HB-LEDs and Solid State Lighting:
Challenges and Opportunities

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Executive Vice President
SEMI

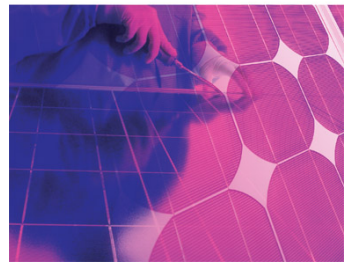
Agenda

- About SEMI
- LEDs and Solid State Lighting
  - Why the excitement?
- Current Market Outlook for LEDs and SSL
- Focus 2020
  - Manufacturing Cost Reduction
  - The Role of Manufacturing Standards in Long-Term Cost Reduction
- Focus 2020
  - Accelerating Consumer Acceptance

About SEMI

- Global industry association
- ~2000 members
- Established in 1970 to serve the semiconductor supply chain
- Today serves members interests in the following industries:
  - Semiconductor
  - Flat Panel Display
  - Photovoltaic/Tech-Energy
  - LEDS
  - MEMS

Bangalore
Berlin
Brussels
Grenoble
Moscow
Shanghai
Seoul
San Jose
Singapore
Taipei
Washington DC



Current SEMI LED Activities

- Major Events:
  - **6th Annual LED Korea**, co-located with SEMICON Korea (Feb. 7-9, 2012)
  - **China HB LED Manufacturing Forum and Pavilion**, SEMICON China (March 20-22)
  - LED/SSL Market Forum, SEMICON Russia, Moscow, (May 15-16, 2012)
  - LED Manufacturing Forum, SEMICON West (July 11, 2002)
  - LED Pavilion and Manufacturing Forum, SEMICON Taiwan (Sept 5-7, 2012)
  - Japan New Technologies Pavilion, LED Symposium, SEMICON Japan (Dec 5-7, 2012)
  - SSL Summit, India (Sept 3-5, 2012)
- Industry Research-Opto/LED Fab Watch and Forecast
- Manufacturing Standards development
- Public Policy

LED Manufacturing Seminar, Taiwan, 2011

LED Manufacturing Forum, SEMICON China

LED Day, SEMICON West, 2010

LED Korea, 2011

Standards Workshop, China SSL, Nov. 2011

LED Forum, Taiwan,

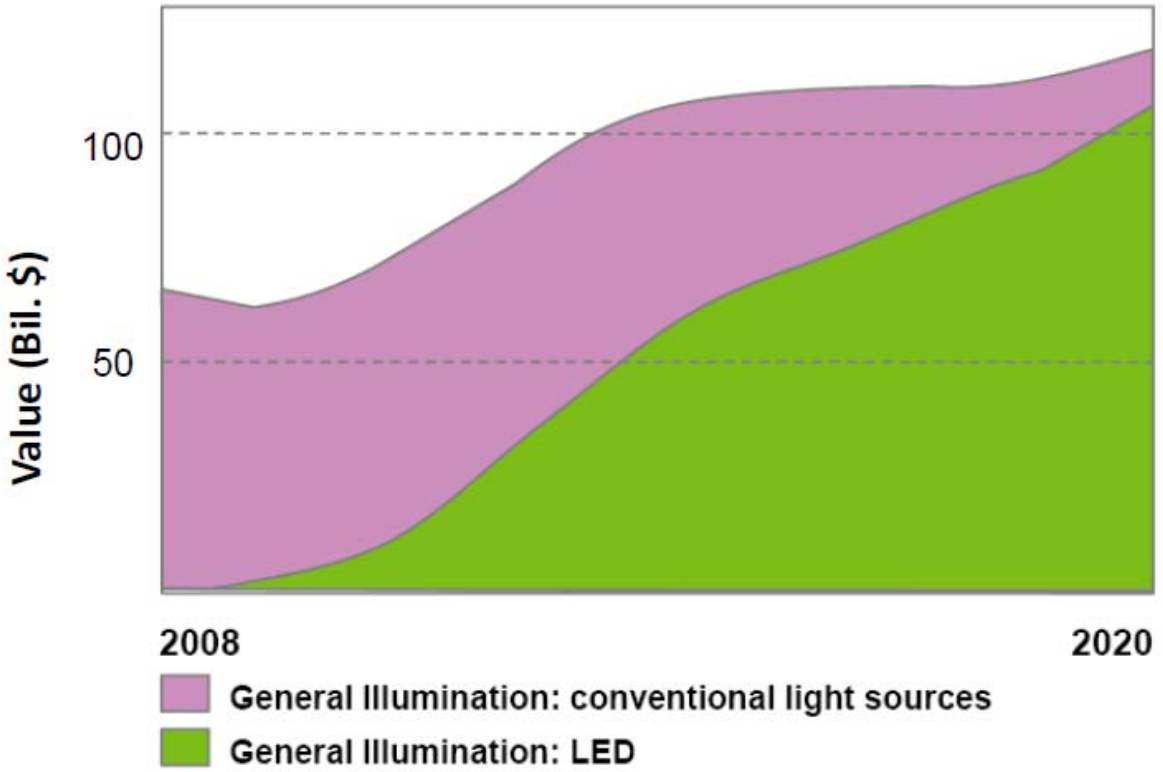
SEMI LED Advisory Committees

North American and Europe
China
India
Korea

Participating Companies (partial list)

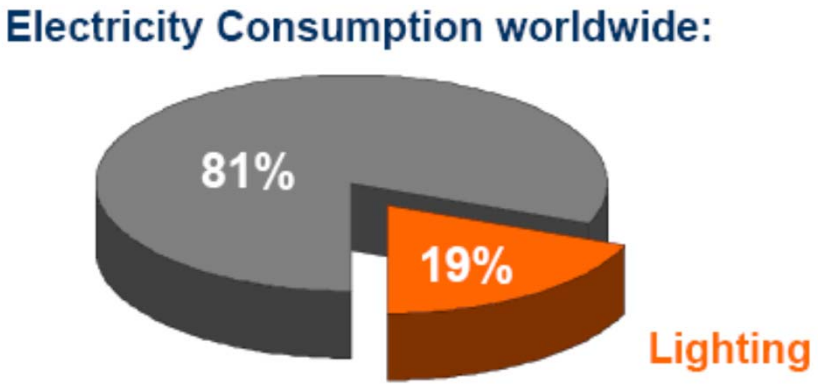
Solid State Lighting:
Why the Excitement

Industry Transformation



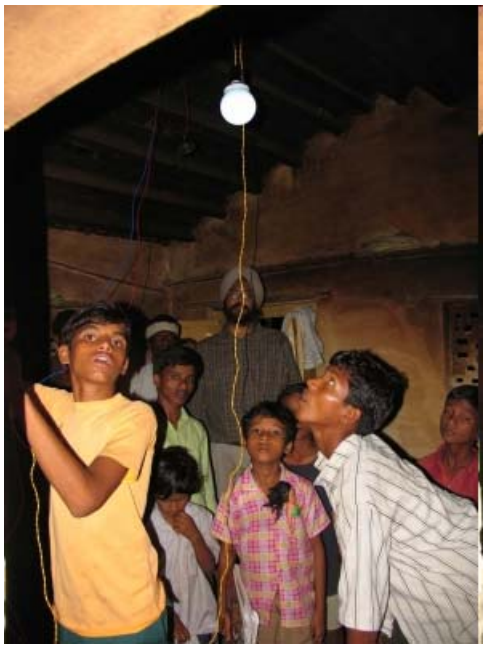
Solid State Lighting (SSL)

- Over 1/3 of the electricity for lighting could realistically be saved: nearly 900 billion kWh (OSRAM)
- Japan IEE report estimates Japan electricity consumption can be reduced 9% with LED lighting
- SSL can save by 2025*:
  - 1 billion barrels of oil
  - Reduce the need for 250 nuclear power plants
  - Annual energy savings in US alone of 1.5 Peta (10^{15})W/h
  - Reduce CO_2 emissions by 952 metric tons

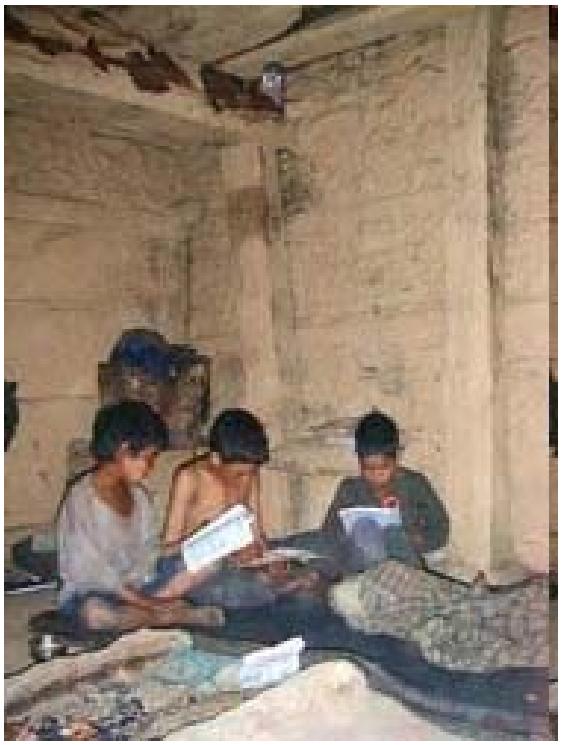


Rensselaer Polytechnic Institute, Smart Lighting Center, SSL Summit, 2011

LED/Solar Lighting Systems

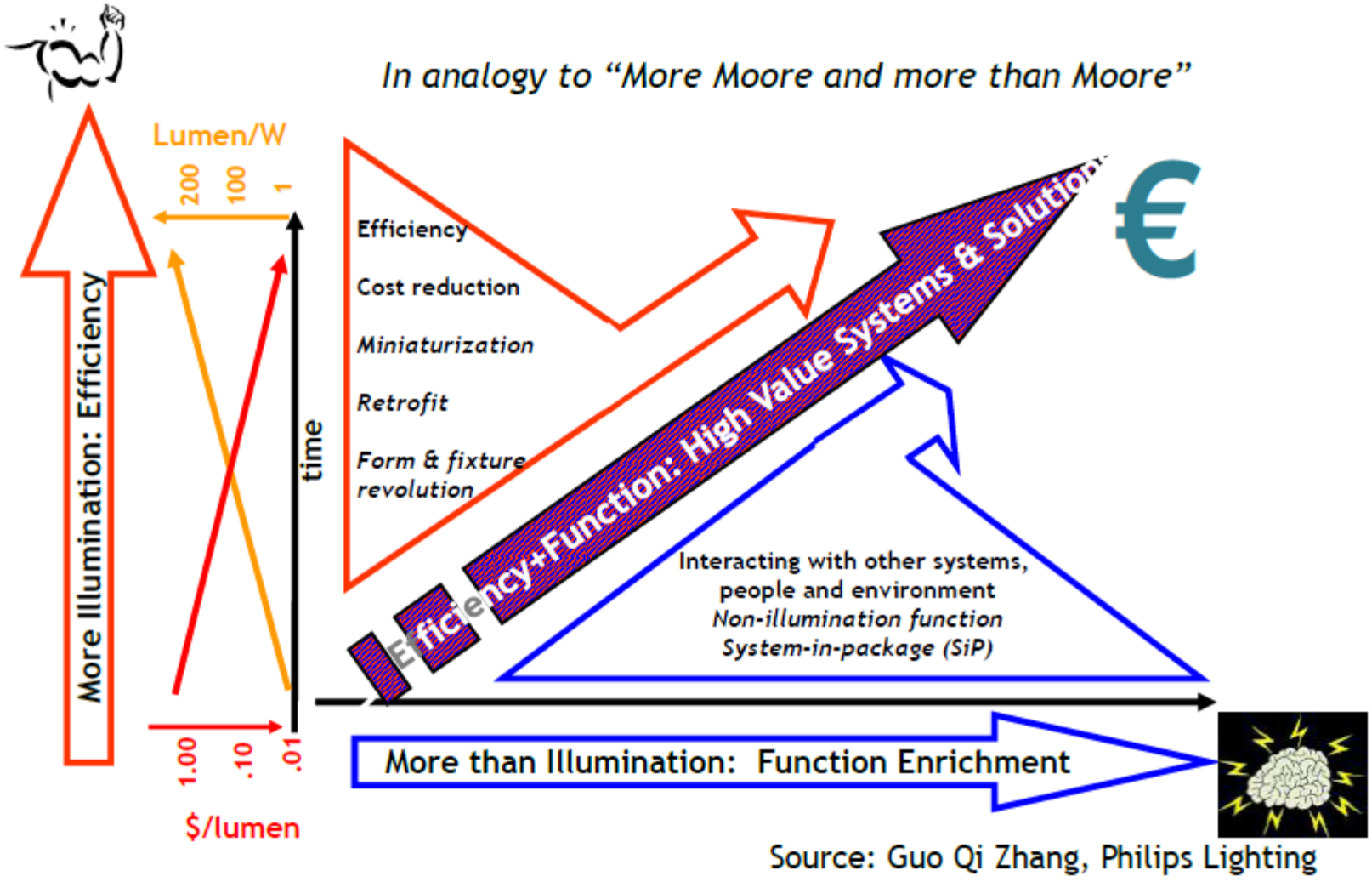


India Off Grid LED/Solar Lighting Systems
Source: Light Up the World



"Renewable Energy based Solid State Lighting is arguably the most important Agent of Change available to the Developing World in the past 100 years!"
Light Up the World

More Illumination and More Than Illumination



Source: Guo Qi Zhang, Philips Lighting

Revolution in Smart Lighting

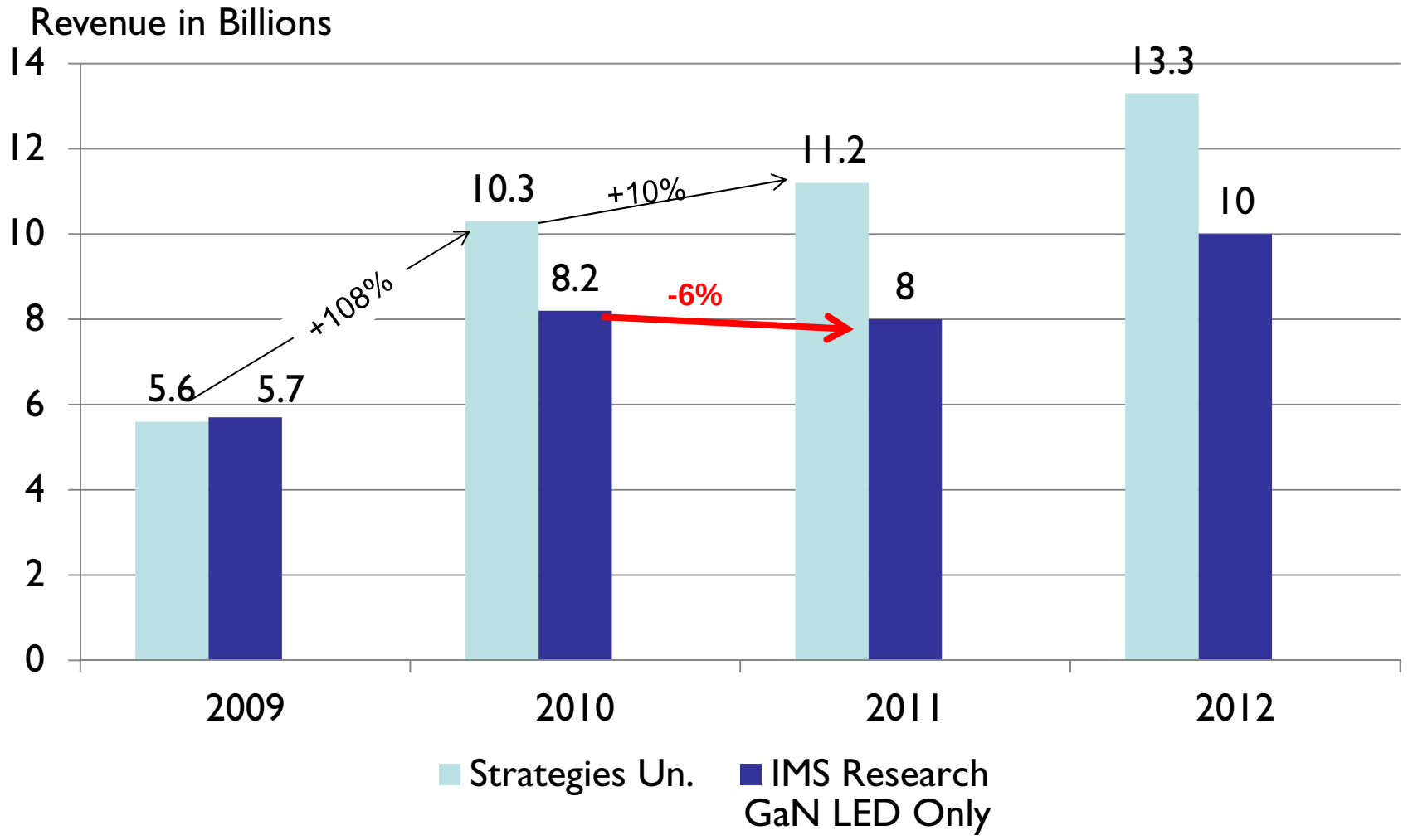
- Fully integrated systems with sensors and controls
- Any color, any time
- Data with illumination
- Illumination with video
- Pollution and health monitoring
- Biochemical sensing and mitigation
- Circadian corrected lighting
- Adaptive lighting



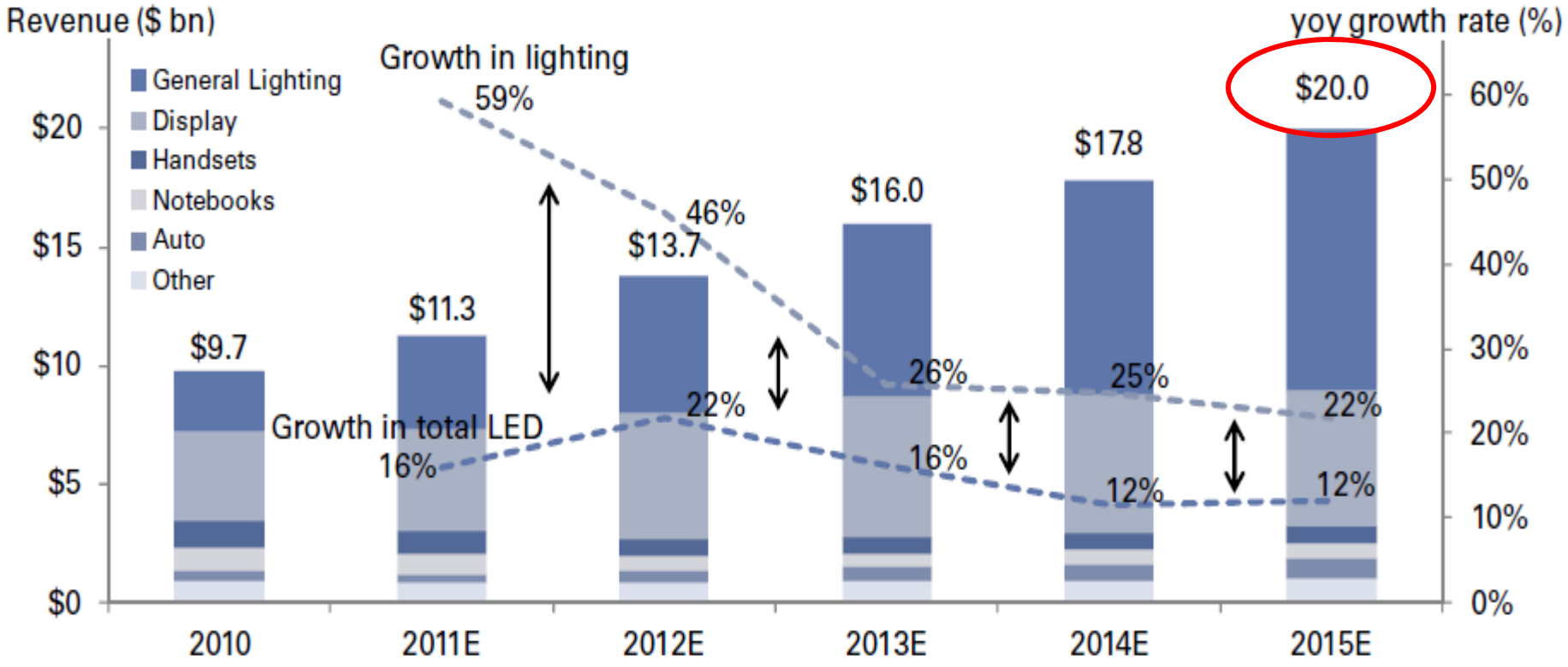



LEDs and SSL:
Where we are today

LED Market Size and Growth



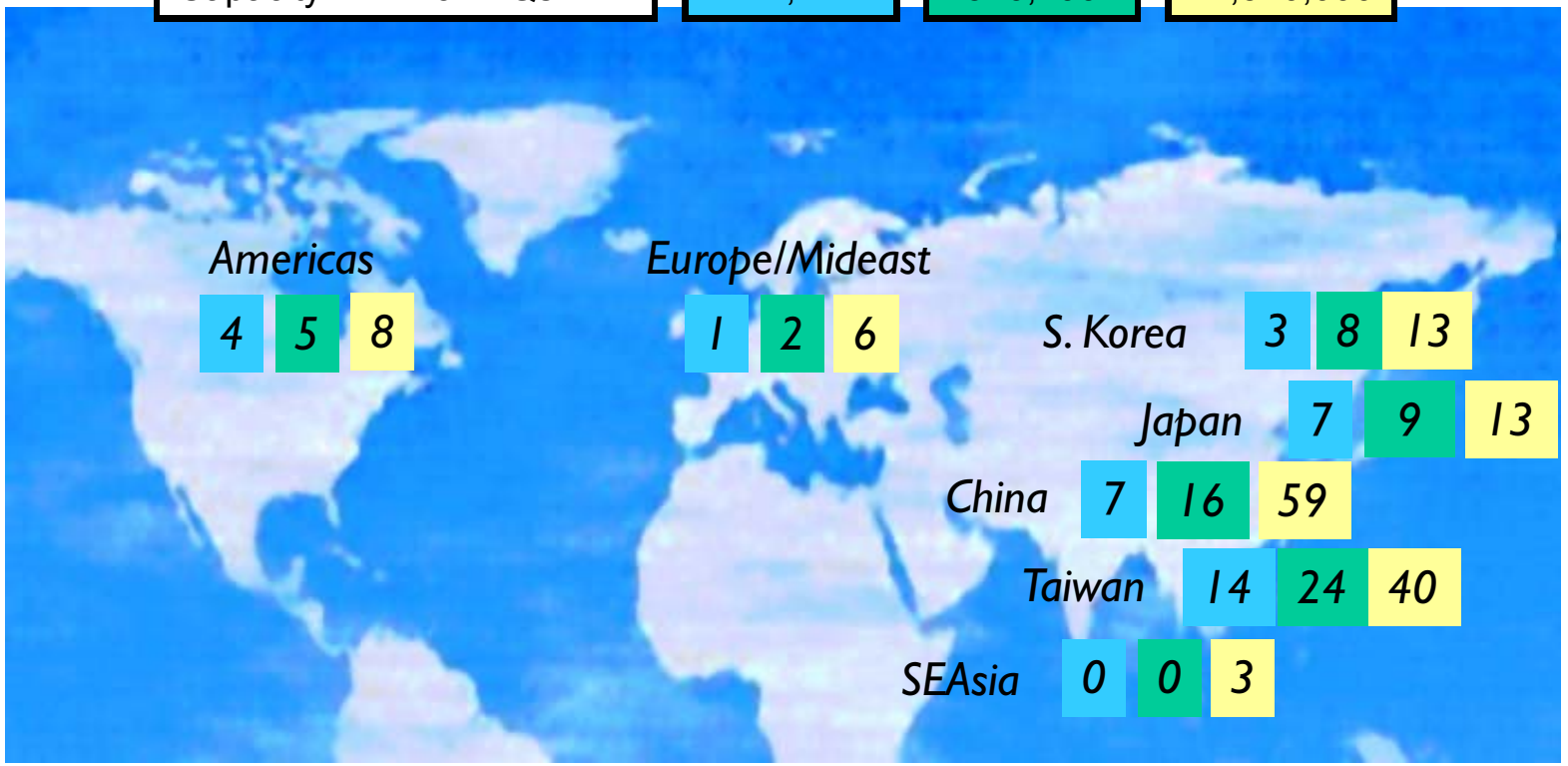
LED Market Sizing – Lighting as the Key Driver



Source: DOE, Goldman Sachs

LED Dedicated Fabs
Changing LED Landscape

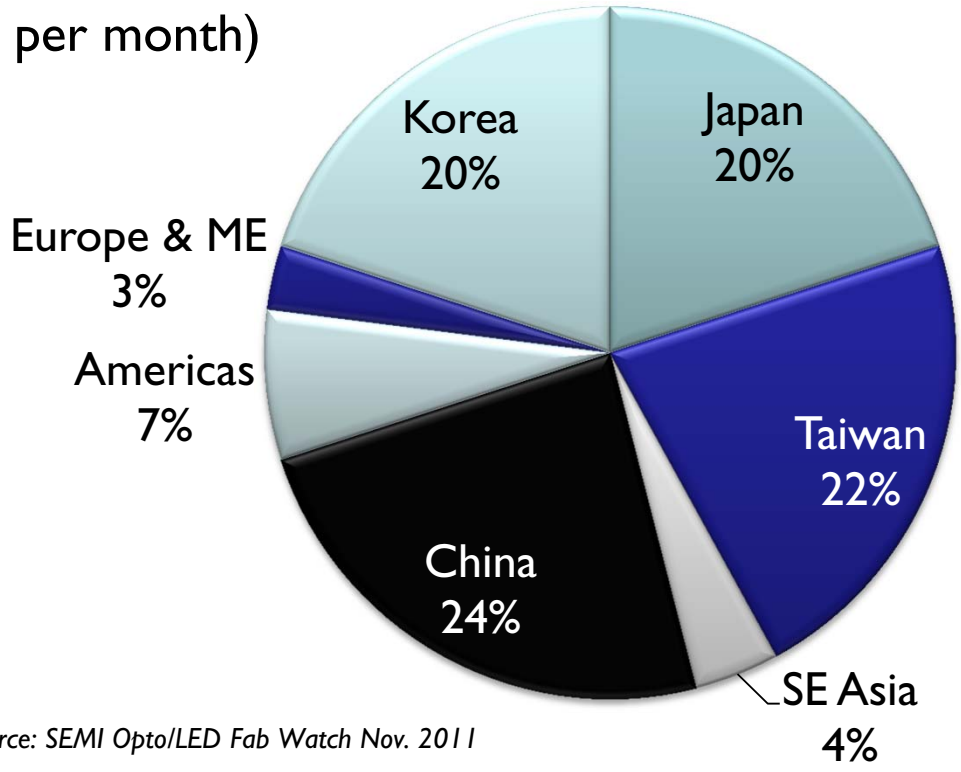
Year (begin operation)	2001	2006	2011 (est)
Total count of LED fabs	36	64	142
Capacity in 4-inch EQs w/m	127,124	376,400	~1,570,000



Source: SEMI Opto/LED Fab Forecast, Nov. 2011

LED Fab Capacity by Region, 2012

Worldwide LED Capacity 2.33M in 2012 (4" equivalent per month)



Source: SEMI Opto/LED Fab Watch Nov. 2011

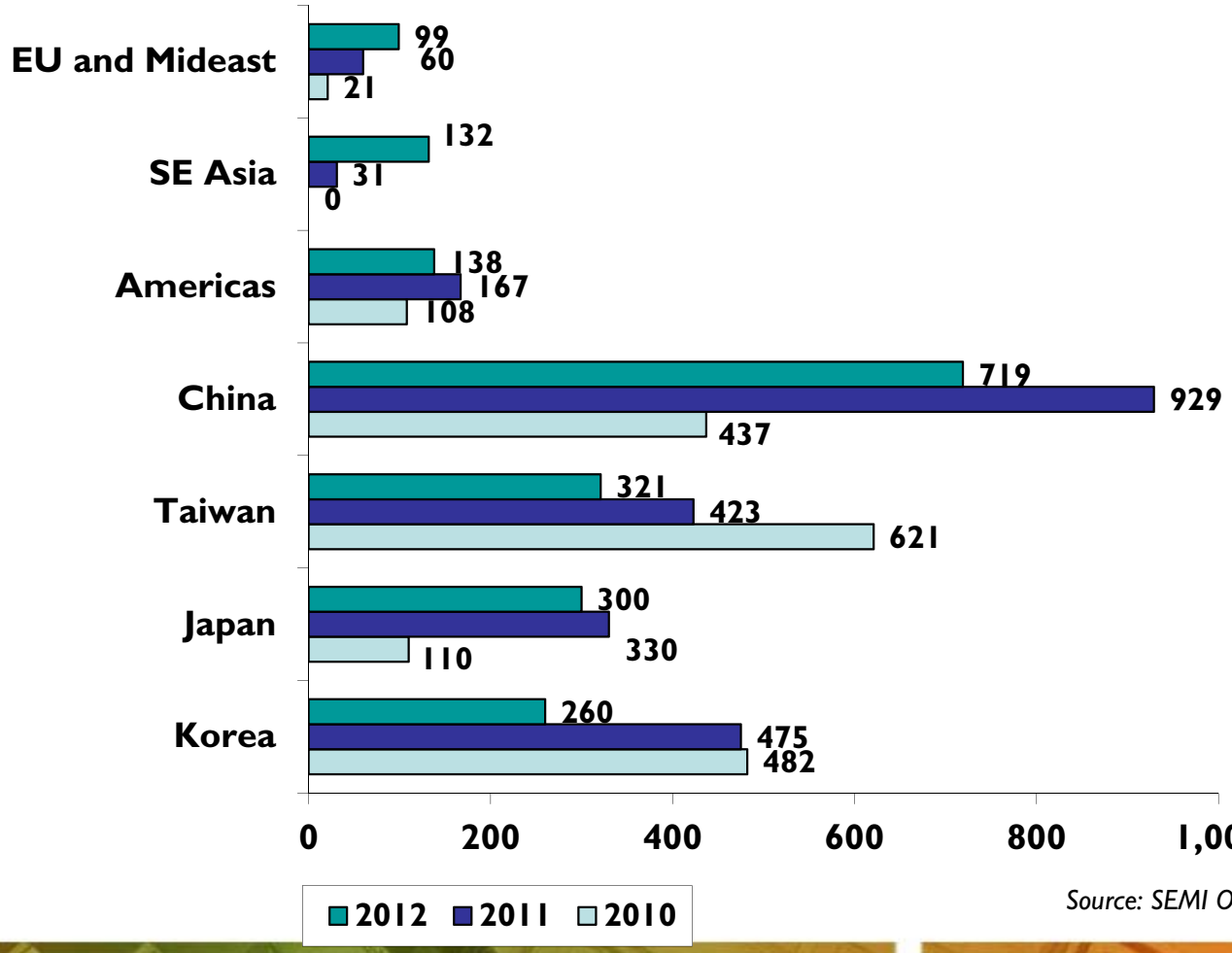
Top 10 Pkg LED Suppliers

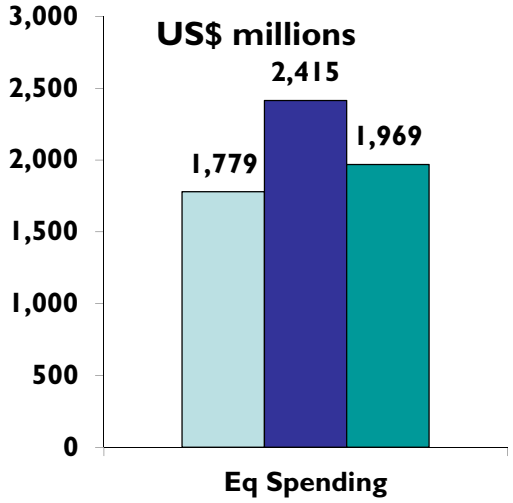
1. Nichia
2. Samsung LED
3. Osram
4. LG Innotek
5. Seoul Semiconductor
6= Cree*
6= Philips Lumileds*
8. Sharp
9. Toyoda Gosei
10. Everlight

Source: Strategies Unlimited

LED Equipment Spending

In $US Millions





Source: SEMI Opto/LED Fab Watch Nov. 2011

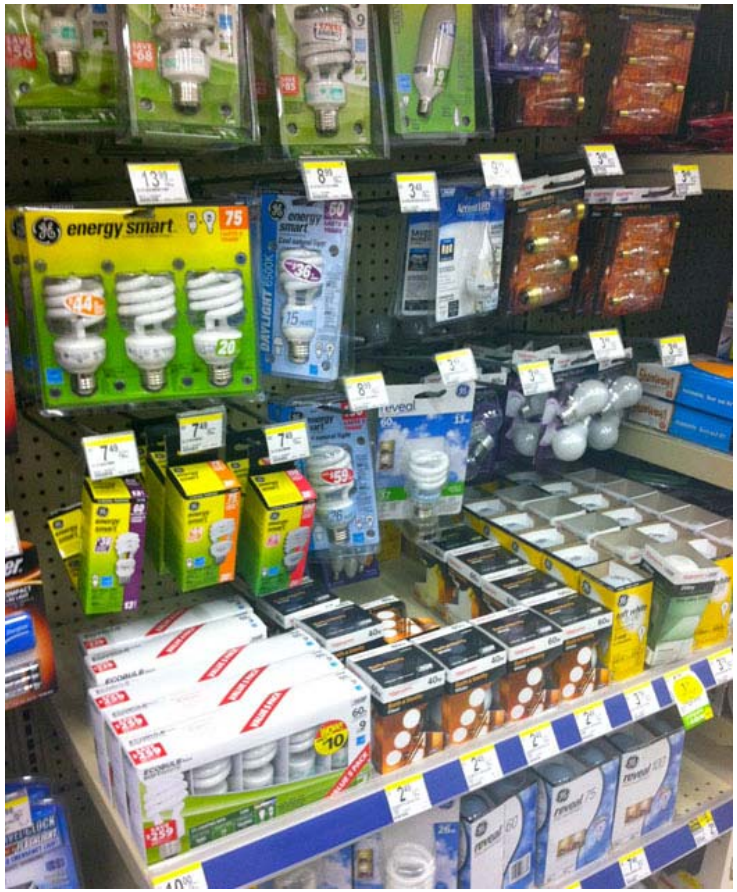
Market Situation Summary

- Recent market slowdown due to weaker demand for LCD panels and less LEDs per panel:
  - New TV models, and purchasing schedules expected to drive demand pick up from 1Q12 onwards
- 2011 LED ASP decline ~25-40%
- Rapid capacity increase followed by low fab utilization (~50-80%)
- Solid state lighting to become key market driver in 2012 and beyond
- MOCVD shipment is expected to slow down significantly next year after two years of aggressive investment
- Opportunities increasing for larger wafers and non-MOCVD equipment

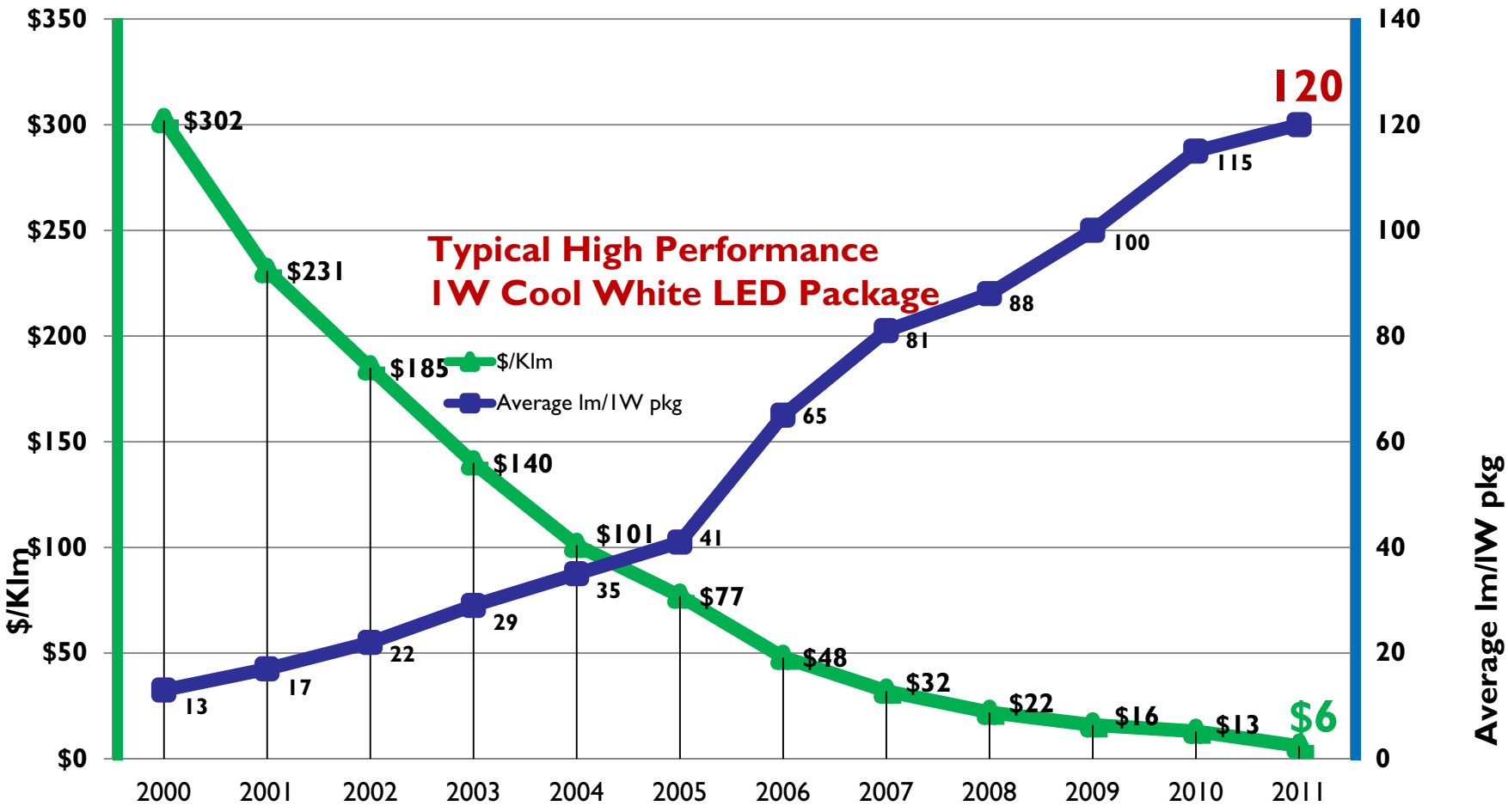
Challenges to 2020

Manufacturing Cost Reduction

Consumer Acceptance



Cost/Performance History



Source: Strategies Unlimited, SiL 2012

LED Cost Reduction Roadmap

Solid State Lighting Cost Reduction Roadmap

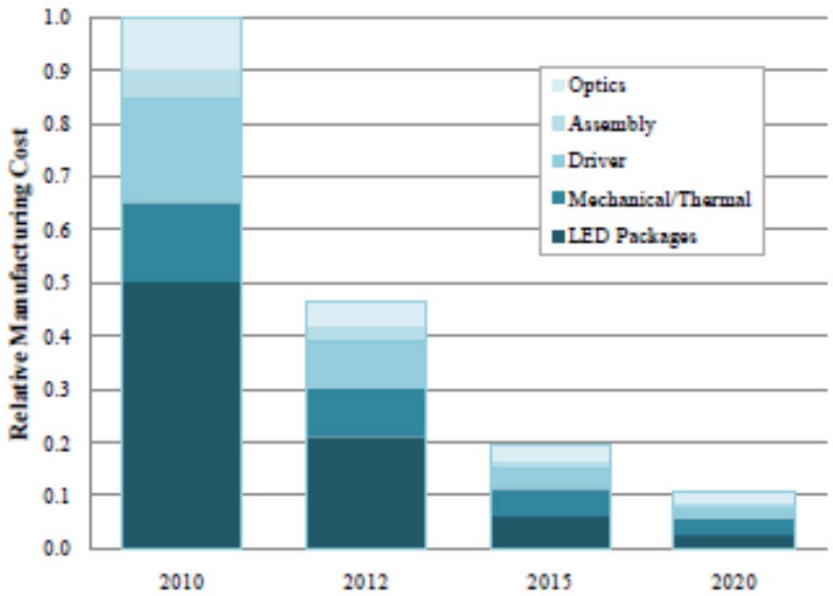


Figure 1. Projected LED-based Cost Track (Downlight Luminaire)
Source: Data provided by the 2011 Manufacturing Roundtable Attendees

LED Package Cost Reduction Roadmap

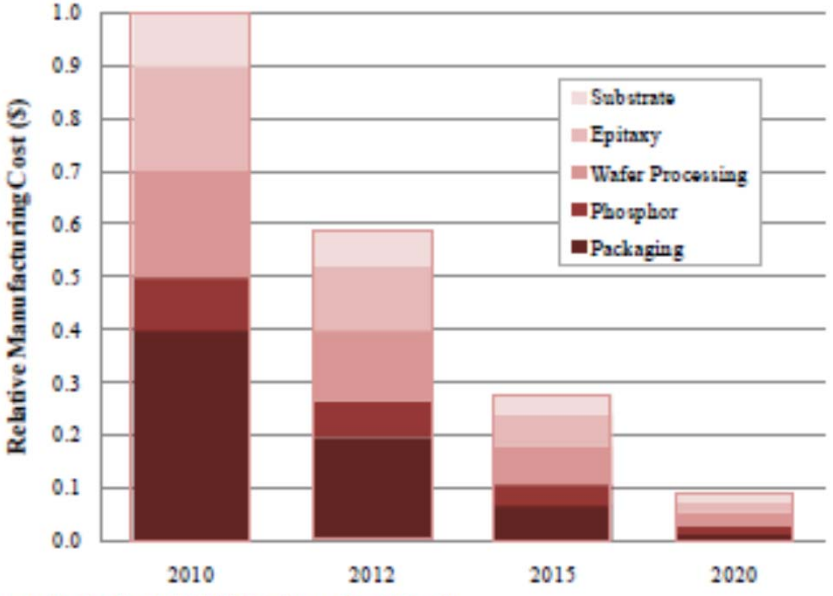


Figure 2. Projected LED Package Cost Track.
Source: Provided by the 2011 Manufacturing Workshop and Roundtable Attendees

Manufacturing standards are essential to meet the industry's long term cost reduction needs

Importance of Manufacturing Standards

LED Manufacturers

- Effective global standards allow manufacturers to buy equipment and materials from multiple vendors with minimal adaption

LED Suppliers

- Effective global standards allows suppliers to focus on innovation and critical price and performance variables

Standards: Passport to Global Innovation

SEMI Standards

- Standards Development for over 35 years
  - ~1800 standards , 4000 volunteers, 20 Technical Committees and 200 Task Forces
  - Formed HB-LED Standards Committee in November 2010
    - 150 participants
  - Current Status
    - Wafer Task Force- 6” Sapphire Wafer Standard in Ballot
    - Factory Automation Task Force
    - Environmental Health & Safety Task Force
    - Sapphire Defects and Impurities Task Force

SEMI® International Standards

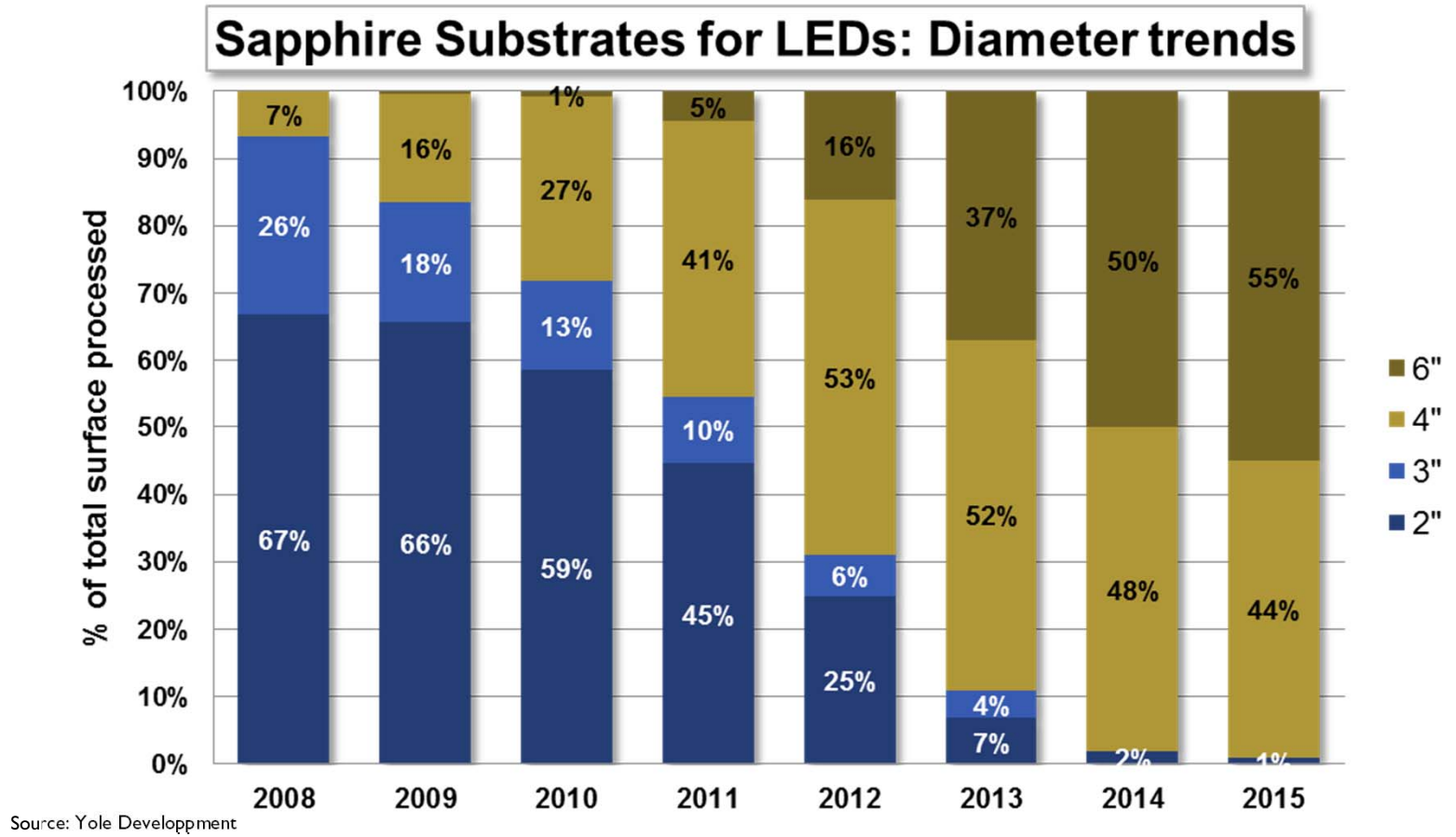
Why 6" Wafer Standards?

Wafer Size and CoO

56x2" → 14x4"	56x2" → 8x6"	56x2" → 5x8"
1. Investment ♦ Capacity $A = n \cdot \pi \cdot r^2$ A(4")/A(2") = 1 => same capacity ♦ with 3mm edge exclusion $A = n \cdot \pi \cdot (r-e)^2$ A(4")/A(2") = 1.14 => +14% capacity ♦ System investment $/1.14 = 0.88 => 88%	**1. Investment** ♦ Capacity $A = n \cdot \pi \cdot r^2$ A(6")/A(2") = 1.29 => +29% capacity ♦ with 3mm edge exclusion $A = n \cdot \pi \cdot (r-e)^2$ A(6")/A(2") = 1.53 => +53% capacity ♦ System investment $/1.53 = 0.65 => 65%	**1. Investment** ♦ Capacity $A = n \cdot \pi \cdot r^2$ A(8")/A(2") = 1.43 => +43% capacity ♦ with 3mm edge exclusion $A = n \cdot \pi \cdot (r-e)^2$ A(8")/A(2") = 1.74 => +74% capacity ♦ System investment $/1.74 = 0.58 => 58%
2. Running Cost $/1.14 => 88%	**2. Running Cost** $/1.53 => 65%	**2. Running Cost** $/1.74 => 58%
3. Chip Process Assume 150% processing time of 4" compared to 2": $(4^2/1.5)/(2^2/1)$ = 2.7x Throughput	**3. Chip Process** Assume 200% processing time of 6" compared to 2": $(6^2/2)/(2^2/1)$ = 4.5x Throughput	**3. Chip Process** Assume 250% processing time of 8" compared to 2": $(8^2/2.5)/(2^2/1)$ = 6.4x Throughput

Source: AIXTRON

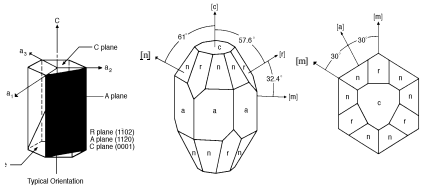
Substrate Trends

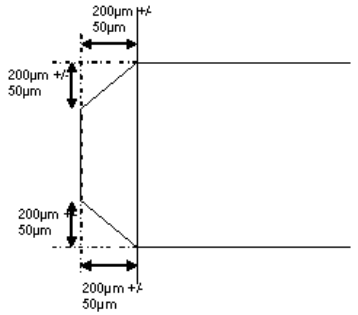


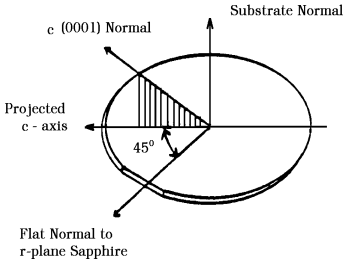
Source: Yole Developpment

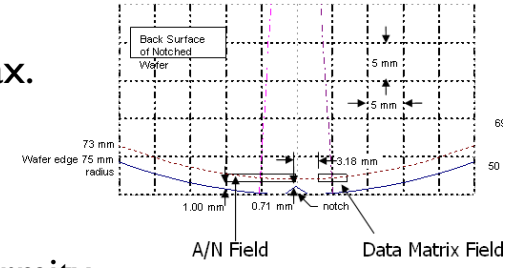
150 mm Wafer Standards

- Critical for factory automation and other standards
- Currently in ballot
- Covers 4 150 mm wafer geometry options
  - Flat and Notched
  - 2 thickness options
- 17 Key Parameters
  - •Total Impurity Content
  - •Wafer ID Marking
  - •Front Surface Condition
  - •Edge Surface Condition
  - •Back Surface Condition
  - •Diameter
  - •Fiducial Type
  - •Fiducial Dimensions
  - •Flat Length
  - •Fiducial Notch Depth & Notch Angle
  - •Fiducial Orientation
  - •Edge Profile Template
  - •Thickness, Center Point
  - •Total Thickness Variation, Max.
  - •Bow and Warp, Max.
  - •Inclusions or Bubbles
  - •Dislocations
  - •Thermal Conductivity Uniformity









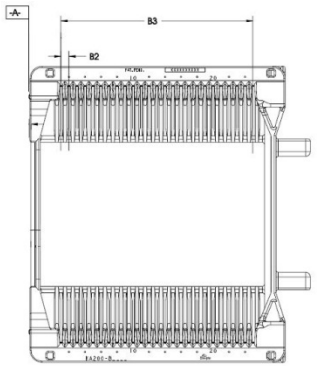
Factory Automation Interfaces

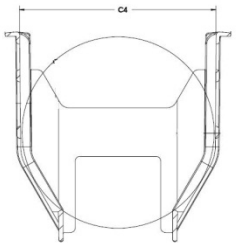
- **Critical Requirements:**
- Cassette
  - Open cassette
  - Process tray cassette
- Load Port
- Automated tracking
  - Cassette/wafer
  - Process Tray
- Shipping Carrier

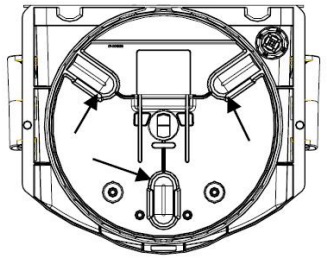
Ballot Expected Mid Year 2012

Cassette Specifications Identified for Industry Standard

Pitch
Capacity
Loadport coupling
Material
ID type and location (for automated tracking)
Wafer support
End effector exclusion
First wafer height
Pocket volume
Windows / open sidewalls
Wafer plane
Overall dimensions
Manual grips
Electrical continuity
Automated gripping features
Wafer orientation features
Mapping







Kinematic Coupling

Challenges to Market Acceptance

- SSL Lamps are complex systems
- Quality of light is subjective
- Quality of products will vary
- Cost competiveness in many segments will remain a challenge
- Consumers resist change/complexity

Compact Fluorescent Lighting: Lessons Learned

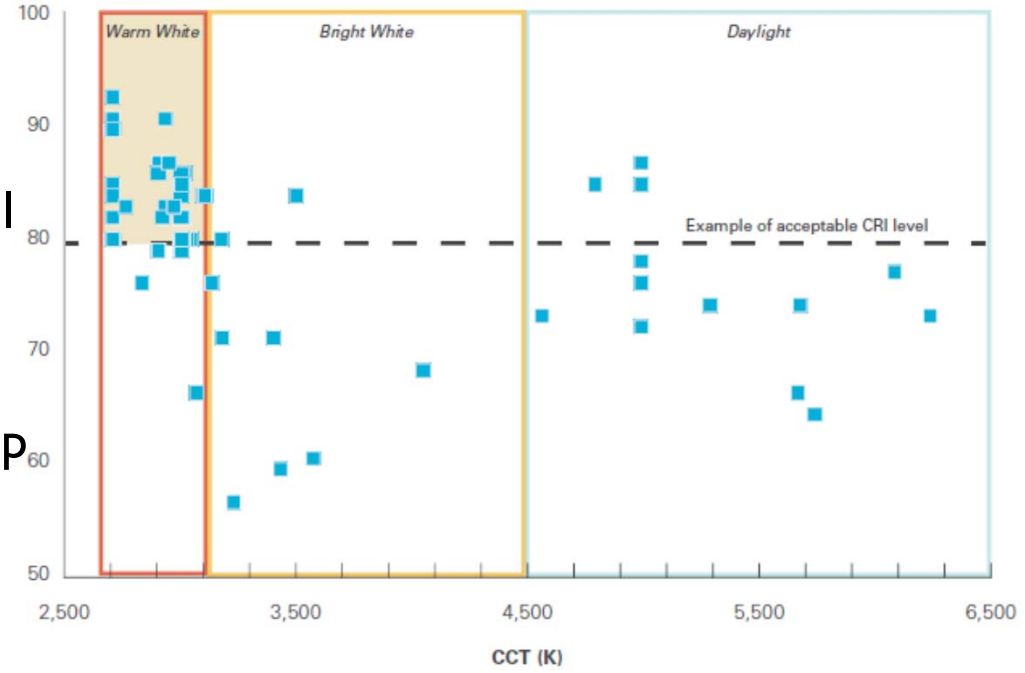
- Introduced in 1970's—Market Share 2000: 0.6%
- Early consumer experience generated bad reputation:
  - Too big
  - Buzz and flicker
  - High cost
  - Poor color quality (high CCT, low CRI)
- Marketing Mistakes by fractionated industry
  - Exaggerated life expectancy claims
  - Inconsistent incandescent equivalency claims
  - Inconsistent specifications and terminology

Challenges in Consumer Acceptance

US Department of Energy, Lighting Facts 2011

- 67% of current A4 replacement lamps on market fall below 450 lumens (40W equivalency), 56% fall below acceptable color quality
- Only 2 commercially available LED reflector lamps offer comparable light output than 75W PAR 30 lamp
- LED replacements for 4-ft linear fluorescents produce on average one-half the light output and use more energy

CRT and CCI Values of Commercially Available LED A4 Replacements



Complex Regulatory/Standards Environment

International Standards Organizations

IEC

CSA INTERNATIONAL

IES

NEMA

CIE

NIST National Institute of Standards and Technology

Zhaga

ANSI American National Standards Institute

Underwriters Laboratories Inc.

IEEE

Certifications/Labeling

CQC

Brightness 820 lumens

Estimated Energy Cost $7.23 per year

Lighting Facts Per Bulb

Brightness 820 lumens

Estimated Yearly Energy Cost $7.23

Based on 3 hrs/day, 11¢/kWh

Cost depends on rates and use

Life

Based on 3 hrs/day 1.4 years

Light Appearance

Warm Cool

2700 K

Energy Used 60 watts

CQC ENVIRONMENTAL LABEL

PSE PSE

CE

Energy A

200 Lumen

5 Watt

15000 h

この商品の省エネ性能は？

ENERGY STAR

Summary

- SSL is a new industry with enormous economic potential and environmental benefit
- A 10X improvement in $/klm at the packaged LED level is required to support widespread adoption of solid state lighting
- The majority of this cost reduction will occur through yield, throughput, productivity, and materials cost reduction
- Manufacturing Standards will accelerate cost reduction in packaged LEDs and will become the platform for advanced, automated LED manufacturing in the future
- Consumer labeling, quality certifications, and consumer education just beginning.