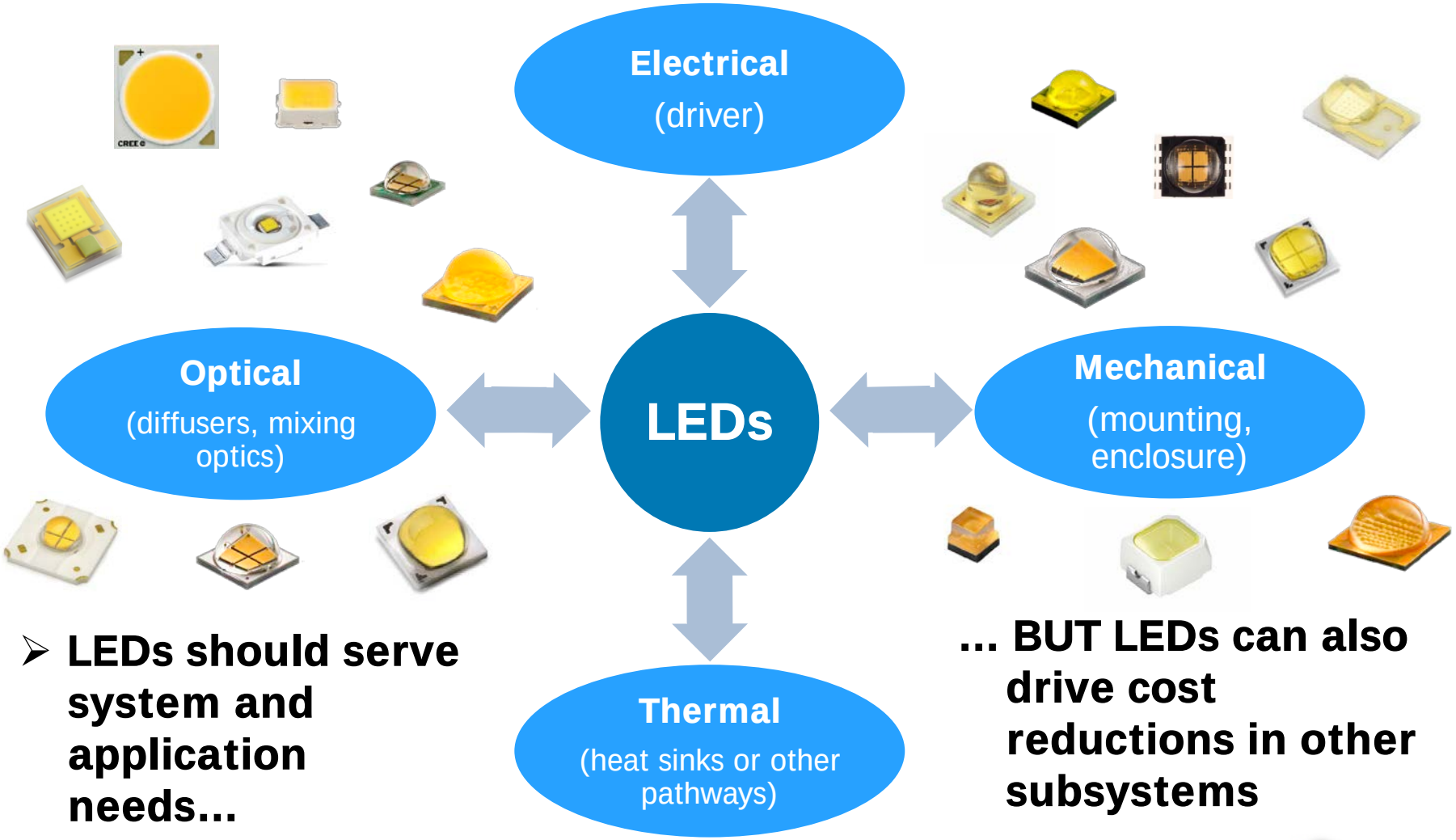
LEDs in Various Applications

- **The value that LED characteristics add to the system varies widely by application**



LEDs vs. Other Luminaire Subsystems

- **LED requirements directly affected by other subsystems**

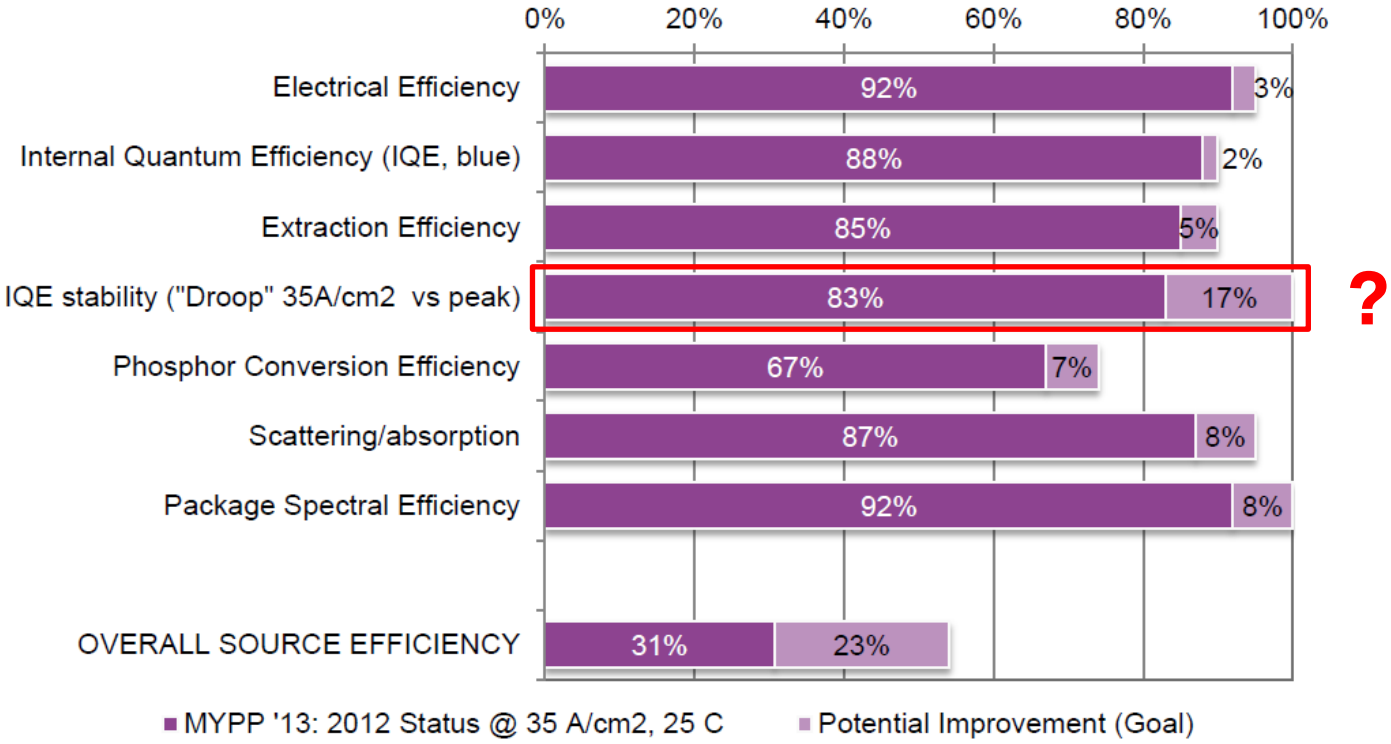


- **LEDs should serve system and application needs…**

- **… BUT LEDs can also drive cost reductions in other subsystems**

Chips – is Blue “there”?

- **Most LEDs contain blue chip + Y/G/R phosphor blend**
  - **Blue chip IQE: estimated at ~80-90%**
  - **Blue chip extraction efficiency: ~80-90%**
  - **EQE: incremental progress from here**



Blue Chip Droop

- **How important is blue EQE current droop?**
  - **Depends on system implementation, cost constraints**

MR16

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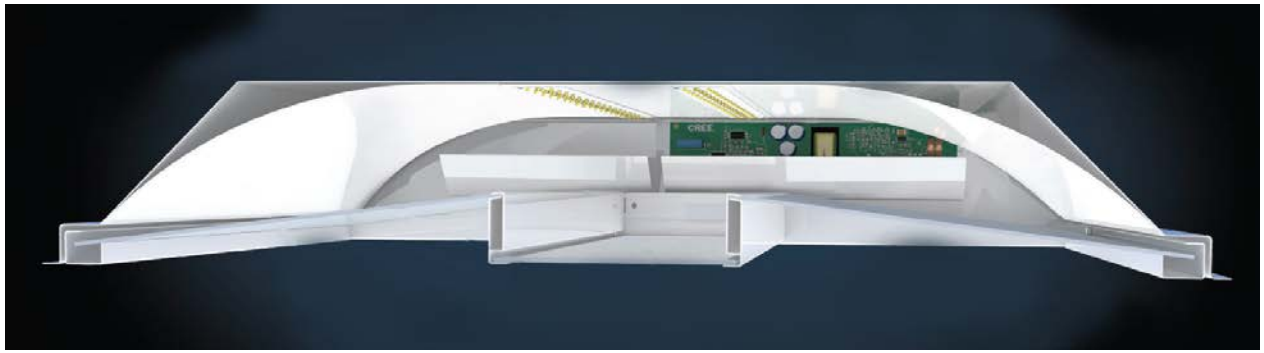


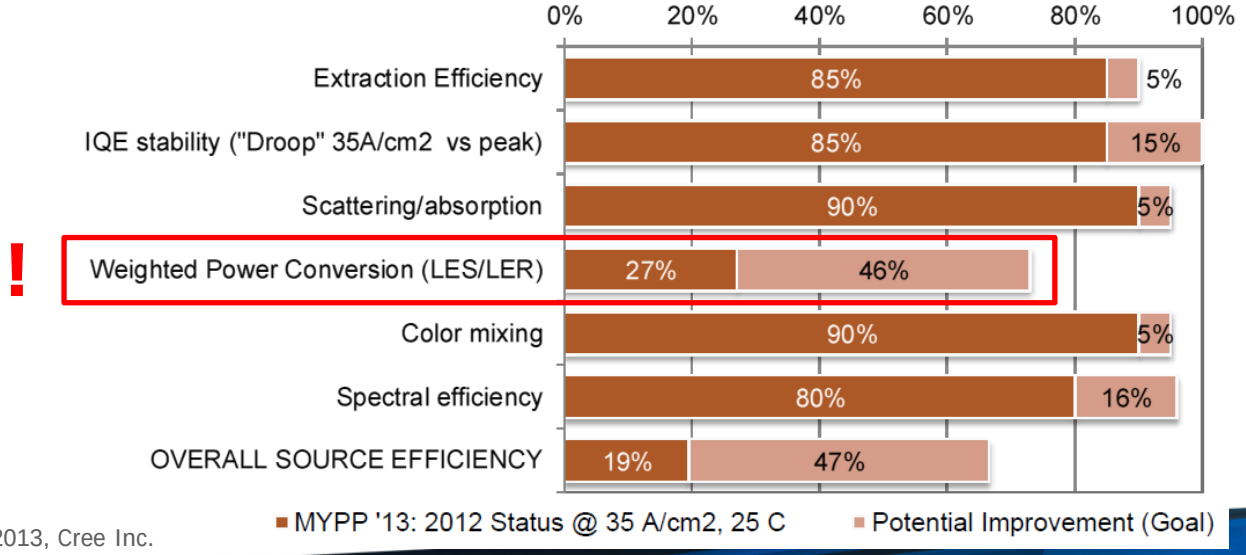
- **YoY blue chip cost reductions: easier to negotiate LED efficacy/cost with system cost constraints**
- **"Throw epi at the problem" ?**

What about Red / Green / Amber?

- **DOE MYPP anticipates that RGBA efficacy will be superior to blue + phosphors**

	Color-mixed			Phosphor-converted		
CCT (K)	Efficacy for 67% Conversion (lm/W)			Efficacy for 54% Conversion (lm/W)		
	CRI 70	CRI 85	CRI 90	CRI 70	CRI 85	CRI 90
5000	255	245	239	189	182	179
3800	273	261	254	199	190	189
2700	287	273	264	211	200	196

- **Where will efficiency come from? Green, Amber, Red?**

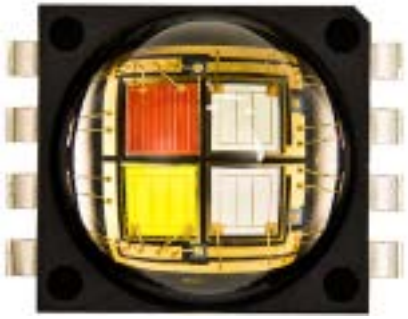


What about thermal droop?

Multi-Color Mixing and Controls

- **Will RGBA color mixing require closed-loop control?**
  - ***e.g.*** **within fixture: centralized sensor in (and specific to?) luminaire**
  - ***e.g.*** **within LED package: desirable for "universal" implementation**

- **Intra-package color mixing/control**
  - **Cost adder for color sensor(s) and circuit?**
  - **Space constraints**
  - **Absorption of light (*e.g.* of blue light by red chip)**



➢ **Application and system requirements will steer intra- vs. extra-package mixing and control**

Summary

- **LED chips and packages must be designed and implemented with system and application requirements in mind**
- **LED characteristics can directly benefit cost reduction in other subsystems**
- **Multi-color chip solutions may bring efficacy benefits and added features, but also trade-offs**
- **The biggest challenge in the RGBA approach appears to be red, green, and amber chip efficiency (and thermal droop?)**

Q & A

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