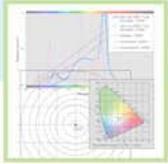


# CALiPER

COMMERCIALLY AVAILABLE LED PRODUCT EVALUATION AND REPORTING



## How LED Lighting “Measures Up”

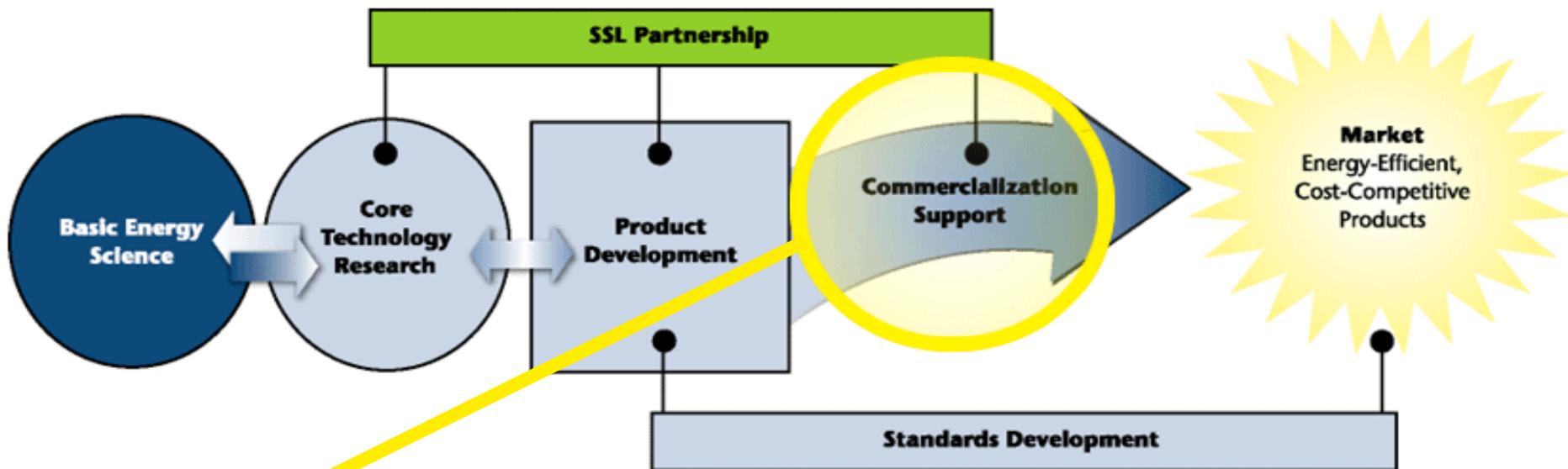
**Mia Paget**

**Pacific Northwest National Laboratory**



# DOE SSL Commercialization Support

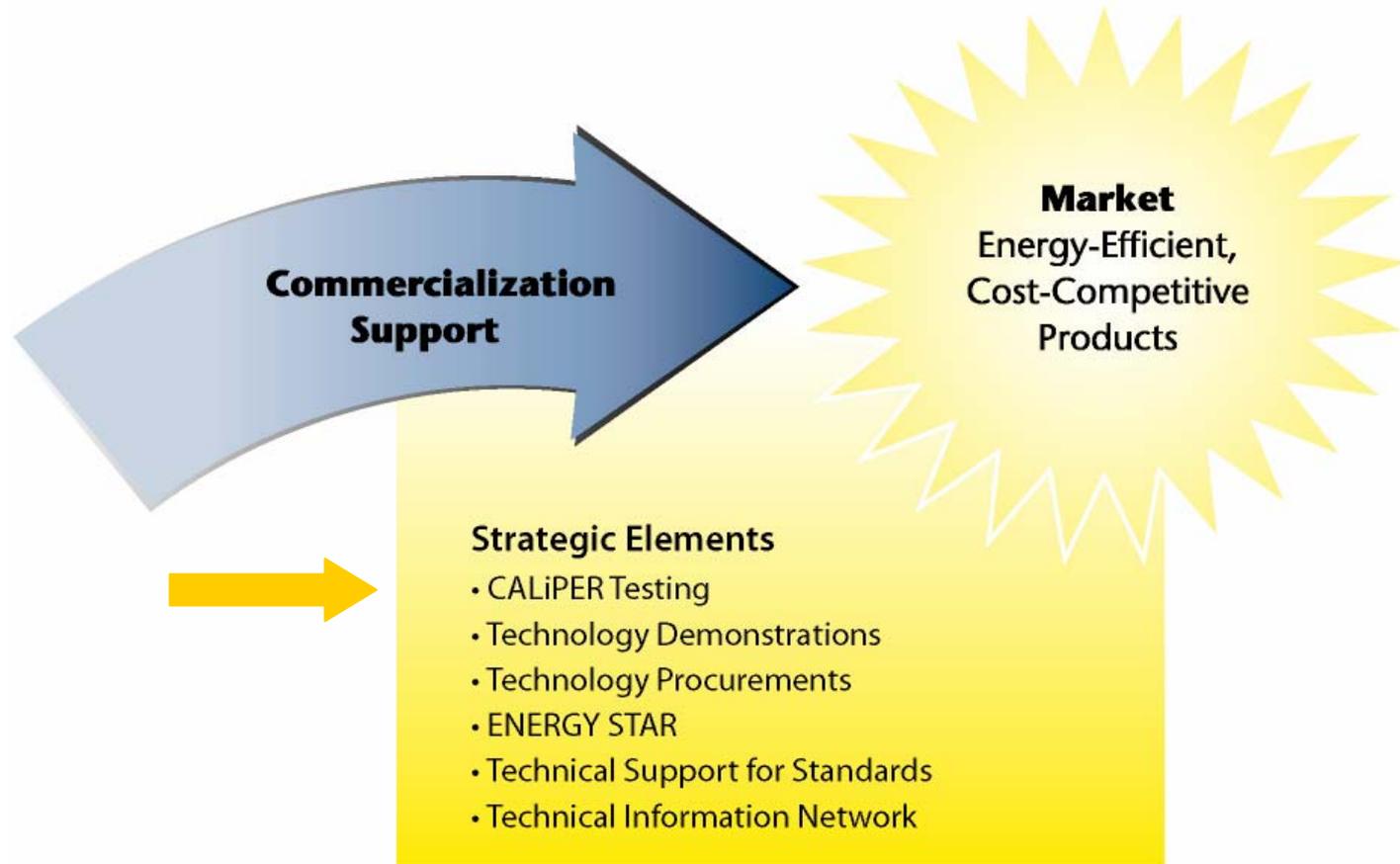
## DOE SOLID-STATE LIGHTING PORTFOLIO



*Guiding technology advances from laboratory to marketplace*

<http://www.netl.doe.gov/ssl/>

# DOE SSL Pathways to Market



# Purposes of CALiPER

- Provide objective, high quality performance information
- Know performance of market available products
  - To support R & D planning
  - To support ENERGY STAR
- Inform industry test procedures and standards development
- Discourage low quality products
- Reduce SSL market risk due to buyer dissatisfaction from products that do not perform as claimed



**YOU MAY NEVER CHANGE  
ANOTHER LIGHT BULB**

- ✓ *Long life*
- ✓ *Energy efficient*
- ✓ *Easy to install (standard socket)*
- ✓ *Natural white, superb color rendering*

# Testing Program Scope

Commercially-available SSL products for the general illumination market

- Luminaires and replacement lamps (white light)
- Indoor and outdoor
- Residential and commercial



# CALiPER Testing Process

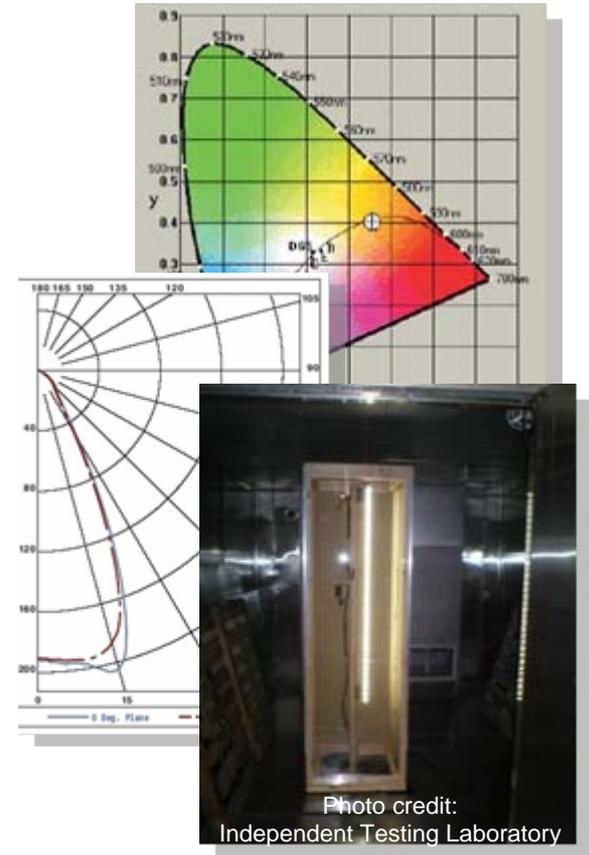
- Quarterly product selection & acquisition
- Multiple independent test labs
- Assembly and analysis of results
  - Courtesy sharing of results with manufacturers
  - Retesting options
- Publication of results
  - Summary reports
  - Detailed test reports
  - Analyses and studies
- “No Commercial Use” Policy



Photo credit: Luminaire Testing Laboratory

# Types of CALiPER Testing

- Basic photometry (following IESNA LM-79)
  - Integrating Sphere and Goniophotometry
    - Luminaire light output, efficacy
    - Color qualities (spectral power distribution, CCT, CRI)
    - Beam characteristics and intensity distributions
    - Electrical measurements, thermal characteristics
  - Benchmarking (other light sources)
- Other, non-standardized testing
  - “In Situ” Testing (relative measurements)
    - Environmental chamber
    - Insulated ceiling, recessed can
  - Lumen depreciation testing
    - Draws from IESNA LM-80 draft
  - Exploratory testing
    - Thermal imaging, dimming...



# SSL Luminaire Testing

**SSL energy efficiency is a function of:**



**LED device efficacy**



+



**Thermal management**



**Luminaire design**

+



**Driver/power supply efficiency**

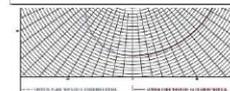
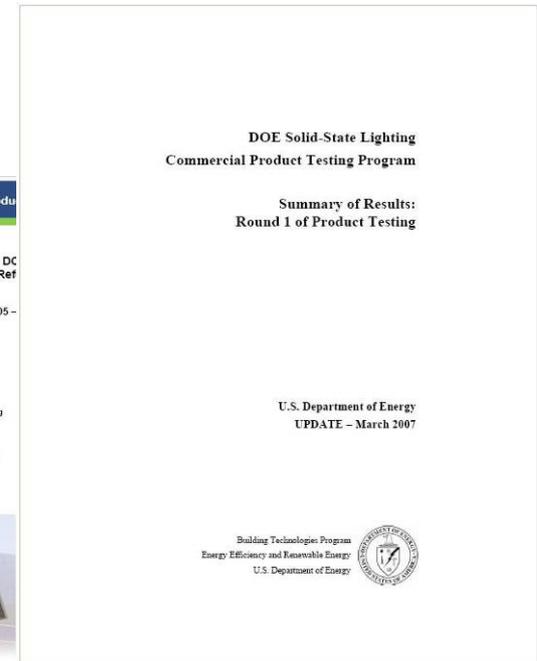
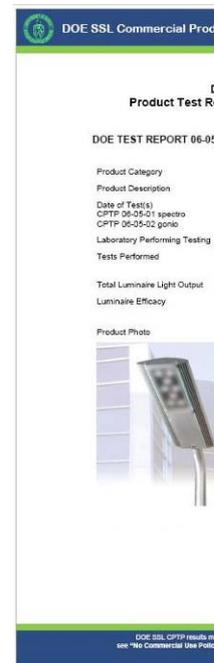
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- Must measure luminaire as a complete system
- Uses ‘absolute photometry’ rather than ‘relative photometry’
- Based on IESNA standard LM-79 for SSL photometric testing
- Stakeholders are not all familiar with these new testing paradigms

# Testing Rounds 1-5 Results

- Over 100 products tested
- Focus: overall luminaire performance
- Wide range in products & results

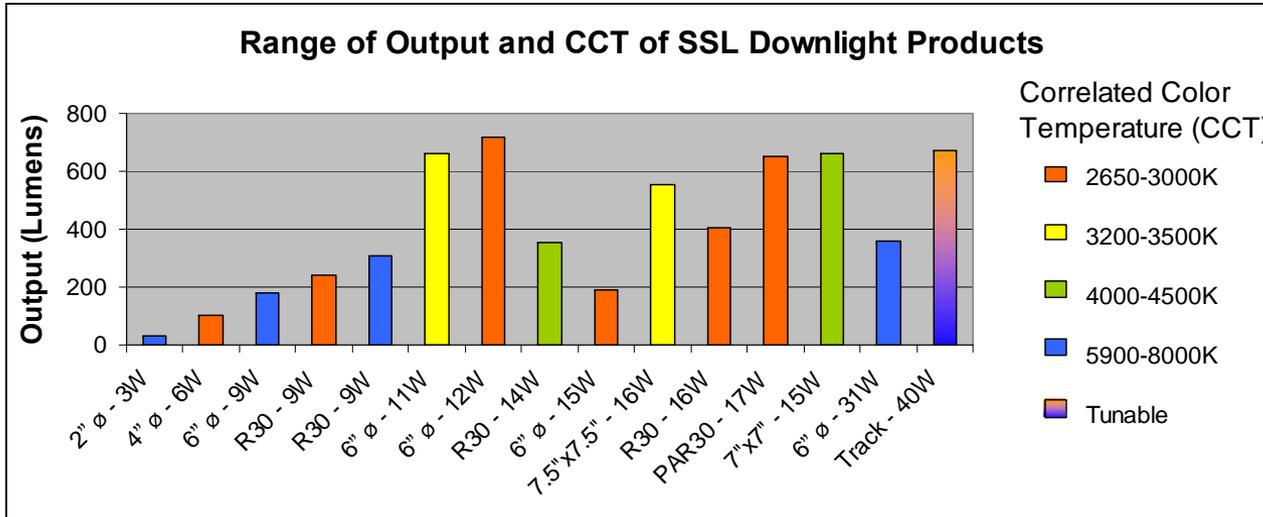


DOE SSL CPTP results may not be used for commercial purposes under any circumstances, see "No Commercial Use Policy" (<http://www.eere.doe.gov/commerce/info/ssl>) for more information.

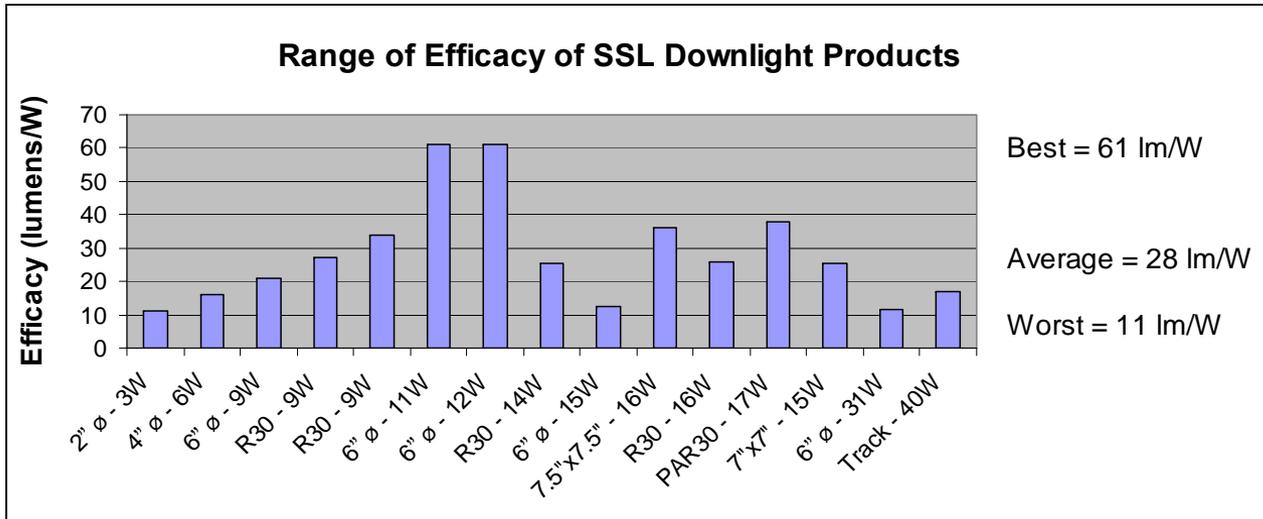


# Downlights

# SSL Downlight Performance

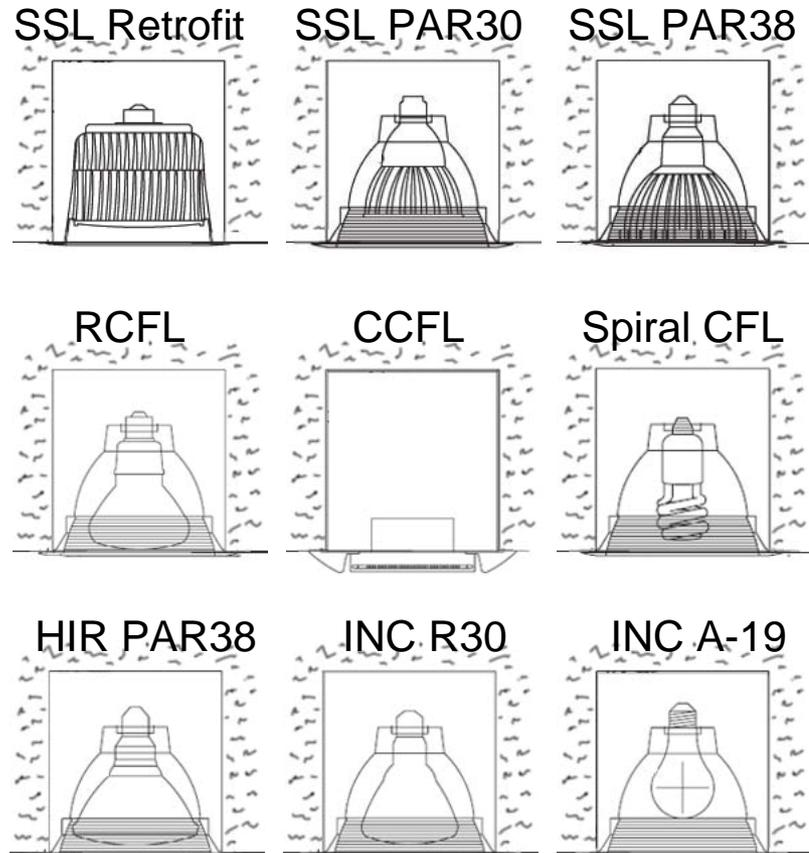


- Different sizes and configurations
- Different color temperatures
- Outputs
  - From 29 to 719 lumens
  - 389 lumens on average
- Efficacies
  - From 11 to 61 lm/W
  - 28 lm/W on average
- CRI
  - Maximum = 95
  - Average = 76
  - 3 RGB products

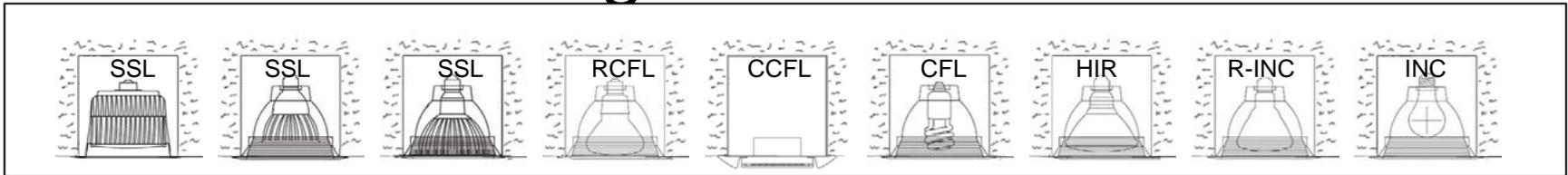


# Round 5 Downlight Series

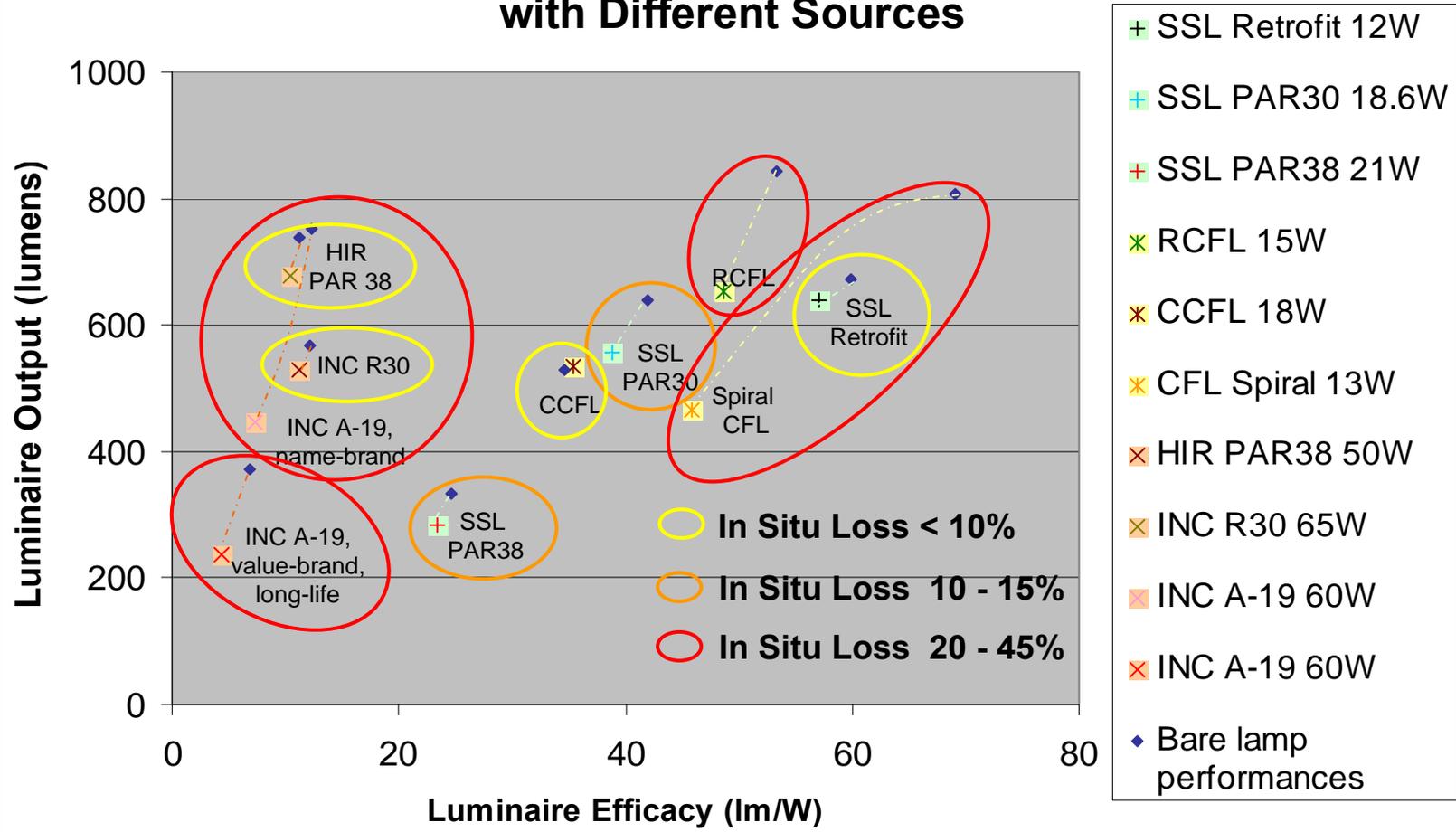
- Replacement or retrofit lamps
  - Bare lamps, tested in integrating sphere
  - Lamps mounted in insulated recessed can, tested in goniophotometer
- Round 5 results show
  - Manufacturer ratings versus bare lamp performance
  - Output and efficacy of downlight with each lamp 'in situ'
  - Delivered footcandles & intensity distributions
  - Fixture losses for each lamp (including thermal effect)



# Downlight In Situ Losses



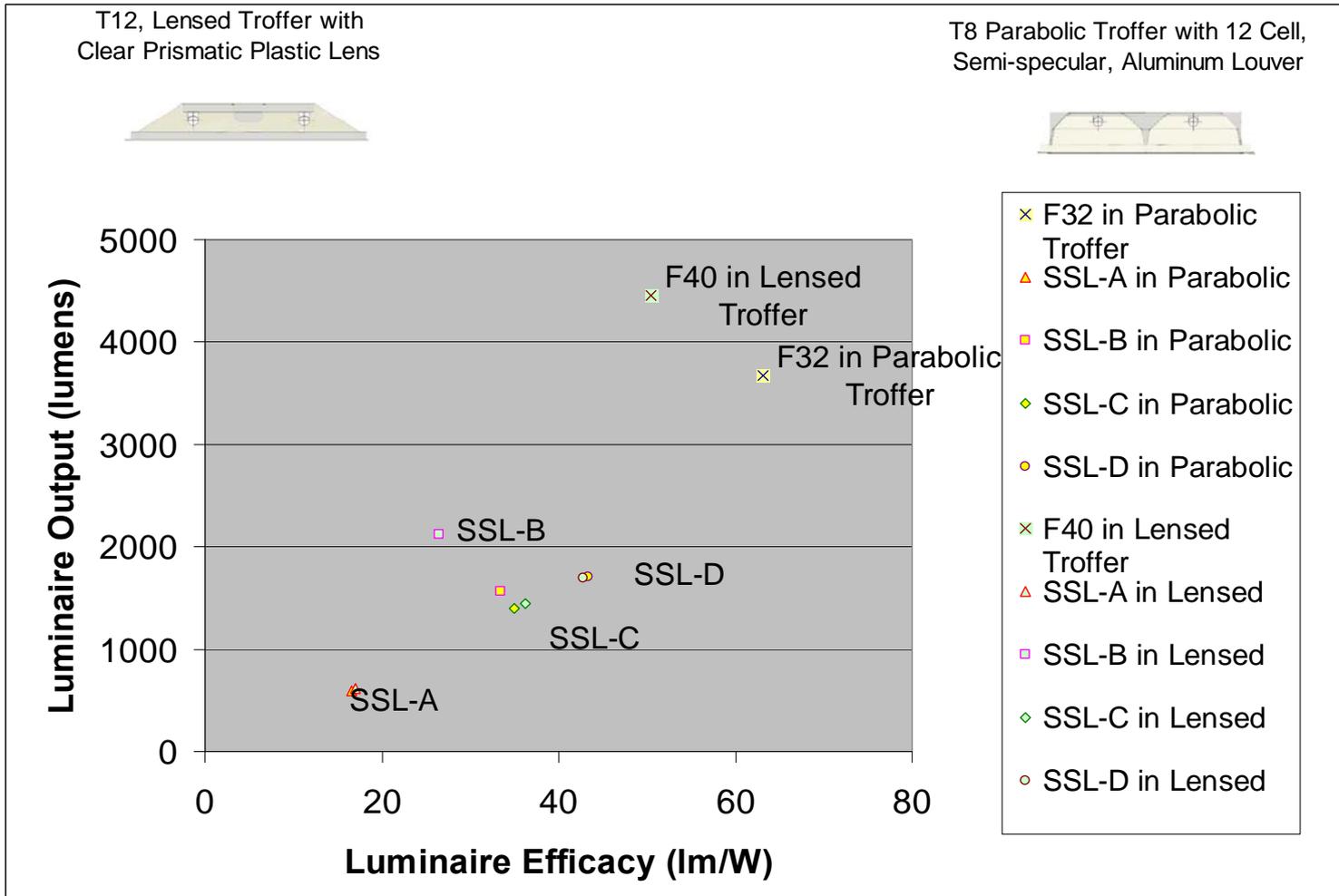
**Performance of 6" Recessed Downlight with Different Sources**





# Replacement Lamps

# SSL Linear Replacement Lamps



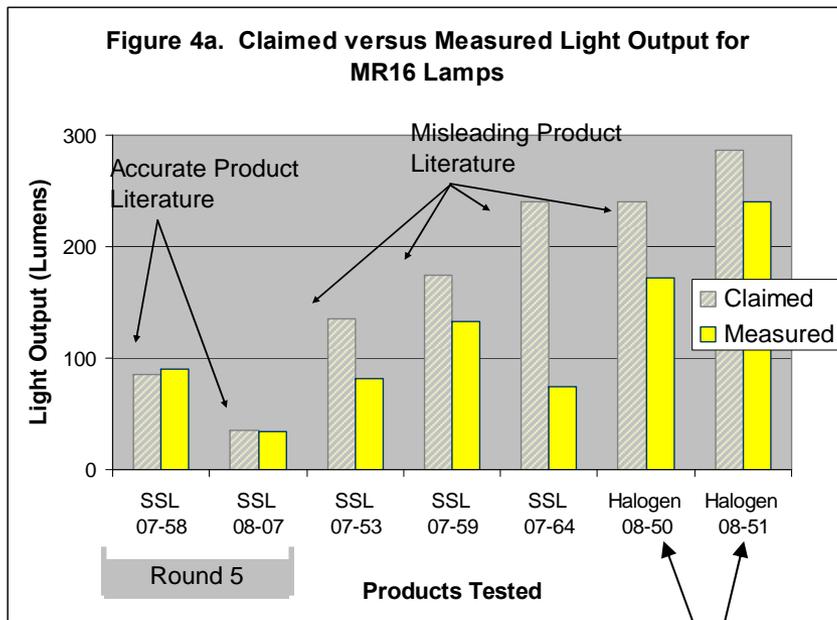
- 4 different SSL replacement tube products were used (2 samples each)
- SSL-B uses troffer ballast. SSL-A, C, & D bypass troffer ballast

# SSL Linear Replacement Lamps

- T8-T12 : SSL photometry and direct comparisons with fluorescents in troffers
  - ↓ Performance: not yet competitive with fluorescent in output or efficacy
  - ↓ Misleading manufacturer literature: SSL replacement lamps emit less than ½ the output expected based on spec. sheets
  - May be suitable for specific applications (e.g., cold or rugged environments, low output needs...)

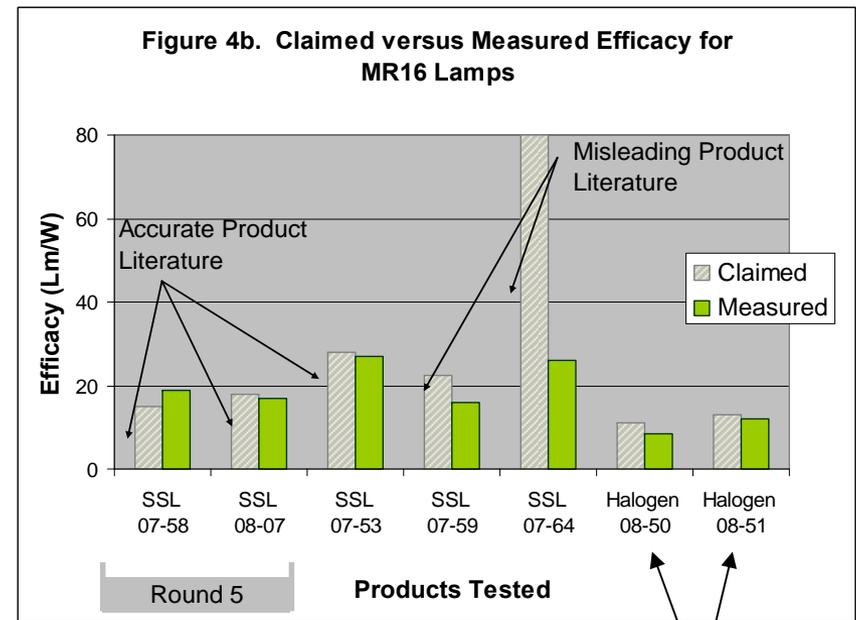
# MR16 Replacement Lamps

## LIGHT OUTPUT



HALOGEN  
BENCHMARKS

## EFFICACY



HALOGEN  
BENCHMARKS

# MR16 Replacement Lamps

- SSL MR16 not quite competing with 20W Halogen MR16
  - ↑ Efficacy: SSL-MR16 @ 16-27 lm/W > 20W Halogen flood @ 8-19 lm/W
  - ↓ Output: SSL-MR16 @ 33-133 lm < 20W Halogen flood @ 170-450 lm
  - ↓ CBCP: SSL-MR16 @ 59-283 cd << 20W Halogen flood @ ~350-500 cd
- Inconsistent product literature
  - Some SSL MR16 products overstate output and efficacy
  - Halogen benchmark MR16s have somewhat overstated output and efficacy
  - On average, performance claims for SSL MR16s are more overstated than performance claims for halogen MR16s
- SSL MR16 may be suitable for niche applications requiring lower output (e.g., equivalent to hypothetical 5-10W halogen MR16)

# Replacement A-Lamps

- Small A-lamps: Low wattage level (2-5W), advantage or disadvantage?
  - ↑ Efficacy: SSL A-lamps @ 28-42 lm/W >> small incandescents @ 4-10 lm/W
  - ↓ Poor power factor on SSL A-lamps
  - Misleading manufacturer literature: claim to replace 40W incandescent, in reality they can replace 15-30W incandescents

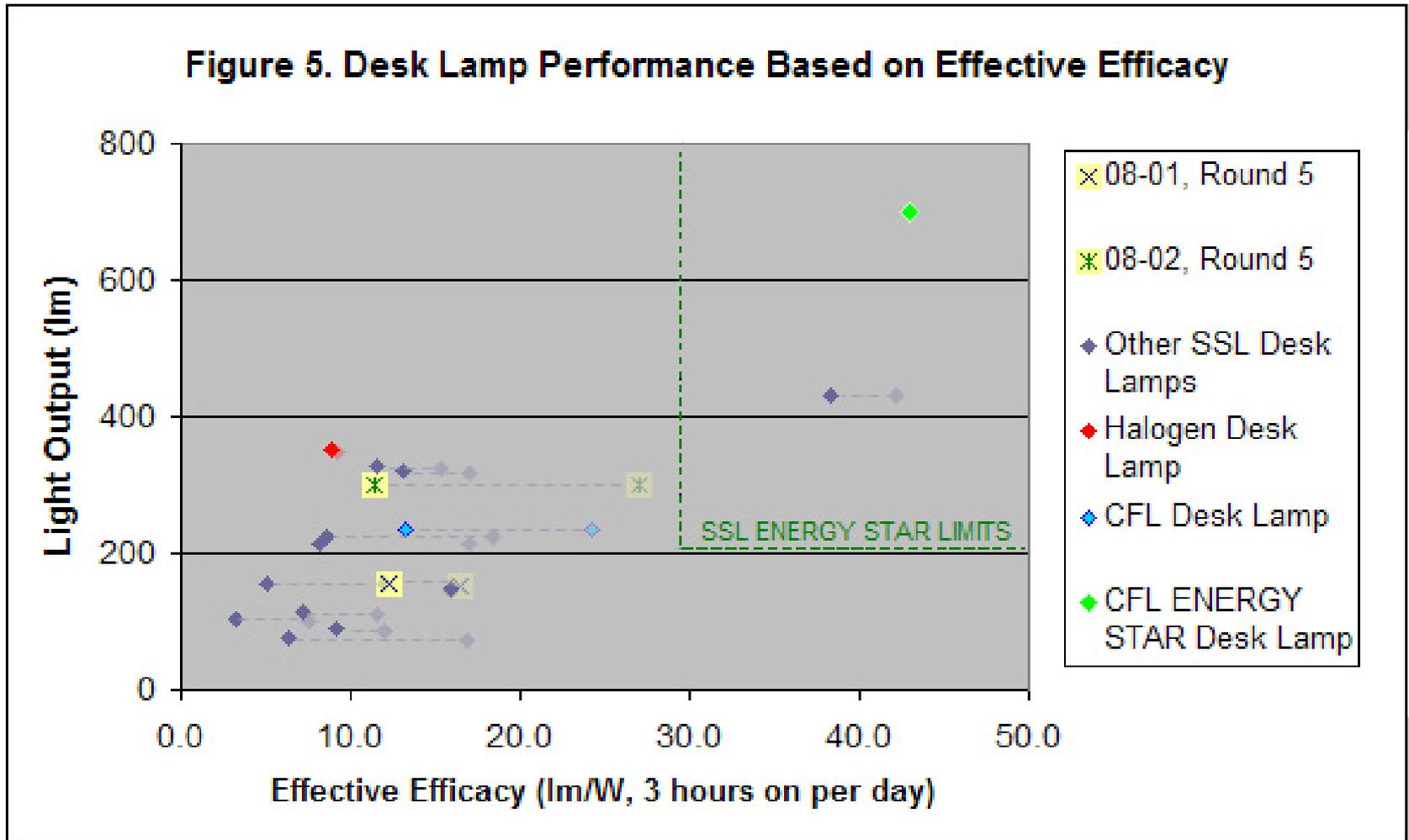
Round 5 Replacement A-Lamp Performance							
Replacement Lamps	Manufacturer Reported Performance	CALiPER Measurements					
		Power (W)	Output (lm)	Efficacy (lm/W)	CCT	CRI	Power Factor
SSL (08-03)	95-105 lm (41-46 lm/W)	3	81	31	3127	92	0.55
SSL (08-25)	230 lm (57 lm/W)	5	194	39	3418	86	0.33
INC 25 W (08-47)	210 lm (8.4 lm/W)	24	181	8	2551	99	1
INC 40W (08-48)	390 lm (9.8 lm/W)	39	387	10	2610	99	1
INC 60 W (08-49)	780 lm (13 lm/W)	61	739	12	2703	100	1



# SSL Task Lamp Performance

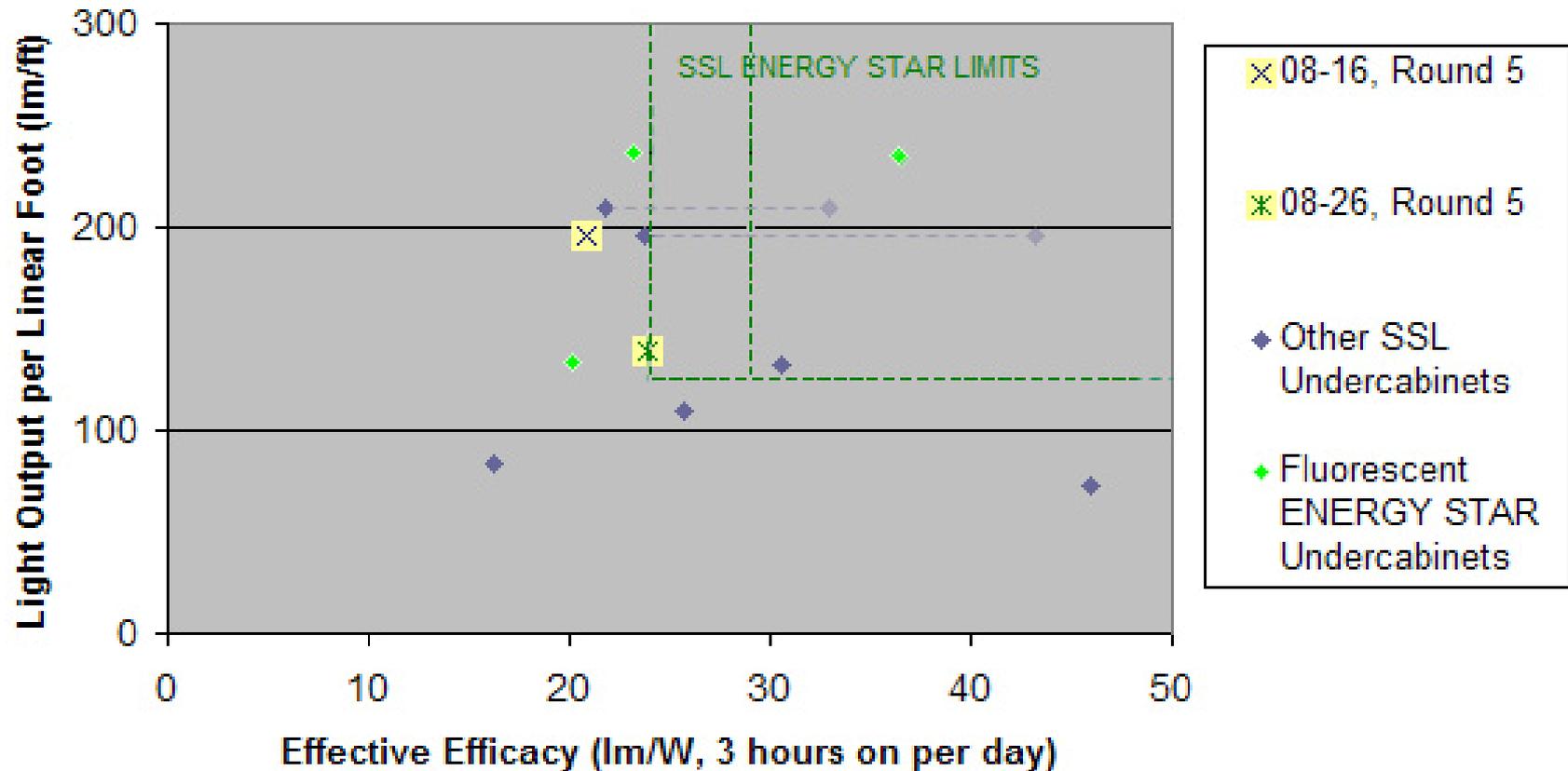
- Task lamps tested to date
  - 8 SSL undercabinets, 13 SSL desk lamps
  - 3 fluorescent tube undercabinets, 2 CFL desk lamps
  - 1 halogen desk lamp
- SSL undercabinets
  - ↑ Perform as well or better than the benchmark fluorescent undercabinets in output and efficacy
  - ↓ But, two SSL undercabinet luminaires draw off-state power
  - ↓ Light distribution is typically too narrow
- SSL desk lamps
  - ↑ One SSL desk lamp rivals CFL energy star desk lamp
  - ↓ Off-state power use ranges from 0 W to 2.6 W, reducing efficacy
  - ↓ Majority have poor power factor

# SSL Desk Lamp Performance



# SSL Undercabinet Performance

Figure 6. Undercabinet Performance Based on Effective Efficacy



# Desk Lamp Direct Comparisons

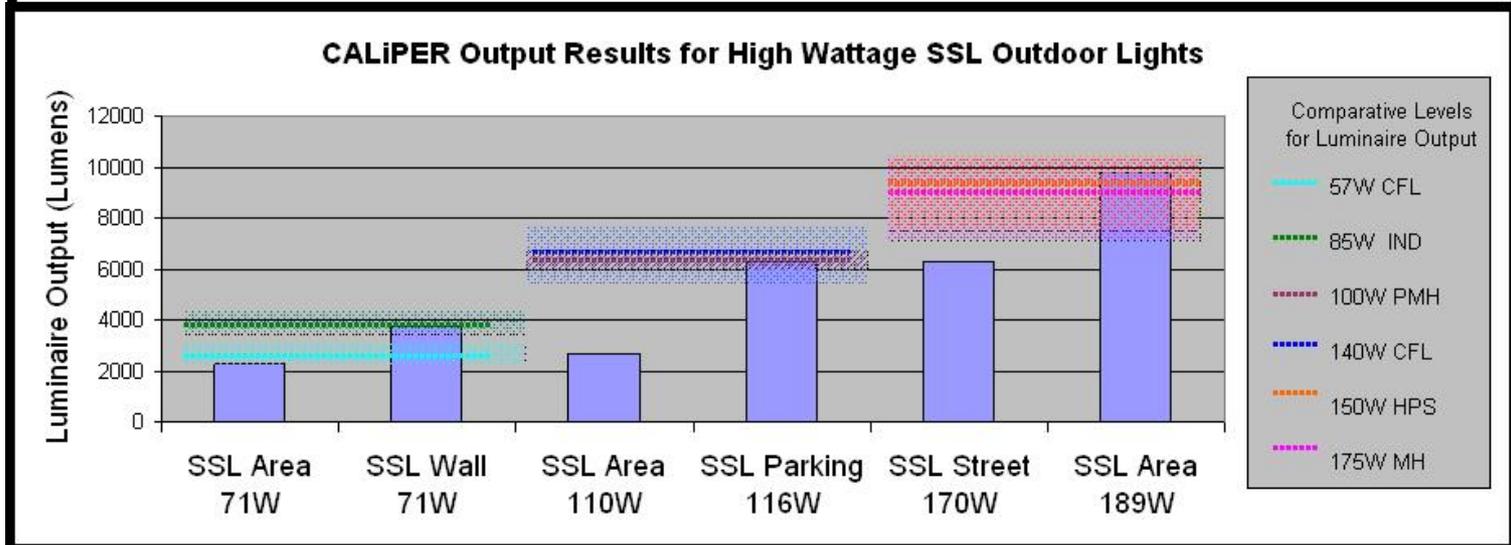
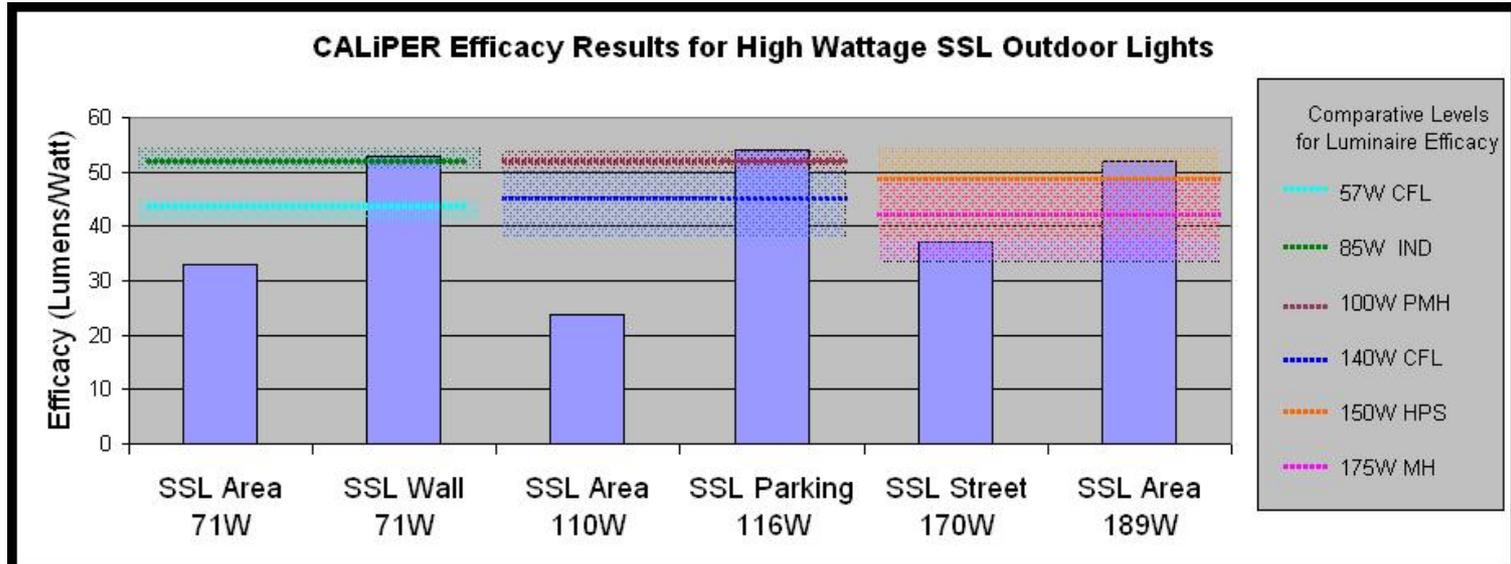
Same desk/task light, two different sources

Example Luminaire 1	CFL	LED
Luminaire Output (lm)	236	226
Luminaire Efficacy (lm/W)	24.2	18.4
CCT	3432	5939
CRI	79	74
Power Factor	0.54	0.92

Example Luminaire 2	Halogen	LED
Luminaire Output (lm)	351	157
Luminaire Efficacy (lm/W)	9.2	12
CCT	2856	3204
CRI	99.5	74
Power Factor	1.0	0.79



# Outdoor Luminaires



# Round 4 Direct Comparisons

Same Recessed Wall Fixture, Different Sources

Measured Values					
Recessed Wall Fixture	Luminaire Output (lm)	Luminaire Efficacy (lm/W)	CCT	CRI	Power Factor
Halogen (20W)	174	8	3085	98	0.99
CFL (13W)	199	16	3956	77	0.97
LED (12W)	154	10	5166	73	0.97

Manufacturer Published Values			
Recessed Wall Fixture	Manufacturer Brochure Output "Lumens"	Efficacy Calculated from Manufacturer IES files (lumens/W)	CALiPER Measured Luminaire Efficacy (lumens/W)
Halogen (20W)	350	8	8
CFL (13W)	900	19	16
LED (12W)	195	5	10

# Round 5 Direct Comparison

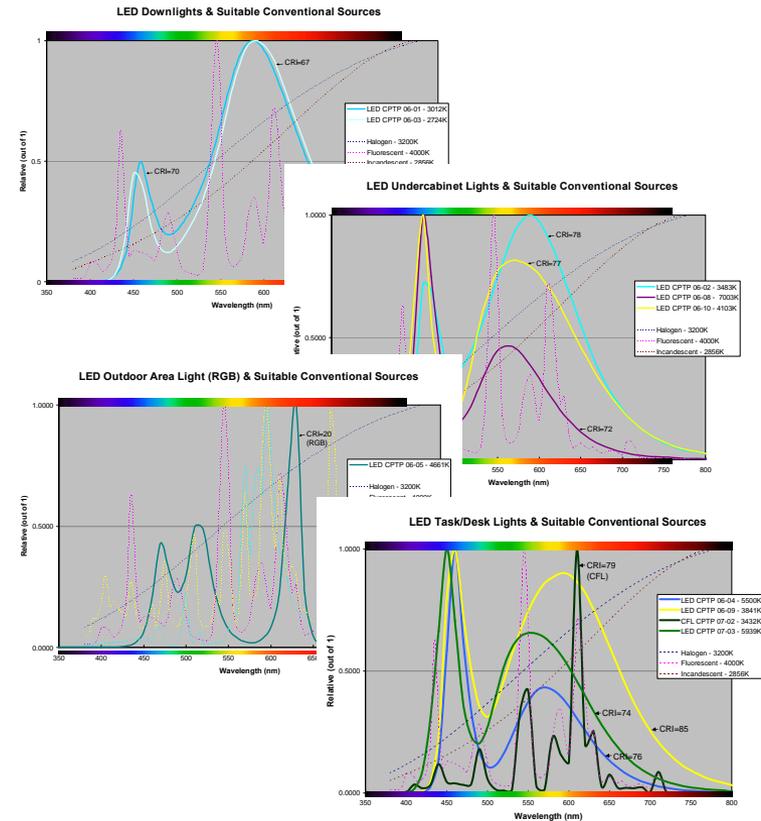
Manufacturer performance claim:  
*“The LED 16 is comparable to our MR-16”*

Same Landscape Light, Different Sources		
	Halogen (22.2W)	LED (10.4W)
Luminaire Output (lm)	185	90
Luminaire Efficacy (lm/W)	8.3	8.6
CCT	2873	6469
CRI	97	78
Power Factor	0.98	0.74
CBCP (at 0°)	1047	1989
Beam Angle	14 °	11.5°

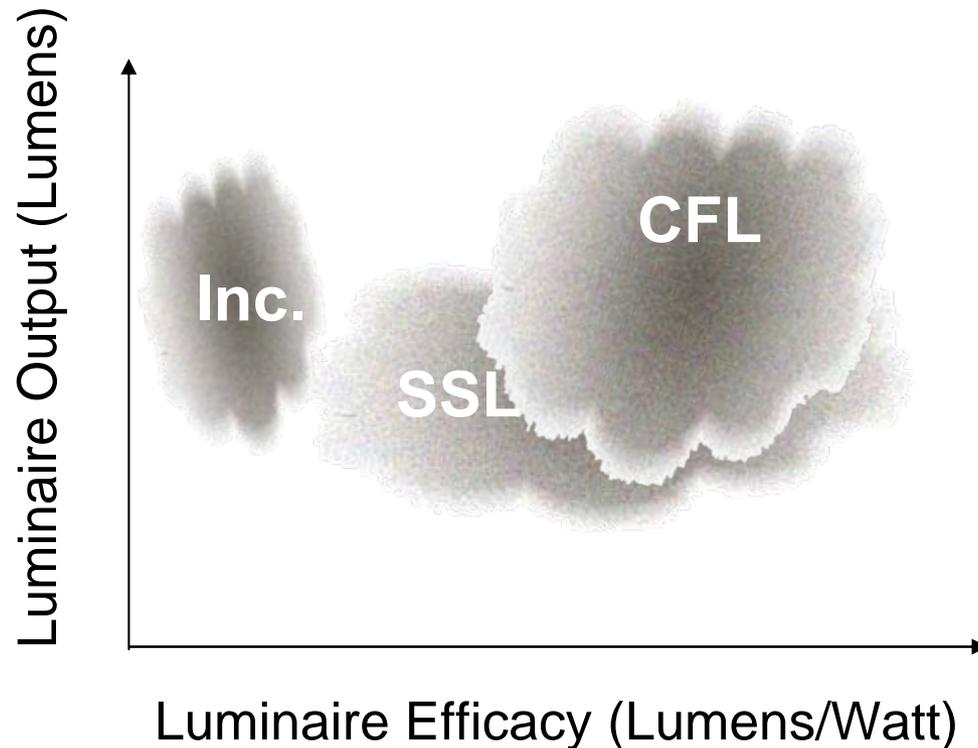


# Round 1-5 Results: Color Qualities

- Range of color qualities
  - CCT range: 2600 K to 36000 K
  - Phosphor-conversion LEDs
  - CRI range: 51-95
  - Three RGB luminaires tested



# Energy Use and Light Output



## General Observations

- Luminaire Outputs: comparable for some products/some applications
  - Undercabinets
  - Desk/Task
  - Downlights
  - Outdoor
- Luminaire Efficacies
  - SSL surpasses incandescent
  - SSL  $\rightarrow$   $\frac{1}{2}$  CFL to surpassing CFL
- Caution:
  - Wide differences  $\rightarrow$  DO NOT generalize
  - SSL evolving
  - More benchmarking
  - Continue testing

# CALiPER Rounds 1-5 Range of SSL Performance Results

- Tests include a wide range of products
- Results show a very wide range of performance

	<i>from</i>		<i>to</i>
Power	0.6 W	↔	189 W
Output	10 lm	↔	6272 lm
Efficacy	4 lm/W	↔	62 lm/W
CCT	2600	↔	>7000
CRI	<50	↔	95



Be careful not to generalize!

# For SSL, 'Can' ≠ 'Does'

- Some products do
  - Perform very well
  - Meet manufacturer specifications
  - Beat other, existing technologies
- Most products on the market today don't
  - Perform as well as LED technology can
  - Meet manufacturer claims
  - Beat existing alternatives

When designed correctly, SSL products are now capable of rivaling traditional sources

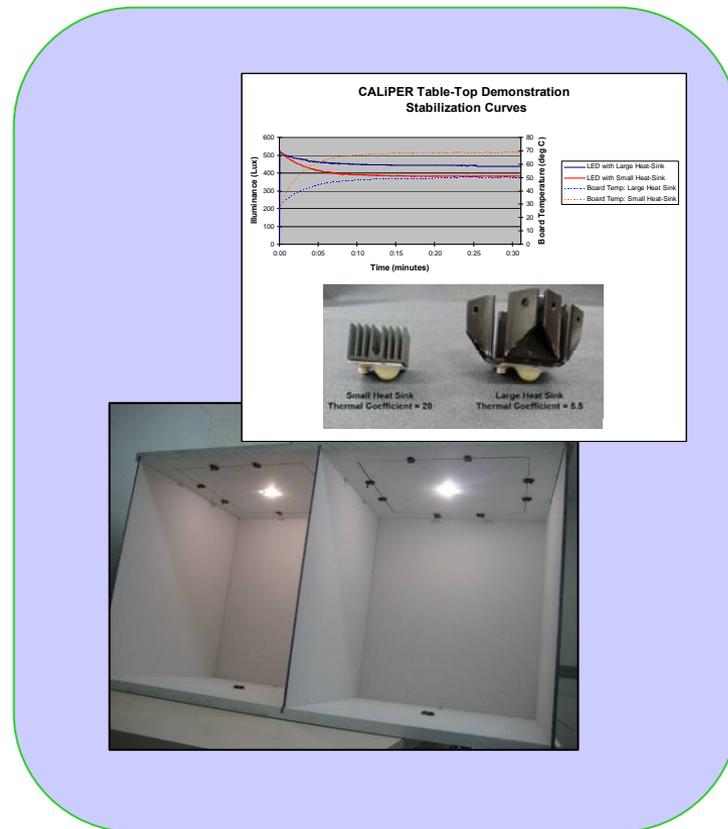


Be careful not to generalize about products  
Request luminaire testing results  
Be informed buyers



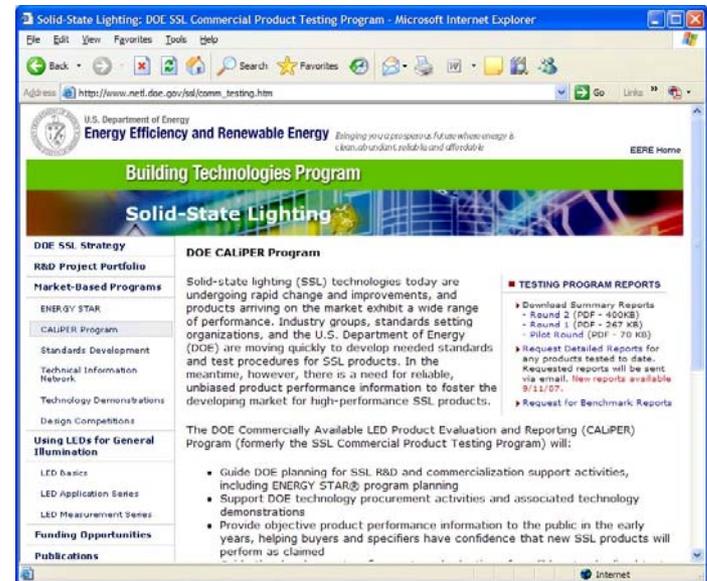
# CALiPER Positive Influences

- Testing standards validation & refinement
  - CALiPER Roundtable interactive meeting of experts (proceedings on-line)
  - Benchmarking traditional sources
- Market/industry awareness & involvement
  - Improvements in SSL product literature
  - Articles and discussions
  - CALiPER Booth
- Preparation for ENERGY STAR



# More Info on CALiPER

- Via website
  - Summary reports
    - Performance, comparisons
    - Variability and Repeatability
    - Lumen Depreciation
  - Detailed reports
    - New search and download function
    - Must agree to adhere to 'No Commercial Use Policy'



[http://www.netl.doe.gov/ssl/comm\\_testing.htm](http://www.netl.doe.gov/ssl/comm_testing.htm)



# Be an Informed Buyer

- Bottom-line: understand and request SSL luminaire testing
- ENERGY STAR<sup>®</sup> for SSL is coming shortly
  - Effective date set for September 30, 2008
  - Products tested for:
    - Total luminous flux (light output) of luminaire
    - Luminaire efficacy
    - Correlated Color Temperature
    - Color Rendering Index
    - Intensity distributions
    - Steady State Module/Array Temperature
    - Maximum Power Supply Case/TMP Temperature

# No Commercial Use Policy

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Energy Efficiency and Renewable Energy

**Thank You!**

**We hope you enjoy the workshop!**