



System and Power Supply Design Considerations to Address Lifetime and Cost Goals for Broad Market Acceptance of LED Lighting Applications

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Lighting-Class LEDs are Not One Product

Lighting Is Not One Application

LAMPS



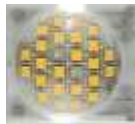
MX-6

XP-G

MC-E



XP-E



MP-L

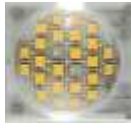


ML-E

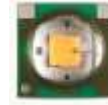
FIXTURES



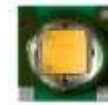
XP-G



MP-L



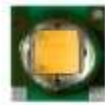
XP-C



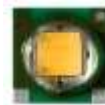
XP-E



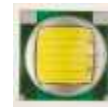
ML-E



XP-E



XP-E



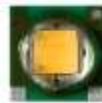
XM-L



MX-3



MX-6



XP-E



XP-G

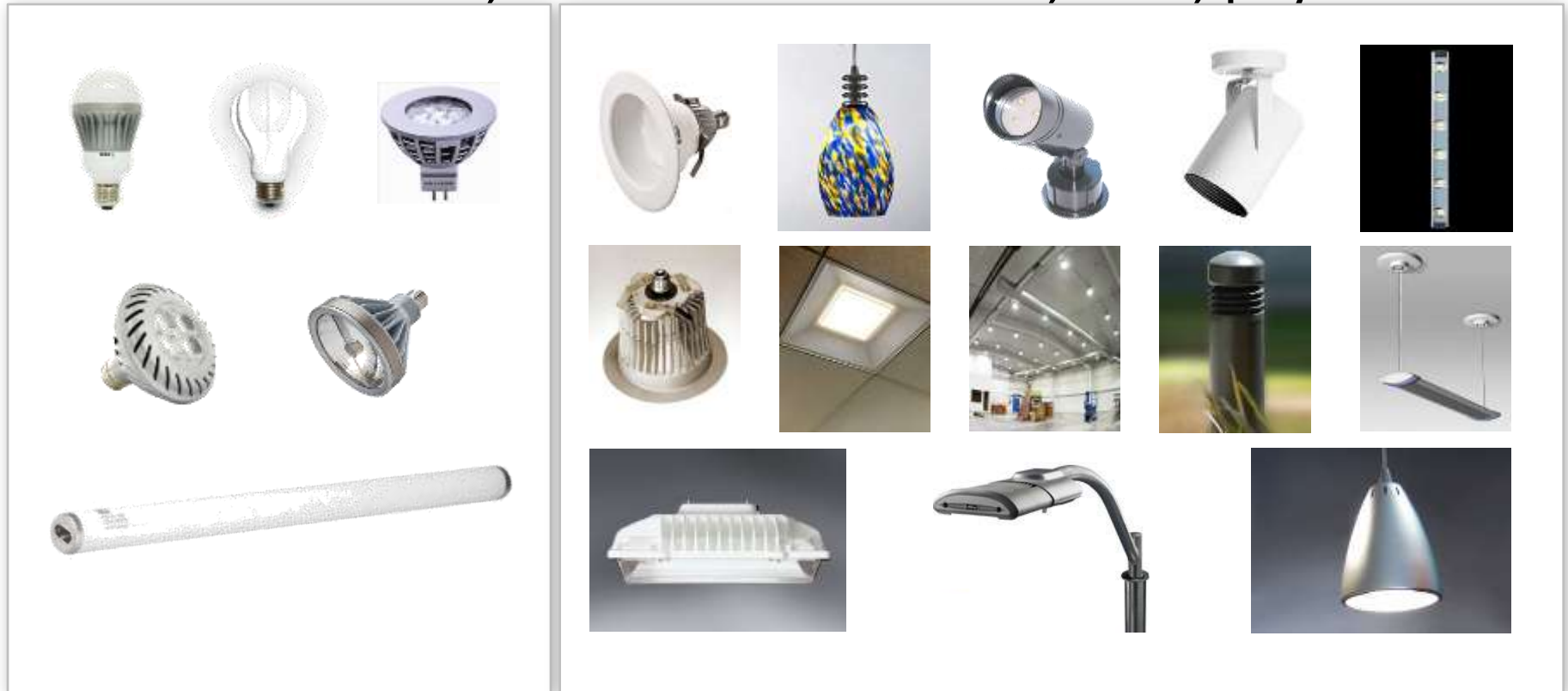


LMR4

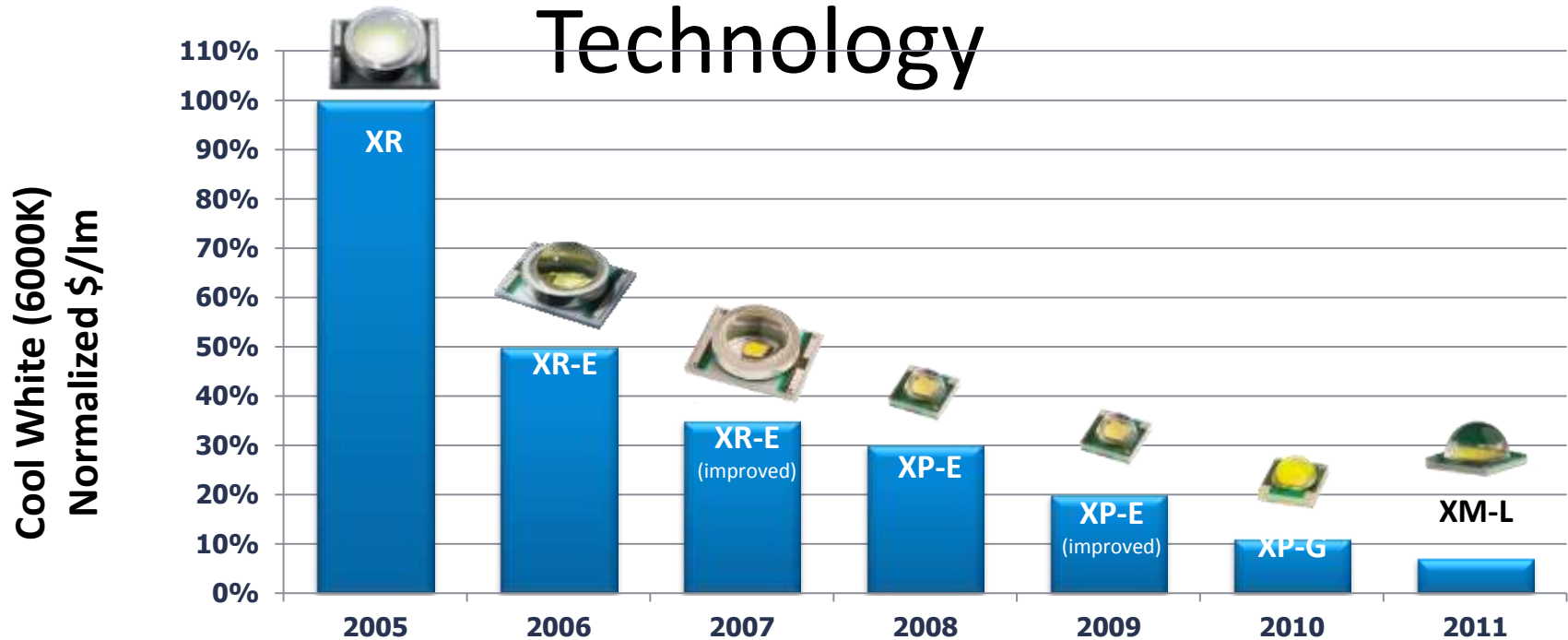
Start with the end in Mind

What Problem am I trying to solve

- We are creating “Lighting Class” Luminaire
- Key metrics: Luminaire Efficacy LPW (Lumen Per Watt), CRI, Life in hours, CBCP, Footcandles (fc)/lux , CCT , Power factor, Candela Distribution, Cost, payback..



Driving Lumen Affordability with Technology



\$/lm Change		-50%	-30%	-14%	-33%	-45%	-36%
Efficacy*	50 LPW	50 LPW	60 LPW	73 LPW	78 LPW	81 LPW	90 LPW
Increase (LPW)		0%	20%	46%	56%	62%	80%

* At maximum drive current (except XR)

Not a Binning Problem (Poor LED Selection)

Time zero



**LED Puck
84.1% Drop**



**16.5" Linear
97.8% Drop**



**22" Linear
96.9% Drop**



Lighting Applications Have Varied Requirements

		OUTPUT & CONTROL		QUALITY OF LIGHT		RELIABILITY	
		Flux and Efficacy	Optical Control	Color Quality (CRI)	Color Consistency	Color Stability	Lumen Maintenance
Value							
INDOOR	Omnidirectional, A-bulb						
	Accent, Track, PAR, MR bulb						
	Ceiling-mounted, Recessed						
	Linear, Commercial, Retail						
	Industrial, High Bay						
OUTDOOR	Roadway, Parking, Bollard						
	Landscape						
PORTABLE	Consumer						
	High-end, High-output						

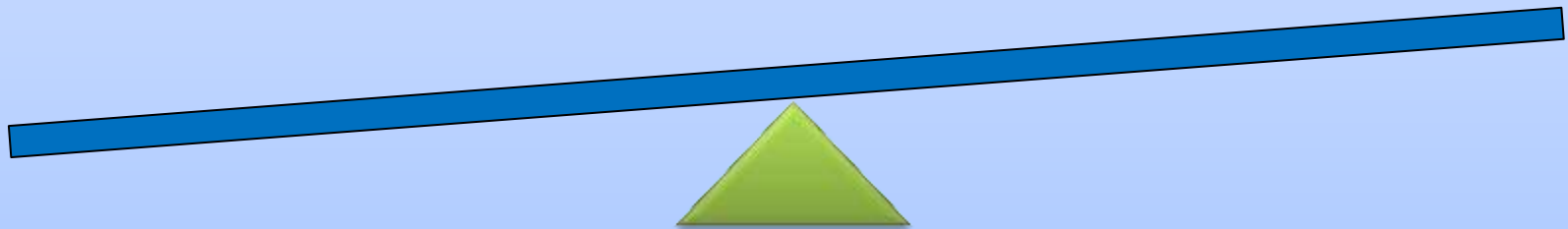
Best Performance for Low System Cost

Design Performance

- Highest Efficacy
- Lowest Input Power
- Highest CRI
- Highest Power Factor
- Variety of Color Temperatures
- Driver Efficiency
- Excellent Dimming
- Versatile Form Factor

System Costs

- Smallest Upfront Cost
- Decreased Design Complexity
- Increased Design Re-use
- Lowest Manufacturing Complexity
- Fewest Part Suppliers
- Smallest Part Inventory



Benefits

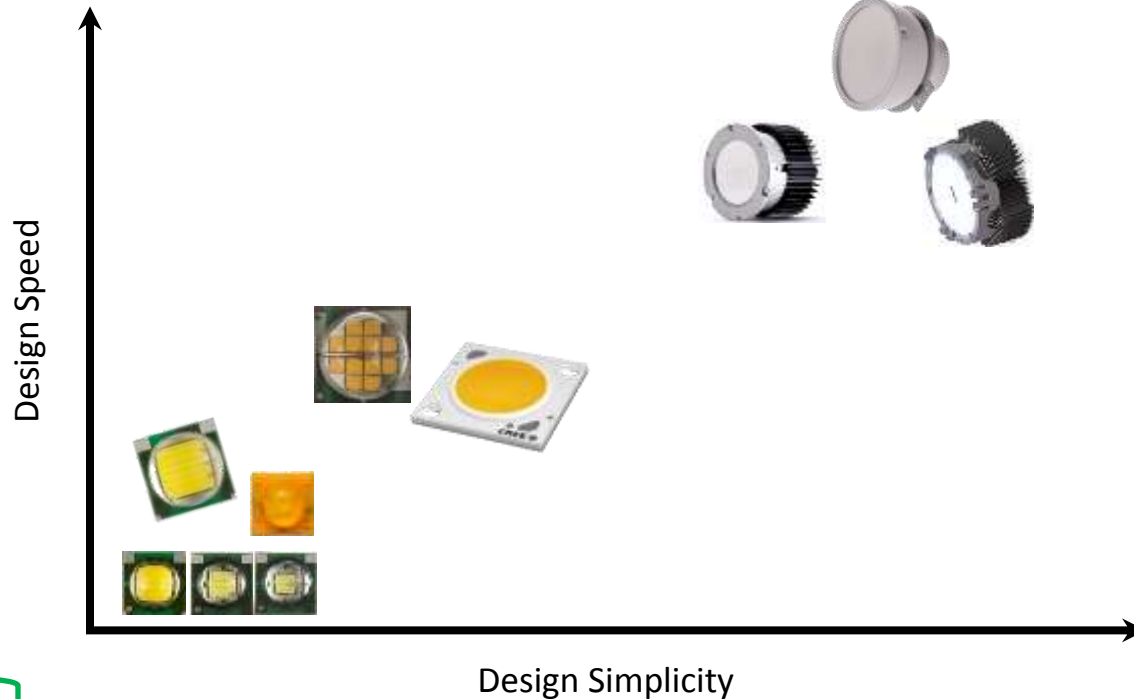
- No color-mixing or binning issues
- Simplified supply chain & inventory requirements
- Lowest upfront cost/risk
- Design flexibility
- Maximum optical control
- Form factor flexibility
- Lowest BOM cost

Luminaire Manufacturer Profile

- Lower time to market pressure
- Have LED & driver expertise
OR
Willing to outsource light engine design & driver supply

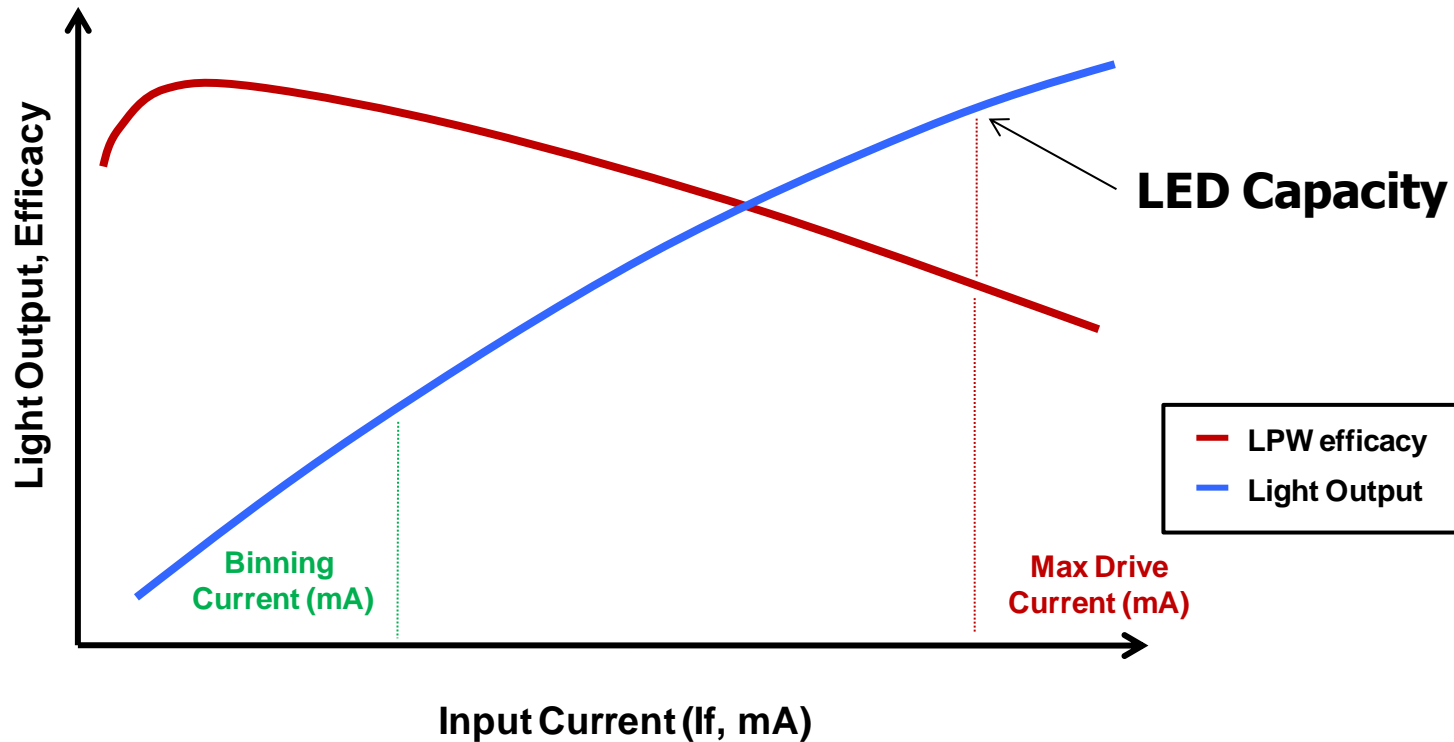
COMPONENTS & ARRAYS

MODULES

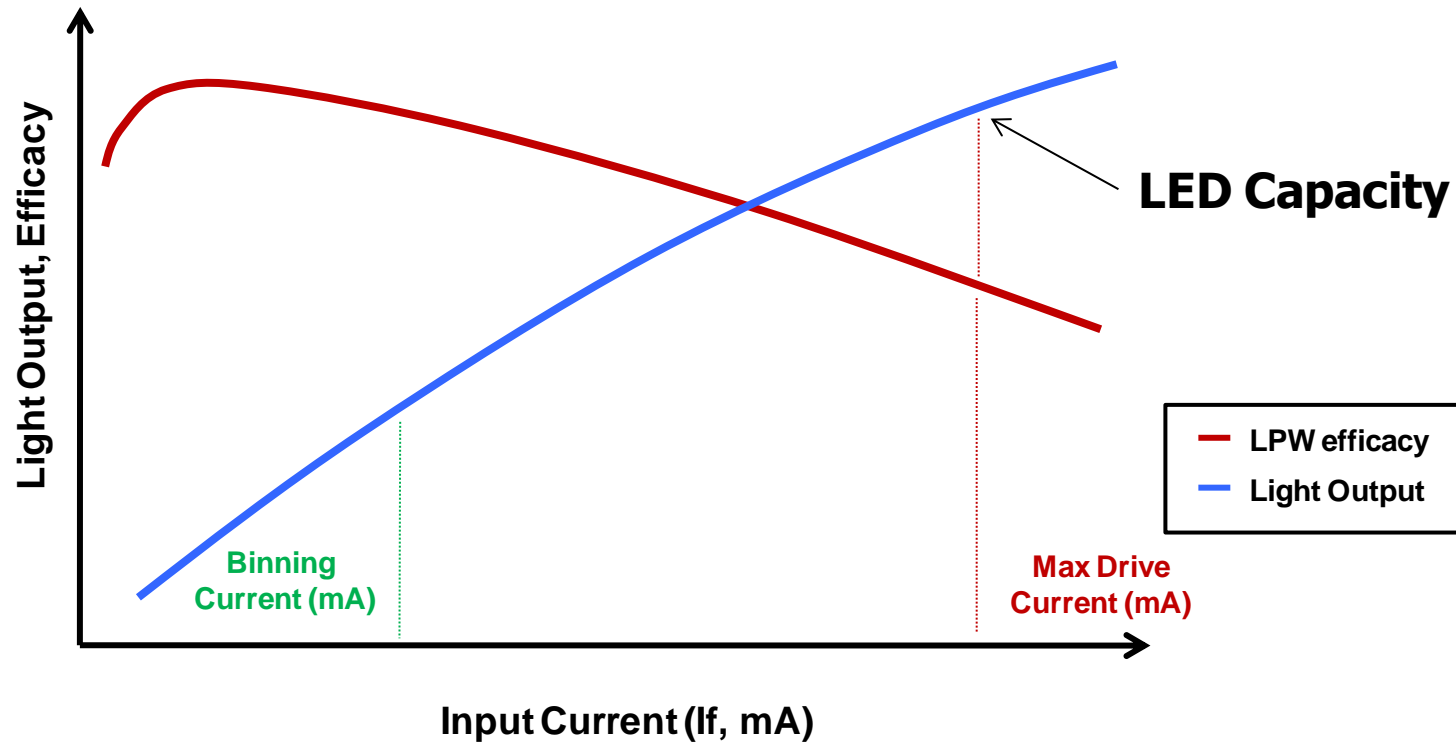


- Need to make a broad play into LED market quickly
OR
New to LED design

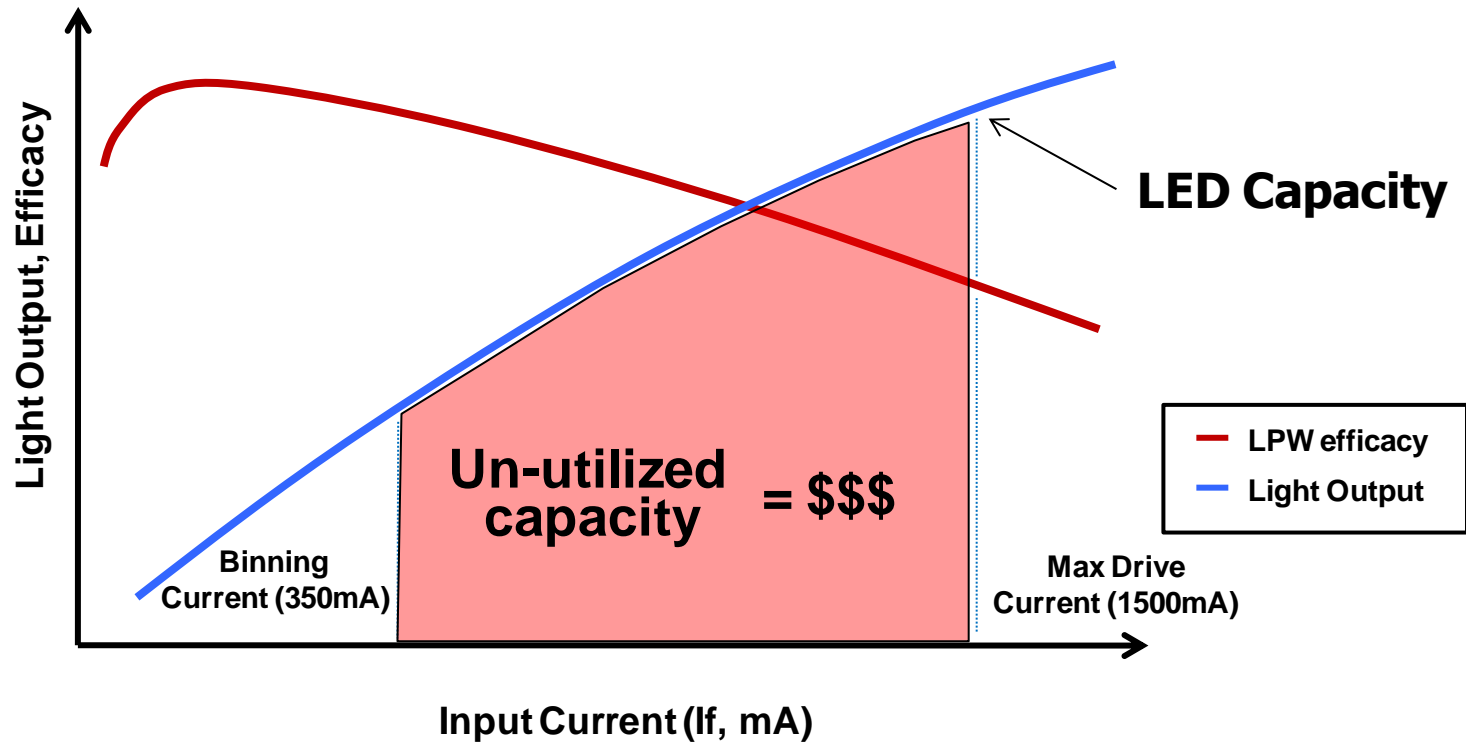
LED Capacity Concept



This Trade-Off Is An Opportunity To Lower System Cost

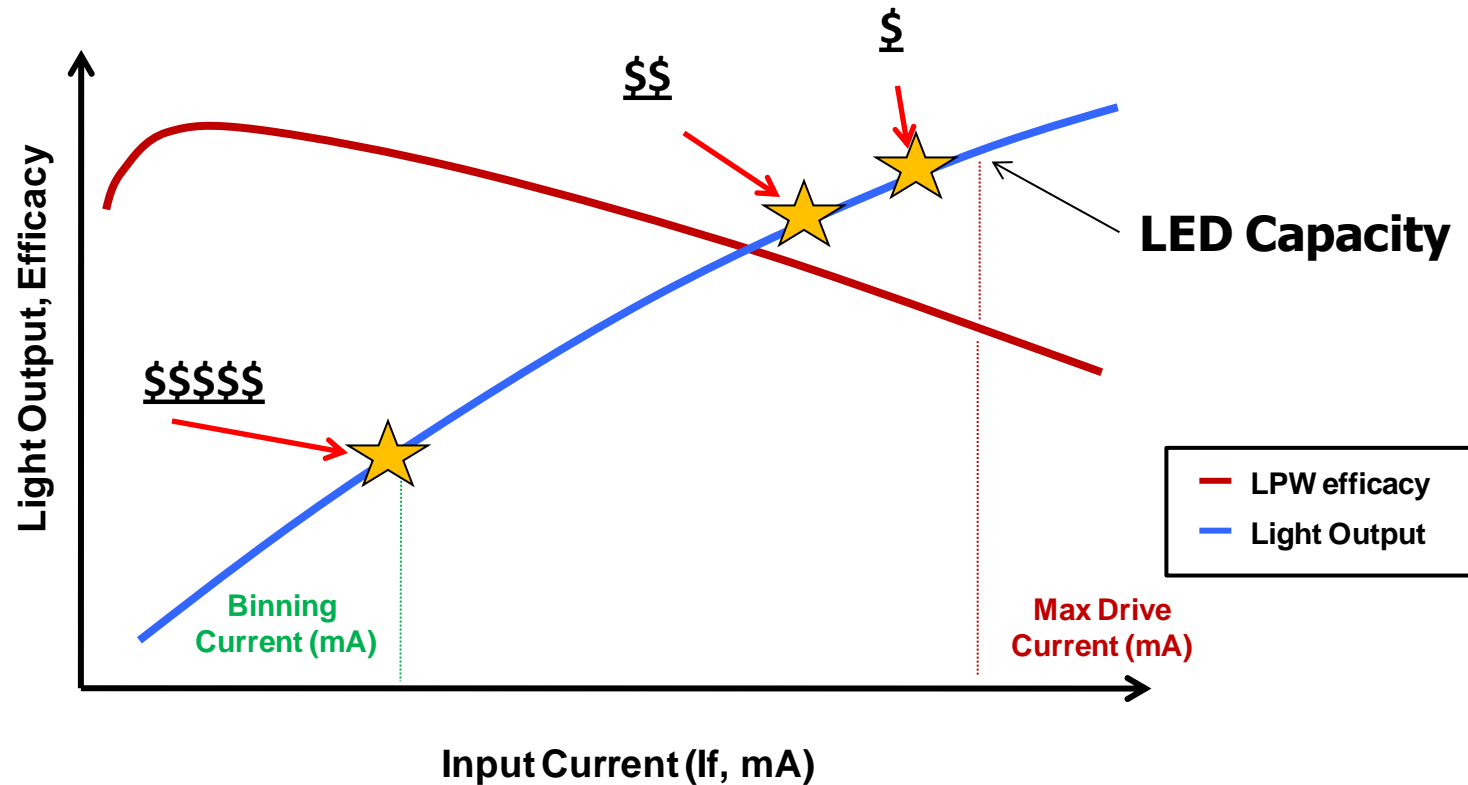


- Capacity of LED is Luminous Flux @ Max Drive Current
 - Running above binning current is not “over-driving” the LED...



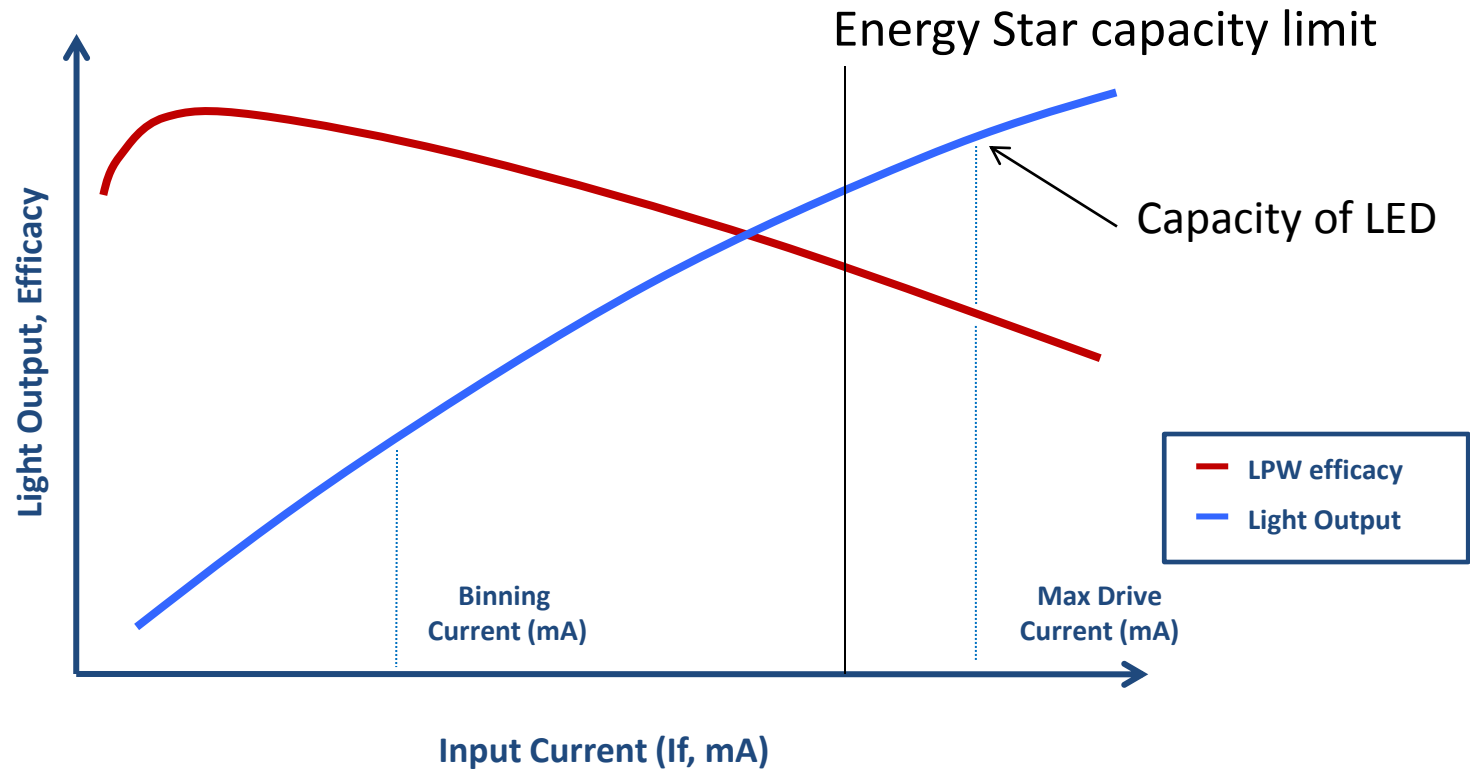
- At the binning current only 23% of the capacity of this LED is utilized; 77% of the LED goes UNUSED! (These are wasted lumens)
- There are, of course, practical limitations to this...
 - ENERGY STAR efficacy requirements
 - LED L70 lifetime
 - System thermal capacity

Good design: Balance design trade-offs



Cree enables you to optimize your design by matching the right LED for the application (Price/Optical/Voltage/integration)

Other Capacity Limits – Energy Star

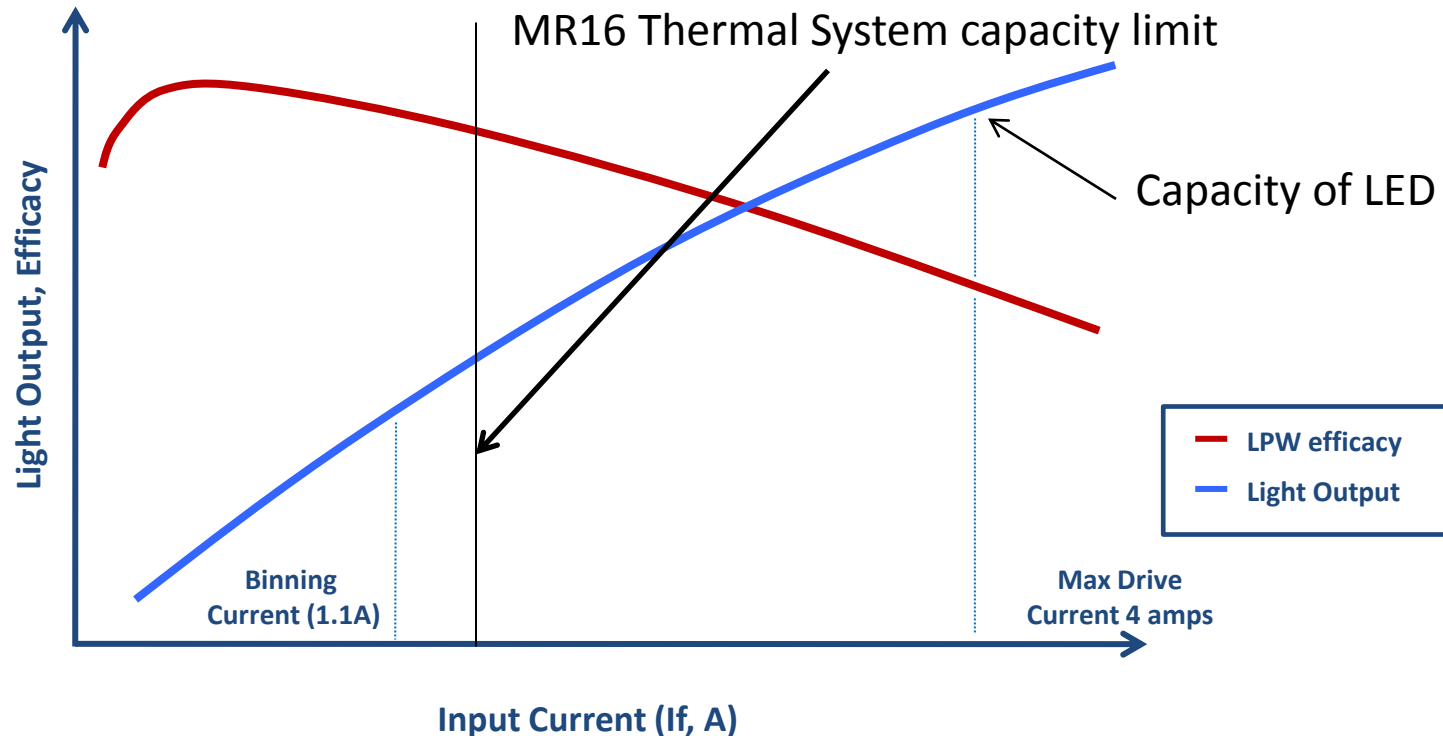


- Energy Star Requirements may be the capacity limit
- Energy star potential capacity limits:
 - LM80 test data
 - System efficacy minimum

Other Capacity Limits – Thermal



(MR16, MT-G)



- System Thermal capacity is the limiting factor !

Choose Lighting Class LEDs

- Choose LEDs with high capacity to lower your system cost

XLamp XP-G

up to **493 lm @ 5W**



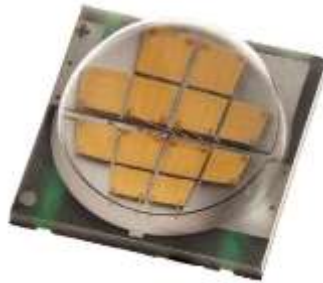
XLamp XM-L

up to **1000 lm @ 10W**



XLamp MT-G

up to **1525 lm @ 24W**



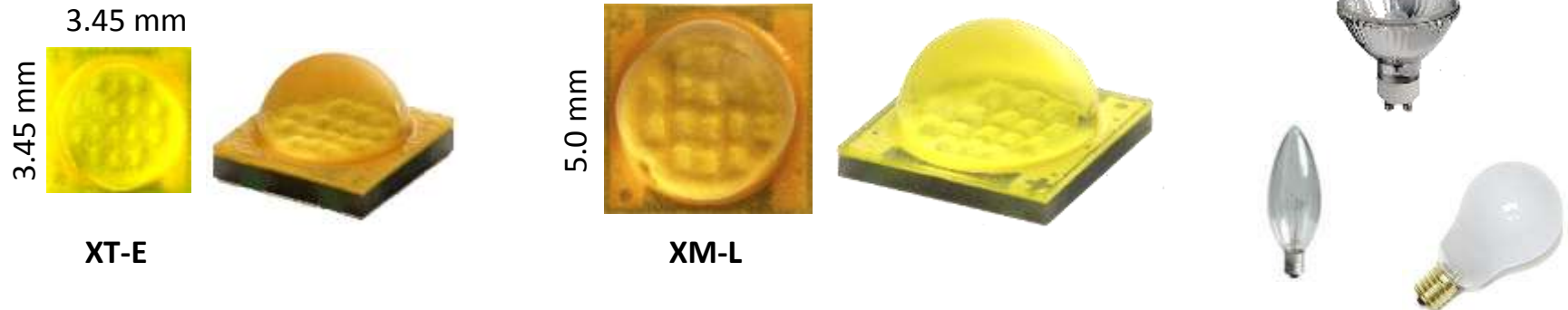
XLamp CXA2011

up to **4000 lm @ 47W**



- Understand how LEDs will behave at currents different than binning current

XLamp[®] High Voltage White

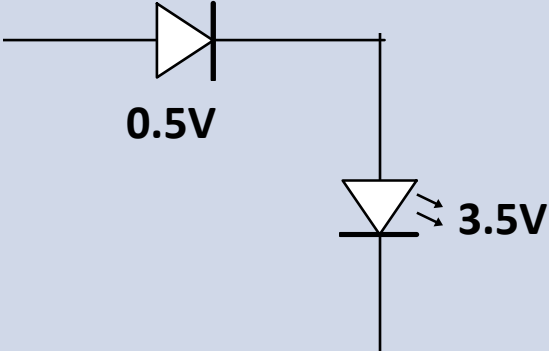
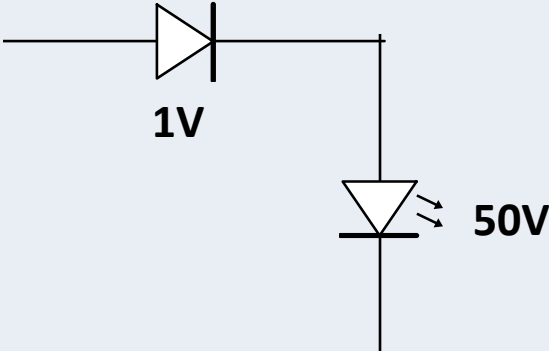


Highest performance available in discrete-size HV LEDs

- 46V drop in the size of a discrete LED (15-40x smaller than arrays)
 - Enables the use of lower cost, smaller size and higher efficiency LED drivers
 - Provides more room for LED driver & heat sink in space-constrained designs
- Right combination of flux & efficacy to enable 25W & 40W B10
 - One XT-E = 25W replacement; One XM-L = 40W replacement
- Optimized for non-directional lighting & small LED replacement lamps (B10, GU10, E17, A19)

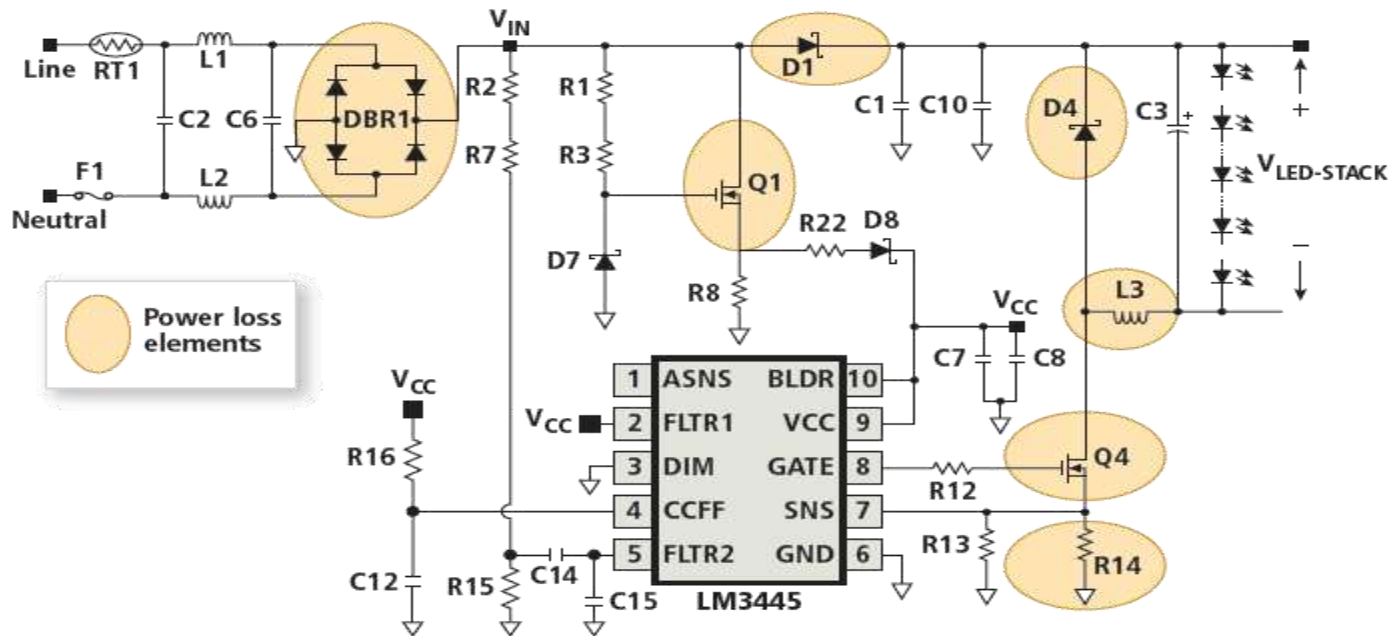
Why HV LEDs Make Drivers More Efficient

- Most basic building block: Rectifier + LED

Total Voltage	Schematic	System Efficiency
4V	 <p>A schematic diagram showing a diode with a 0.5V forward voltage drop in series with an LED that has a 3.5V forward voltage. The total voltage across the series combination is 4V.</p>	$3.5V / 4V = 87.5\%$
51V	 <p>A schematic diagram showing a diode with a 1V forward voltage drop in series with an LED that has a 50V forward voltage. The total voltage across the series combination is 51V.</p>	$50V / 51V = 98\%$

**High voltage yields 10.5 percentage point improvement
in the most basic system (LED + Diode)**

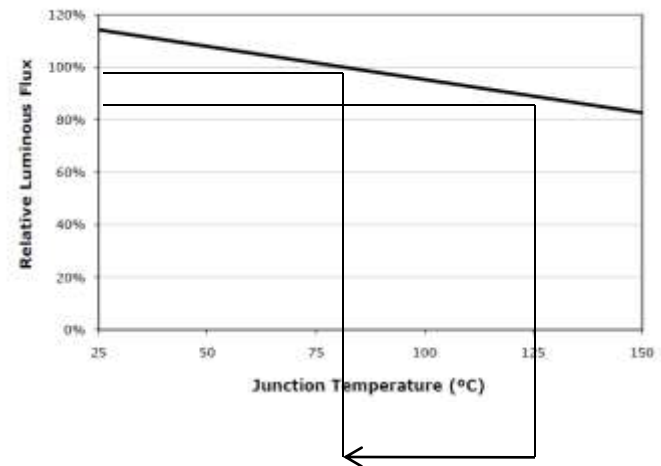
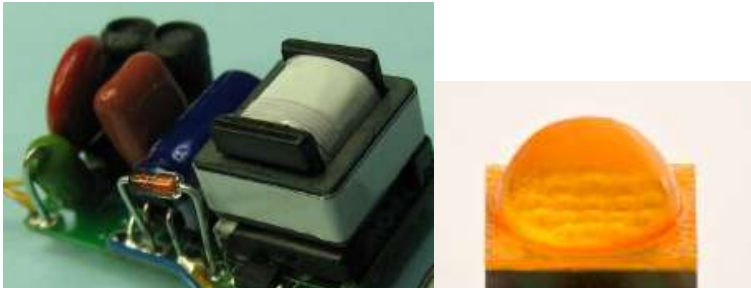
HV LEDs Make Driver Smaller & More Efficient



Component	% smaller	% more efficient	% lower cost	% lower temp
Bridge	Same	0-10%	Same	0-25%
Diode	0-50%	50%	50%	10-25%
FET	25%	25%	25%	10%
Inductor	30%	50%	20%	30%
Overall	15%	10-20%	10%	10%

Less Power Waste = More Lumens!

**In a shared heat sink system,
heat from the power supply lowers the LED Lumens**



Application: B10 Candelabra

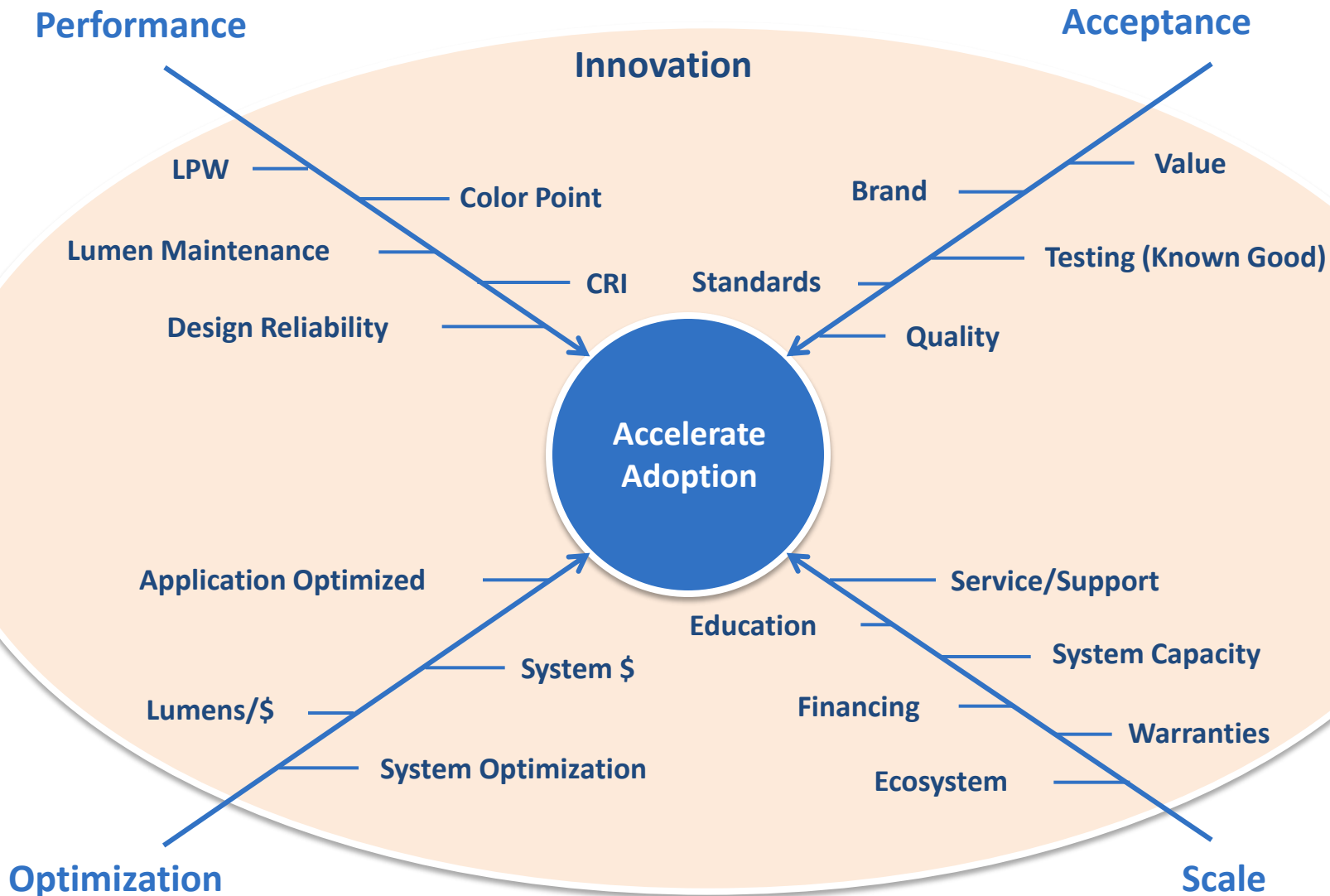
Design Target:

- 200 lm (25W), 300 lm (40W)
- 3000K CCT
- 85% optical efficiency
- 90% electrical efficiency
- $T_{sp} = 85^{\circ}\text{C}$
- 5W maximum power
- Reference Design Available



B10 Equiv.	LED			System		
	Model	# LEDs	Electrical	Lumens	Power	Efficacy
25W	XLamp XM-L EasyWhite	1	11.6 V, 340 mA	204 lm	4.1W	50 LPW
	XLamp XT-E High Voltage	2	95.7 V, 43.8 mA	235 lm	4.9W	48 LPW
40W	XLamp XM-L High Voltage	1	48.8 V, 92.3 mA	292 lm	5.2W	57 LPW

Adoption Factors



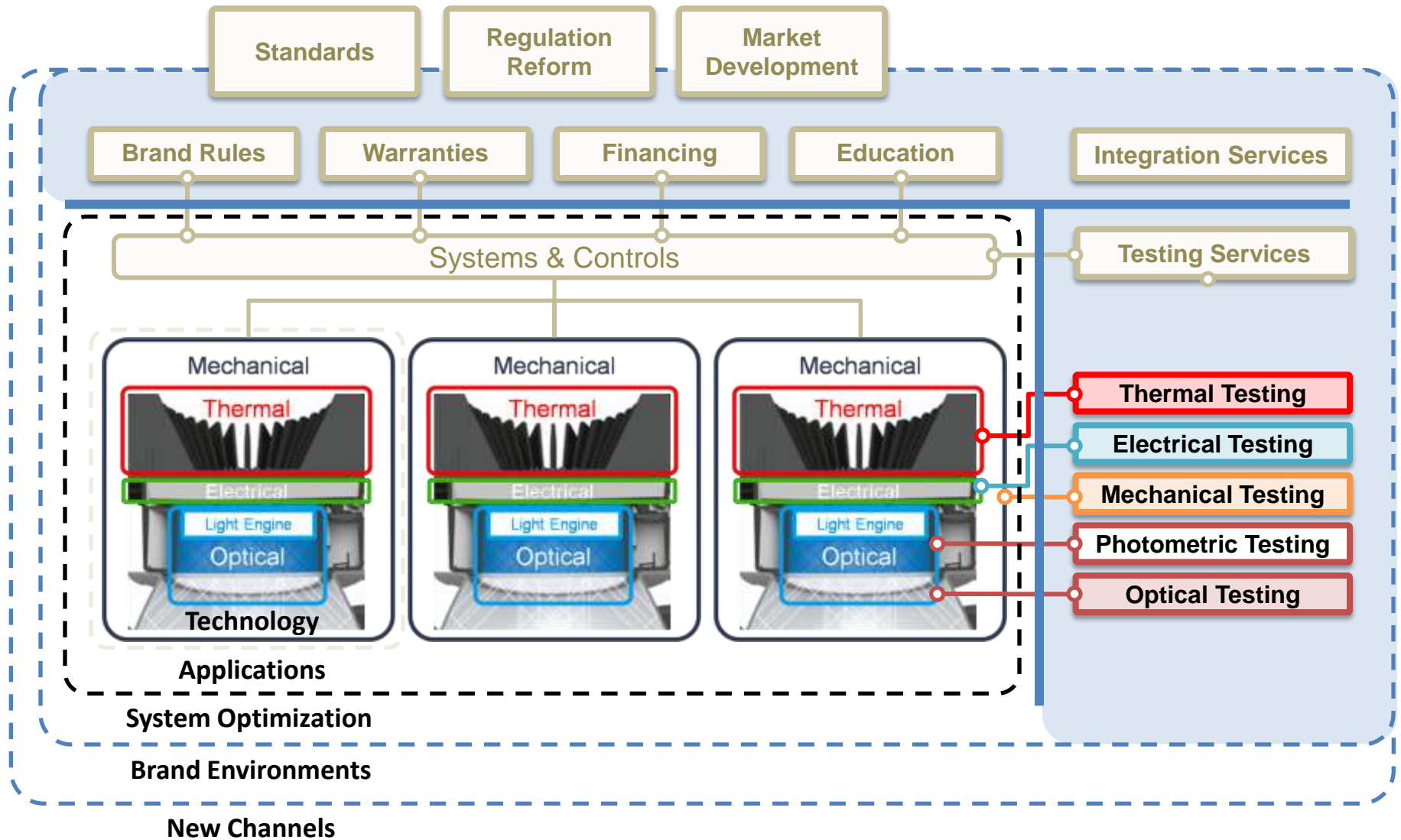
The graph illustrates the 'Chasm' model, showing Demand on the Y-axis and Time on the X-axis. The model is divided into five phases by vertical dashed lines:

- CREATE** (Orange area): The initial phase where the product is created.
- ENABLE** (Yellow area): The phase where the product is enabled for use. A stick figure is shown in this phase, and a curved arrow labeled 'Value' points from the ADOPTION curve to the DELIVER phase.
- SCALE** (Light blue area): The phase where the product is scaled.
- ADOPTION** (Dark blue area): The phase where the product is adopted by the market.
- DELIVER** (Light blue area): The final phase where the product is delivered to the customer.

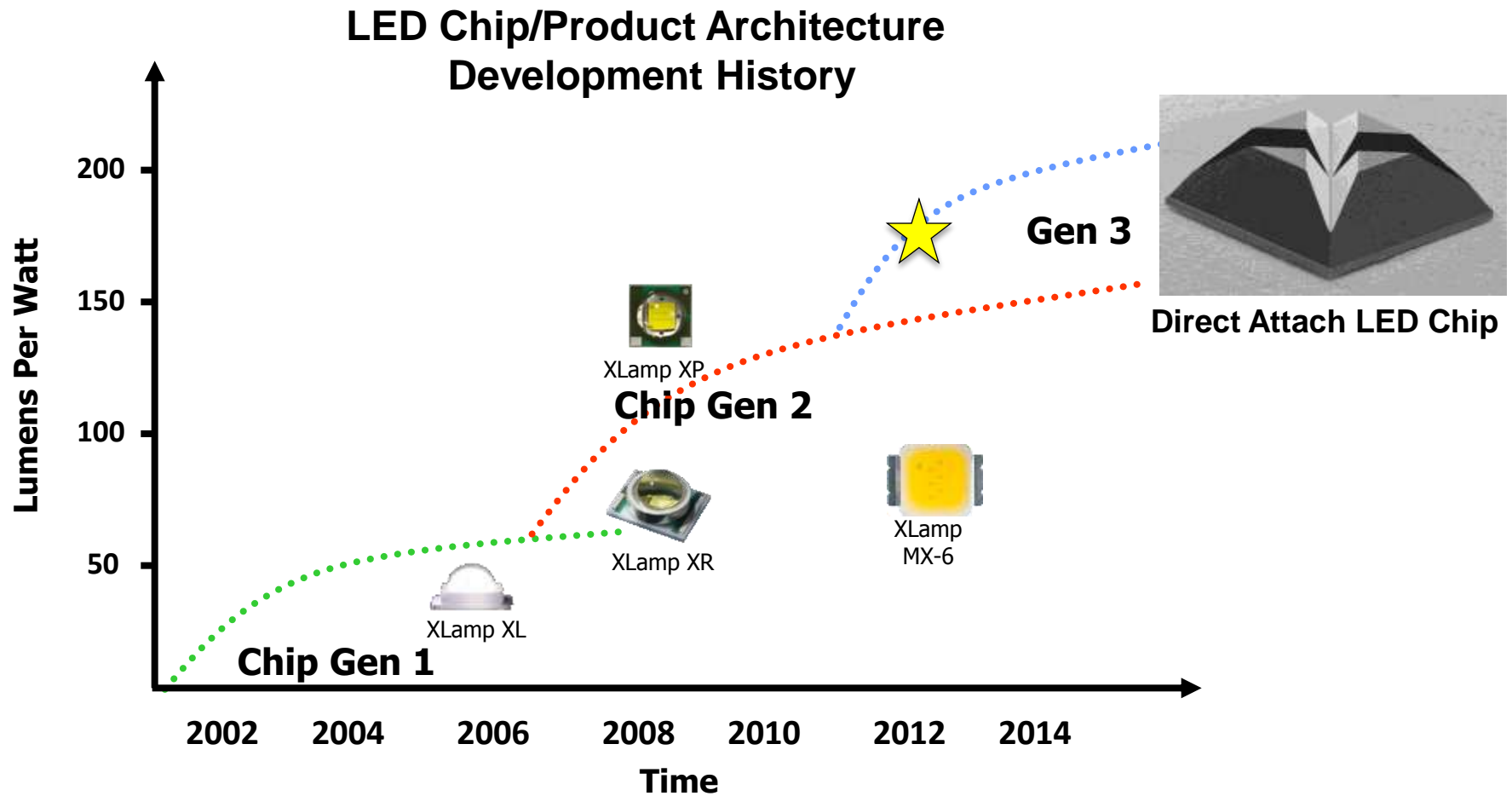
The 'Chasm' is the gap between the ENABLE and SCALE phases. The 'ADOPTION' curve is a dashed line that rises sharply during the ADOPTION phase. The 'DELIVER' curve is a solid line that peaks during the ADOPTION phase and then declines.

Need Transition from Products to Value

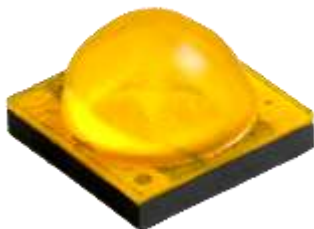
Delivering Value Doesn't Look Like a \$5 Bulb



The Engine of the LED Market

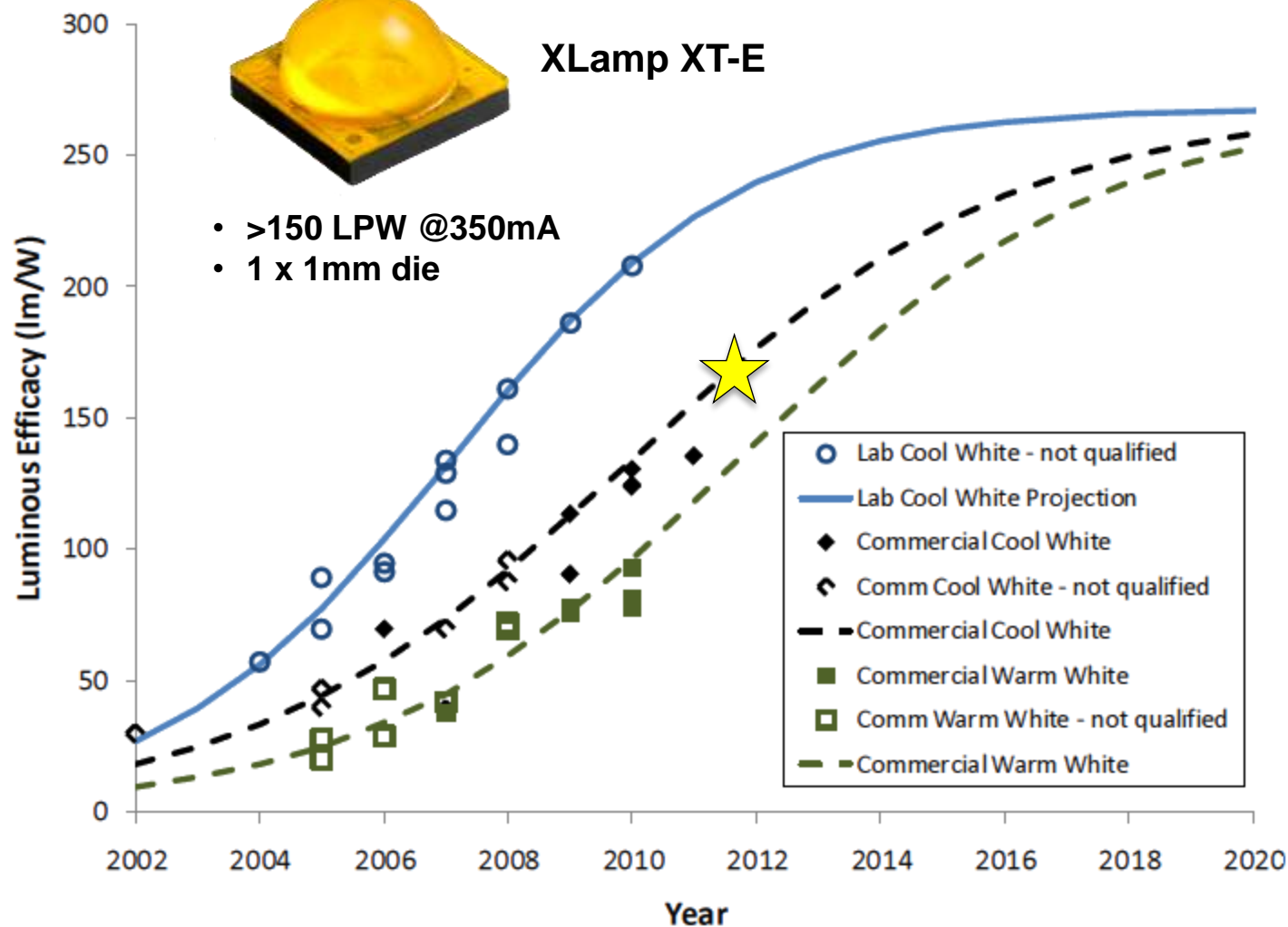


DOE LED Roadmap



XLamp XT-E

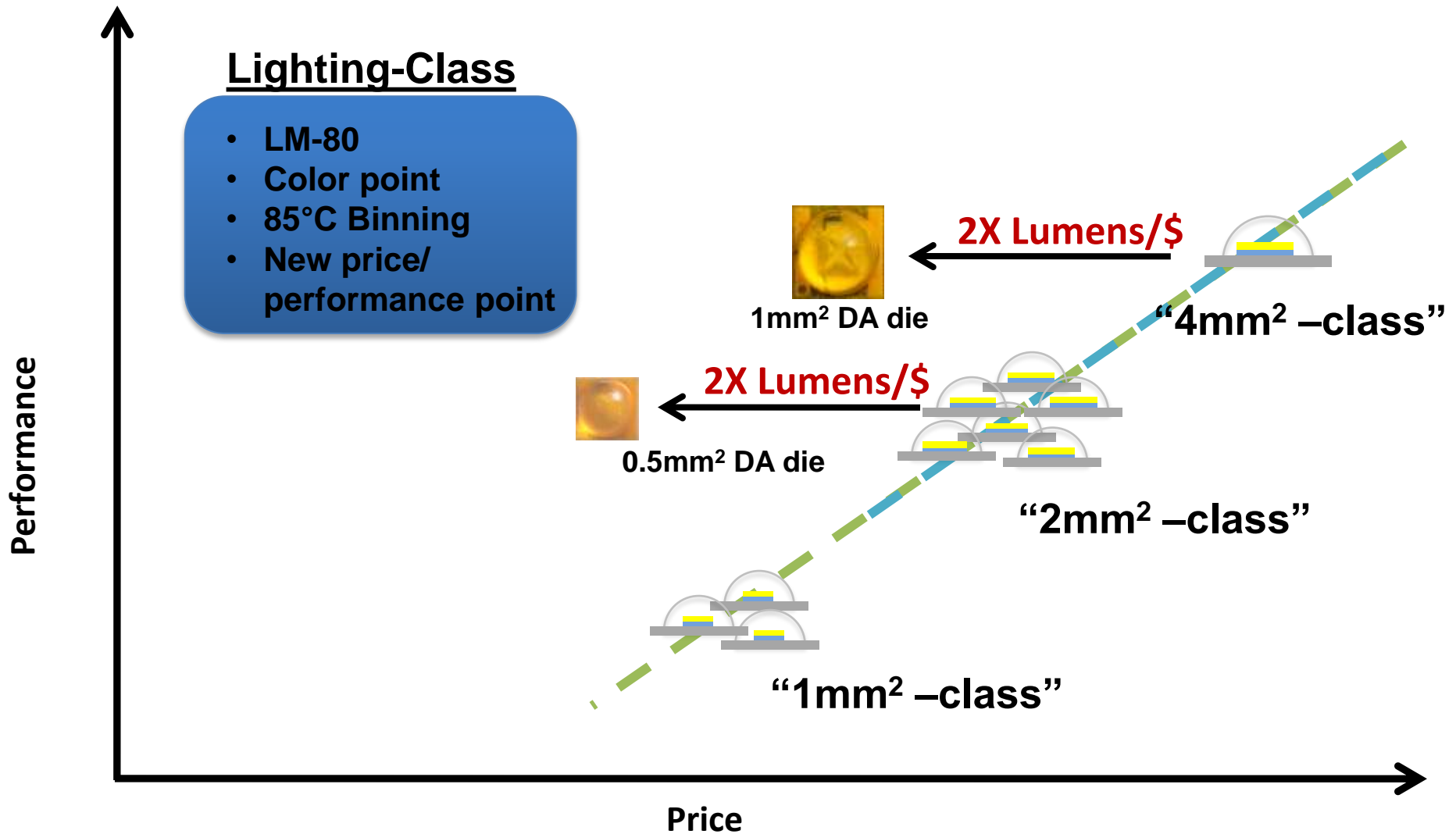
- >150 LPW @350mA
- 1 x 1mm die



New lm/\$ Vector

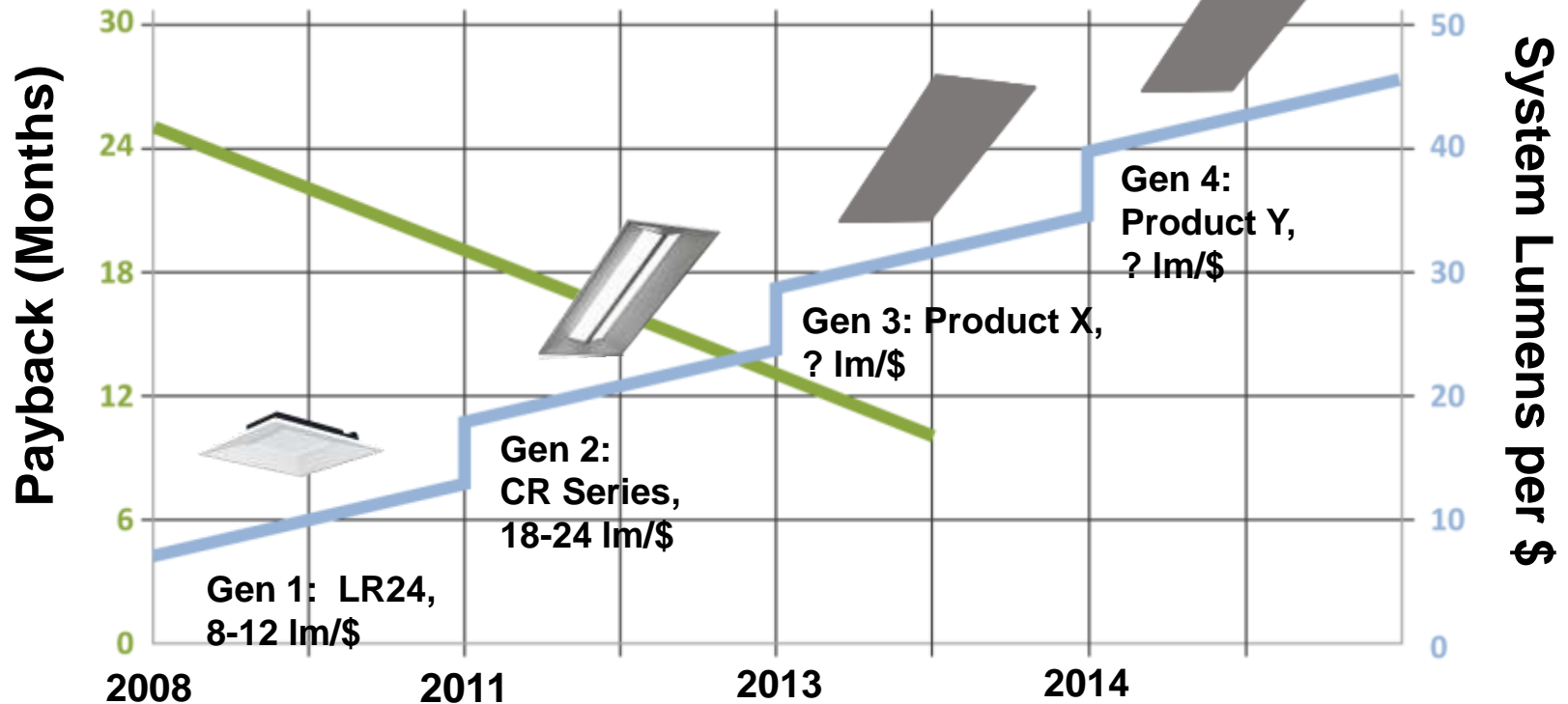
Lighting-Class

- LM-80
- Color point
- 85°C Binning
- New price/
performance point



Payback Implication

TROFFERS



Chip innovations and fixture design reduces first cost, improves lm/\$

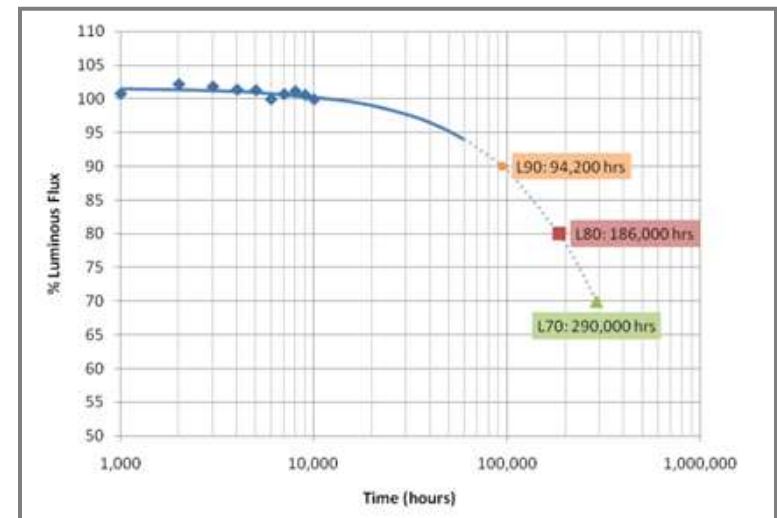
Payback shortens from 4+ Yrs to less than 1 year

Data to Back-up our Claims

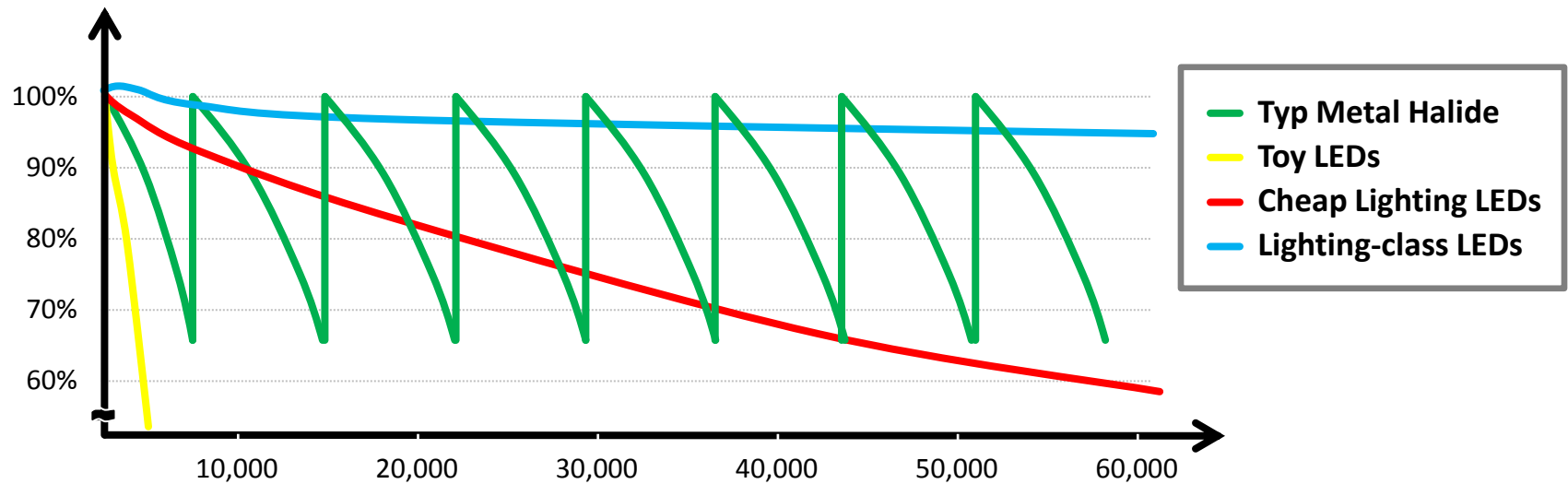
LED Lifetime (IES TM-21-2011)

Description of LED light source tested	XLamp XP-G White Data Set 11		
Sample size	20		
LED drive current used in the test	1000 mA		
Tested case temperature	85°C		
Test duration	10,080 hours		
Test duration used for projection	t=5,040 to t=10,080		
α	1.284E-06		
β	1.016E+00		
Calculated Lifetime	L70(10k) = 290,000 hours		
Reported Lifetime	L70(10k) > 60,500 hours		

Lifetime	Calculated	Reported	Graph?
L70	L70(10k) = 290,000 hours	L70(10k) > 60,500 hours	<input checked="" type="checkbox"/>
L80	L80(10k) = 186,000 hours	L80(10k) > 60,500 hours	<input checked="" type="checkbox"/>
L90	L90(10k) = 94,200 hours	L90(10k) > 60,500 hours	<input checked="" type="checkbox"/>



Lighting-class Data Matters



- The industry is under the impression that we must design to L_{70} for LED –
 - Not so anymore for Lighting-class LEDs with well-documented LM-80 data