Light Quality & Lower System Cost Design

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GM of Asia Marketing, Cree

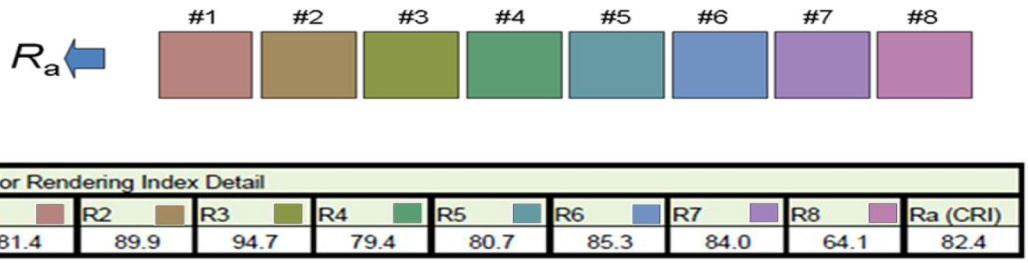
Taipei: 23rd Oct, 2015

Agenda

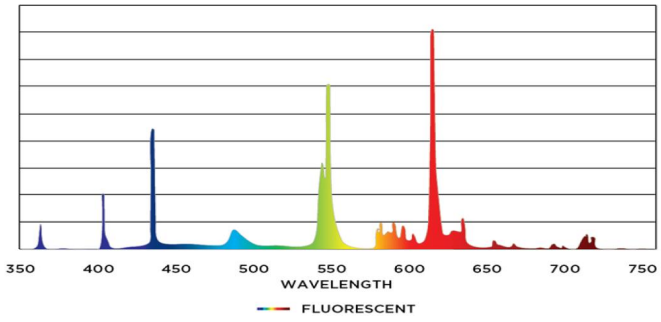
- **Brief Market Demand**
- **Quality of Light**
- **Lower System Cost Design**
  - **LED Level**
  - **System Level**
- **High Intensity for Maximum Candela**

Quality of Light – TM30

Definition of Color Rendering Index CRI



Color Rendering Index Detail								
R1	R2	R3	R4	R5	R6	R7	R8	Ra (CRI)
81.4	89.9	94.7	79.4	80.7	85.3	84.0	64.1	82.4

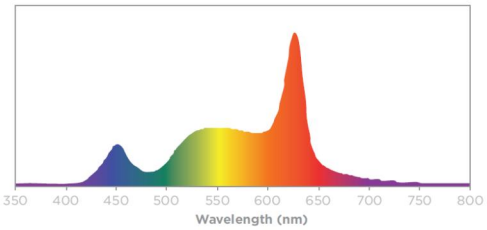


Sunlight

Color Quality

Consistent color and quality of light throughout the entire space

- 90 min CRI for all CCTs
- Color consistency: 3-Step MacAdam Ellipse



CCT	CRI	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14
3000K	92	96	95	81	89	97	94	93	95	93	81	89	76	99	86
4000K	93	95	93	87	93	91	89	98	95	83	79	90	63	94	91

Listed CRI values are representative values for Cree TrueWhite® Technology LED Modules. These values are provided for information only and are not a specification. For more information, please see the product specifications on cree.com.

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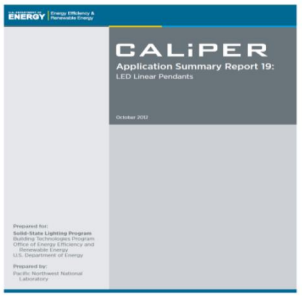
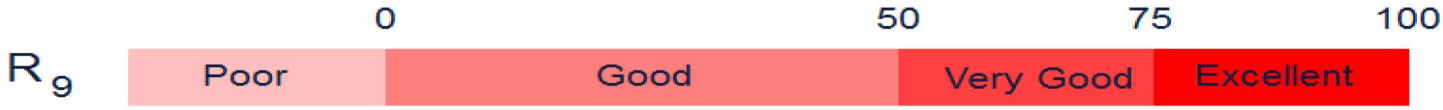
Definition of R9

DOE Comments on R9 Values

Special Color Rendering Index R_9

A measure of color fidelity that characterizes the similarity in color appearance of deep red objects under a given source relative to a reference source of the same CCT. The maximum possible value is 100, with higher scores indicating less difference in chromaticity for the color sample illuminated with the test and reference source. R_9 and R_a (CRI) are part of the same CIE Test-Color Method, but the R_9 color sample is not included in calculation of R_a. R_9 values should not be compared to R_a (CRI) values. As a shorthand approximation, an R_9 less than zero is poor, an R_9 greater than zero is good, an R_9 greater than 50 is very good, and an R_9 greater than 75 is excellent.





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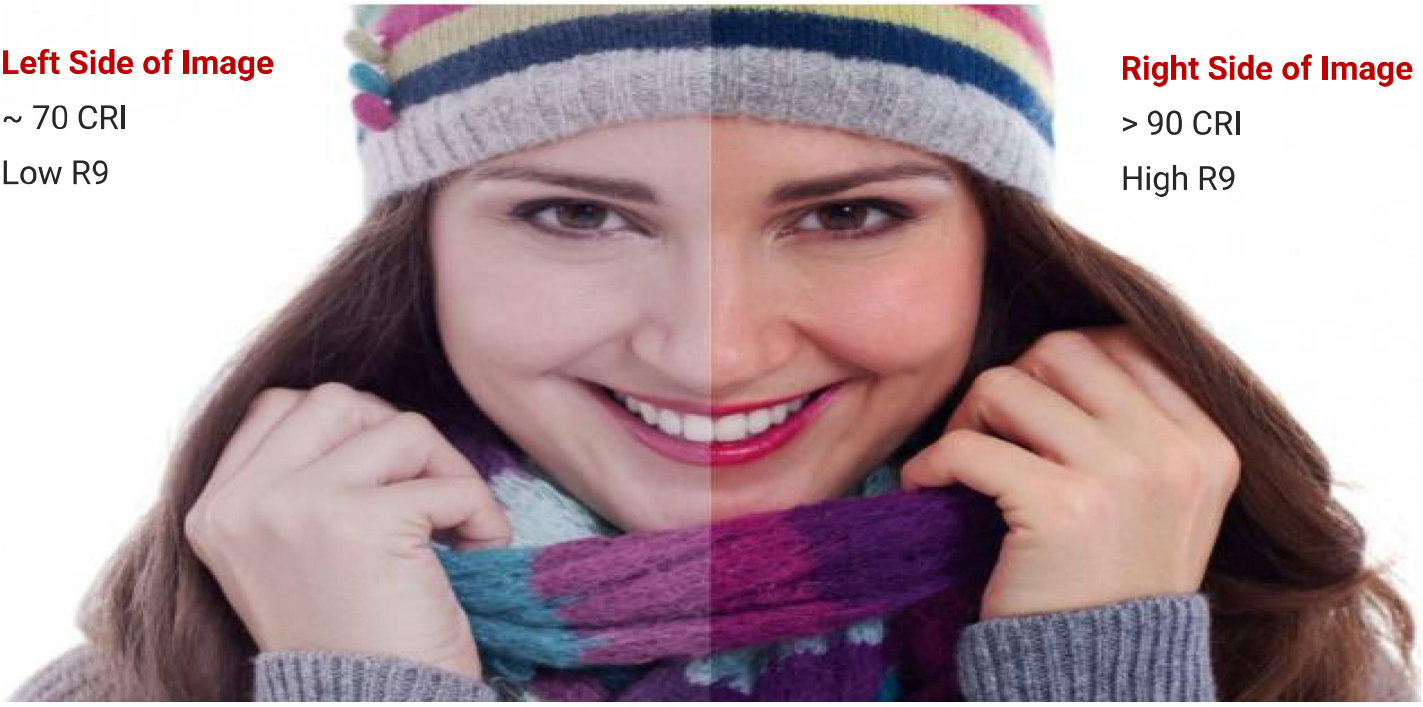
Both CRI and R9 Matter

Left Side of Image

~ 70 CRI

Low R9



Right Side of Image

> 90 CRI

High R9

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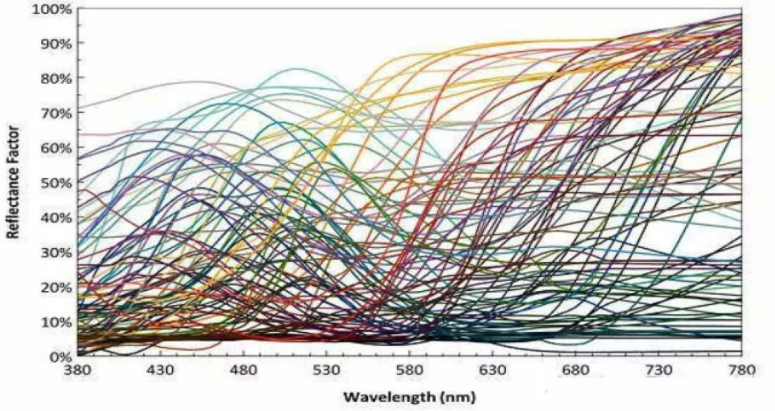
High Rf and Rg to Meet Demands of Better Color Quality

Among 105,000 colors, IES TM-30-15 adopt 99 standard color which represent the color we can see frequently.

Develop easy-to-use two distinct dimensions metrics to support exisitng one dimensional CRI Ra/R9 metrics

- **Rf = Fidelity**
- **Rg = Gamut**



99 color samples

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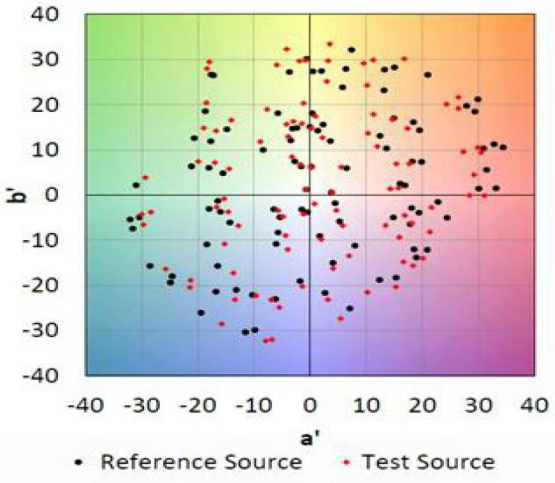
Color Fidelity (Rf)

Color Fidelity (R_f)



- Average similarity in appearance of test and reference sources
- Equal weight to all directions of shift
- Doesn't necessarily correlate with any single object
- Most important when trying to match the look of the reference source
- Perfect fidelity does not always mean the perfect source for the application

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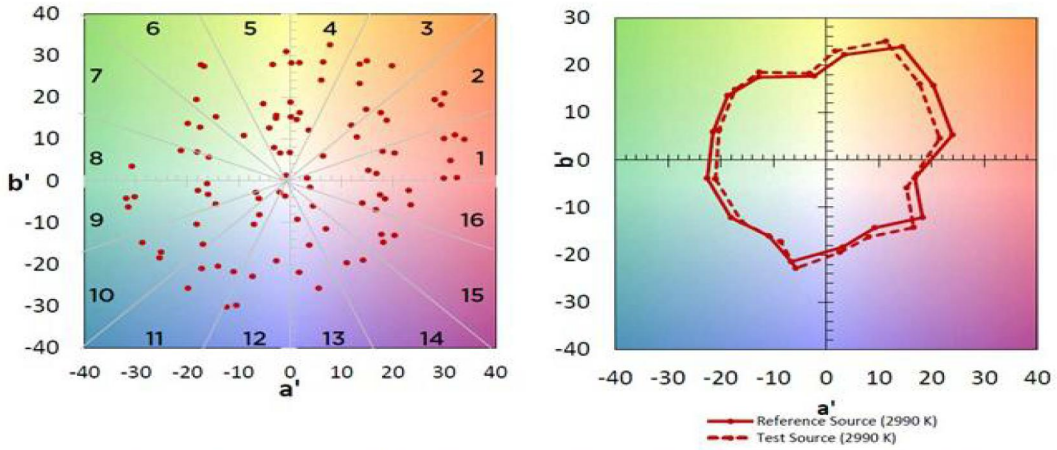
Color Gamut (Rg)

Gamut (R_g)



Gamut is generally considered a measure of overall saturation. An R_g value greater than 100 indicates an average increase in saturation, whereas an R_g value less than 100 indicates an average decrease in saturation.

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IES TM-30 Metrics

Color Fidelity (Rf)	Color Gamut (Rg)
"On average, how **faithfully** does the test source illuminate the 99 color samples compared to the reference source?"	"On average, how much **more saturated** does the test source illuminate the 99 color samples compared to the reference source?"
Scale: 0-100 100 = perfect match	Scale: (no limits) >100 = test oversaturates vs reference <100 = test undersaturates vs reference

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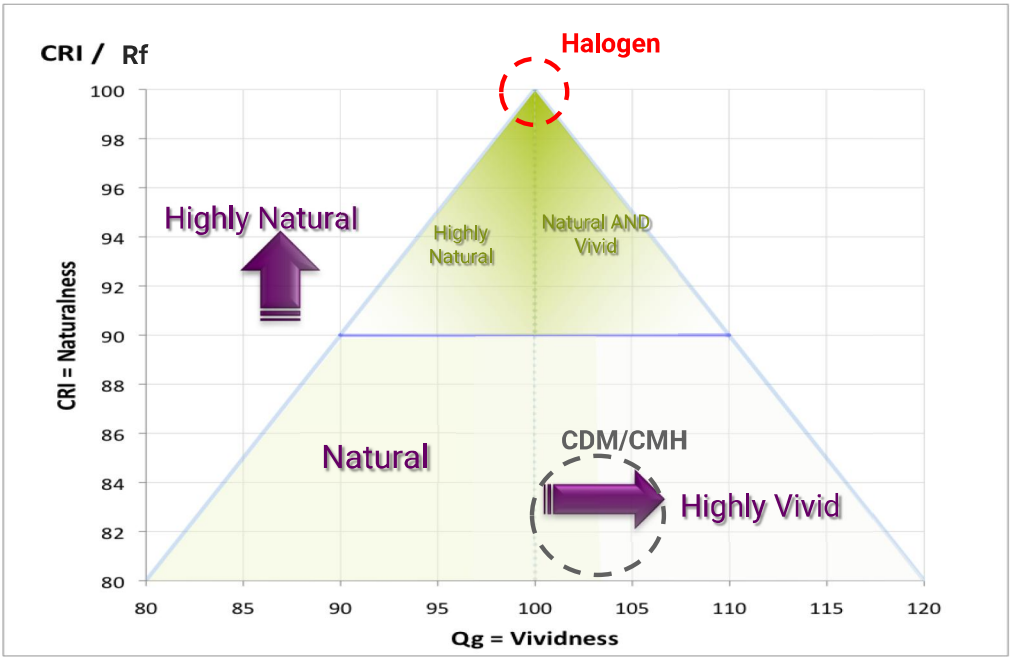
Navigating Rf & Rg



- Application specific either one or both may be desired:
  - **Retail = Vivid**
  - **Home, Hospitality = Natural**
- Highly vivid sources have to deviate from naturalness = preference *will be* application specific

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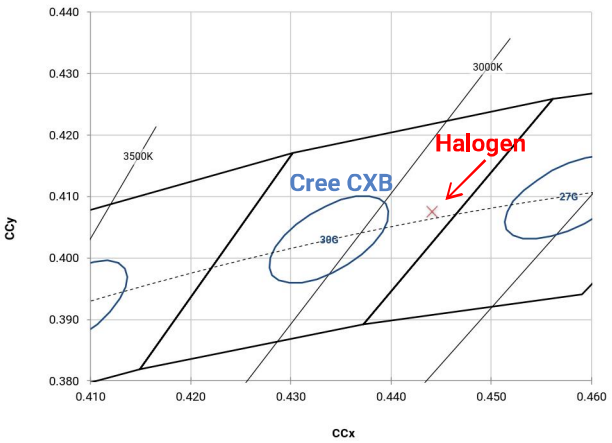
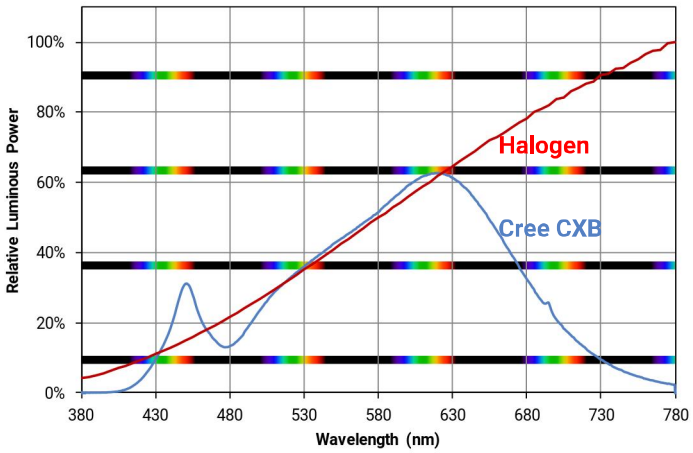
Cree LED Light Quality for Halogen-Style Retail Lighting

Color Point



- 3000K on BBL bin (30G) approximates Halogen appearance
- Centered in the ANSI 3000K bin for ENERGY STAR/DLC

Spectral Content



- Very close color match across the entire visual range

	Cree CXB
CRI Ra	91
CRI R9	56

Note: Color values provided are for reference only and are not a specification or warranty

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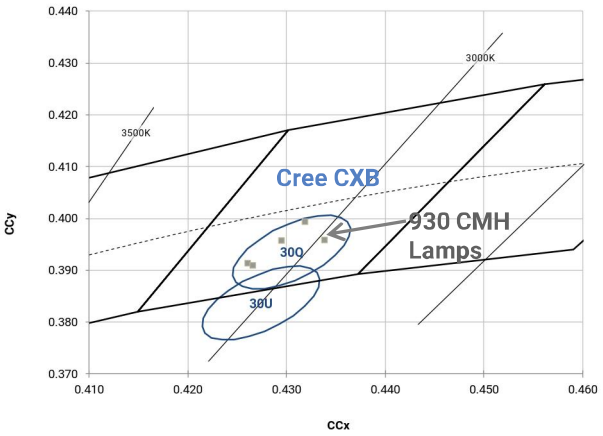
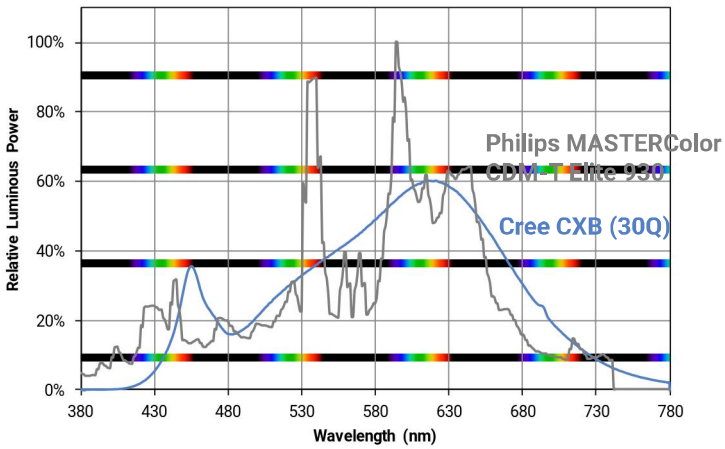
Cree LED Light Quality for CMH/CDM-Style Retail Lighting

Color Point



- 3000K below BBL bin (30Q) matches 930 CMH color point
- 30Q bin stays within the ANSI bin for ENERGY STAR/DLC
- 30U bin option for pink/vivid effect

Spectral Content



- Cree CXB matches CRI Ra & R9 of Philips MASTERColor Elite

	CDM-T	Cree CXB
CRI Ra	92	92
CRI R9	52	58

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LED Lighting in Retail Display Markets

?

Light Style	Halogen	CMH/CDM	*Possible Third Option*
Market Size	Large	Large	Non-existent
Descriptors	warm rich	clean pop	vivid saturated
How LED should be evaluated	1. Color point on BBL 2. CRI Ra >90, R9 >50	1. Color point below BBL 2. CRI Ra >90	*No consensus from end customers*

- Halogen & CMH styles easily addressed with today's COB LED solutions
  - Getting better in terms of CRI, color point, efficacy & lifetime
- The "third option" is a hot topic of discussion among LED suppliers

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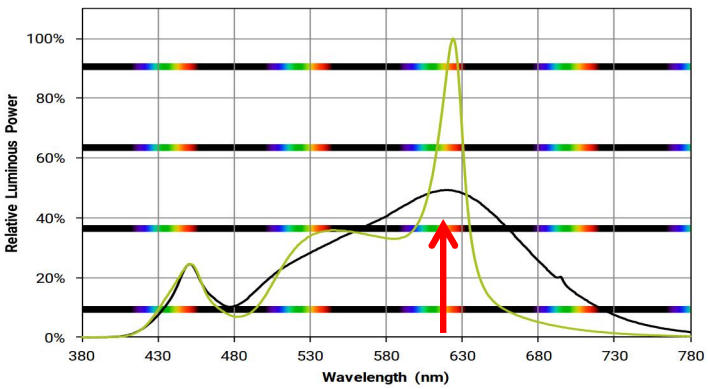
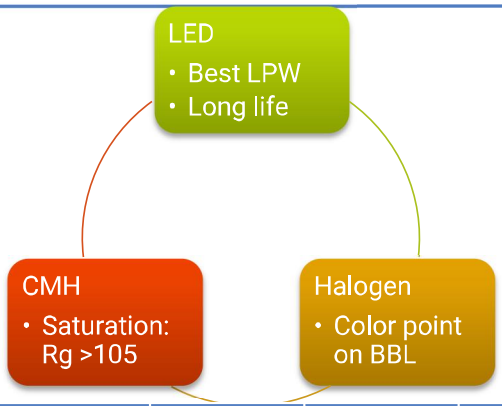
Most Efficient & Best Color Quality: Two-Channel Color Mixing





	90 CRI LED	90 CRI CMH	TrueWhite® LED
Light Source LPW	Up to 100	~100	140
CRI Ra	96	90	93
CRI R9	85	33	62
TM-30 Rf	92	85	88
TM-30 Rg	98	104	105

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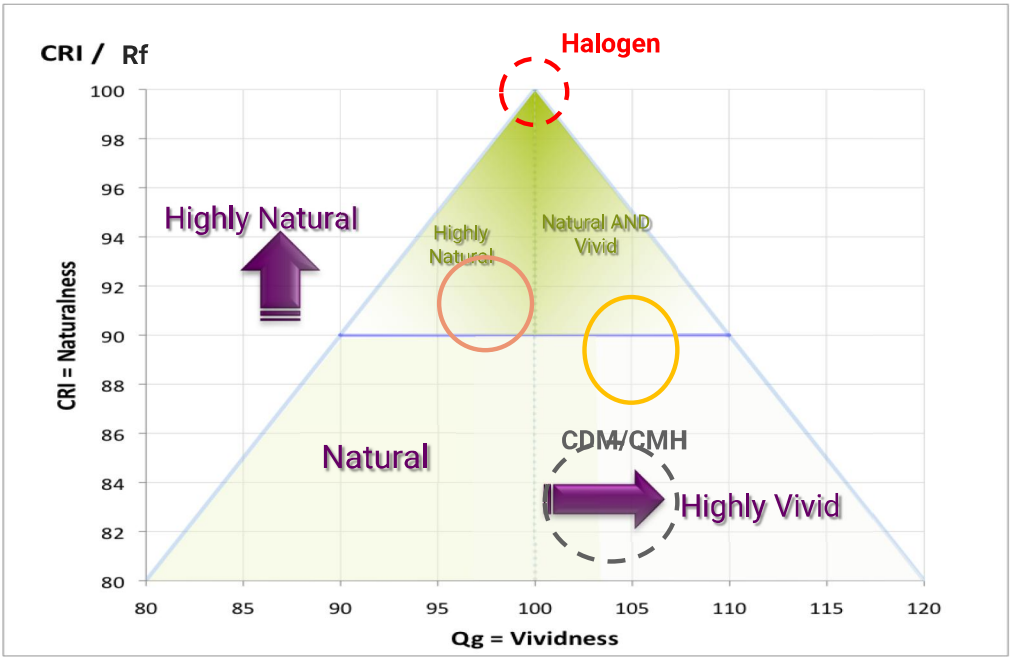
Navigating Rf & Rg



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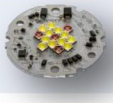
How LED should be evaluated	1. Color point on BBL 2. CRI Ra >90 3. CRI R9 >50	1. Color point below BBL 2. CRI Ra >90	*No consensus from end customers*
Recommended Cree Solution	CXB 3000K, 90 CRI 	CXB 3000K, Below BBL 	CTA 3000K 

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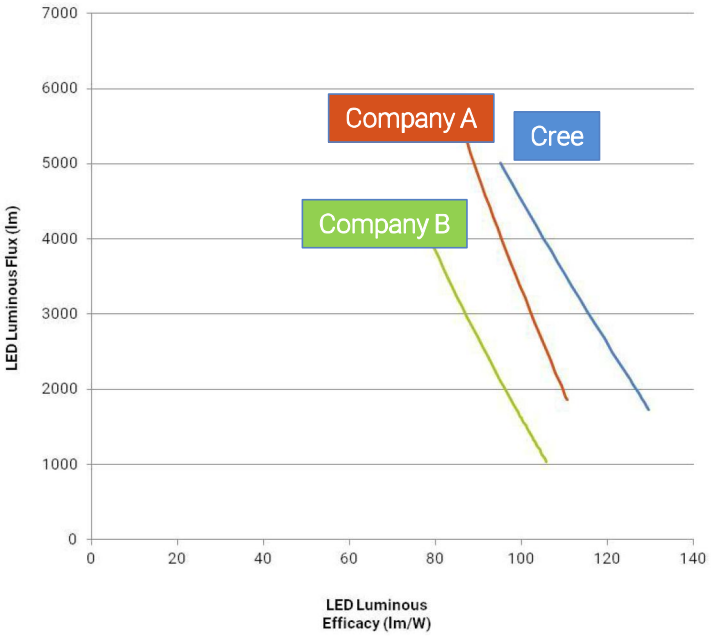
Performance Comparison: CMH/CDM-Style @ 14/15mm LES

Cree Below BBL

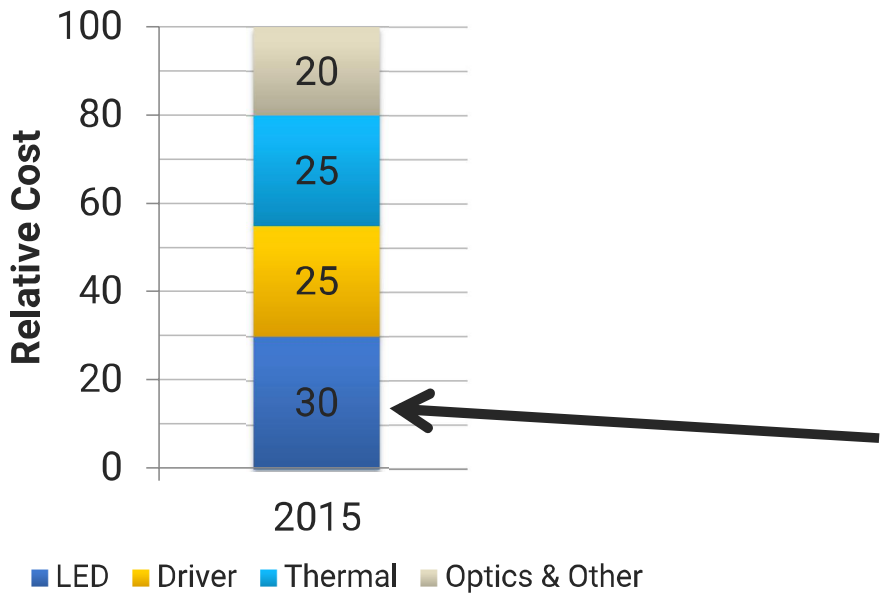
- Based on latest CXA2 technology for best efficacy & lumen maintenance
  - 10%-15% LPW better than Company A
  - L90 >36k hours
- Best optical control capability (Smallest LES)
- Optional colors
  - 30Q : CMH/CDM color
  - 30U : More pink/vivid



LED	Model	Flux	Temperature
LED 1	Cree XLamp CXB1830 LES 14r {EZW}	T2 [3200]	Tc (°C) = 70
LED 2	Company A :S 15r {W}	2887	Tc (°C) = 70
LED 3	Company B	3000K 92CRI typ [28	Tsp (°C) = 70

Lower System Cost Design

The LED Lighting System Cost Problem



Very aggressive LED cost reductions in the past 2 years have decreased the LED portion of system BOM to 30% or less

So, how can we further reduce SYSTEM costs?

Make the LEDs free and you've only decreased costs by 30%....

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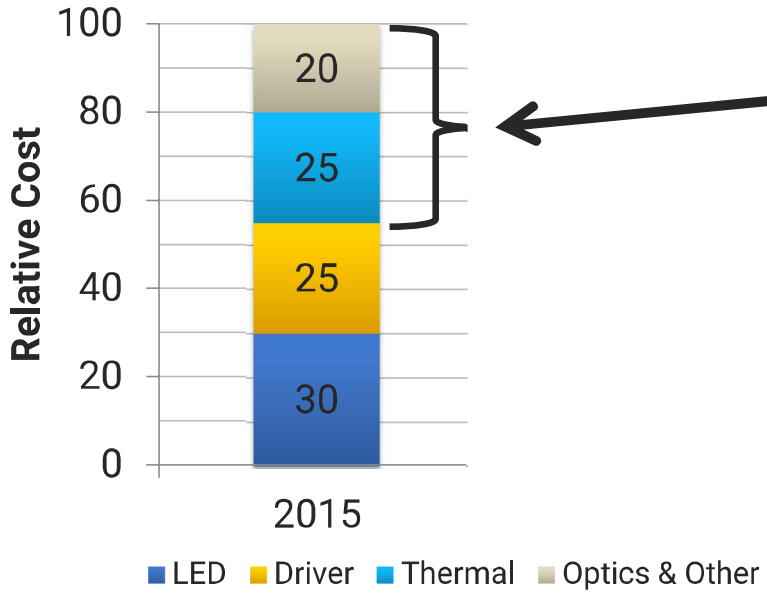
The LED Lighting System Cost Problem



The industry needs to address the thermal and optical costs, which now dominate today's BOM costs at ~45%.

Mid-power LEDs are becoming a very popular solution to address the LED BOM but make the thermal and optical solutions more costly and cumbersome than they need to be.

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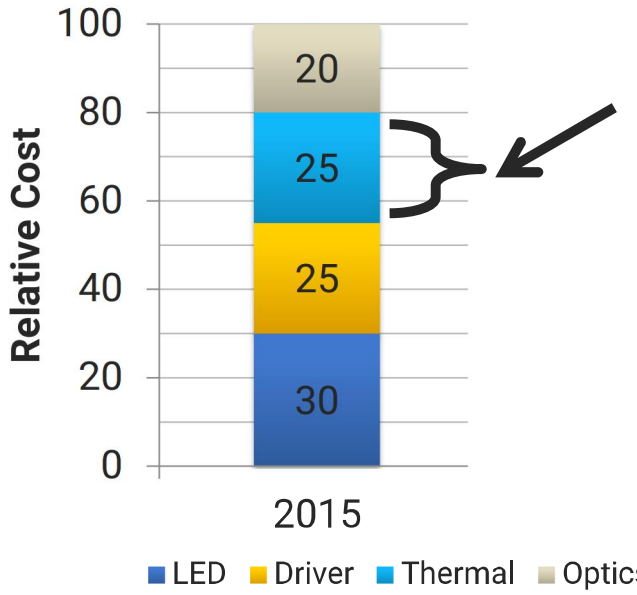
The LED Lighting System Cost Problem



Maybe thermal costs will go down?

LED Driver Thermal Optics & Other

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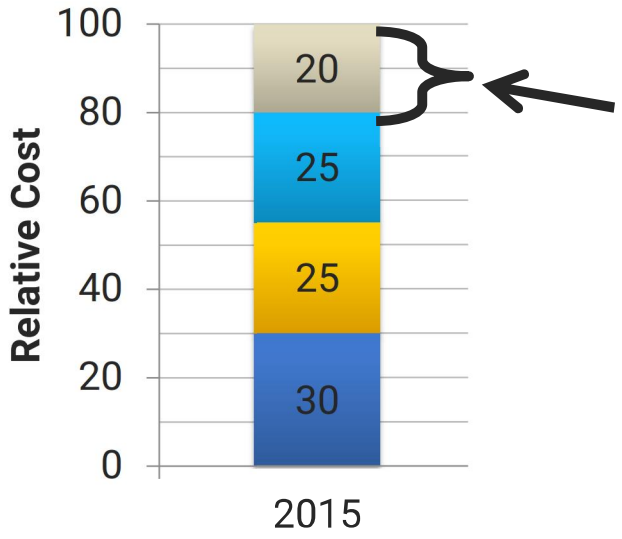
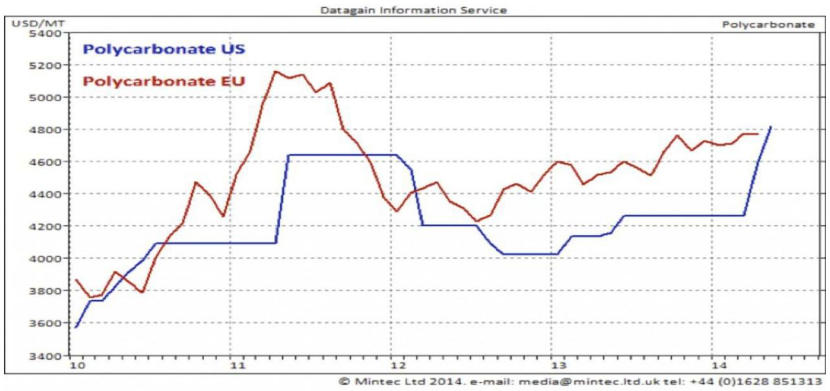
The LED Lighting System Cost Problem



Optics costs?



LED Driver Thermal Optics & Other

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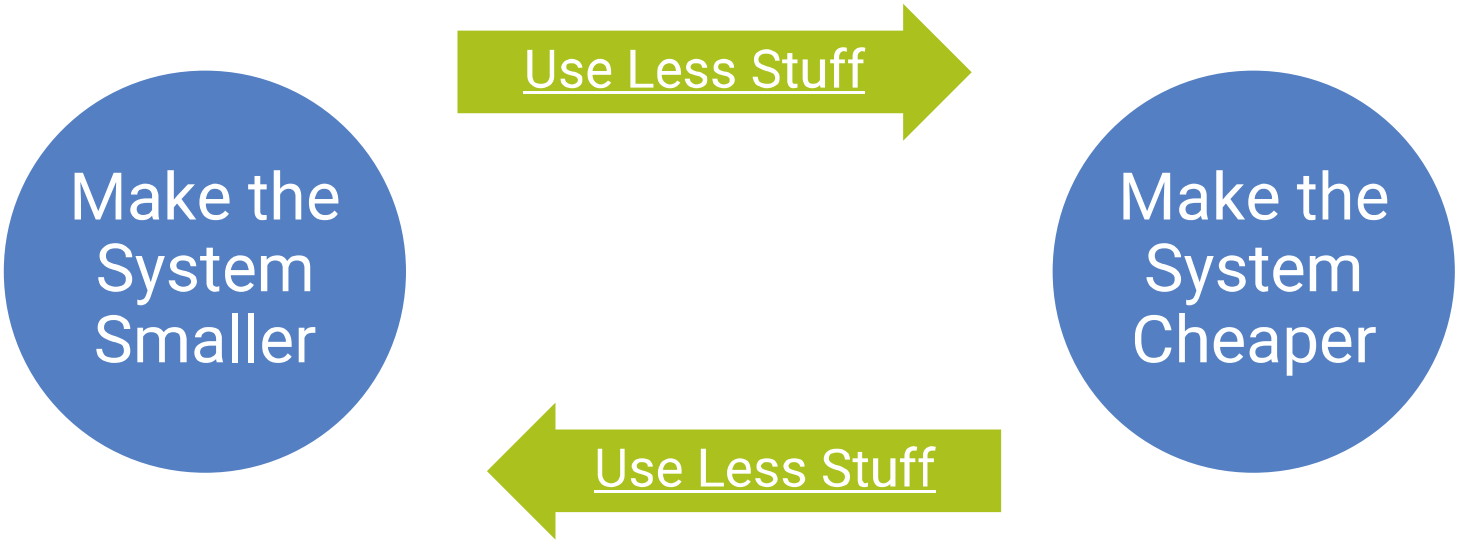
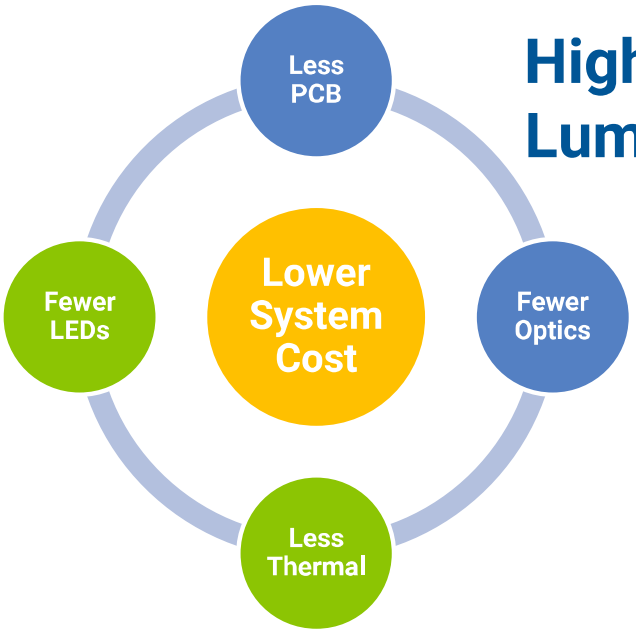
Need to move away from “LED lm/$” thinking to total system cost thinking



How Can LEDs Enable You to Use Less Stuff?



Higher LED Lumen Density

Higher LED Reliability

SC5 Technology Platform: LED Components

Best Lumen Density

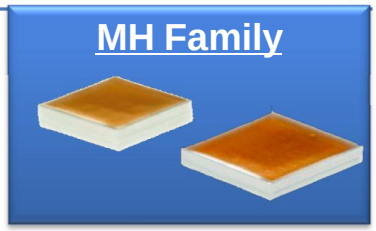
+

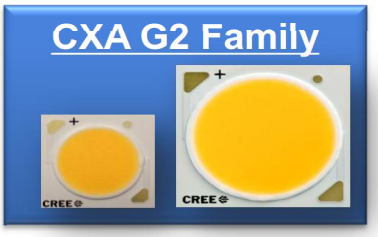
Best Reliability

→

SC5 Technology

- Radically lower system cost





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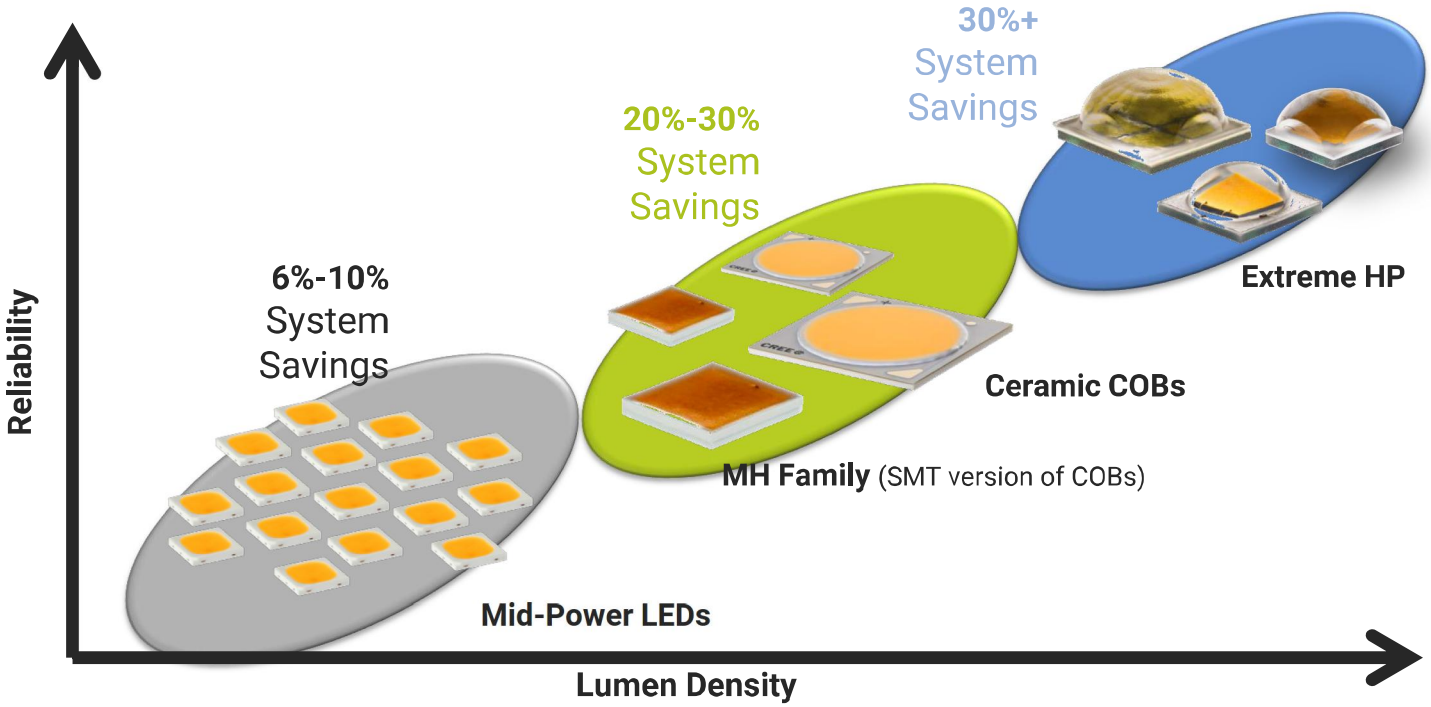
Defining System Level Value: Lumen Density & Reliability



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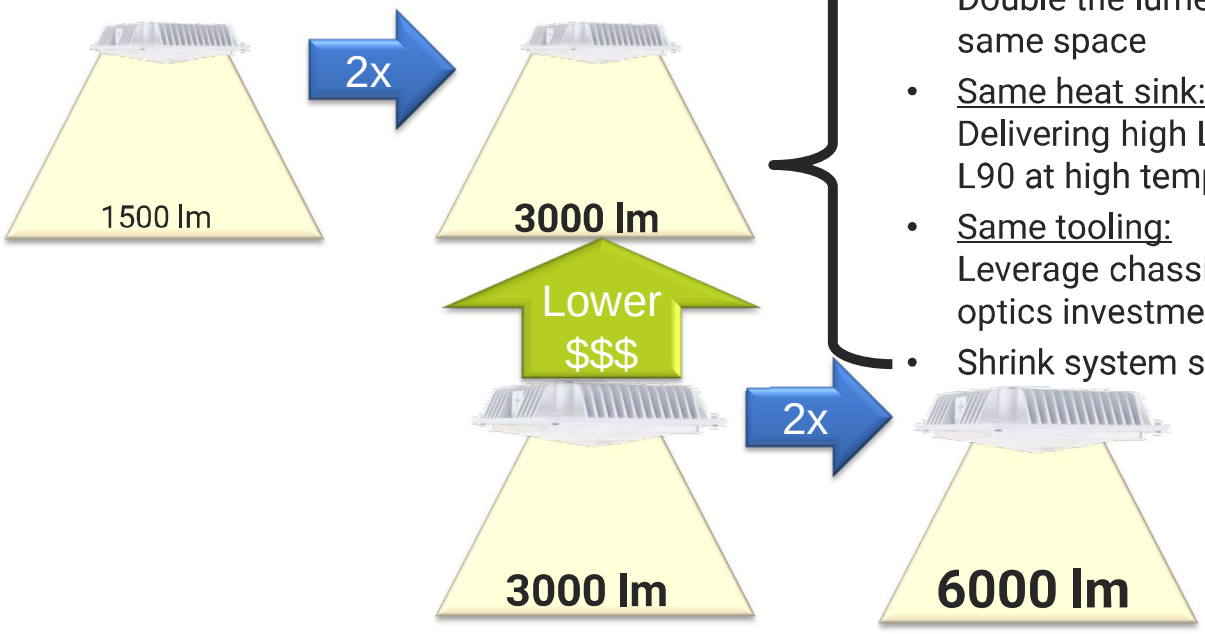
System Value of Lumen Density & Reliability

Outdoor Lighting Design Example



- Twice the light output: Double the lumens in the same space
- Same heat sink: Delivering high LPW & L90 at high temperature
- Same tooling: Leverage chassis & optics investments
- Shrink system size

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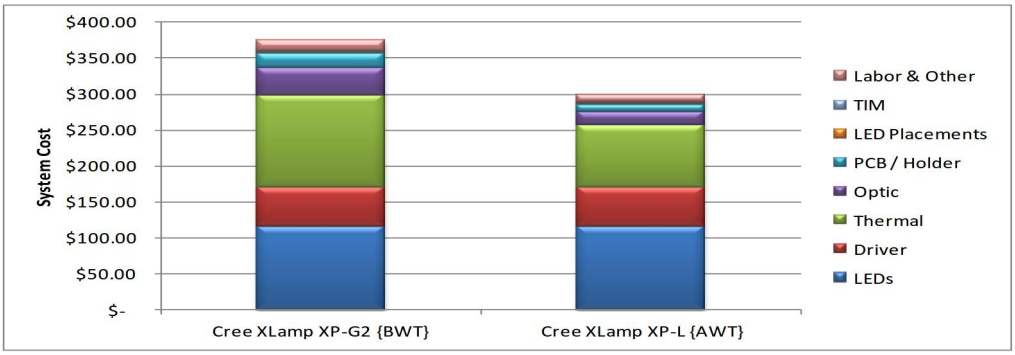
Lower Cost with LED Lumen Density & Reliability

144 XLamp XP-G2 LEDs

Tsp = 55°C, 26,000 lumens, 111 LPW

72 XLamp XP-L LEDs

Tsp = 85°C, 28,000 lumens, 112 LPW



30% reduction in non-LED BOM:

- 30% savings on thermal
- 50% savings on optics
- 50% savings on PCB
- 30% savings on labor

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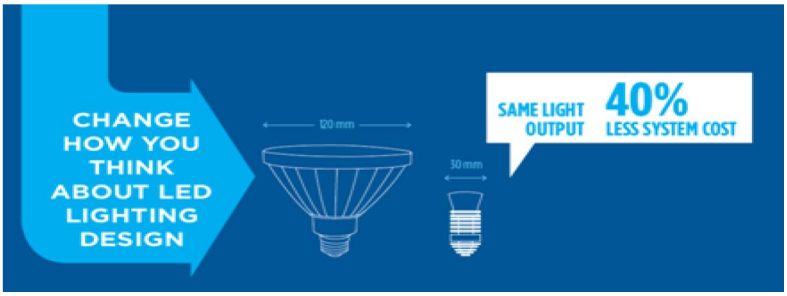
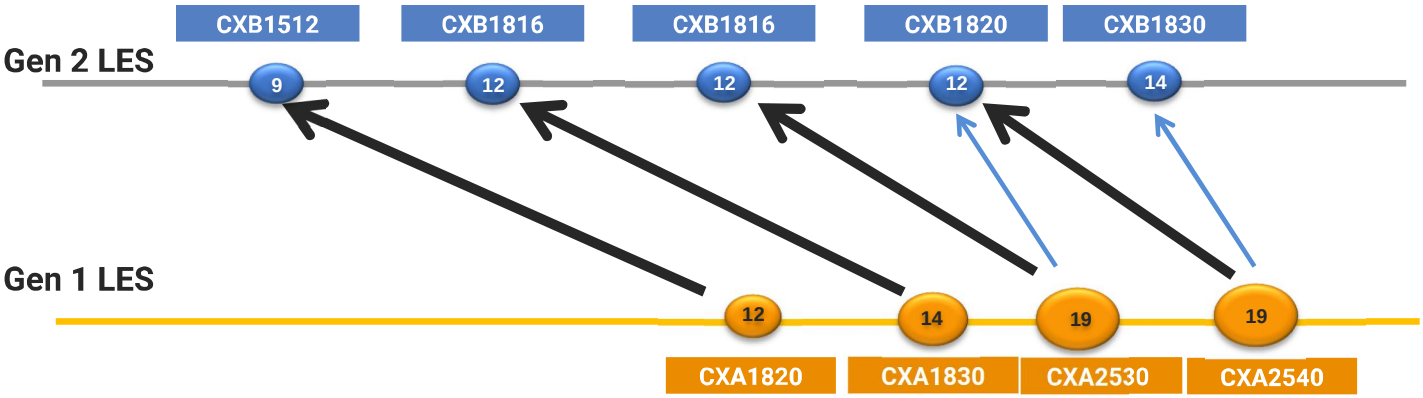
New Generation of Spot Light Luminaires: CXA Gen 2

CXA Gen 2 Value:

- Smaller LES than Gen 1
- Improved LED performance
- Better optical control





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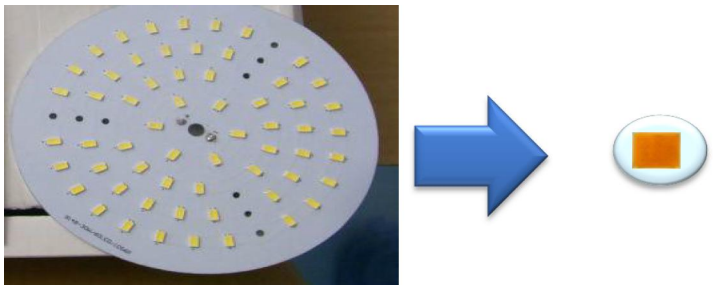
XLamp MH Advantage over Mid-Power: PCB

The Mid-Power Way **XLamp MH**



XLamp MH reduces board complexity & cost while increasing reliability

- Fewer LEDs to place
- Fewer potential system failure points
- Smaller PCB
- Shorter design cycle

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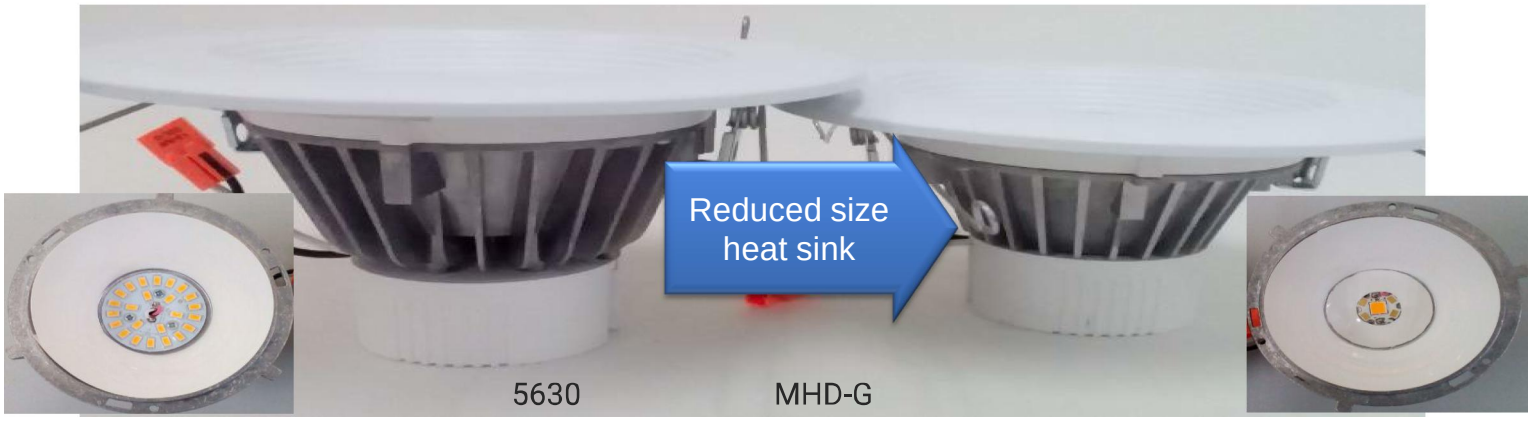
Downlight Retrofit: 5630s vs XLamp MHD-G

Heat sink size & weight reduced to lower system cost



LED Type	Output	Heat Sink	LED Tsp	Power	Efficacy	CCT	CRI
5630 (25 pcs)	777 lm	**192 g**	60°C	11.5 W	67.5 LPW	2999K	83
XLamp MHD-G (1 pc)	857 lm	**104 g**	73°C	10.9 W	78.6 LPW	2968K	80

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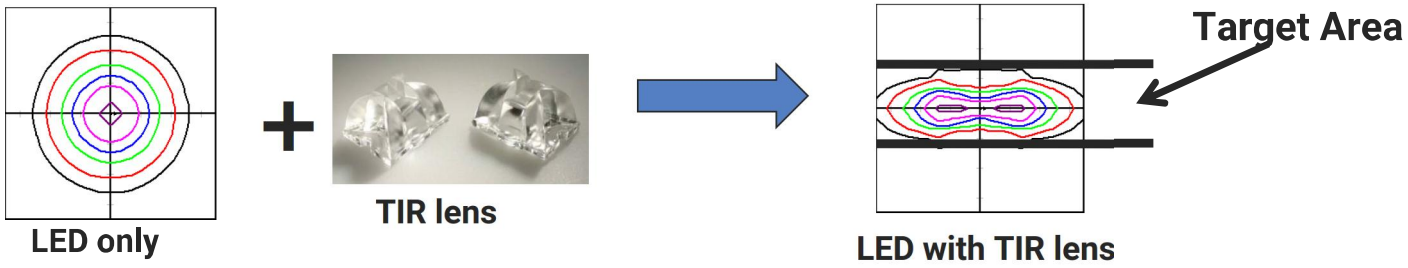
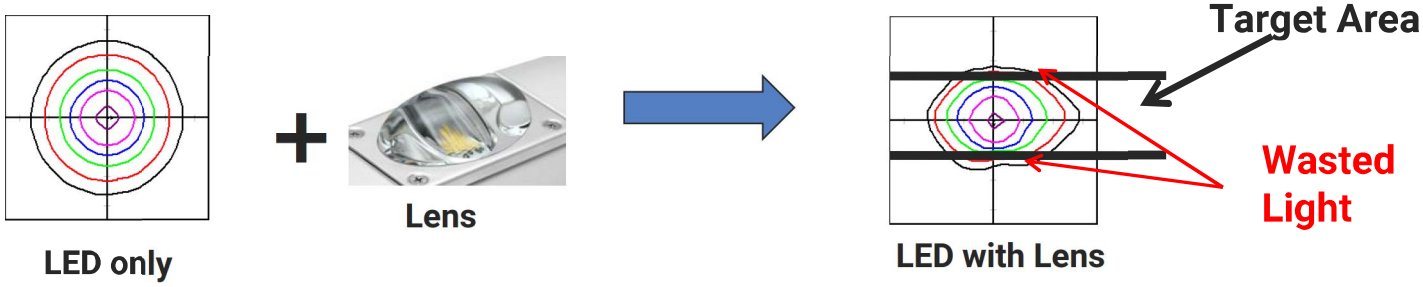
Optics Comparison

High Power LED with TIR lens



Mid Power LEDs with lens



Mid Power LED optics cost is higher and NOT efficient

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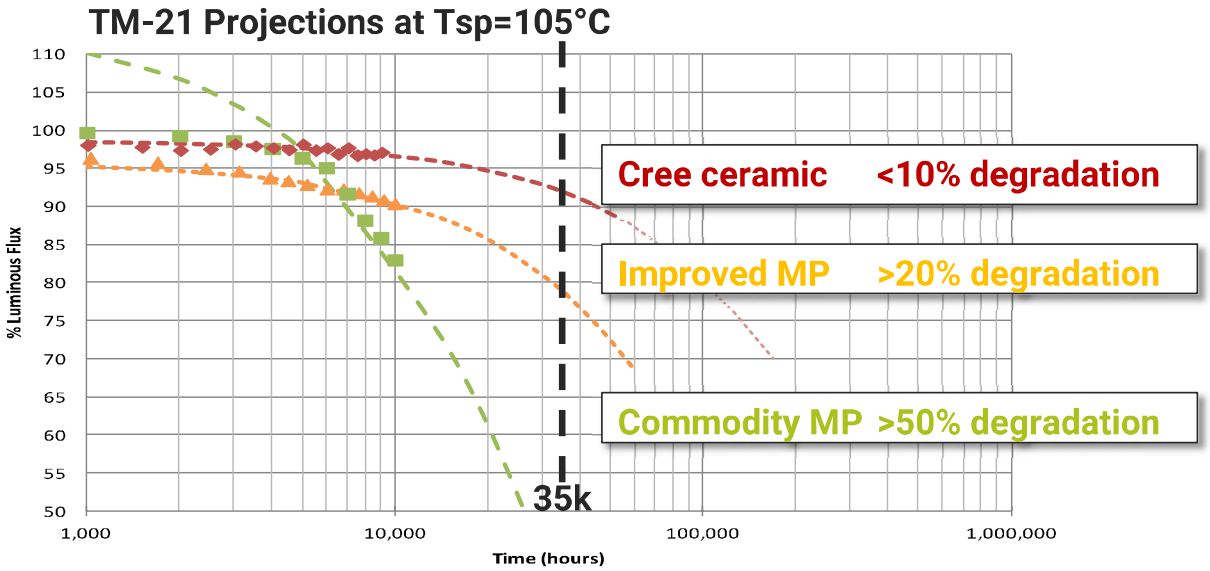
XLamp MH Advantage over Mid-Power: Lifetime



XLamp MH increases your lifetime to L90 >35k hours, even at 105°C

- Use less heat sink (higher Tsp) and still provide long lifetime

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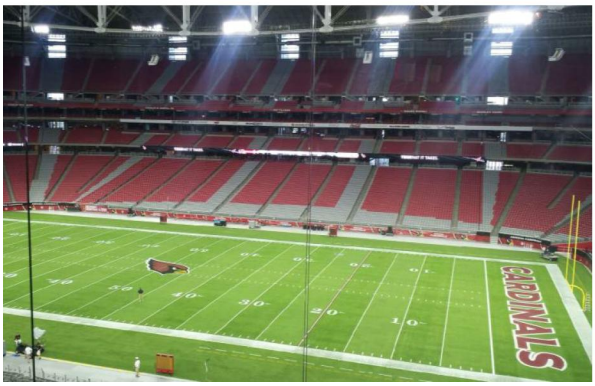
High Intensity for Maximum Candela

Applications Requiring High Intensity

- Stadium
- Entertainment
- Flashlight
- Retail



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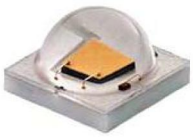
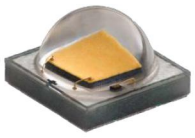
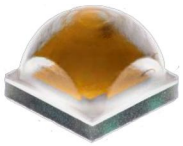
Example of LED Optical Trade-Offs

carclo Optics

20.0mm Medium Spot Plain TIR (10003)







	XP-E2	XP-G2	XP-L
Beam Angle	8°	11°	17°
Cd/lm	40.3	20.5	7.8
Max lm	309 lm	590 lm	1250 lm
Max cd	12,450 cd	12,095 cd	9,750 cd
Power @ Max lm	3.3W	4.9W	10.4W
Cd/W	3,772	2,468	937

Increase in optical source size reduces Cd/W

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Cree's Chip Scale Package Evolution

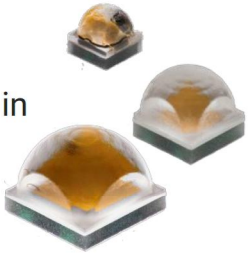
Industry's largest chip scale package portfolio
Optimized for different applications

March 2013 | **2014** | **2015**

Cube Optics
Optimized for omni-directional lighting

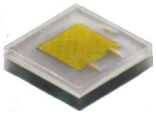
XQ-B & XQ-D

High Density
Optimized for maximum lumens in minimum space



XQ-E, XB-H, XP-L

High Intensity
Optimized for maximum candela through secondary optics



XQE HI
XP-L HI
XHP35 HI

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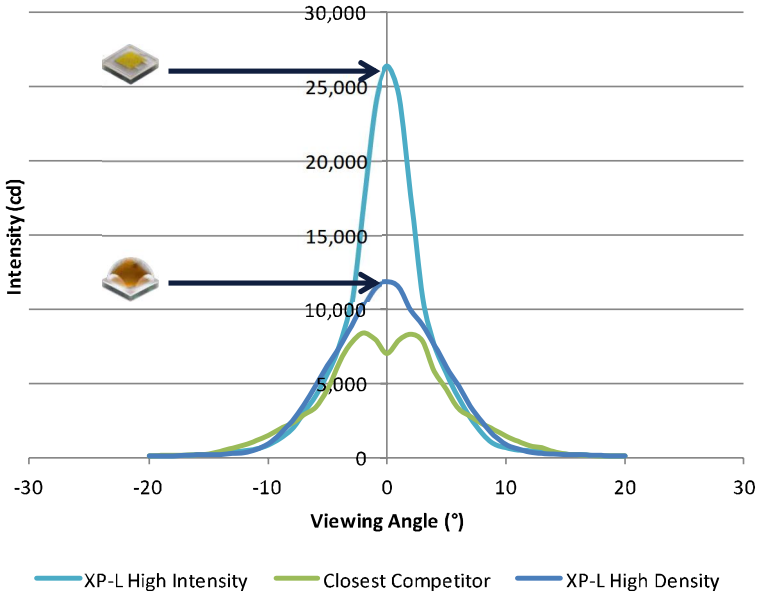
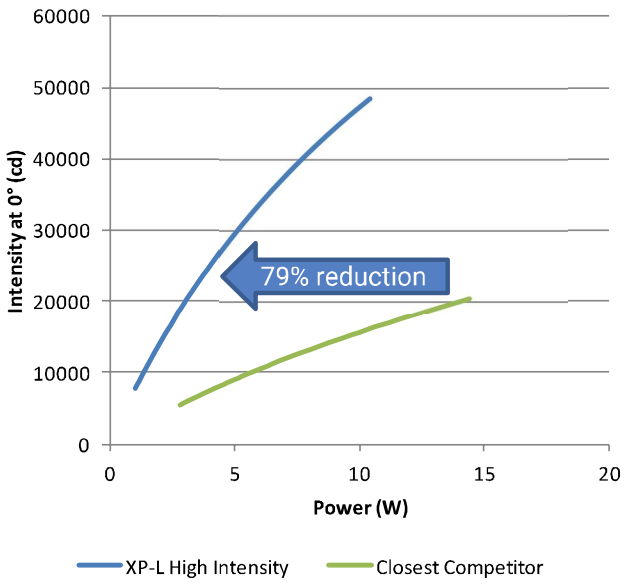
Breakthrough Performance

Measured using Carclo 10755R1 TIR optic





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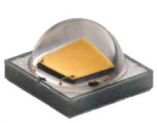
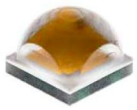
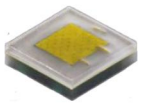
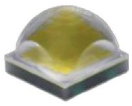
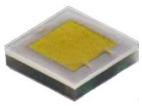
XP Optical Source Size Comparisons

	XLamp XP-G2	XLamp XP-L High Density	XLamp XP-L High Intensity	XLamp XHP35 High Density	XLamp XHP35 High Intensity
Avg Surface Luminance per Lumen (cd/cm^2/lumen)	 8.2	 3.2	 7.8	 2.84	 5.4
Optical Source Size	1 X	1.5 X	~1 X	1.7 X	1.4 X
Maximum Lumens	613 lm	1226 lm	1095 lm	1528 lm	1490 lm

Reduction in Optical Source Size

Reduction in Optical Source Size

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20,000 cd Spot light by XHP35 HI (High Intensity)

Test data - DC

LED and No	Lens Type	Voltage (DCV)	Current (mA)	Flux (lm)	Power (W)	LPW lm/W	Angel °	CBCP cd	Cd/lm	lx (1m)	CCT (K)	CRI
XHP35 HI C2 1pcs	BLU03	11.88	700	618.7	8.32	74.3	7.4	20107	32.5	20113	3000	80
	Reflector	11.85	480	540.7	5.69	95.0	6.5	20541	37.9	20539	3000	80
XHP35 HI E2 1pcs	BLU03	11.80	480	611.5	5.66	108.0	7.2	20329	33.2	20327	5700	70
	Reflector	11.73	400	551.2	4.69	117.5	6.6	20592	37.3	20592	5700	70

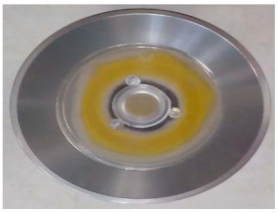
LEDlink-BLU03

Reflector

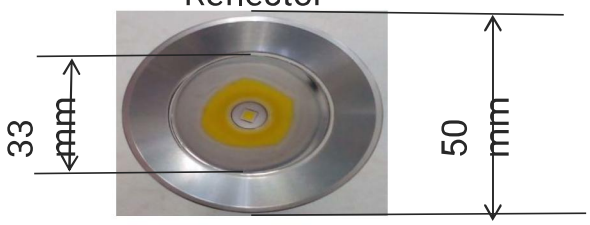
CREE

Lamp pictures

LEDlink-BLU03



Reflector



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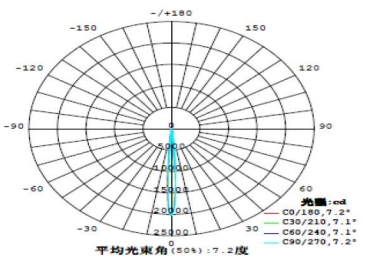
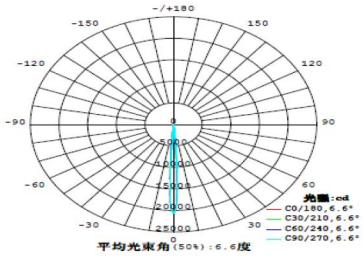
Lamp Pictures

Optical curve lines-5700K

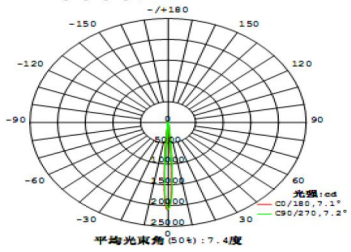
LEDlink-BLU03
5700K



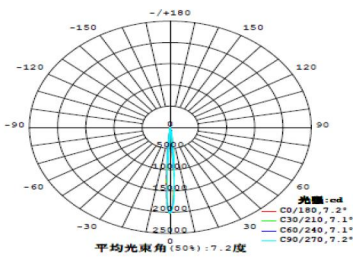
Reflector
5700K



LEDlink-BLU03
3000K

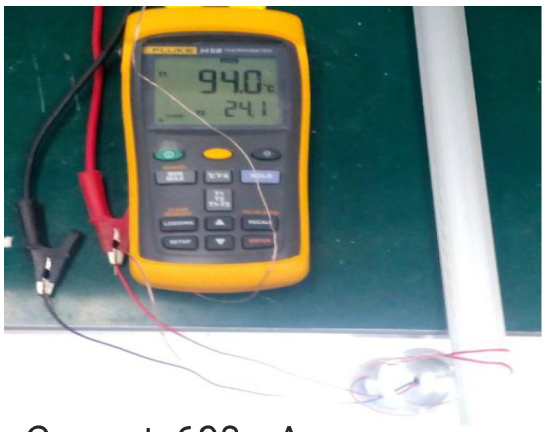


Reflector
3000K



Thermal test

LEDlink-BLU03 5700K
600mA



Current: 600mA
Tsp=94.0 ℃

Reflector 5700K
500mA

Current: 500mA
Tsp=79.0 ℃

Optical pictures

LEDlink-BLU03

Reflector

Cree LED Components Strategy

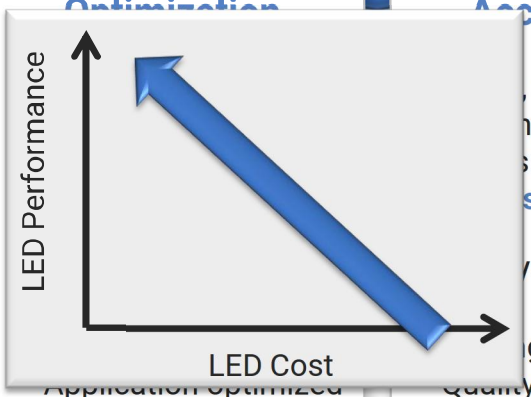
INNOVATION

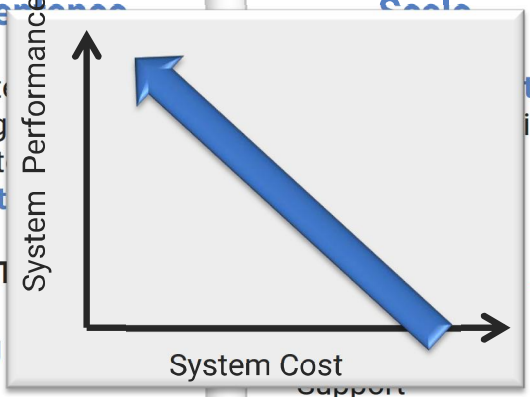
Performance

Higher performance **enables lower system cost** & creates definable value for customers.

Lighting Class LEDs

- Efficacy (LPW)
- Color consistency
- CRI
- Reliability





- Ease of use
- Total system cost
- System Lumens/$

- Standards
- Brand

- Education
- Vertical integration
- Ecosystem

CREE

Thank You