從美國能源部計畫案之規劃看固態照明的未來發展

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民國100年11月4日(五)

成功大學電機系館1F 靄雲聽

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大綱

- 簡介
  - 市場走向與規格預測、主導單位、Energy Star
- 能源署推動的固態照明相關計畫案
  - Retailer Energy Alliance (REA)
  - Commercially Available LED Product Evaluation and Reporting (CALiPER)
  - L Prize- Bright Tomorrow Lighting Prizes
  - Technical Information Network (TINSSL)
  - Solid-State Lighting GATEWAY Demonstrations
  - SSL Quality Advocates
  - 多年期計畫案
  - 標準
  - 未來工作

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照明 2014年超越背光

- DisplaySearch報告
  - LED電視成長未如預期快速，而晶片數量卻大增，2011年呈現**供過於求**
    - LED晶片**功率提升、成本縮減**
    - 每台LCD TV背光所使用的LED晶片**數量**將相對**減少**
  - 預計2014年**LED照明**將取代電視**背光**，成為應用主流
    - 預估2010年LED照明市場滲透率為**1.4%**
    - 2014年將達到**9.6%**

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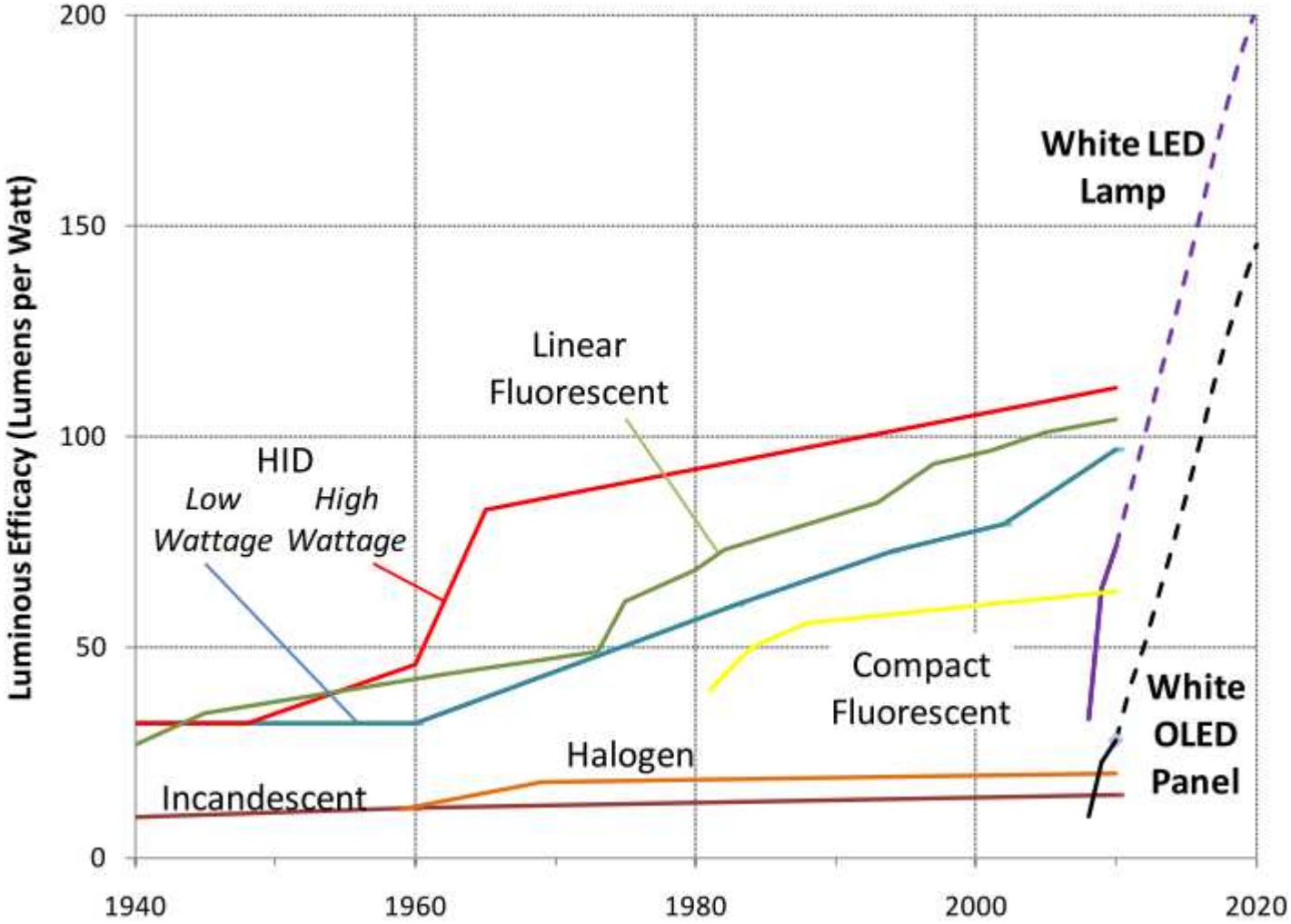
Historical and Predicted Efficacy of Light Sources



Source: Navigant Consulting, Inc - Updated Lumileds' chart with data from product catalogues and press releases
Note: Efficacies for HID, fluorescent, and LED sources include driver or ballast losses.

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SSL Performance Compared to Conventional Lighting Technologies in **2010**

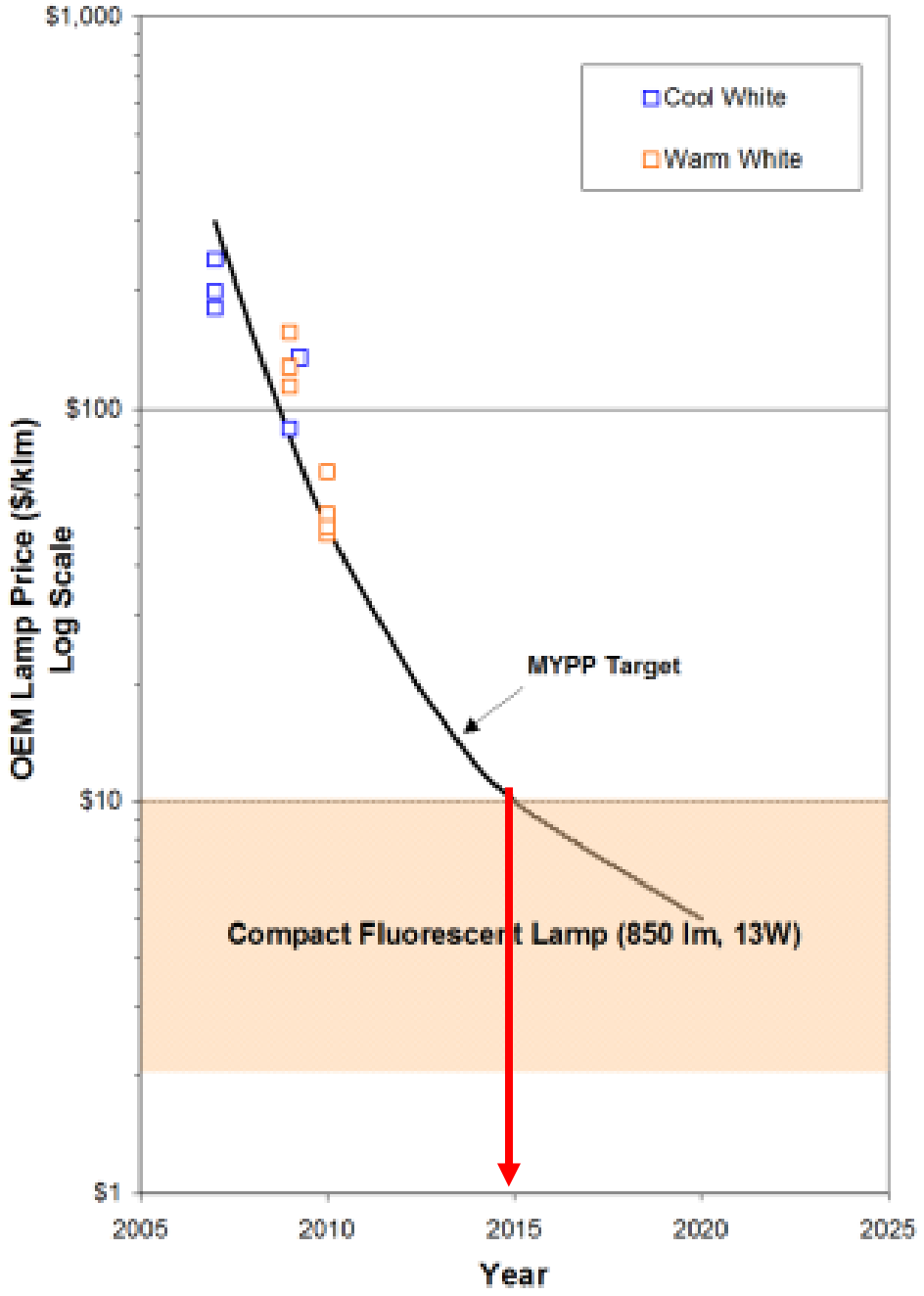
Product Type	Luminous Efficacy	Luminous Output	Wattage	CCT	CRI	Lifetime
LED White Package (Cool)	130 lm/W	130 lm	1 W	5650 K	70	50k hours
LED White Package (Warm)	93 lm/W	205 lm	2.2 W	3500 K	80	50k hours
LED A19 Lamp (Warm White)[41]	64 lm/W	800 lm	12.5 W	2700 K	80	25k hours
LED PAR38 Lamp (Warm White)[42]	52.5 lm/W	1050 lm	20 W	3000 K	80	25k hours
OLED Panel[43]	28 lm/W	50 lm	2W	2700-6500 K	80	8k hours
HID (High Watt) Lamp and Ballast	120 lm/W 111 lm/W	37800 lm	315W 341W	3000 K	90	20k hours
Linear Fluorescent Lamp and Ballast	118 lm/W 108 lm/W	3050 lm 6100 lm	26W 56W	4100 K	85	25k hours
HID (Low Watt) Lamp and Ballast	104 lm/W 97 lm/W	7300 lm	70W 75W	3000 K	90	12k hours
CFL	63 lm/W	950 lm	15W	2700 K	82	12k hours
Halogen	20 lm/W	970 lm	48 W	2750 K	N/A	4k hours
Incandescent	15 lm/W	900 lm	60W	3300 K	100	1k hours

省電燈泡

Source: GE 2010, Cree 2010, Philips Lighting 2010, OSRAM Sylvania 2010 product catalogs, LED lamp based on Lighting Facts product registrations.

Cost of Light Sources

Incandescent Lamp (A19 60W high efficiency)	$0.5	per kilolumen
Compact Fluorescent Lamp (13W)	$2	per kilolumen
Compact Fluorescent Lamp (13W dimmable)	$10	per kilolumen
Fluorescent Lamp and Ballast System (F32T8)	$4	per kilolumen[44]
LED Lamp (A19 60W dimmable)	$50	per kilolumen[45]
OLED Panel[43,46]	$2,560	per kilolumen[47]



White Light Integrated LED Lamp Price Projection

Summary of LED Package Price and Performance Projections

Metric	2010	2012	2015	2020
Cool White Efficacy (lm/W)	134	176	224	258
Cool White Price ($/klm)	13	6	2	1
Warm White Efficacy (lm/W)	96	141	202	253
Warm White Price ($/klm)	18	7.5	2.2	1

Note

- Projections for
  - **Cool** white packages assume CCT=**4746-7040**K and CRI=**70-80**
  - **Warm** white packages assume CCT=**2580-3710**K and CRI=**80-90**
- All efficacy projections assume that packages
  - measured at **25˚C**
  - with a drive current density of **35 A/cm^2**
- Package life
  - approximately **50,000 hours** assuming **70%** lumen maintenance at a drive current density of **35 A/cm^2**

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美國能源部固態照明發展計畫

- DOE旗下固態照明發展計畫委員會
  - **2020**年
    - 冷白光LED**燈具**平均發光效率目標為**219 lm/W**
      - 代工價格目標為**每千流明1美元**
    - **OLED**燈具發光效率目標為127 lm/W
      - 代工價格目標則為**每千流明6美元**或每平方公尺80美元
  - 2020年LED照明市場化的里程碑
    - 目標為市售**一般**等級**燈具**發光效率達**140 lm/W**
    - 價格為**100美元以下**

U.S. Energy Policies/Organizations

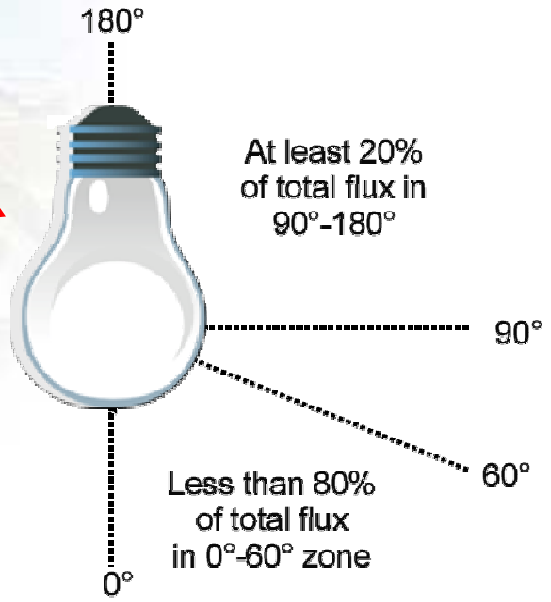
- EISA (Energy Independence and Security Act) 2007
- U.S. Department of Energy Programs
- U.S. EPA (Environmental Protection Agency) **Energy Star**
- NGO (Non-governmental organization) Programs
- Government & NGO Rebates

Energy Star for Integral Lamps

- Minimum efficacy: 50/55 LPW (<10W/≥10W)
- Minimum lumens: Varies by thermally stabilized "wattage equivalent"
- Minimum CRI: **75**, **$R_9 > 0$**
- Lumen Maintenance (L_{70}): 25,000 hours
- CCT: 2700 K, 3000 K, 3500 K, or 4000 K
- Duv tolerances: per ANSI C78.377-2008
- Power Factor: **>0.7** for lamps **≥5W**
- Intensity distribution:
  - 0~60°總光通量<80%；>90°總光通量>20%
- Dimming NOT required (very desired)
- Must provide:
  - IES LM-79-2008, sec 10 goniophotometer report
  - IES LM-80-2008 report on LEDs used
- 需要使用 "Lighting Facts" label
- 保證3年

2008/9月開始生效
自願性項目

Wattage Equivalent	Lumens
25	200
35	325
40	450
60	800
75	1,100
100	1,600



U.S. Department of Energy Programs

Retailer Energy Alliance

L PRIZE™

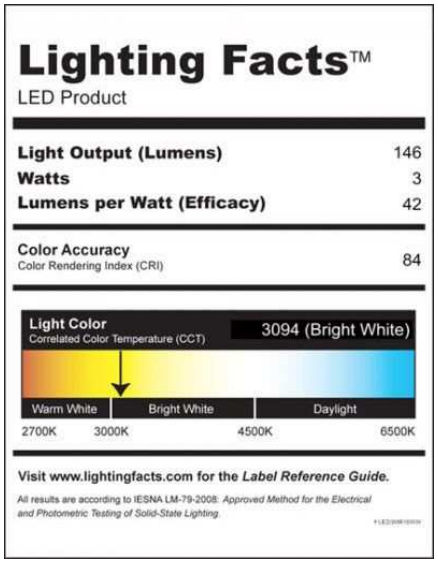
LIGHTING for tomorrow

CALiPER

LIGHTING for tomorrow

Technical Information Network

GATEWAY Demonstrations



SSL Quality Advocates

STANDARDS

NEXT GENERATION LUMINAIRES

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Retailer Energy Alliance (REA)

- 零售賣場佔全美商業能源消耗的**20%**
- 連鎖零售賣場的建築設計多採**複製模式**，**公司間**的學習與技術移轉也相對容易
- REA委員會找出最節能的設計
  - 使用合適的加熱、通風、空調(HVAC)與冷藏設備系統
  - 室內外照明
  - 看板
  - 使用再生能源

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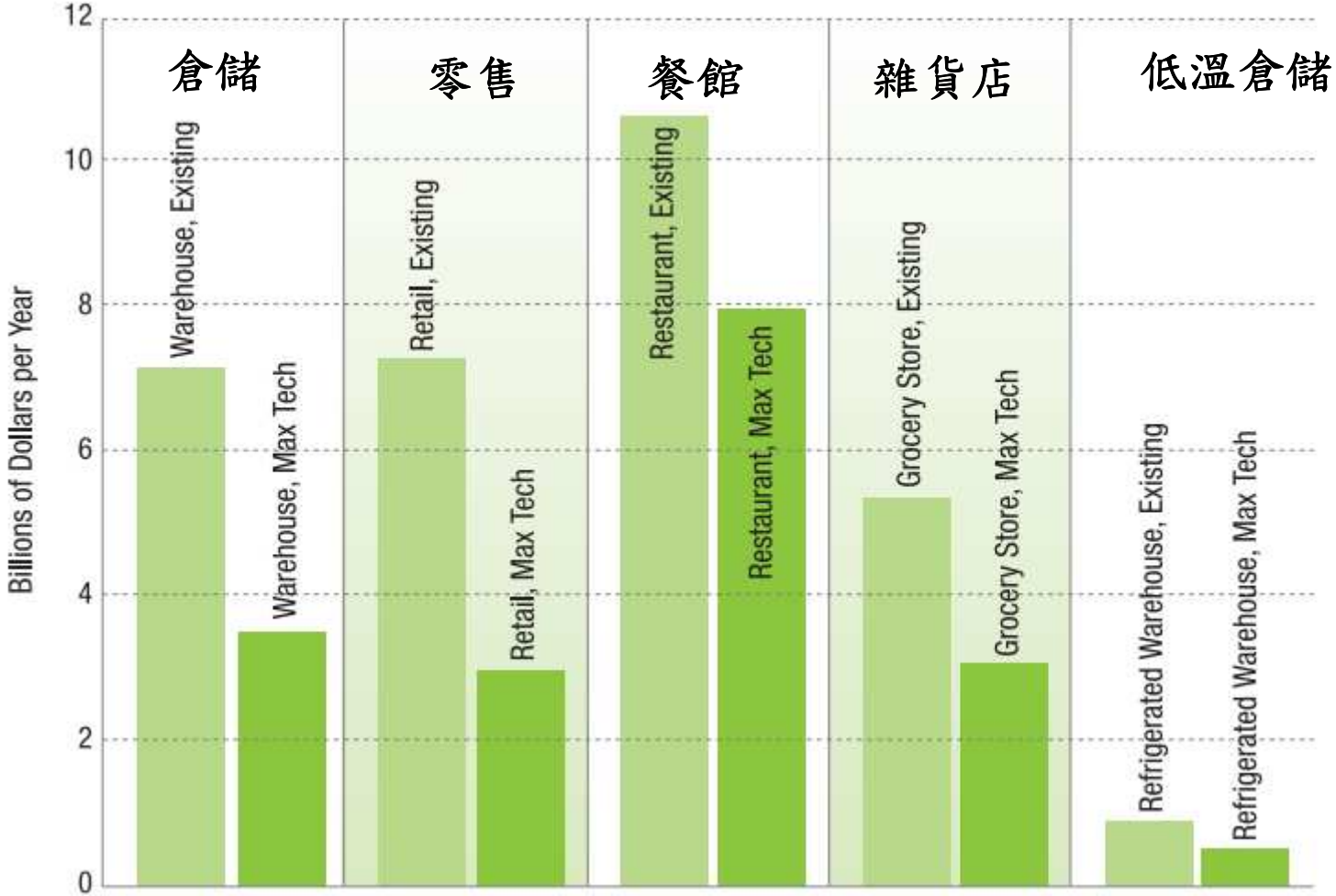
使用最佳技術能節省的能源成本



http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/retailer_energy_alliance_fact_sheet.pdf

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CALiPER Program

- Solid-state lighting (SSL)技術日新月異
  - 市場上的產品特性差異很大
  - 需要客觀的性能評估，鼓勵高性能產品
- Commercially Available LED Product Evaluation and Reporting (CALiPER)
  - 一般照明SSL產品測試報告，僅提供非商業或教育目的
  - 提供姓名、單位、同意書(非商業用途)後可取得報告的細節

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L Prize- Bright Tomorrow Lighting Prizes

- 第一個由美國政府贊助的技術競賽
  - 發展高品質、高效率SSL產品，以取代傳統燈泡

誰是下一個得獎人

高門檻

以10W
取代60W白熾燈

商機在等著你

Philips snags $10M L Prize with energy-efficient light bulb

- The U.S. Department of Energy announced
  - Philips has snagged **$10 million** in the L Prize
- The LED bulb
  - **900 lumens**
  - Consuming around **10 watts** of electricity
  - lifetime of around **25,000 hours**
- LED lighting is still much too expensive
  - **$18 per kilolumen** produced
  - incandescent bulbs were around **$2.20** per kilolumen
- probably won't reach that point until **2015**

Philips snags $10M L Prize with energy-efficient light bulb

Philips AmbientLED 17 Watts LED Lightbulb

http://www.treehugger.com/files/2011/08/philips-ambientled-led-light-bulb-review-17-watts-75w.php

Next Generation Luminaires

- The Next Generation Luminaires™ (NGL) Solid State Lighting (SSL) Design Competition
  - 節能商業化LED照明燈具設計競賽
- 第三屆首獎(2011/2)
  - The Lighting Quotient Inc. (West Haven, Connecticut): Awarded "best-in-class" for its Linear Concealed LED Luminaire cove lighting fixture.
  - Philips Color Kinetics (Burlington, Massachusetts) : Awarded "best-in-class" for its eW Burst Powercore facade lighting fixture.
  - Koncept Technologies Inc. (Monterey Park, California): Awarded "best-in-class" for its Equo **LED Desk Lamp task lighting fixture**
  - USAI (New Windsor, New York): Awarded "best-in-class" for its NanoLED recessed accent lighting fixture.

Equo LED Desk Lamp task lighting fixture (Koncept)

http://www.ngldc.org/10/winners/bestinclass_EquoLED.stm

Technical Information Network (TINSSL)

- 會員
  - 區域能源效率組織、計畫贊助人/單位、州與地方能源辦公室、燈具貿易商
- 收到SSL技術發展的最新資訊

Solid-State Lighting GATEWAY Demonstrations

- LED示範照明研究
  - 目標- 節省超過75%的能源使用
- 商業與住家的一般照明
  - 提供SSL產品特性與成本效益的實際操作數據
  - 提供消費者可靠的產品性能

SSL Quality Advocates

- DOE與Next Generation Lighting Industry Alliance (NGLIA)合作
  - 品質宣告- 確保LED燈具特性被正確標示
- Lighting Facts® label
  - quick and simple summary of product performance data as measured by the **new industry standard** for testing photometric performance, IES LM-79-2008
  - It reports product performance results in five areas
    - lumens, efficacy, watts, correlated color temperature (CCT) and color rendering index (CRI)

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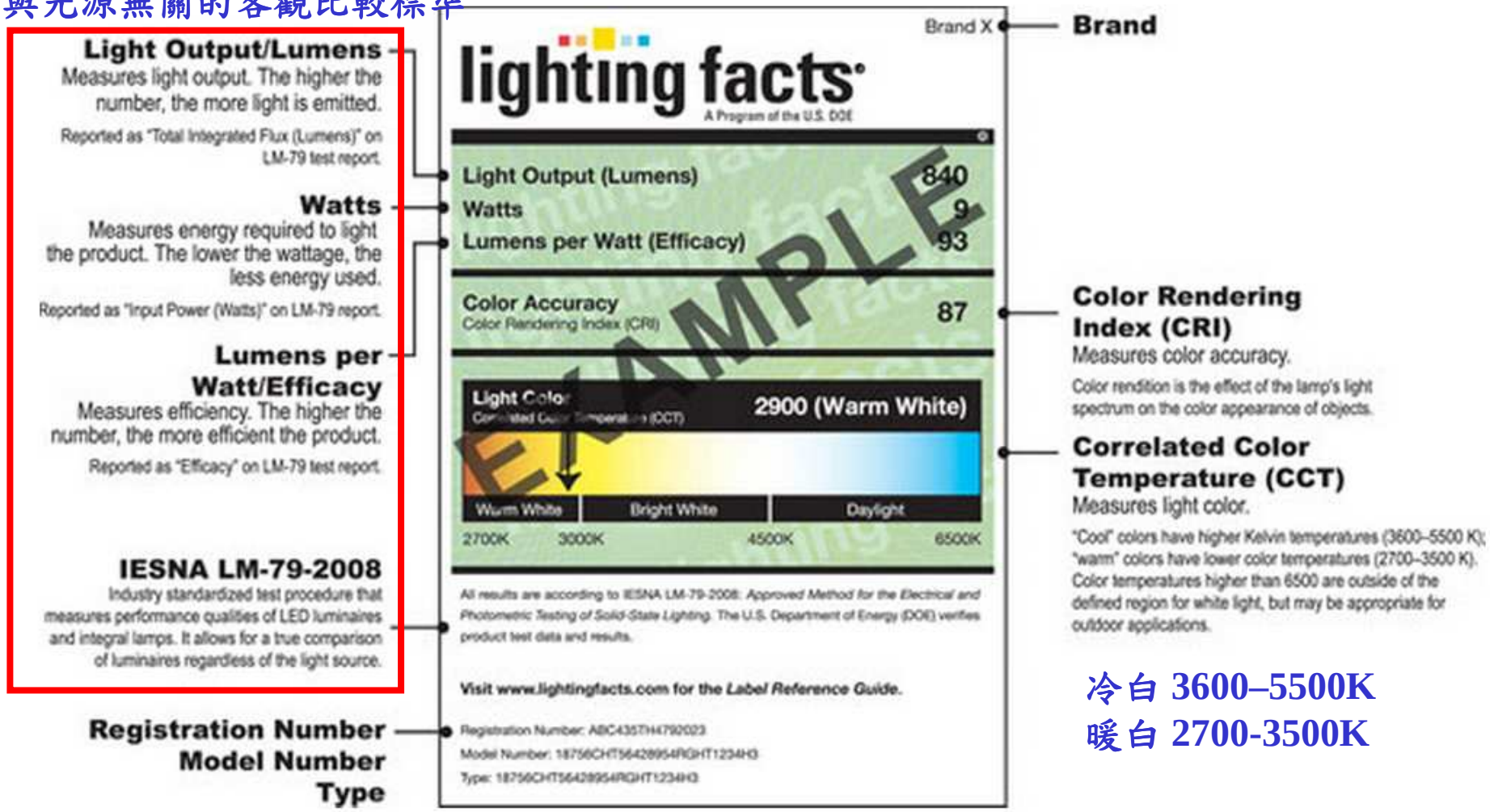
Anatomy of the Label

LM79:2008

與光源無關的客觀比較標準



冷白 3600–5500K

暖白 2700-3500K

http://www.lightingfacts.com/default.aspx?cp=content/label

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2011 Project Portfolio
Solid-State Lighting

- DOE與產業、大學、國家實驗室合作加速改進SSL技術
- 目標：節能、全光譜白光光源應用在一般照明
- DOE支持SSL研究6大項目
  - 量子效率
  - 壽命
  - 穩定性與控制
  - 封裝
  - 基礎結構
  - 降低成本

pc-LED Package and Luminaire Loss Channels and Efficiencies

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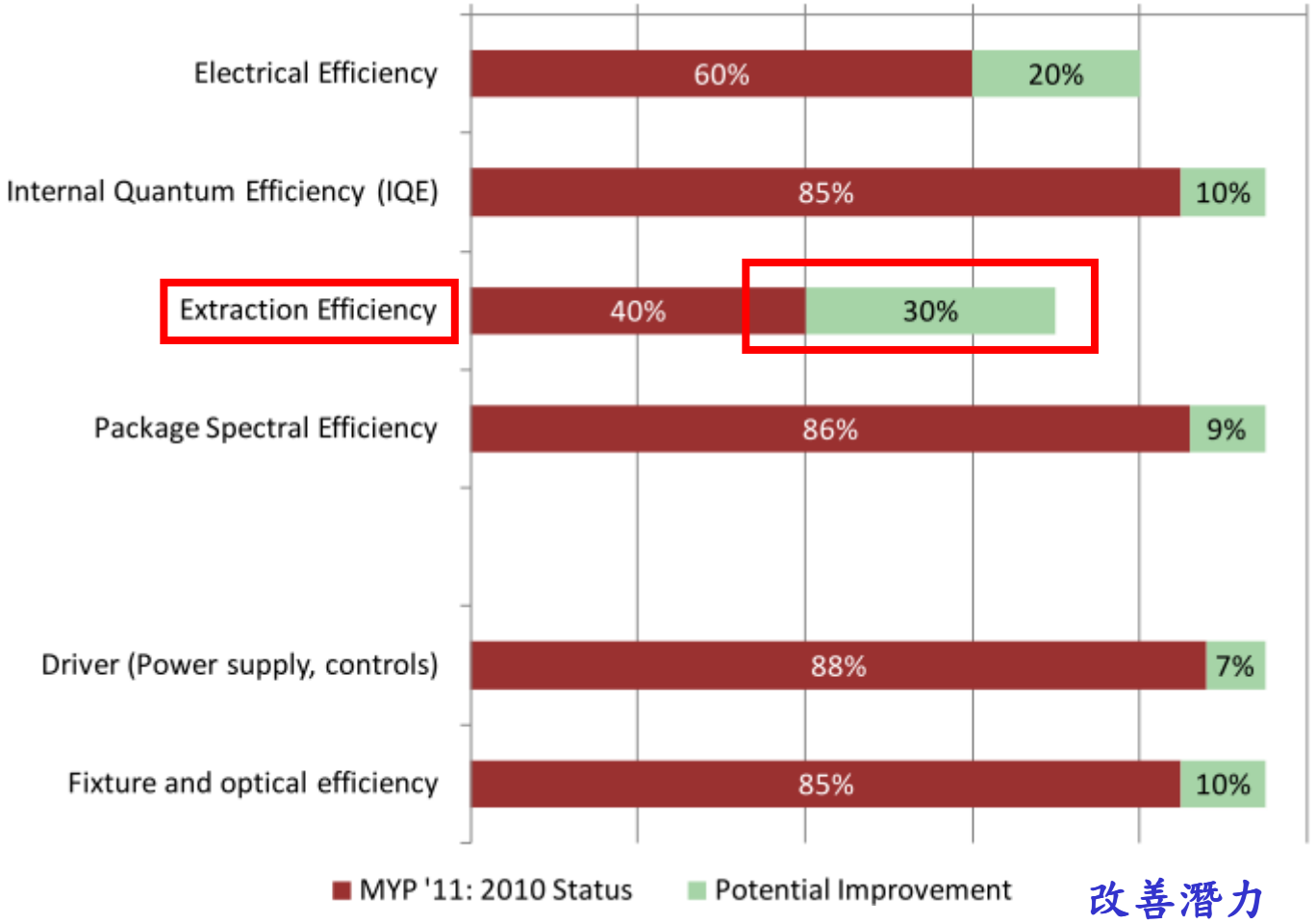
OLED Panel and Luminaire Loss Channels and Efficiencies



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Current SSL Project Portfolio

- Group 1: **Inorganic** SSL **Core Technology Research**
- Group 2: Inorganic SSL **Product Development**
- Group 3: Inorganic SSL **Manufacturing R&D**
- Group 4: **Organic** SSL Core Technology Research
- Group 5: Organic SSL Product Development
- Group 6: Organic SSL Manufacturing R&D

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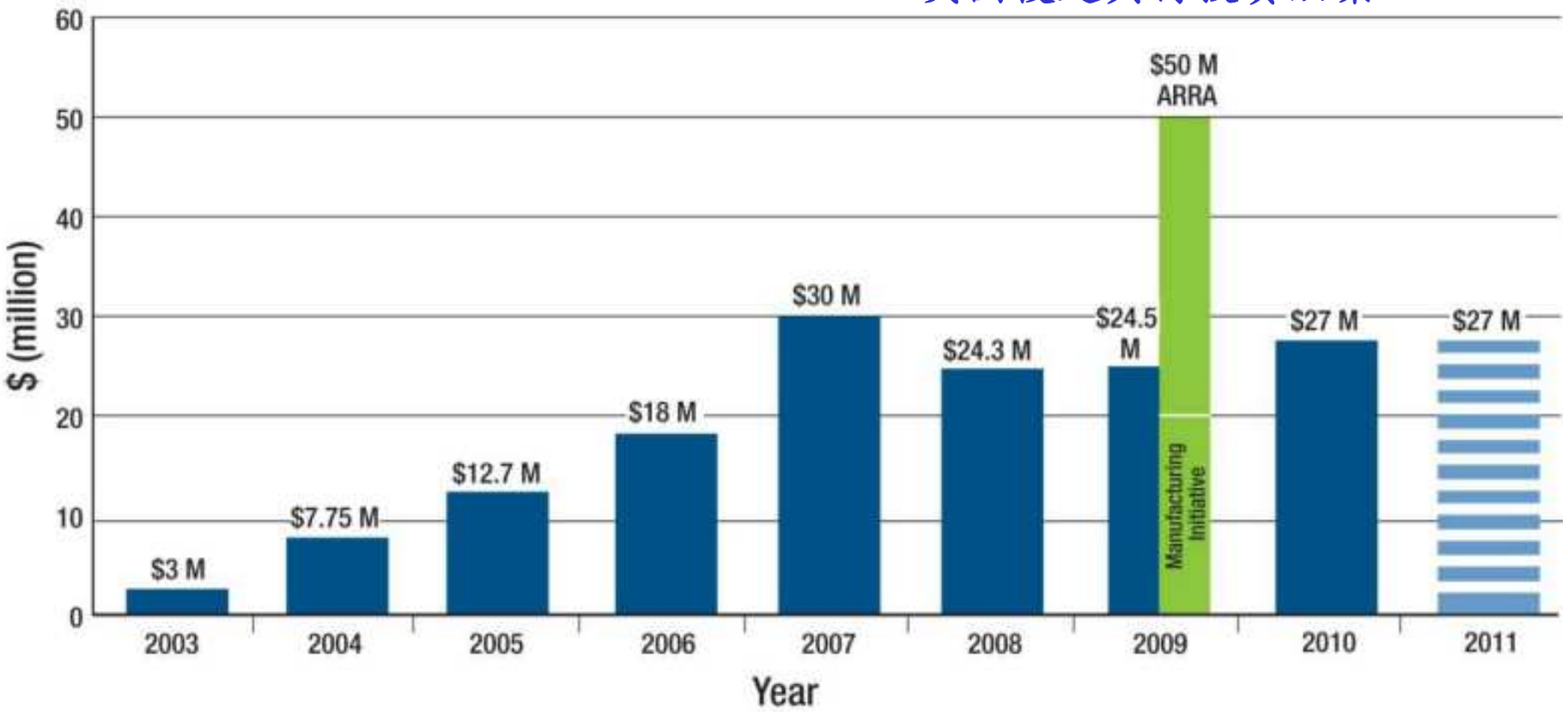
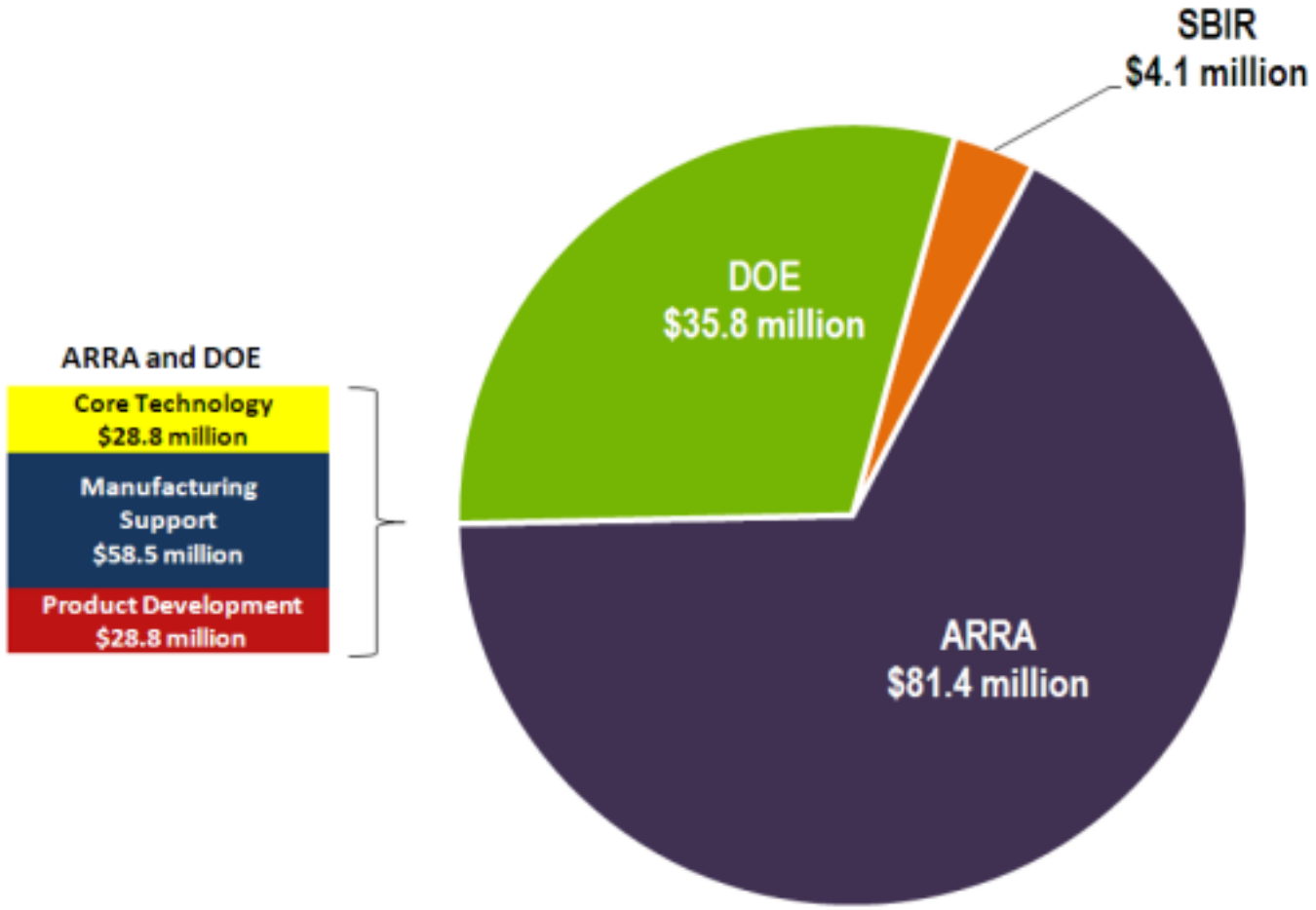
Congressional Appropriation for SSL Portfolio, 2003-2011

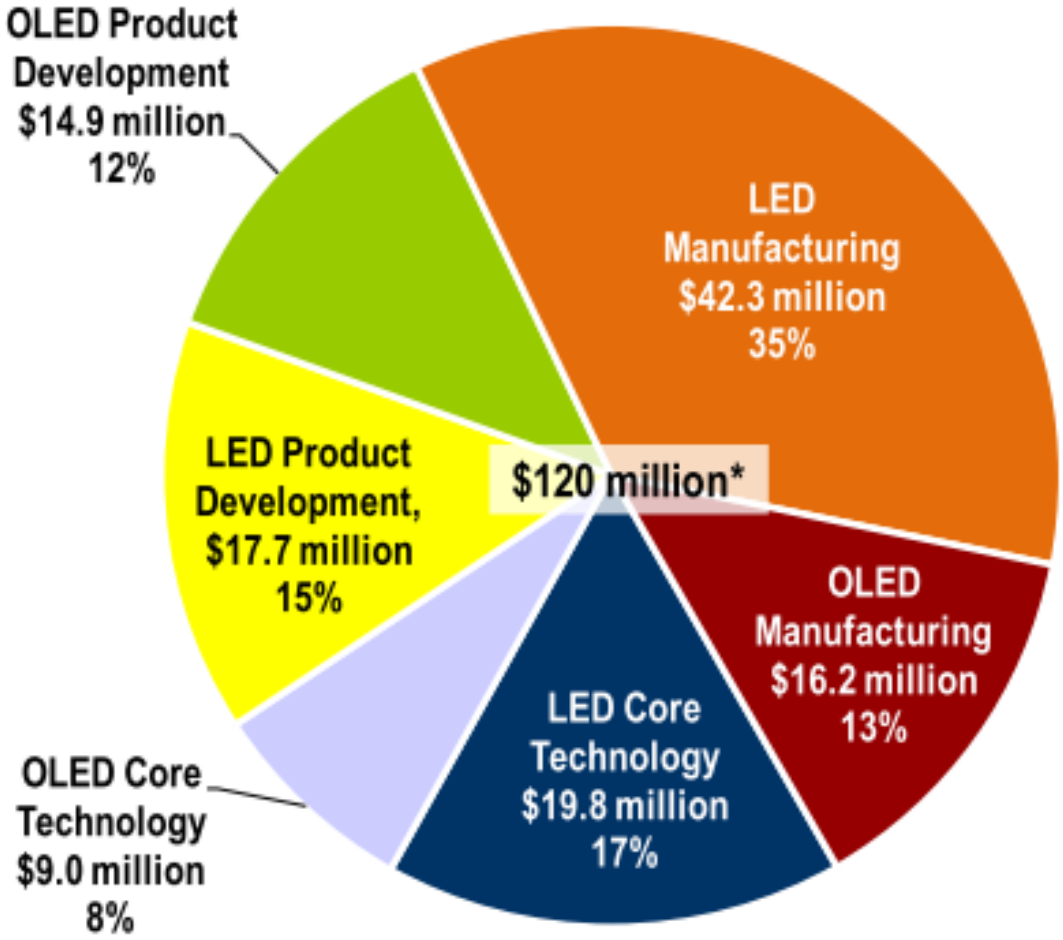
美國復甦與再投資法案



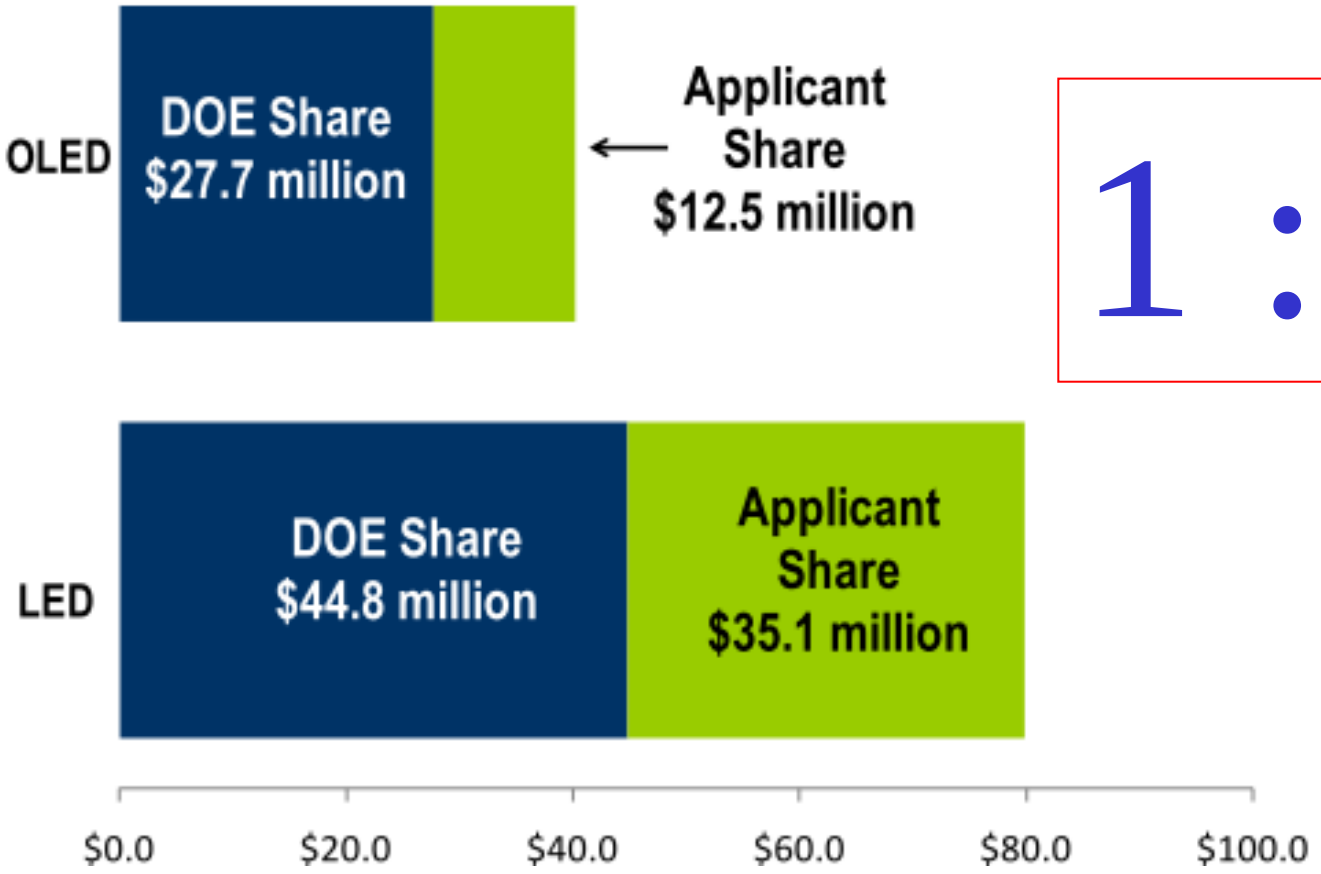
Cumulative SSL R&D Portfolio Funding Sources, March 2011



DOE SSL Total Portfolio Summary, March 2011



Funding of SSL R&D Project Portfolio by Funder, March 2011



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SSL R&D Portfolio: **Core Technology**, March 2011

	Number of Projects	$ Funding (Million)
Light-Emitting Diodes		
Emitter Materials Research	6	$11.4
Down-converters	3	$5.3
Novel Emitter Materials and Architectures	1	$1.1
Optical Component Materials	1	$2.0
Total LED	**11**	**$19.8**
Organic Light-Emitting Diodes		
Novel Device Architecture	1	$1.1
Novel Materials	4	$5.2
Material Degradation	1	$0.8
Electrode Research	1	$2.0
Total OLED	**7**	**$9.0**
TOTAL	**18**	**$28.8**

SSL R&D Portfolio: **Product Development**, March 2011

	Number of Projects	$ Funding (Million)
Light-Emitting Diodes		
Semiconductor Materials	1	$2.3
Phosphors	2	$4.7
Emitter Thermal Control	1	$0.1
Luminaire Thermal Management Techniques	3	$5.7
Electronic Components Research	3	$4.8
Off-Grid Lighting	1	$0.1
Total LED	**11**	**$17.7**
Organic Light-Emitting Diodes		
Practical Implementation of Materials and Device Architectures	2	$6.6
Substrate Materials	2	$2.2
Luminaire Mechanical Design	1	$2.4
Luminaire Thermal Management	1	$0.1
Large Area OLED	1	$2.0
OLED Light Extraction	3	$1.6
Total OLED	**10**	**$14.9**
TOTAL	**21**	**$32.6**

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Research Organization	Project Title
Sandia National Lab	Novel Defect Spectroscopy of InGaN Materials for Improved Green LEDs
Cree, Inc.	SSL Luminaire with Novel Driver Architecture
PhosphorTech	High Extraction Luminescent Materials for Solid State Lighting
Georgia Tech Research Corporation	Fundamental Studies of Higher Efficiency III-N LEDs for High-Efficiency High-Power Solid-State Lighting
Yale University	Multicolor, High Efficiency, Nanotextures LEDs
Osram	Highly Efficient Small Form Factor LED Retrofit Lamp
Philips	High Efficiency Driving Electronics for General Illumination LED Luminaires
Soraa	High Efficiency m-Plane LEDs on Low Defect Density Bulk GaN Substrates
Sandia National Lab	Semi-polar GaN Materials Technology for High IQE Green LEDs
Cree, Inc.	Ultra-Compact High-Efficiency Luminaire for General Illumination
GE	Optimized Phosphors for Warm White LED Light Engines
Lightscape Materials	Nitride- and Oxynitride-Based Phosphors for SSL
Osram	High-Flux Commercial Illumination Solution with Intelligent Controls
Lumileds	130 Lm/W, 1000 Lm Warm White LED for Illumination
Rensselaer Polytechnic Institute	High Efficacy Green LEDs by Polarization Controlled Metalorganic Vapor Phase Epitaxy
U.S. ARMY Research Laboratory	Exploiting Negative Polarization Charge at n-InGaN/p-GaN Heterointerfaces to Achieve High Power Green LEDs without Efficiency Droop
Eastman Kodak	High Efficiency Colloidal Quantum Dot Phosphors
UCSD	Phosphors for Near UV-Emitting LEDs for Efficacious Generation of White Light
White Optics	Low-Cost, Highly Lambertian Reflector Composite for Improved LED Fixture Efficiency and Lifetime
Sandia National Lab	Novel Defect Spectroscopy of InGaN Materials for Improved Green LEDs

SSL R&D Portfolio: Current OLED Research Projects, March 2011

Research Organization	Project Title
PNNL	Charge Balance in Blue Electrophosphorescent Devices
UDC	High Efficacy Integrated Under-Cabinet Phosphorescent OLED Lighting Systems
Dupont Displays, Inc.	Solution-Processed Small-Molecule OLED Luminaire for Interior Illumination
PPG	Low-Cost Integrated Substrate for OLED Lighting
PNNL	Development of Stable Materials for High-Efficiency Blue OLEDs through Rational Design.
University of Florida	Top-Emitting White OLEDs with Ultrahigh Light Extraction Efficiency
University of Florida	High Efficiency Organic Light Emitting Devices for Lighting
University of Rochester	Development and Utilization of Host Materials for White Phosphorescent OLEDs
Lawrence Berkley National Laboratory	Investigation of Long-Term OLED Device Stability via Transmission Electron Microscopy Imaging of Cross-Sectioned OLED Devices
Cambrios	Solution-Processable Transparent Conductive Hole Injection Electrode for Organic Light-Emitting Diode (OLED) SSL
GE	High Quantum Efficiency OLED Lighting Systems

LED BUILDING TECHNOLOGIES PROGRAM/NETL

- Core Technology III
  - Multicolor, High Efficiency, **Nanotextured LEDs**: Yale University
- Core Technology IV
  - Fundamental Studies of **Higher Efficiency** III-N LEDs for High-Efficiency High-Power Solid-State Lighting: Georgia Tech Research Corporation
  - High **Extraction Luminescent Materials** for Solid State Lighting: PhosphorTech Corporation
  - **Novel Defect Spectroscopy** of InGaN Materials for Improved Green LEDs: Sandia National Laboratories

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- Core Technology V
  - High Efficiency **Colloidal Quantum Dot Phosphors**- Eastman Kodak
  - High Efficacy Green LEDs by **Polarization Controlled** Metalorganic Vapor Phase Epitaxy- Rensselaer Polytechnic Institute
  - Development of High Efficiency **m-Plane** LEDs on Low Defect Density Bulk **GaN Substrates**- Soraa, Inc. 加州
  - **Phosphors for Near UV-Emitting LEDs** for Efficacious Generation of White Light- University of California, San Diego
- Core Technology VI
  - Lattice Mismatched **GaInP** Alloys for **Color Mixing** White Light LEDs- National Renewable Energy Laboratory (NREL)
  - **Semi-polar** GaN Materials Technology for High IQE Green LEDs- Sandia National Laboratories
  - Exploiting **Negative Polarization Charge** at n-InGaN/p-GaN Heterointerfaces to Achieve High Power Green LEDs Without **Efficiency Droop**- U.S. Army Research Laboratory
  - Low-Cost, Highly Lambertian **Reflector** Composite for Improved LED Fixture Efficiency and Lifetime- White Optics

- Product Development V
  - SSL Luminaire with **Novel Driver** Architecture- Cree, Inc.
  - **Highly Efficient Small Form-Factor** LED Retrofit Lamp- Osram Sylvania
  - High Efficiency **Driving Electronics** for General Illumination LED Luminaires- Philips Lighting
- Product Development VI
  - **Ultra-Compact** High Efficiency Luminaire for General Illumination- Cree, Inc.
  - **Optimized Phosphors** for Warm White LED Light Engines- GE Global Research
  - **Nitride and Oxynitride-Based Phosphor** for Solid-State Lighting- Lightscape Materials, Inc.
  - **130 Lumens per Watt 1000 Lumen** Warm White LED for Illumination- Philips Lumileds Lighting, LLC
  - High Flux Commercial Illumination Solution with **Intelligent Controls-** Osram Sylvania

- U.S. Manufacturing I
  - Advanced **Epi Tools** for Gallium Nitride Light Emitting Diode Devices- Applied Materials, Inc.
  - Development of Advanced Manufacturing Methods for **Warm-White** LEDs for General Lighting- GE Lighting Solutions LLC
  - Integrated Automated Yield Management and Defect Source **Analysis Inspection Tooling and Software** for LED- KLA-Tencor Corporation
  - **Low-Cost** Illumination-Grade LEDs- Philips Lumileds Lighting, LLC
  - **Low Cost Lithography** for High Brightness LED Manufacturing- Ultratech, Inc.
  - Driving Down HB-LED **Costs**: Implementation of **Process Simulation Tools and Temperature Control Methods** for High Yield **MOCVD**- Veeco Process Equipment, Inc.

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SMALL BUSINESS INNOVATION RESEARCH

- Phase I
  - **Dielectric** Printed Circuit Board- Advanced Cooling Technologies, Inc
  - Incorporated Smart and Efficient Driver for Big-Chip **Photonic Lattice** LEDs- Luminus Devices
  - **Off-Grid** Solid-State **Agricultural** Lighting- Orbital Technologies Corporation (Wisconsin)

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Off-Grid Solid-State **Agricultural** Lighting
Orbital Technologies Corporation

- 目前有**25%**的溫室觀賞植物與花卉使用**週期照光**栽培
  - 控制開花、改善品質
- 加速SSL滲透不需要電網供電的植物照明新利基市場
- 目標
  - 了解農業照明系統的變數、操作參數與限制
  - SSL取代效率低的白熾燈泡，節省電力成本、減少燈泡的更換
  - 結合太陽能面板與電池
  - 精確控制植物生長時間與品質、減少光污染

Roadmap for Addressing LED and Luminaire Manufacturing Issues

Note: Current activities are shown in darker grey while future activities are shown with a hatched pattern

Issue/Suggestion	Activity	2010	2011	2012	2013	2014	2015	2016
LED Manufacturing								
Standardization of LED package 'footprint'	Standards Development							
LED Performance reporting standard	Standards Development							
LED Epitaxial growth cost and consistency	DOE Manufacturing R&D							
LED Packaging	DOE Manufacturing R&D							
LED Wafer Level Processing	DOE Manufacturing R&D							
Reduced LED Cost related to current and thermal droop	DOE Product Development R&D							
Phosphor Manufacturing and Application	DOE Manufacturing R&D							
LED Drivers								
Driver Cost	DOE Manufacturing R&D							
Driver ease of integration	DOE Manufacturing R&D							
Driver performance reporting standard	Standards Development							
Test and Inspection								
Test/validation/inspection of components	DOE Manufacturing R&D							
Testing/Qualification of luminaires within Manufacturing Process	DOE Manufacturing R&D							
LED Manufacturing Process Test and Inspection	DOE Manufacturing R&D							
Luminaire Performance Standards								
Expedited compliance testing and certification (UL, Design Lights Consortium, Energy Star)	Standards Development Bodies							
Internationally reciprocated standards (UL, Design Lights Consortium, Energy Star)	Standards Development Bodies							
Harmonization of international standards	Standards Development Bodies							
Luminaire Manufacturing								
Luminaire/Module Manufacturing	DOE Manufacturing R&D							
Color Perception/Consistency/Tolerances by lighting application	External R&D and Standards Development							
Education in Luminaire Design and LED technology	DOE Commercialization Effort							
Luminaire Reliability								
Uncertainty in luminaire reliability	DOE Product Development R&D							
Uncertainty in driver/power supply reliability	DOE Product Development R&D							

Future Activities
Existing Activities

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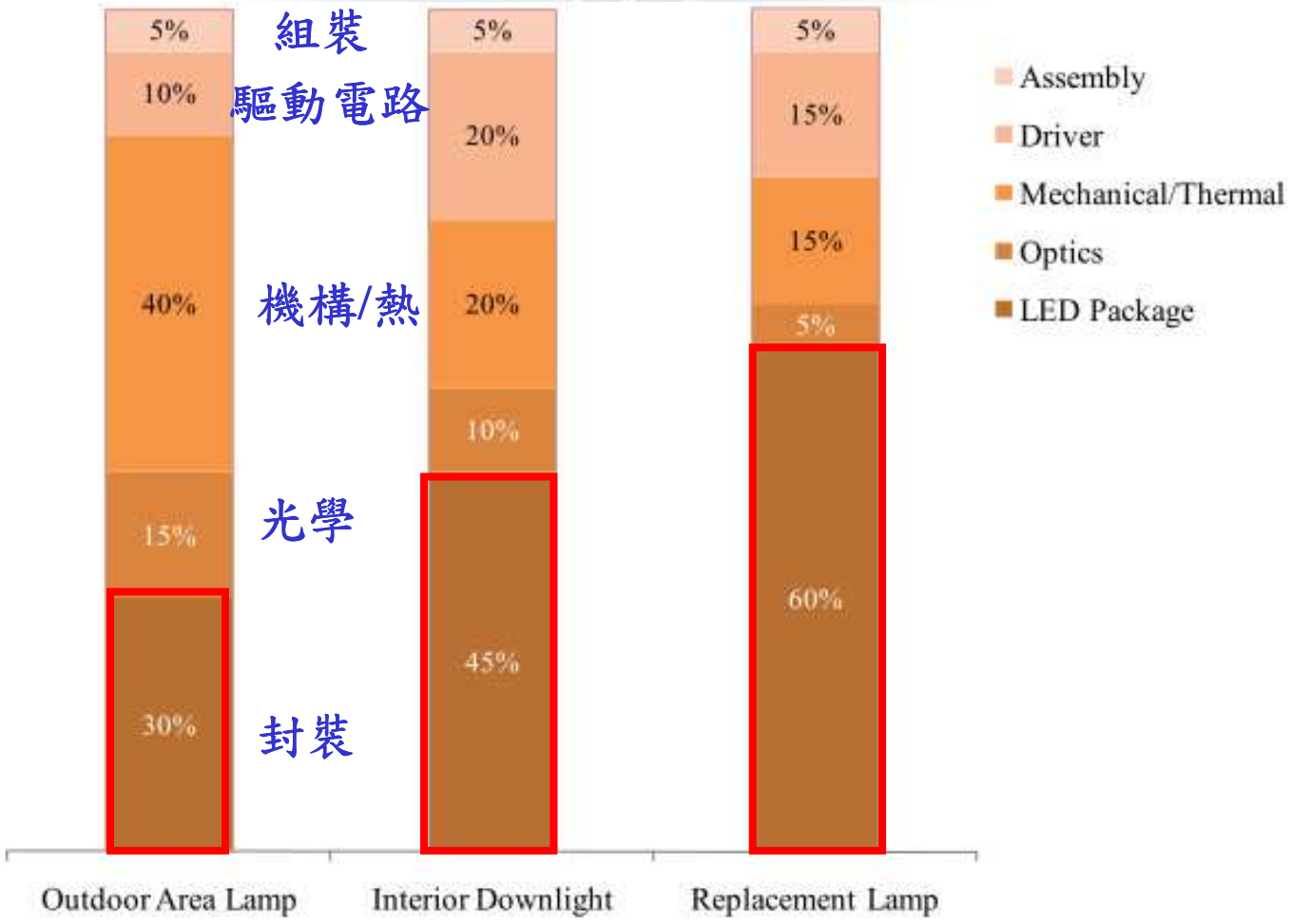
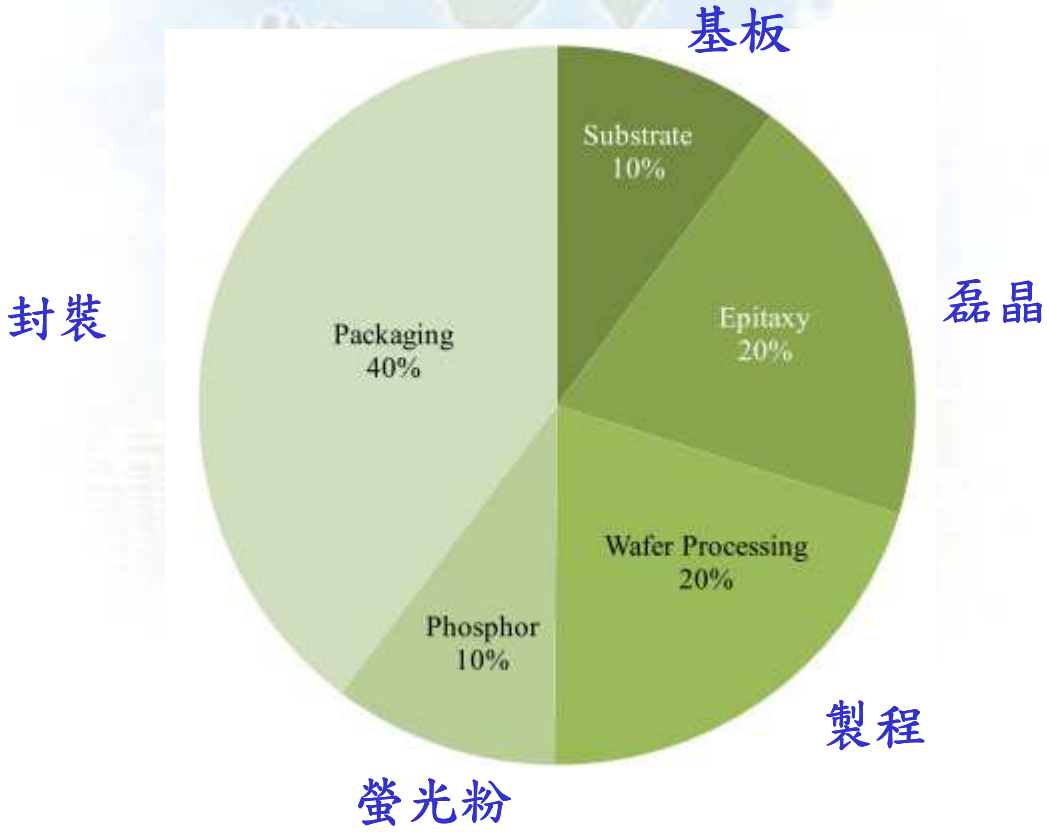
Approximate Cost Breakdowns for LED-based Luminaires in 2011



Source: Provided by the 2011 Manufacturing Workshop and Roundtable Attendees

Typical Cost Breakdown for an LED Package in **2010**

(100 mm sapphire substrate; **1 mm^2 die**; phosphor converted; high power package)



Source: Provided by the 2011 Manufacturing Workshop and Roundtable Attendees die; phosphor converted; high power package)

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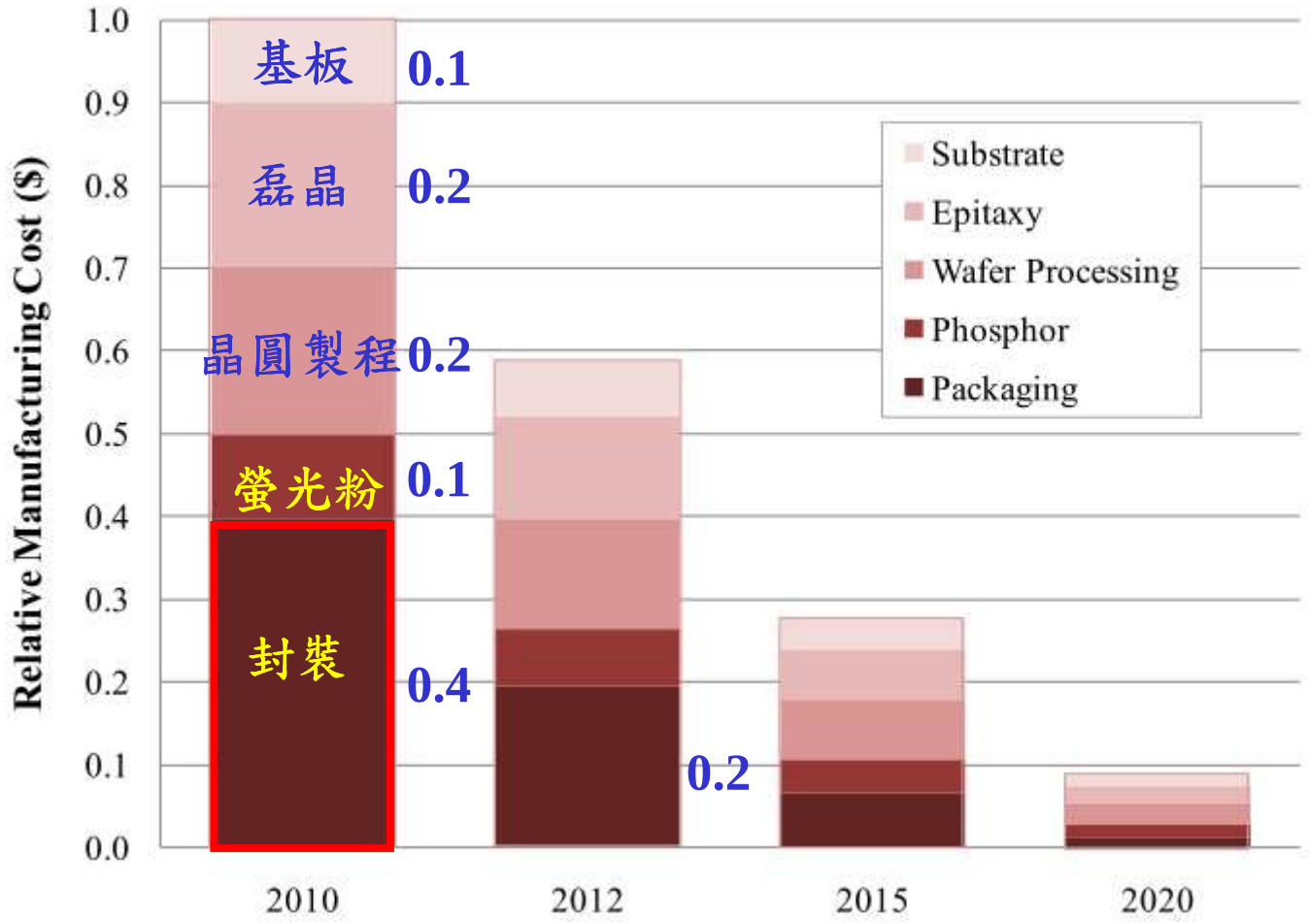
Projected LED Package Cost Track



Source: Provided by the 2011 Manufacturing Workshop and Roundtable Attendees

LED Metrics Roadmap

暖白

冷白

Metric	Unit	2010	2012	2015	2020
LED Efficacy (warm white)	lm/W	96	141	202	253
LED Price (warm white)	$/klm	18	7.5	2.2	1
LED Efficacy (cool white)	lm/W	134	176	224	258
LED Price (cool white)	$/klm	13	6	2	1
OEM Lamp Price	$/klm	50	23	10	5

Note:

1. Projections for cool white packages assume CCT=4746-7040K and CRI=70-80, while projections for warm white packages assume CCT=2580-3710K and CRI=80-90.
2. All efficacy projections assume measurements at 25°C with a drive current density of 35 A/cm^2.

Source: DOE 2011 MYPP

Comparison of different LED package designs from **Philips Lumileds**

Note: Prices are for **1000-off quantities** from Future Electronics.

Product	Luxeon c	Luxeon Rebel ES	Luxeon S
Die area (mm^2)	1.0	2.0	9x2.0
Package footprint (mm^2)	2.0x1.6	3.0x4.5	13.0x14.0
CCT (K)	5700-6500	5650	3000
Price ($)	0.99	1.95	15.50
Lumens (@35 A/cm^2)	85	235	1,300
Price ($/klm)	12	8	12

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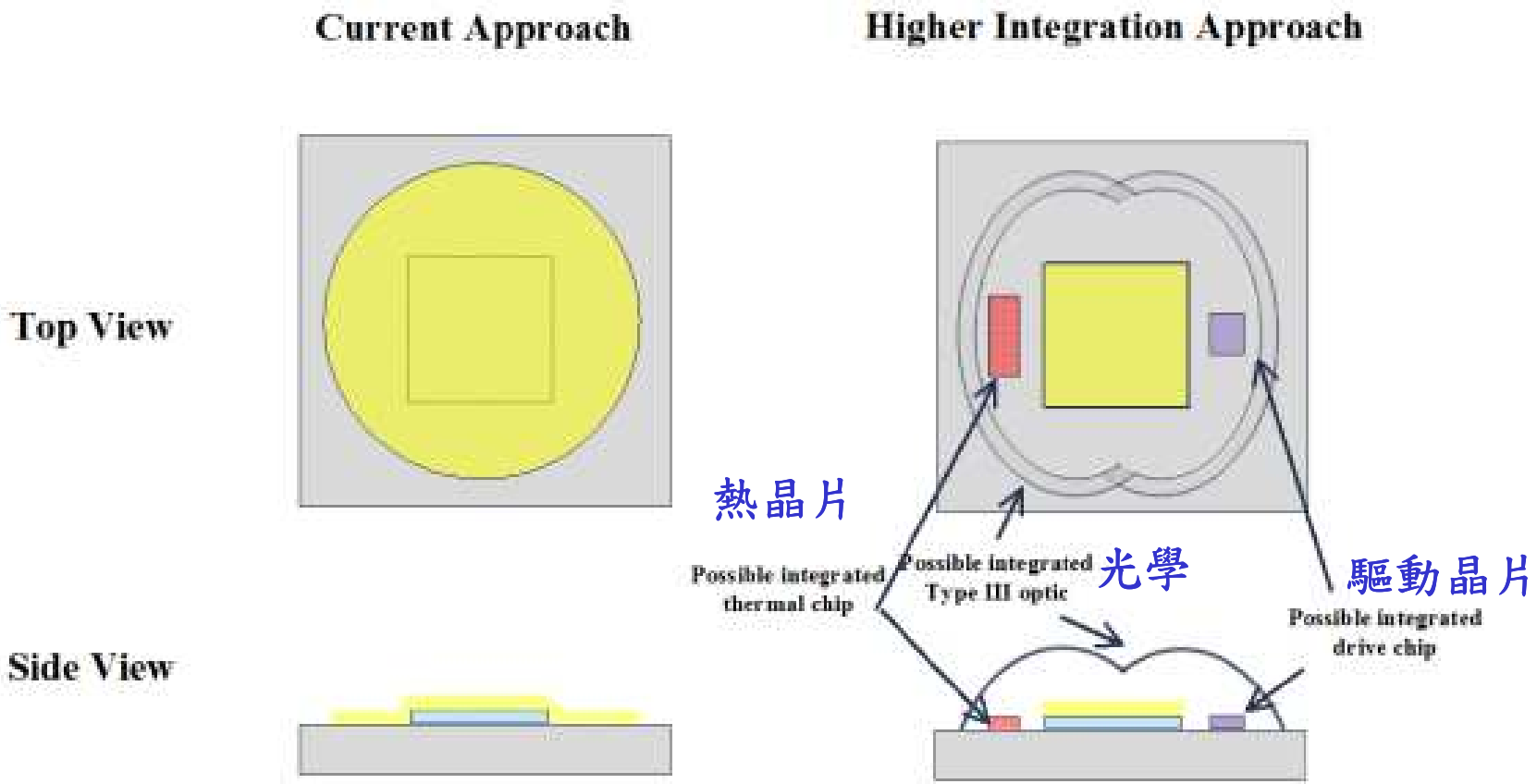
Schematic Representation of Possible **Hybrid Integration** Approach to Simplify SSL Luminaire Manufacturing and Reduce Costs



Source: Mark McClear, Cree, Inc., “An Integrated Approach to SSL Manufacturing”, Vancouver, OR, June 2009

Epitaxy Roadmap

Category	Task	2010	2011	2012	2013	2014	2015
MOCVD Epitaxy							
	Modeling: Apply Computational Fluid Dynamics (CFD) models to uniformity improvement and source efficiency optimization						
	Process control: Implement active control using in-situ measurements						
	Automation: Cassette-to-cassette						
	Reduce cost of ownership by factor of 2 every 5 years						
HVPE Epitaxy							
	Develop multi-wafer equipment						
	Automation: cassette to cassette						
	Reduce cost of ownership by factor of 2 every 5 years						

Source: Provided by the 2011 Manufacturing Workshop Attendees

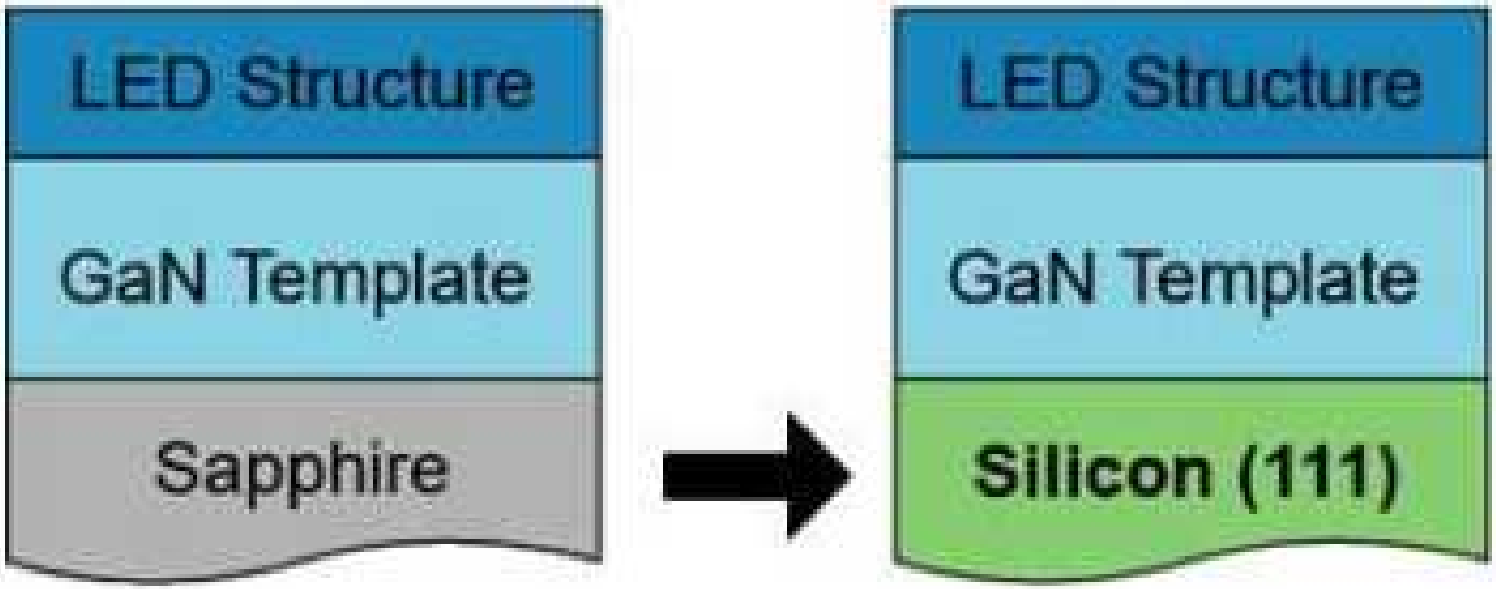
Epitaxy Metrics

Metric	Unit	2010	2012	2015	2020
Wafer Uniformity (standard deviation of wavelength for each wafer)	nm	1.5	1.0	0.5	0.5
Wafer-to-wafer Reproducibility (maximum spread of mean wavelength for all wafers in a run)	nm	1.1	0.9	0.6	0.5
Run-to-run Reproducibility (maximum variation from run-to-run of the mean wavelength for all wafers in a run)	nm	1.5	1.1	0.9	0.75
Cost of Ownership	-	Factor of 2 reduction every 5 years			
Epitaxy Cost	$\$/\mu m \cdot cm^2$	0.45	0.28	0.14	0.05

Source: Provided by the 2011 Manufacturing Workshop Attendees

Philips Lumileds

- 6”Si基板取代藍寶石，降低磊晶成本60%



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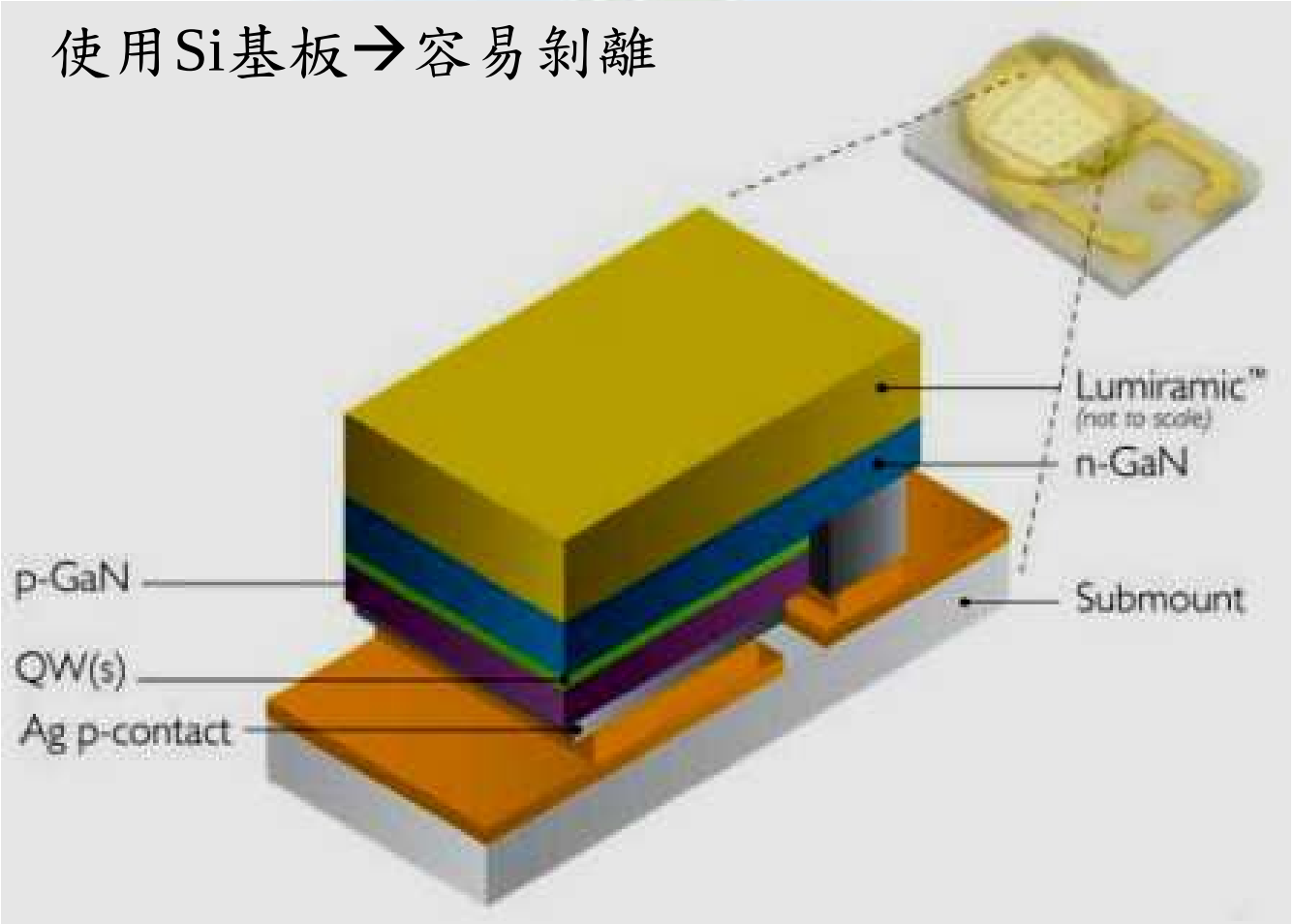
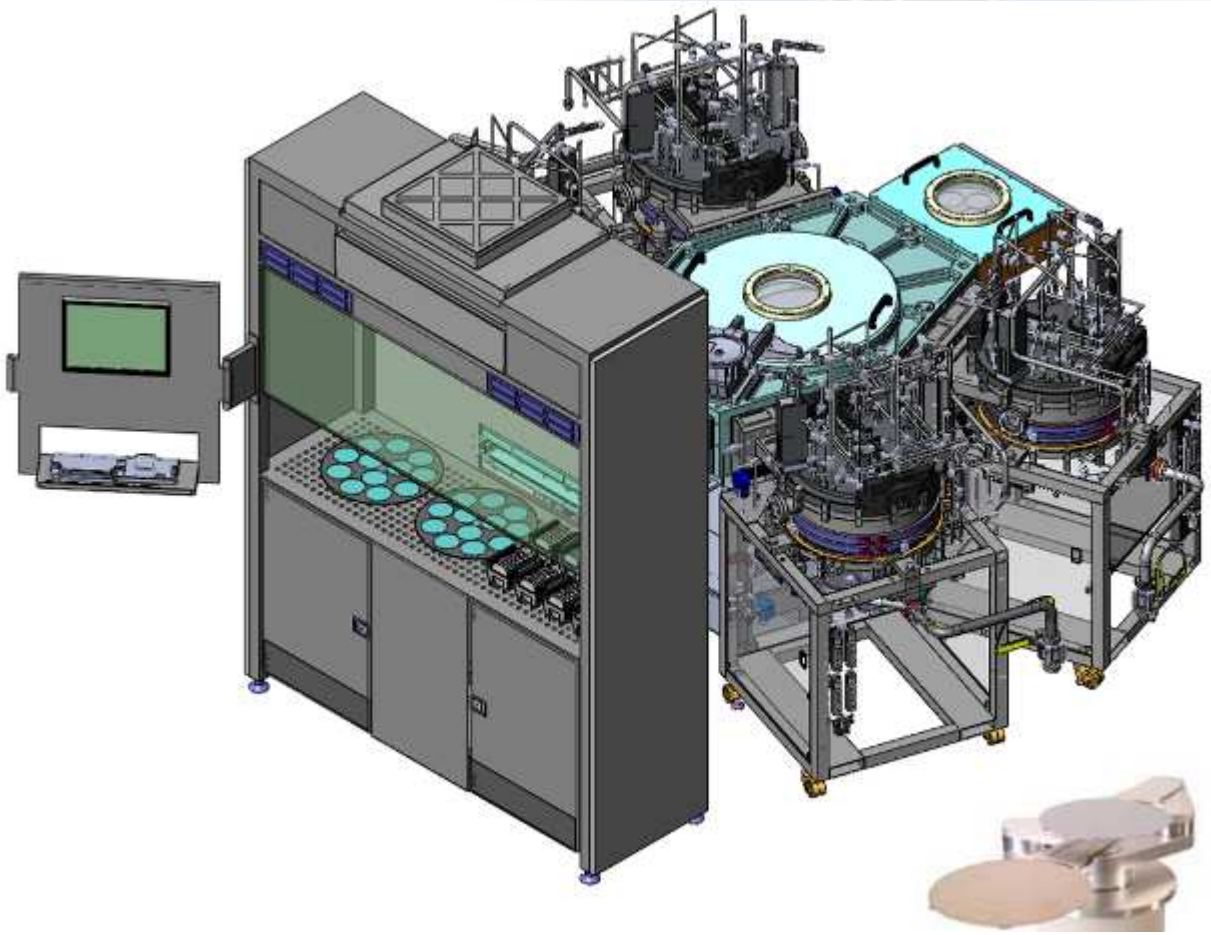
Philips Lumileds



Veeco發表用於生產HB LED的 MaxBright™ GaN MOCVD

- 利用Veeco的FlowFlange ®集群架構自動化技術
  - 模組化的兩個或四個反應器組合
  - 生產能力達216×2，56×4，24×6或12×8晶圓
  - 無縫轉移K465i配方
  - 可單腔或多腔層生長
- 節省空間達2.5倍
  - 相較於K465i提供了500%的產能

MaxBright™ GaN MOCVD



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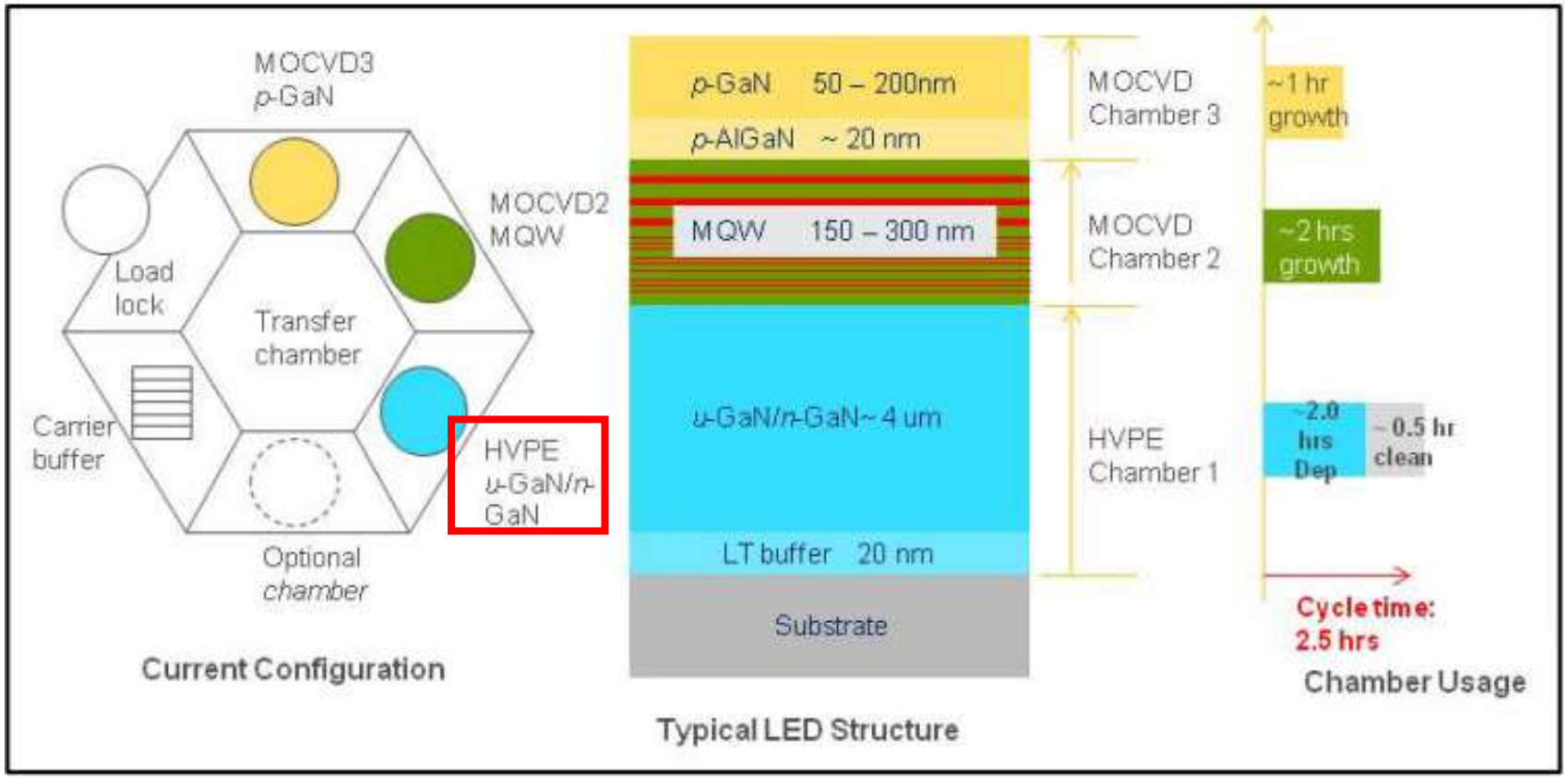
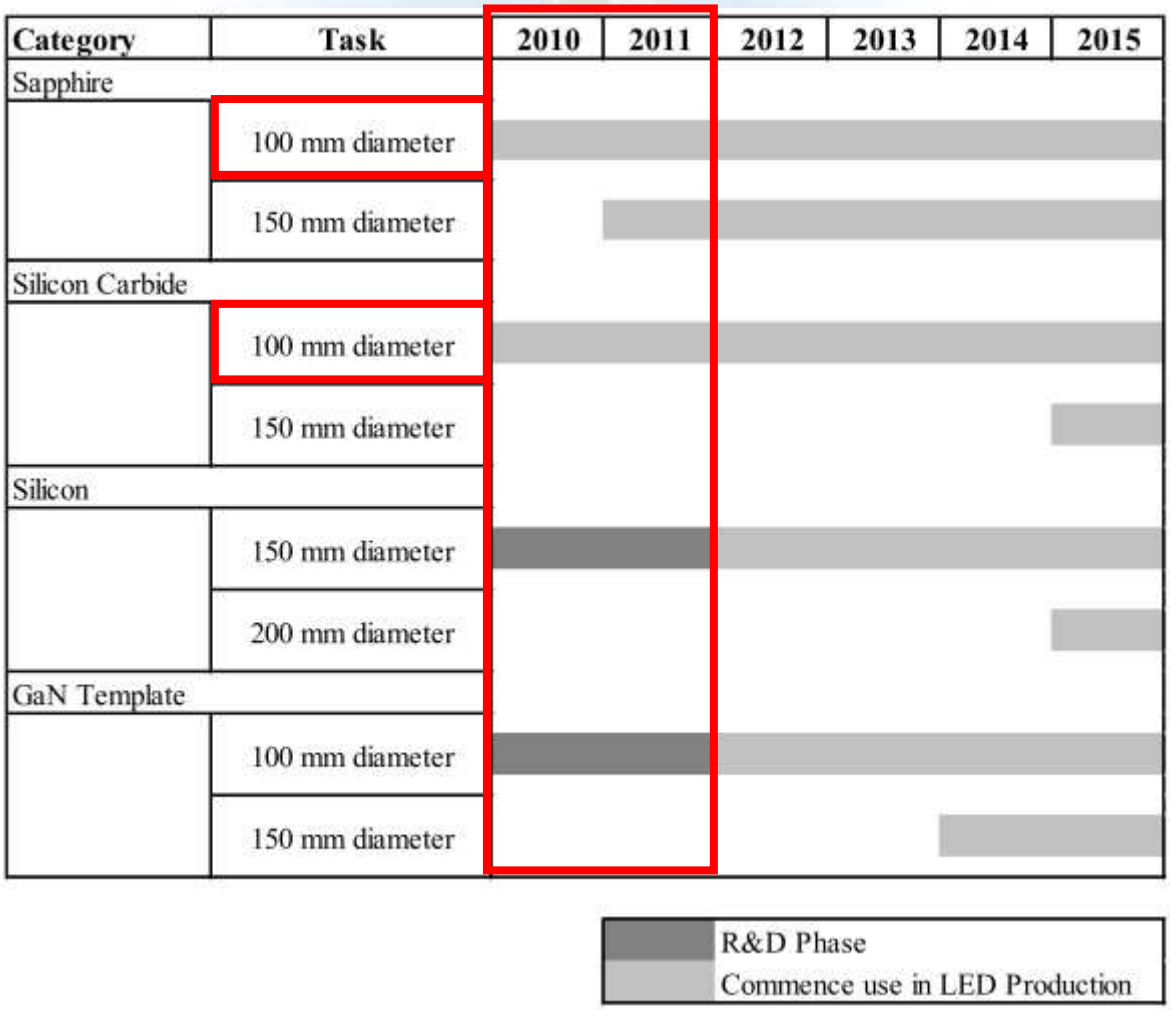
Applied Material

- LED結構的三個主要磊晶層，使用不同的MOCVD反應腔
- 沒有人干擾的多次連續成長



Substrate Roadmap



Source: Based on recommendations from the 2011 Manufacturing Workshop Attendees

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Luminaire/Module Manufacturing

- 發展
  - 先進LED封裝與晶粒整合(COB, COF)
  - 更有效利用地利用原料
  - 簡化散熱設計
  - 減輕重量
  - 生產效率最佳化(容易組裝)
  - 增加機械、電力與光學功能的整合
  - 減少製造成本
- 需要展示高品質產品
  - 改善了色彩一致性
  - 較低的系統成本與改善
  - 透過成功整合系統設計縮短上市所需時間
  - 供應鏈管理
  - 品質控制

Luminaire/Module Manufacturing

Metric(s)	Current Status	2015 Target(s)
Downtime		50% reduction
Manufacturing Throughput		x2 increase
OEM Lamp Price	$50/klm	$10/klm
Assembly Cost ($)		50% reduction every 2-3 years
Color Control (SDCM)	7	4

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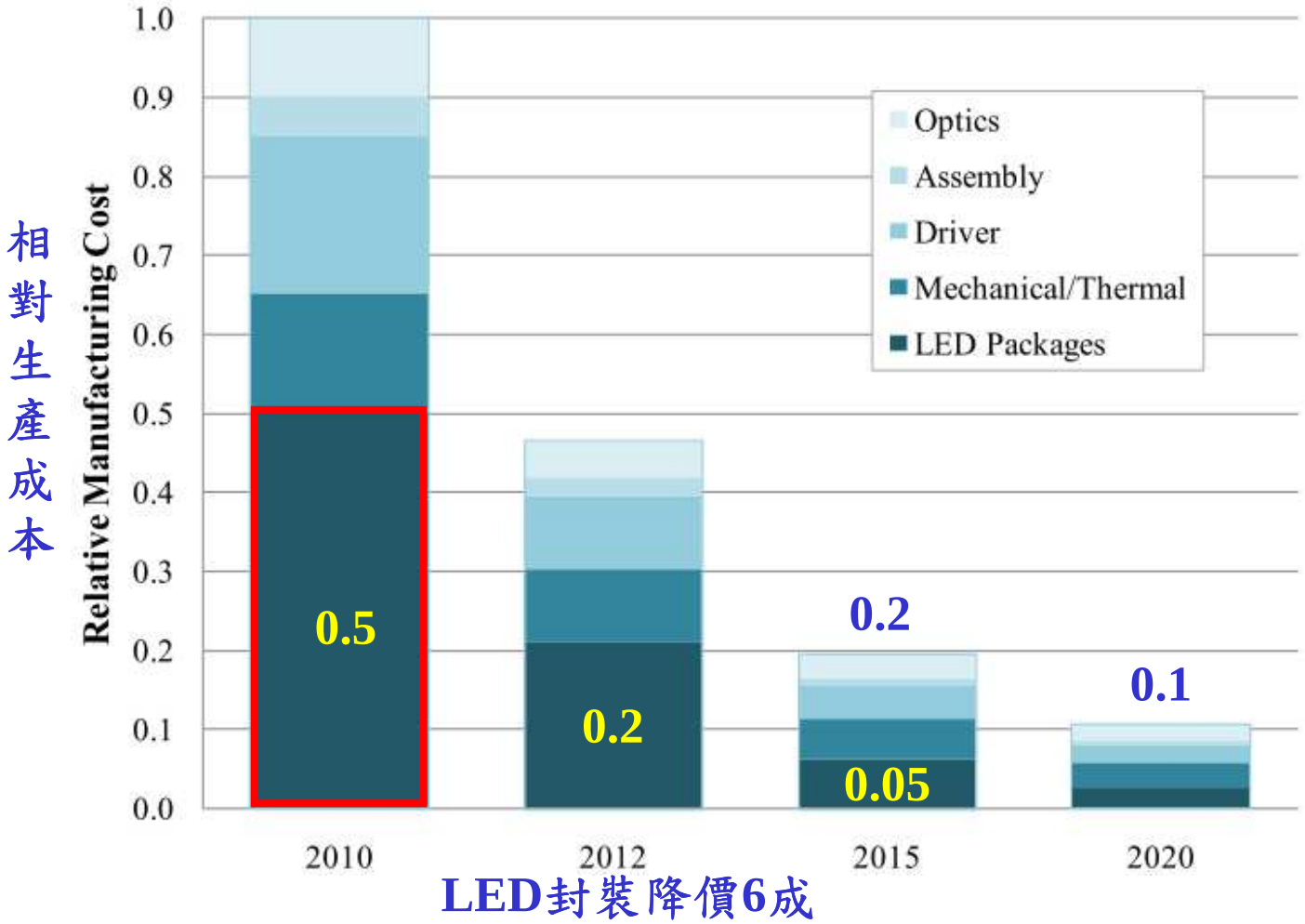
Test and Inspection Equipment

- 補助發展高速、高解析、非破壞測試設備
  - 具有標準化測試程序，在半導體晶圓、磊晶層、LED晶粒、封裝、模組、燈具與光學組件均有適當特性指標
  - 進料檢驗設備、即時製程監測、線上製程控制、終端產品測試與分類
  - 發展、展示有效整合測試與監視設備，應用在量產設備或製程線，以進行檢測與改善良率

Metric(s)	Current Status	2015 Target(s)
Throughput (single bin units per hour)		x2 increase
Cost of Ownership		2-3x reduction every 5 years
$/Units per hour		

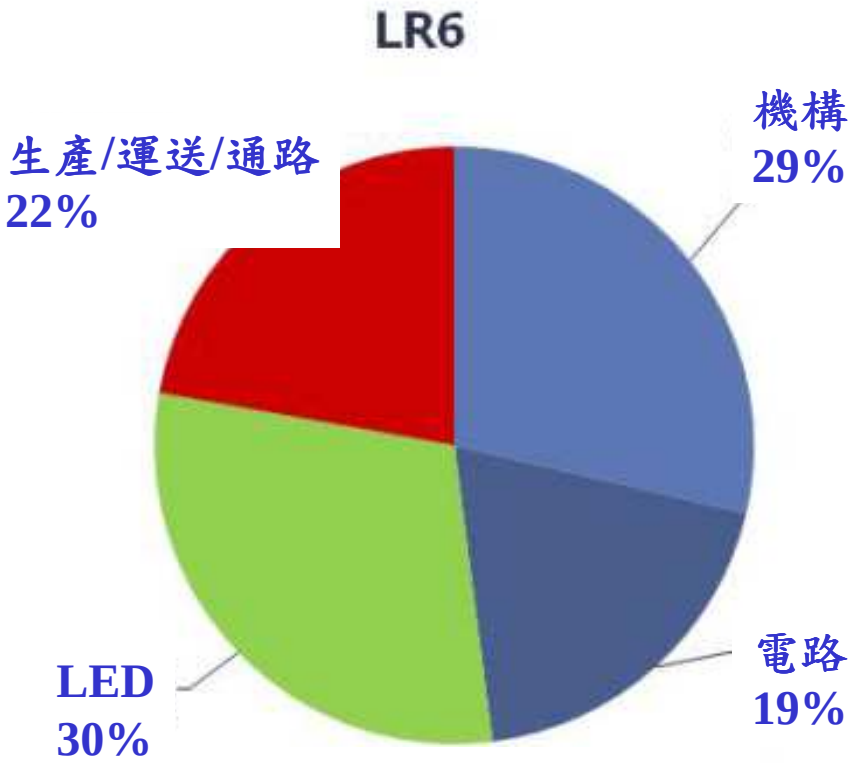
Projected LED-based Cost Track (Downlight Luminaire)

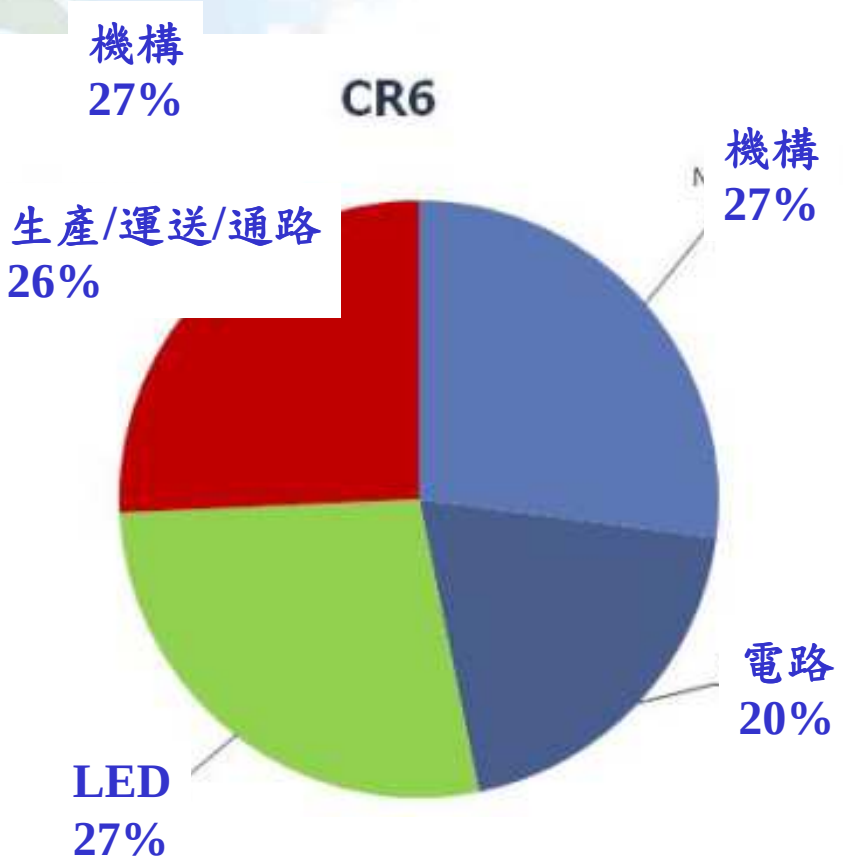


Source: Data provided by the 2011 Manufacturing Roundtable Attendees

Cree Downlight

- 從第一代LR6到第二代CR6變化不大，但成本減少30%





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標準

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Current SSL Standards and White Papers

- IEC- International Electrotechnical Commission
- IES- Illuminating Engineering Society北美
- CIE- International Commission on Illumination
- CE- EUROCERT 歐證
- ANSI- American National Standards Institute
- UL- Underwriter Laboratories Inc.
- CSR- Corporate social responsibility
- NEMA- **National** Electrical Manufacturers Association
- NLST- National Institute of Standards and Technology
- Zhaga-

Current SSL Standards and White Papers

- IES LM-79-2008
  - Approved Method for the **Electrical and Photometric Testing** of Solid-State Lighting Devices, enables the calculation of LED **luminaire efficacy**
    - Luminaire efficacy is **the most reliable way** to measure LED product performance, measuring luminaire performance as a whole instead of relying on traditional methods that separate lamp ratings and fixture efficiency.
  - LM-79 helps establish a foundation for accurate comparisons of luminaire performance, not only for solid-state lighting, but for **all sources**.

- 這些標準將讓照明製造業者、設計師與專家容易地去選擇適合應用的最佳產品
- 產業界專家持續努力標準發展，衍生日益增多的資訊，協助SSL創新、市場接受與成長

LM-80

- IES LM-80-2008
  - 因為封裝後LED的壽命長，實際損壞需要花很多時間，所以失效模式的檢測很重要
  - LM-80建立標準的測試LED lumen depreciation的方法
  - LED光輸出衰減到某特定值，並不適合拿來詮釋燈具的壽命
  - 當其他失效模式也存在時，壽命會縮短

Cree

United States Department of Commerce
National Institute of Standards and Technology

NVLAP®

Certificate of Accreditation to ISO/IEC 17025:2005

NVLAP LAB CODE: 500041-0

Cree SSL Laboratory
Durham, NC

is accredited by the National Voluntary Laboratory Accreditation Program for specific services, listed on the Scope of Accreditation, for:

ENERGY EFFICIENT LIGHTING PRODUCTS

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communique dated January 2009).

2011-02-07 through 2011-12-31
Effective dates

Sally S. Bruce
For the National Institute of Standards and Technology

NVLAP-01C (REV. 2009-01-26)

X-Lamp MC-E White LED –Cree LM-80 Results

Data Set	Case Temp. [T_s]	Ambient Temp. [T_A]	Drive Current [I_F]	Average Lumen Maintenance at 6,000 hours	Average Chromaticity Shift (Δu'v') at 6,000 hours
1	45°C	45°C	350 mA	98.1%	0.0009
2	45°C	45°C	700 mA	99.0%	0.0015
3	55°C	55°C	350 mA	98.4%	0.0010
4	55°C	55°C	700 mA	95.8%	0.0027
5	85°C	85°C	350 mA	98.2%	0.0014
6	85°C	85°C	700 mA	92.8%	0.0070

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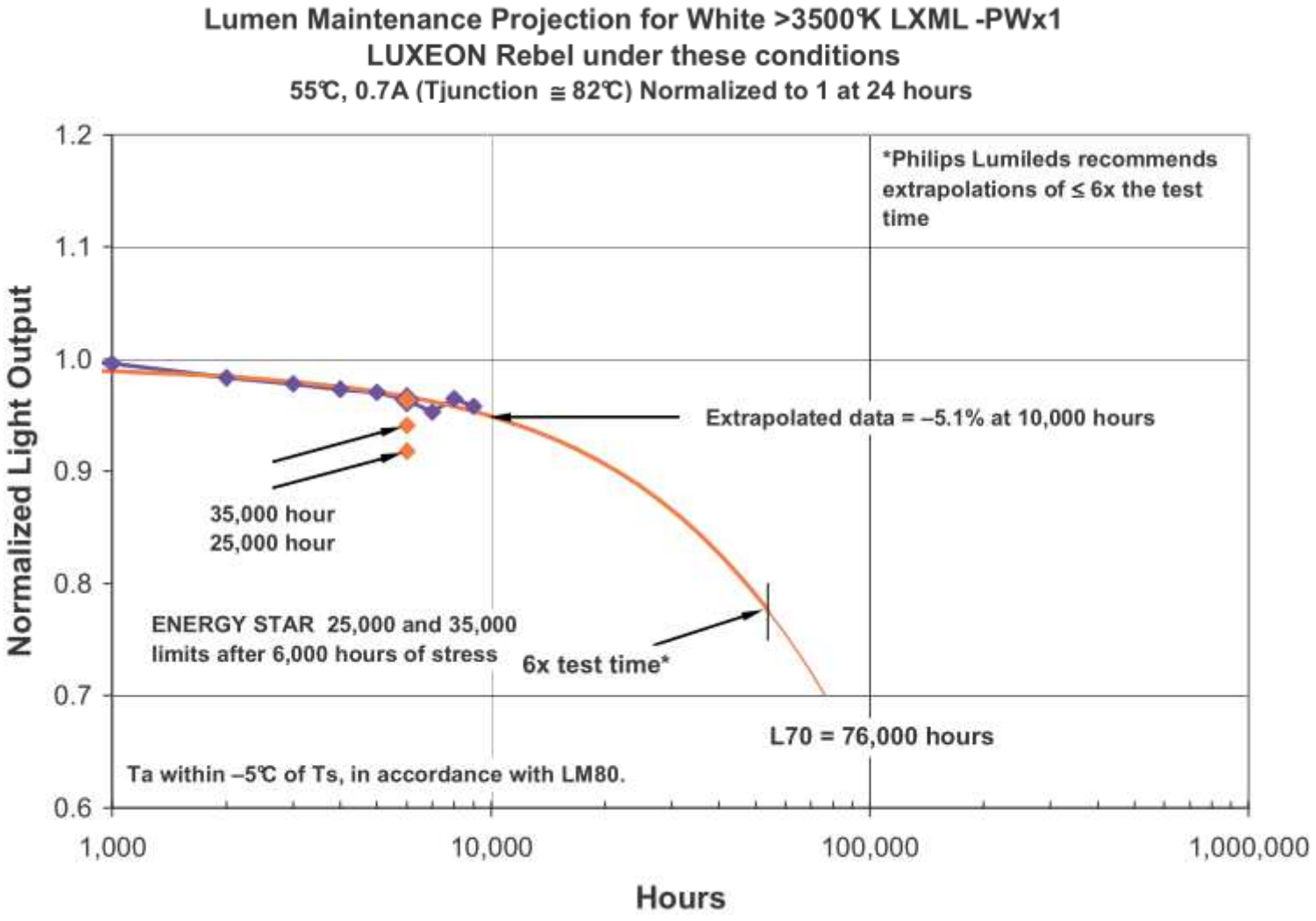
Sample LM-80 Test Report Lumen Maintenance Extrapolation



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製造RD課題

DOE SSL Manufacturing R&D Tasks

- The complete list of SSL Manufacturing R&D Tasks **developed in 2010 and refined in 2011**
  - 2011優先研發課題標示星號
  - 一些未標示星號的項目更新自2010年版

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LED Tasks

***M.L1.**	**Luminaire/Module Manufacturing** Support for the development of flexible manufacturing of state of the art LED modules, light engines, and luminaires.
M.L2.	**Driver Manufacturing** Improved design for manufacture for flexibility, reduced parts count and cost, while maintaining performance
***M.L3.**	**Test and Inspection Equipment** Support for the development of high-speed, high-resolution, non-destructive test equipment with standardized test procedures and appropriate metrics
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** Improve back-end processes and tools to optimize quality and consistency and to lower cost
M.L7.	**Phosphor Manufacturing and Application** This task supports the development of improved manufacturing and improved application of phosphors (including alternative down converters) used in solid state lighting.

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OLED Tasks

***M.O1.**	**OLED Deposition Equipment:** Support for the development of manufacturing equipment enabling high speed, low cost, and uniform deposition of state of the art OLED structures and layers.
M.O2.	**Manufacturing Processes and Yield Improvement:** Develop manufacturing processes to improve quality and yield and reduce the cost of OLED products.
***M.O3.**	**OLED Materials Manufacturing:** Support for the development of advanced manufacturing of low cost integrated substrates and encapsulation materials.
M.O4.	**Back-end Panel Fabrication:** Tools and processes for the manufacturing of OLED panels from OLED sheet material.

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Thanks for your attention.