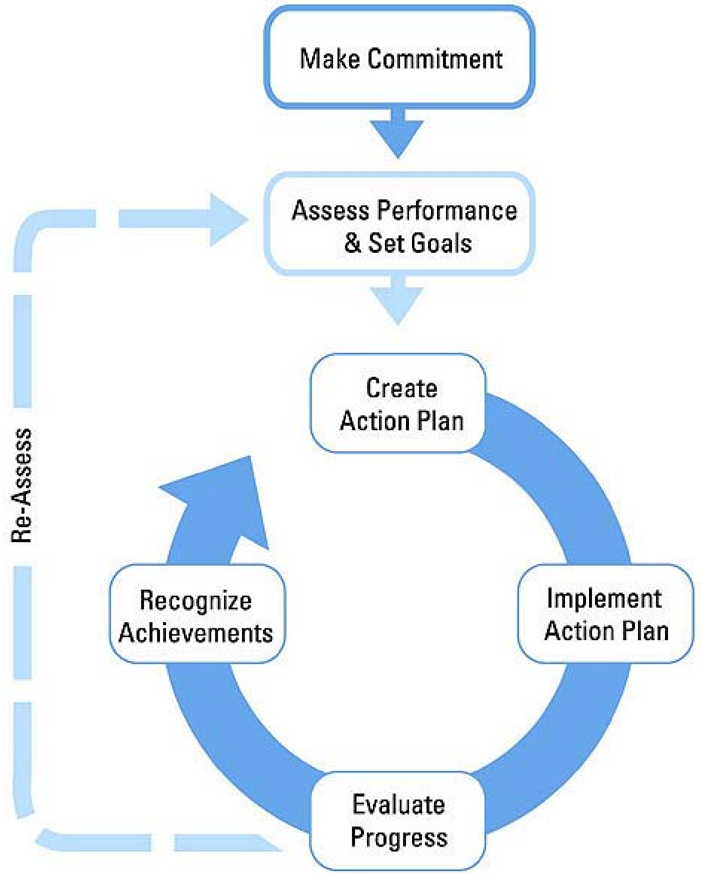
Lighting Technologies & Strategies

Web Conference
March 15, 2006

About The Web Conferences

- **Monthly**
- **Topics are structured on a strategic approach to energy management**
- **Opportunity to share ideas with others**
- **Slides are a starting point for discussion**
- **Open & interactive**



Web Conference Tips

- Mute phone when listening! Improves sound quality for everyone.

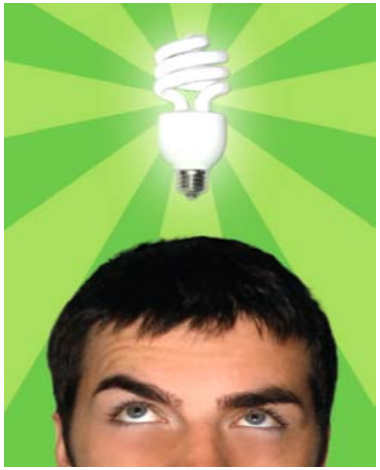
  Use * 6 – to mute and # 6 to un-mute

- Hold & Music – If your phone system has music-on-hold, please don't put the web conference on hold!

- Presentation slides will be sent by email to all participants following the web conference.

Today's Web Conference

- Dan Frering – Lighting Research Center at Rensselaer
- Brad Reed – Toyota Motor Manufacturing North America
- Questions & Discussion
- Announcements



ENERGY STAR

Energy-Efficient Lighting Technology Update

Lighting Research Center
Rensselaer Polytechnic Institute

Lighting Research Center

30,000 ft^2 of research space near campus, Rensselaer Polytechnic Institute

NVLAP-accredited testing laboratory

Research and education = $4-6 million/year

Agenda

- Super T8s
- T5 vs. T8
- Pulse Start Metal Halide
- MH vs. Fluorescent in High Bay
- Lighting Controls
- Load Management
- LEDs
- Energy Policy Act 2005

Are Super T-8s super?

- Another name: High Performance T-8s
- There are no standards that describe what a "super" T-8 is
- Each manufacturer defines the product differently

Standard vs. High Performance T8

	CEE HP T8*	Standard T8
Mean system efficacy (MLPW)	> 90	85-92
Color rendering index	> 81	75-82
Min. initial lamp lumens	> 3100	2800-2900
Lamp life (hrs)	> 24,000	20,000
Lumen maintenance	> 94%	90%-92%

* = Consortium for Energy Efficiency, High Performance T8 Specifications

http://www.cee1.org/com/com-lt/com-lt-specs.pdf

Where do I use Super T8s?

- Retrofit
  - One-for-one replacement of existing lamps
    - Increases work surface illuminance
  - Replace lamp and ballast with Super T8 and low ballast factor ballast
    - Maintain work surface illuminance and reduce energy requirements by 14%
  - Redesign lighting system, reduce number of fixtures
    - Maintain work surface illuminance and reduce energy requirements by 16%

Where do I use Super T8s?

- New construction/remodeling
  - Design lighting system with Super T8
    - Use less fixtures and less energy, assuming necessary fixture spacing can be achieved (lower first cost and operating cost)
  - Design lighting system with Super T8 and low ballast factor ballast
    - Use same number of light fixtures; energy needs are reduced by 14% (lower operating cost)

Reduced Wattage T-8 Options

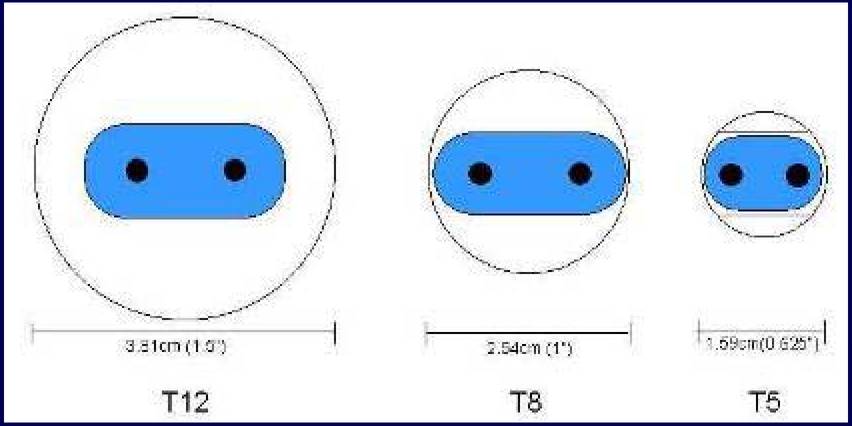
Description	Watts	CCT K	CRI	Initial Lumens	Mean Lumens	Rated Life*
Standard T8 - 800 series Lamps	32	3000 3500 4100	86	2,950	2,800	20,000
Super T8 Lamps	32	3000 3500 4100	86	3,100	2,950	30,000
Energy Saving Lamps	25	3000 3500 4100	85	2,400	2,280	25,000 (12-hr. Start)
Energy Saving Lamps	30	3000 3500 4100	86	2,900	2,750	20,000
Energy Saving Lamps	28	3000 3500 4100	82	2,725	2,560	18,000

T5 vs. T8

- Which is more efficient?

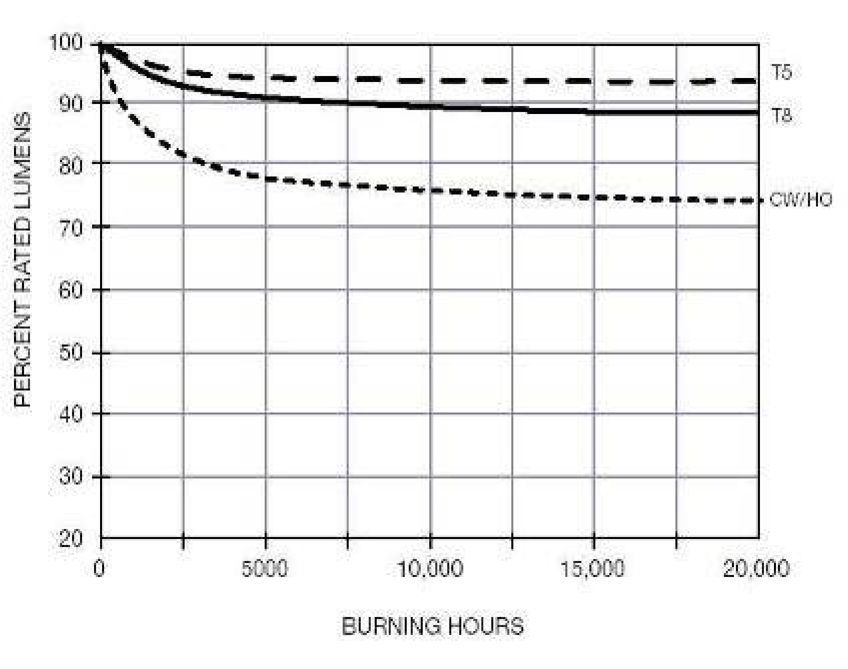
What is a T5?

- The “T” represents lamp shape–tubular.
- The number following represents lamp diameter in eighths of an inch. A T5 has a diameter of 5/8”.
- A T5 has a miniature bi-pin base while T8 and T12 lamps use medium bi-pin bases.



T5 lumen maintenance vs. T8?

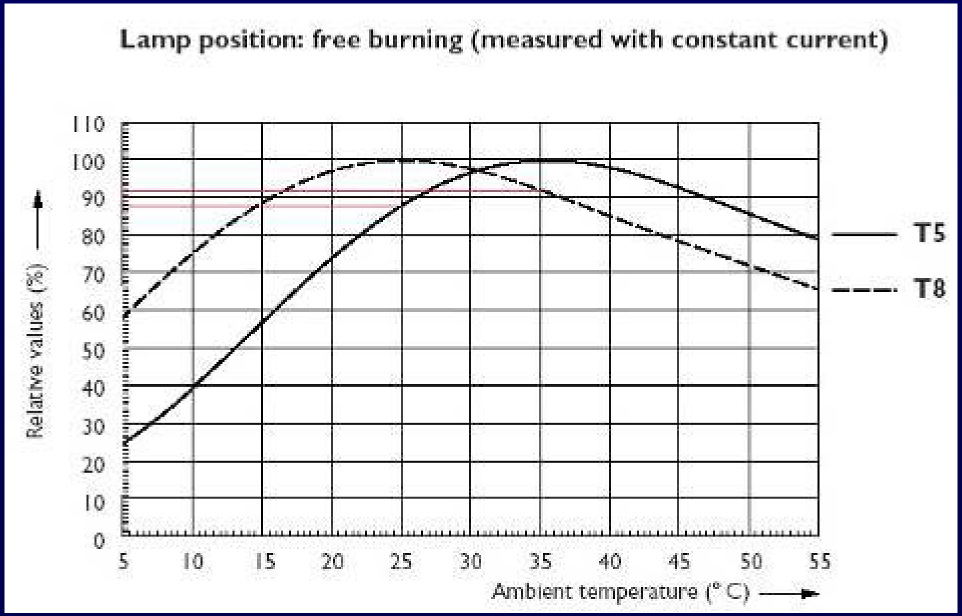
- Both T5 and T5HO lamps keep a better lumen maintenance level than T12 and most T8 lamps.
- They are claimed to retain 95% of light output at 8,000 burning hours (40% of rated average life).
- An improved phosphor coating reduces mercury absorption, leading to a higher lumen maintenance value.



(Online catalog of Philips Lighting)

Do T5 lamps provide more light than standard T8 lamps?

- Ambient temperature significantly affects light output
- T5s rated @35°C
- Ballast loss is another factor
  - The maximum system efficacy at the optimal temperature for each lamp-ballast system (T5 and T8) appears to be nearly identical on average



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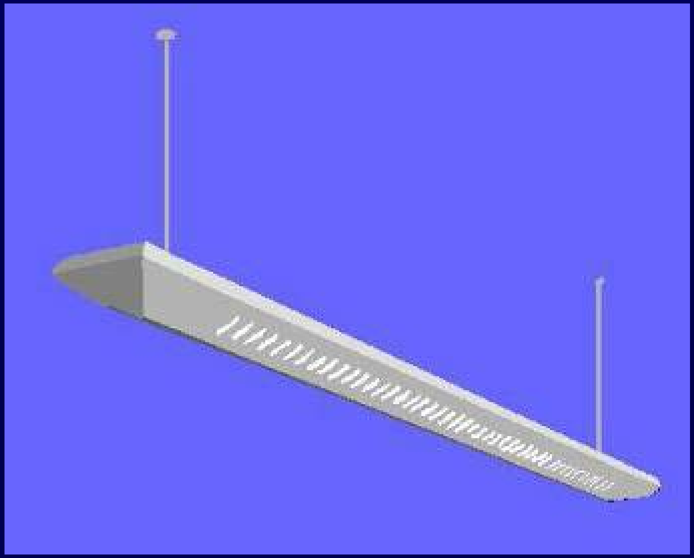
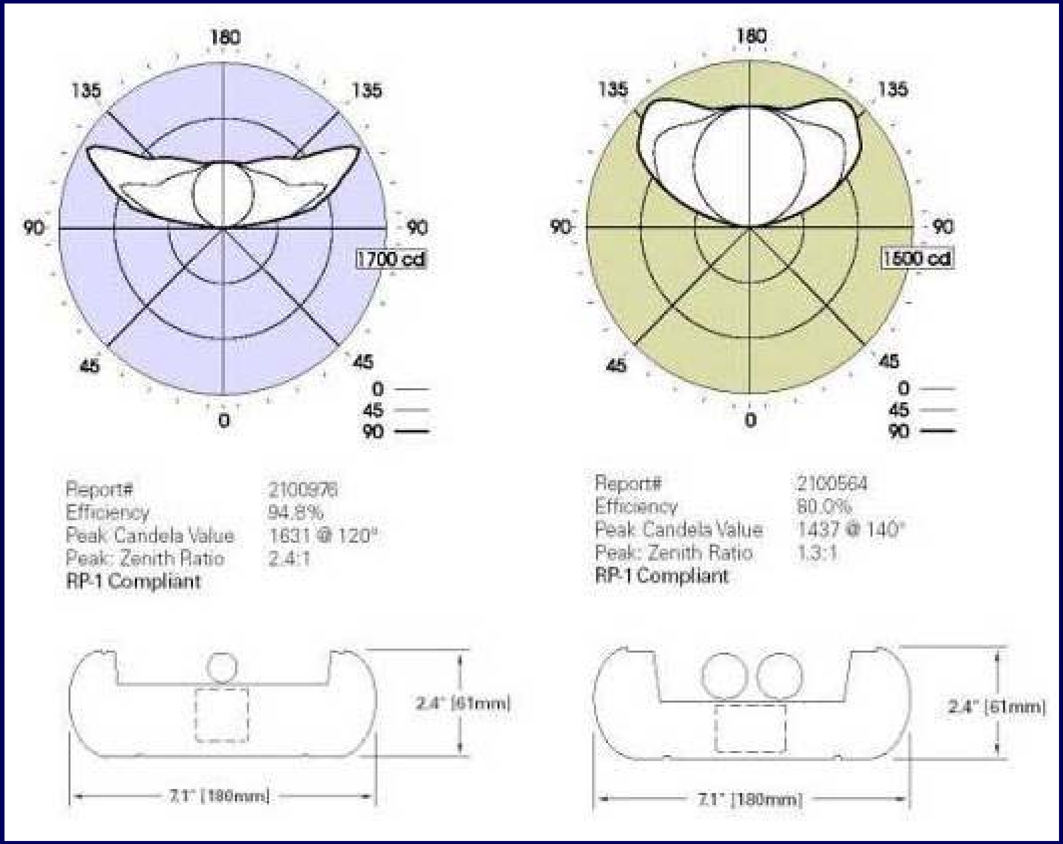
T5 vs. T8

- Catalog data

Lamp type	Lamp efficacy					Lamp-ballast system efficacy							
	Initial lumen (lm)		Watt	Efficacy (lm/W)		Manufacturer A				Manufacturer B			
	25°C	35°C	(W)	25°C	35°C	Input (W)	BF	25°C lm/W	35°C lm/W	Input (W)	BF	25°C lm/W	35°C lm/W
F28T5	2,610	2,900	28	**93**	**104**	63	0.90	75	**83**	62	1.00	84	**94**
F54T5HO	4,400	5,000	54	**81**	**93**	117	1.00	75	**85**	117	1.00	75	**85**
F32T8	2,950	2,714	32	**92**	**85**	59	0.88	**88**	81	59	0.90	**90**	83

Optical Efficiency:
1-lamp T5HO vs. 2-lamp T8





(a) 1-T5HO

(b) 2-T8

T5 Lamps: Conclusions

- Where should T5s be used?

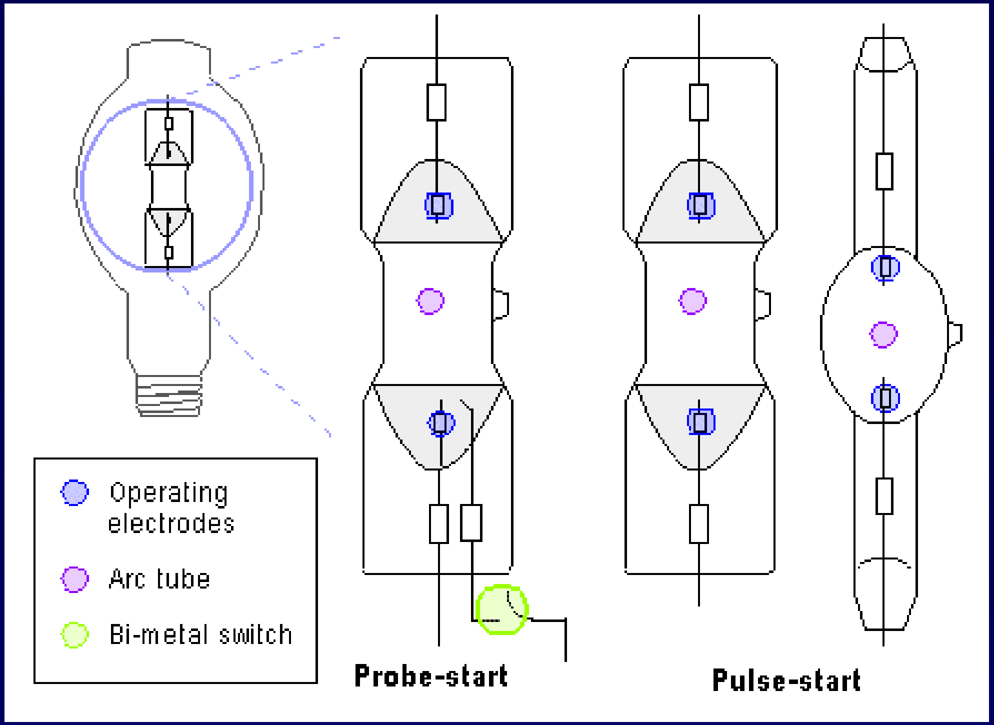
Requirements	T5HO	T5	T8
Higher-end design			
Higher uniformity			
Lower initial cost	Large	<=Project=>	Small
Lower running cost	Similar system efficacy		
Smaller # of luminaires			
Lower ceiling height			

Pulse Start Metal Halide

- Range of wattage - 50 to 450 W
- Lamp efficacy of 60-100 lm/W
- Color rendering index 65 – 75 or better
- Formats available ED17, 28 & 37

Probe-start vs. Pulse-start

- Pulse-start
  - –Faster warm-up and restrike
  - –Improved efficacy
  - –Longer lamp life (up to 50%)
  - –Improved lumen maintenance (33%)
  - –Improved color stability over life



http://www.lrc.rpi.edu/programs/nlpip/publicationDetails.asp?id=882&type=2

HID vs. Fluorescent for High Bay Applications

- Which works better?

Why use fluorescent lighting?

- Uses 10%-20% less energy
- Can be dimmed, switched
- Can be controlled by motion sensor
- Linear source, good for lighting vertical surfaces
- Longer life (24,000 hours)
- Better/more consistent color
- If using fluorescent lighting in high bay applications, ensure fixture optics are suited for this purpose

Why use metal halide?

- Fewer fixtures to install (lower initial cost)
- Fewer lamps to stock and change
- Bi-level operation
- Newer metal halide lamps provide
  - Better color rendering than older technology
  - Higher maintained lumens per watt (pulse start) than older technology

Automatic Shut-off Lighting Controls

- Time clocks
- Occupancy sensors
- Panel relays
- Centralized controls

- These work, but implementation depends on wiring, installation, commissioning, etc.

Motion/Occupancy Sensor Technology Issues

- Three technology types
  - Infrared
  - Ultrasonic
  - Dual technology
- All are mature technologies
- Excellent payback potential
- Work well with proper selection and positioning

Motion Sensor Economics

- How much energy do occupancy sensors save?

	Owned Space	Shared Space
Sporadic Use:	25%	40%
Scheduled Use:		30%

- However, savings for a specific space may vary from these mean numbers.

Photosensor Technology Issues

- Analog design of control algorithm makes it difficult to accurately adjust the photosensor during commissioning
- Lack of manual controls to adjust photosensor to individual preferences
- Minimal integration with other lighting controls, i.e., occupancy sensors

- Can save 20 to 40% of lighting energy if installed and commissioned properly

Fluorescent Lamps Weren't Designed for Dimming

- What compatibility issues exist to allow fluorescent lamps and dimming ballasts to work together without degradation to lamp life?

Daylighting Controls: Making Them Work

- Daylighting controls require:
  - Proper selection of the correct controller for the design situation
  - Proper location of the controls
  - Proper adjustment to ensure correct operation

See "Daylight Dividends Program"

http://www.lrc.rpi.edu/programs/daylighting/index.asp

Lighting and Load Management

- Position: Lighting is an ideal electric end use for load management
  - Available in virtually every building
  - Easy to control
  - Easy to measure the results
  - The load reduced is repeatable
  - Can reduce the amount of lighting rather than turn it off, thereby preserving productivity

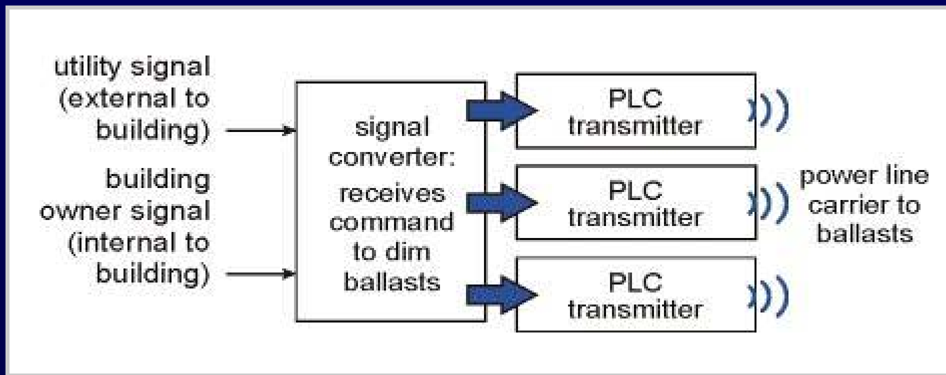
Panel level lighting reducers

- Installed on entire lighting circuits
- Can be used on fluorescent or HID lighting
- Reduces voltage to the ballasts
- Reduce power by 25%
- Cannot be used with self regulating ballasts

See NLPIP publication, Lighting Circuit Power Reducers:

http://www.lrc.rpi.edu/programs/nlpip/publicationDetails.asp?id=218&type=1

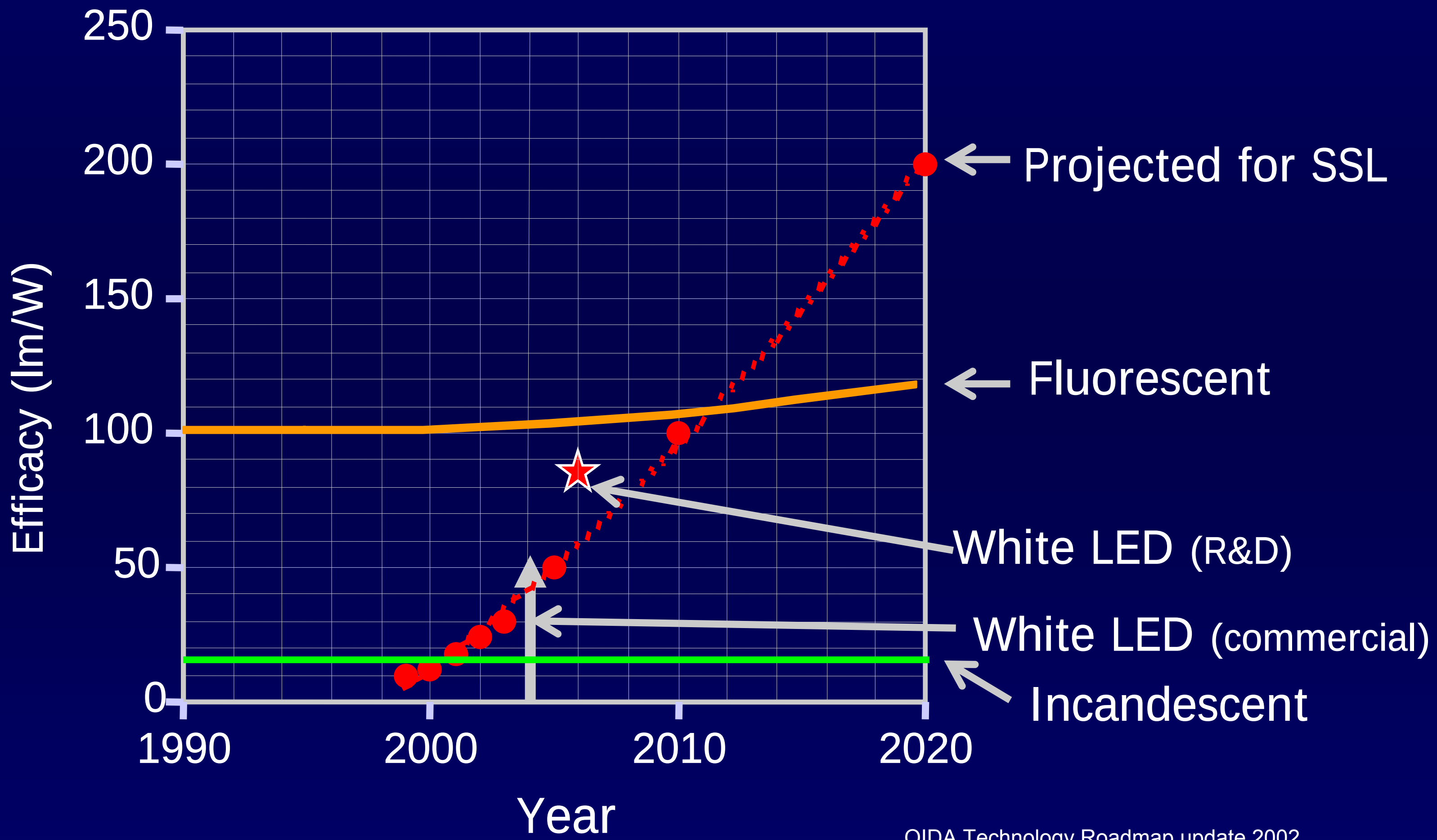
Load-shedding ballast system



Sponsors: CL&P, CEC, NYSERDA

Manufacturing Partners: OSI, Intech 21

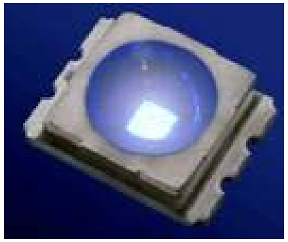
Efficacy & projected efficacy of LEDs



OIDA Technology Roadmap update 2002

LED products: High-power

- All major manufacturers now have at least a 1-W LED version



©Cree – XLamp

umileds – Luxeon

©Nichia – Jupiter

©OSRAM Opto – Dragon

©L	Flux per device (lm)	Efficacy (lm/W)
Cree (Xlamp)	60	34
Lumileds	20 - 120	17 - 30
Nichia	32 - 42	24 - 31
OSRAM Opto	28 - 120	21

See manufacturers' data sheets for exact values

LEDs for general illumination?

• Incandescent	25 l/w
• White LEDs	20–30 l/w
• Fluorescent	90–100 l/w

White LEDs are not ready for general illumination. However, they are ready for niche use to replace incandescent.

LED products: Luminaires

- Hundreds of products at every trade show
  - Colored applications – RGB
  - General illumination – white

- Adjustable color temperature

©io Lighting ©Lumileds

©Color Kinetics

3000 K 3500 K 6500 K

Outdoor signage

- Commonly used light sources:
  - Cold cathode fluorescent
  - Neon
- LEDs are becoming a viable alternative

Chiplite

Chiplite

Retail Display Windows

- The goals of display windows
  - Capture attention
  - Visually pleasing
  - Convey a message

Retail display windows

- Goal of the experiment
  - To investigate the application of colored LEDs to retail display windows and quantify their performance
    - Attention capture
    - Visual appeal
    - Energy savings
- During the experiment, background luminance was unchanged
- Accent light was reduced in steps
  - 100%, 50%, 30%

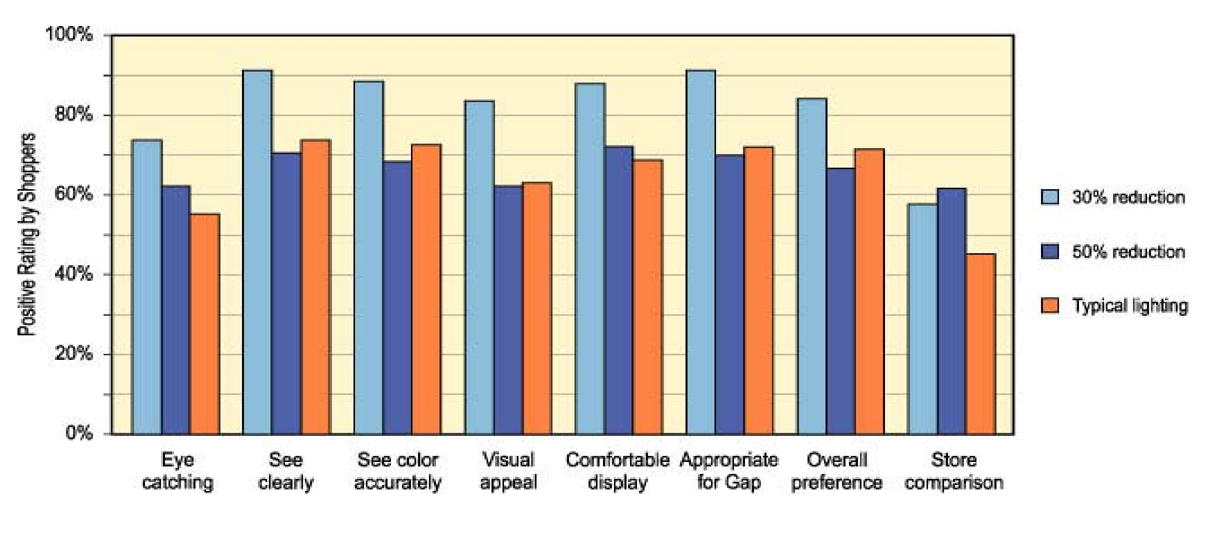
white/white

color/white

Lighting Research Center

Survey results

- Compared with the typical lighting, colored LEDs maintained or improved shoppers' opinions of the display windows.
  - Opinions significantly improved when blue LEDs were combined with a 30% power reduction
  - Blue LEDs combined with a 50% power reduction produced no significant difference in opinion



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Refrigerated display cases

- Limitations of fluorescent lighting
  - Poor lighting
    - Uneven light/heat distribution
  - Low application efficacy
  - Fragile
  - Shortened lamp life
- At cold temperatures, the light output of
  - Fluorescent lamps drop ~ 25%
  - LED light sources remain nearly constant

Refrigerated display cases

- Goal of the experiment
  - To develop an LED-based lighting system and compare it with the traditional lighting system

Total flux
2100 lm

Total flux
1200 lm

LEDs

fluorescent lamp

Summary

- LEDs are evolving very rapidly
- Currently there are many niche applications for LEDs
  - Consumer electronics
  - Automotive/transportation
  - Full color dynamic displays
  - Architectural lighting (colored and white)
- Exploiting the unique attributes of LEDs will lead to successful applications

Energy Policy Act 2005 – Tax Deductions

For buildings brought on line after January 1, 2006, the Energy Bill designated “interim rules” for lighting systems.

- Systems that are at least 40% more efficient (except in warehouses) than the requirements of ASHRAE 90.1-2001 Tables 9.3.1.1 (building area method) and 9.3.1.2 (space by space) get the full $0.60/ sf deduction.
- Systems that are 25% more efficient get $0.30 / square foot deduction (except warehouses with 50% min rule).
- Interpolate in between (30% = $0.40/sf, 35% = $0.50/sf)

http://www.energy.gov/taxbreaks.htm

http://www.cee1.org/resrc/news/06-01nl/06_epact.html

Thank you!

Additional information:

www.lrc.rpi.edu

Toyota North America Lighting Strategies

Toyota Motor Manufacturing North America

Energy Star web conference March 15, 2006
Brad Reed- Asst. Project Manager Facility Engineering

Historical Background

Toyota Motor Manufacturing North America-TMMNA

- 6 Assembly plants-NAMCs
- 3 Engine Plants
- 4 Unit plants (Casting, wheels, etc)
- Production > 1.6M vehicles/year

TMMNA Historic Lighting

- Space lighting technology
  - 400W HID
    - Energy = 458W = 400W lamp + 58W Ballast
    - High initial lumens with rapid drop
      - At EOL lumens level is 40% of new
    - ~3700 Kelvin color temperature
    - CRI 65
    - 24,000 hour life (3 production years)

- Process (task) lighting
  - 4’ and 8’ T-12 HO and VHO 3500 K lamps.
    - Energy 77/111 and 130/228 Watt/lamp.
    - Relatively high lumen loss
      - EOL lumens as low as 60% of new
    - 3500 Kelvin
    - CRI 60-80
    - 10-12,000 hour life (~2 production years)

TMMNA Lighting Improvement Φ 1

- Space Lighting
  - Replaced 400W MVR with 360W using same ballast
  - Energy reduction of 50 Watts/fixture
  - CRI and lumen depreciation unchanged
  - Color temperature may be between 3700-4000 Kelvin
- Task lighting retrofit
  - Replacement of T-12 3500K lamps with F32T8SP/SPX41standard and HO lamps
  - Energy reduction
    - 4' lamps 77/111 W ⇒ 32 W/lamp
    - 8' lamps 130/228W ⇒ 86 W/lamp
  - CRI 60-80 ⇒ 81-86
  - Color temperature 3500K ⇒ 4100K

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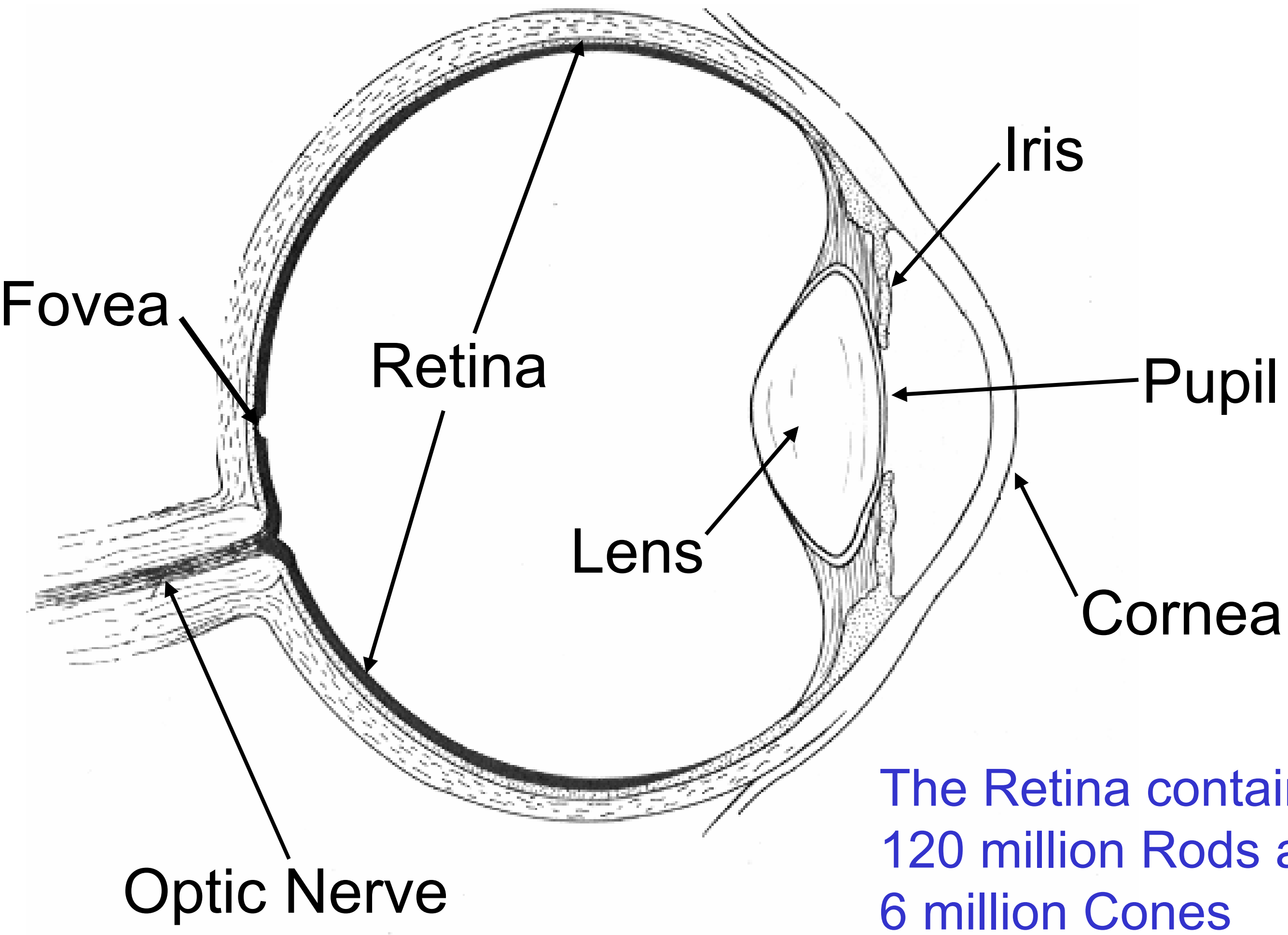
TMMNA Phase Φ 2
Lighting Improvement Goals

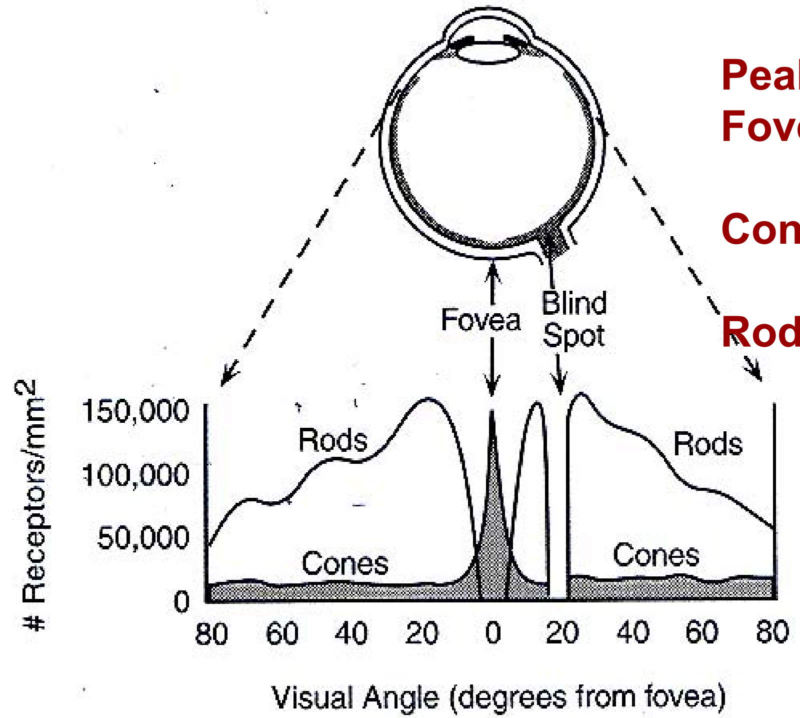
- Space Lighting
  - Reduce energy consumption
  - Improve lighting quality
  - Set standard building lighting illuminance level
    - Evaluate Scotopic/Photopic lighting concepts
    - Utilize IESNA illuminance level recommendation
      - The IESNA Lighting Handbook, Ninth Edition, Figure 10-9, page 10-13.
  - Reduce new construction cost
  - Eliminate or minimize lumen depreciation
  - Maintain or increase lamp life
- Task Lighting
  - Reduce energy consumption
  - Maintain or improve lighting conditions
    - Use the appropriate amount of light for the task
    - Evaluate Scotopic/Photopic lighting concepts
    - Utilize IESNA illuminance level recommendation
      - The IESNA Lighting Handbook, Ninth Edition, page 19-13~21
  - Improve lighting quality
  - Minimize lumen depreciation
  - Maintain or increase lamp life
  - Evaluate safety concerns over broken lamp tubes

Some Background:



The Retina contains
120 million Rods and
6 million Cones

Distribution of Rods and Cones over Retina



Note: No Rods in Fovea

As many as 100 Rods Converge On a single Optic Nerve Fiber

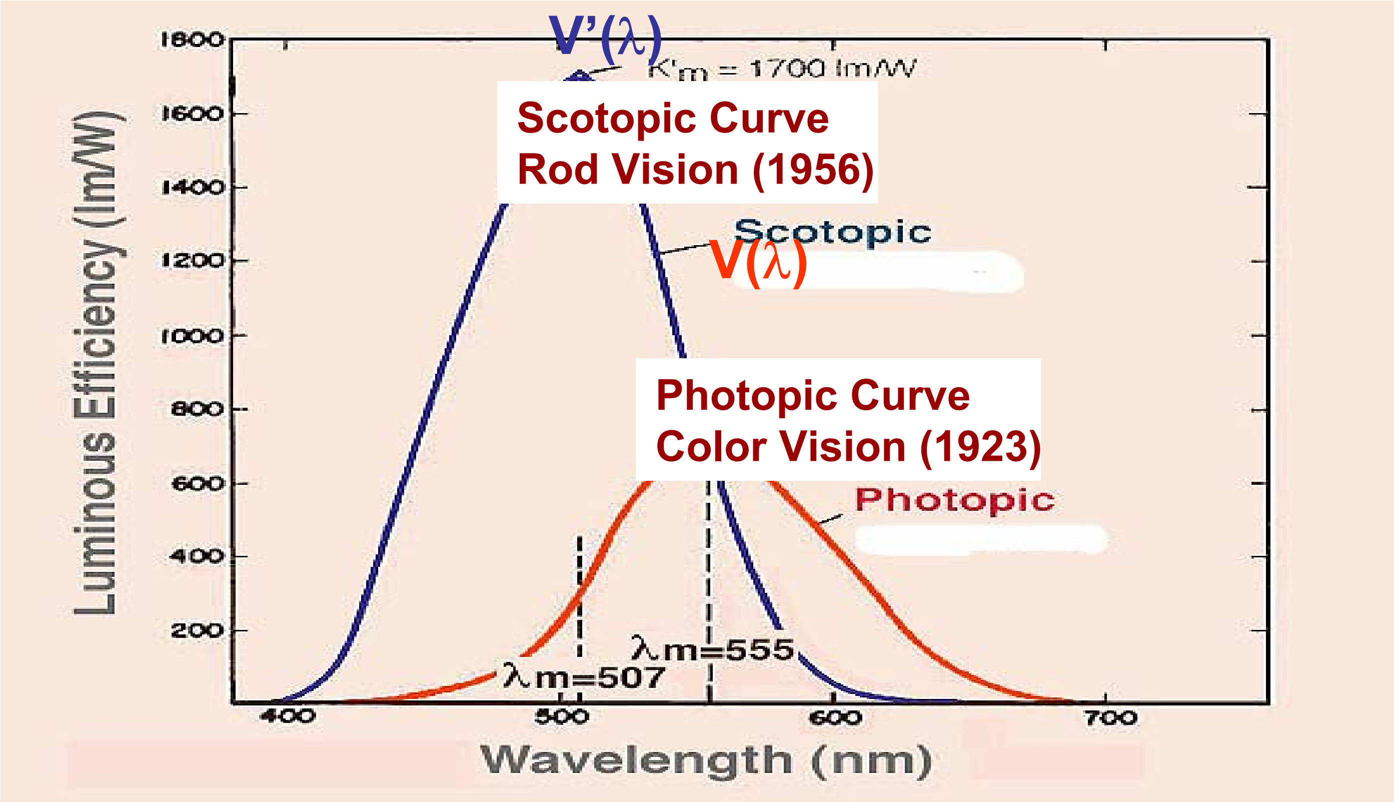
Peak Rod Density ~17 deg from Fovea

Cones see Photopically

Rods see Scotopically

Some Background:

Scotopic and Photopic Functions



Some Background:

The LUMEN, and the FOOTCANDLE, are Based on the Photopic Sensitivity Curve

The LUMEN is the only SI Unit Based on Human Response

The Photopic Sensitivity Curve is Based on the Central 2 Degrees of our Vision, and only at Light Levels that Activate our Cones!

Catalog Lumen Ratings are generated by Summing the Product of Lamp Energy at Each Wavelength of the Lamp Spectral Power Distribution (SPD) Curve times the Photopic Curve Weighting Factor and then Multiplying by a Constant.

Scotopic and Photopic Functions

Photopic Curve
Color Vision (1923)

$$V(\lambda) = 683 \sum_{360}^{800} P_\lambda V_\lambda \Delta\lambda$$

Scotopic Curve
Rod Vision (1956)

$$V'(\lambda) = 1700 \sum_{380}^{780} P_\lambda V'_\lambda \Delta\lambda$$

Where P_λ = spectral power, in watts, of the source at wavelength λ

V_λ = luminous efficiency function value at λ

$\Delta\lambda$ = interval over which values of the spectral power were measured

The SPD of the Lamp Determines the Lamp's Color Temperature, CRI, and Lumen Rating

Photopic Lumens are Based on CONE Sensitivity

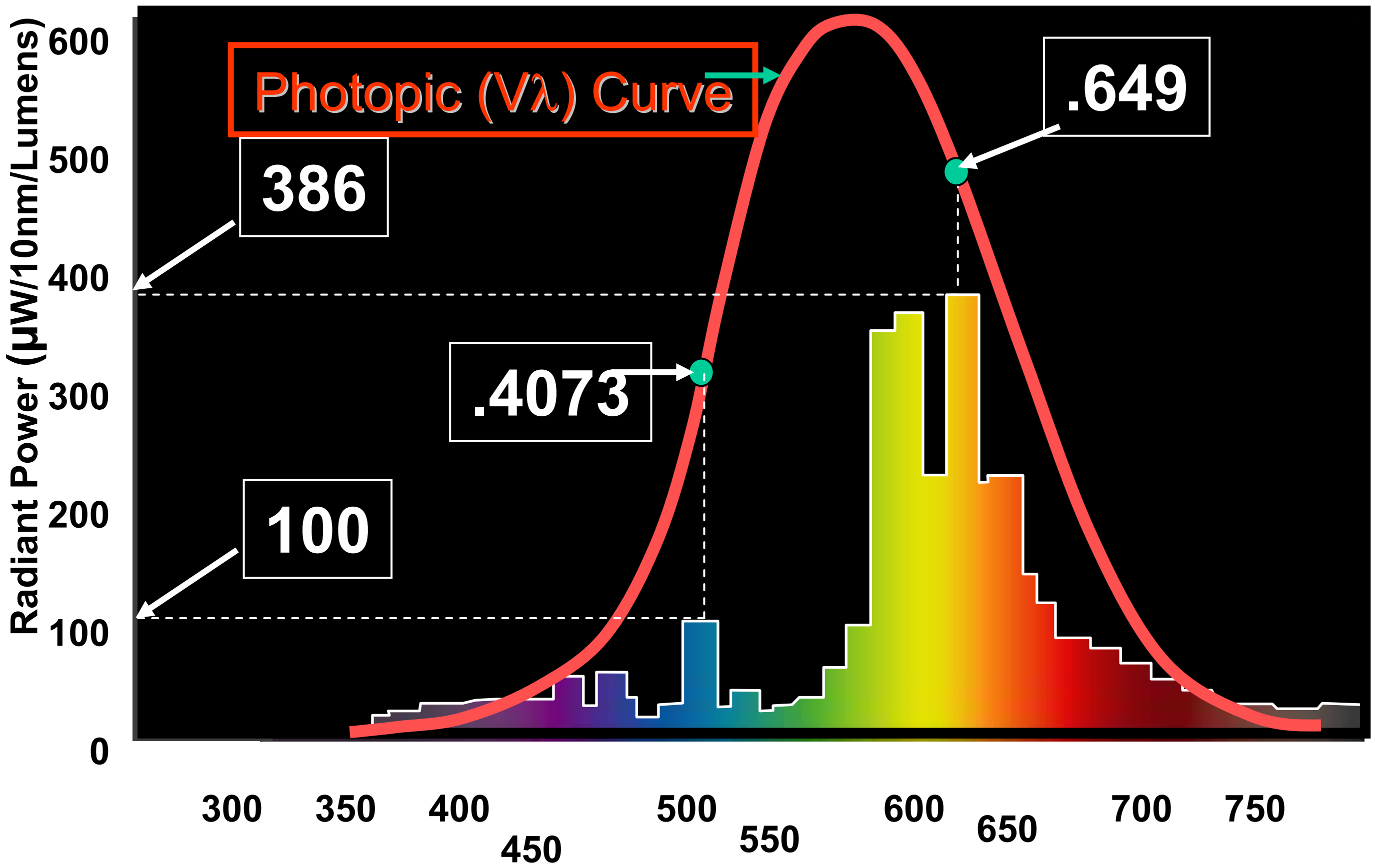
Standard lumens only measure photopic light

Scotopic Lumens are Based on ROD Sensitivity

Every Lamp will Usually have a Different Photopic and Scotopic Lumen Rating

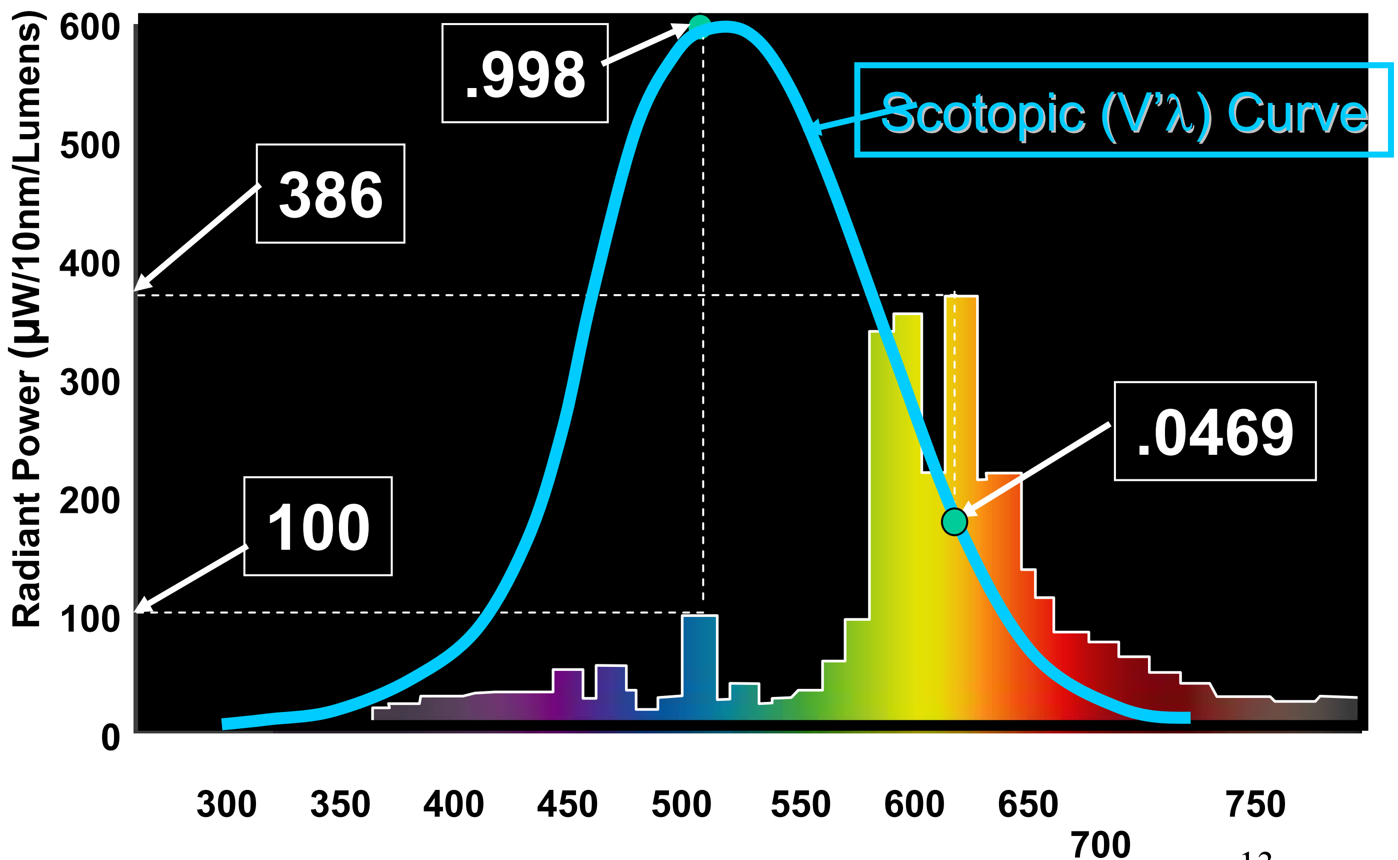
Calculating "Lumens"

***Spectral Power Distribution* - Lucalox**



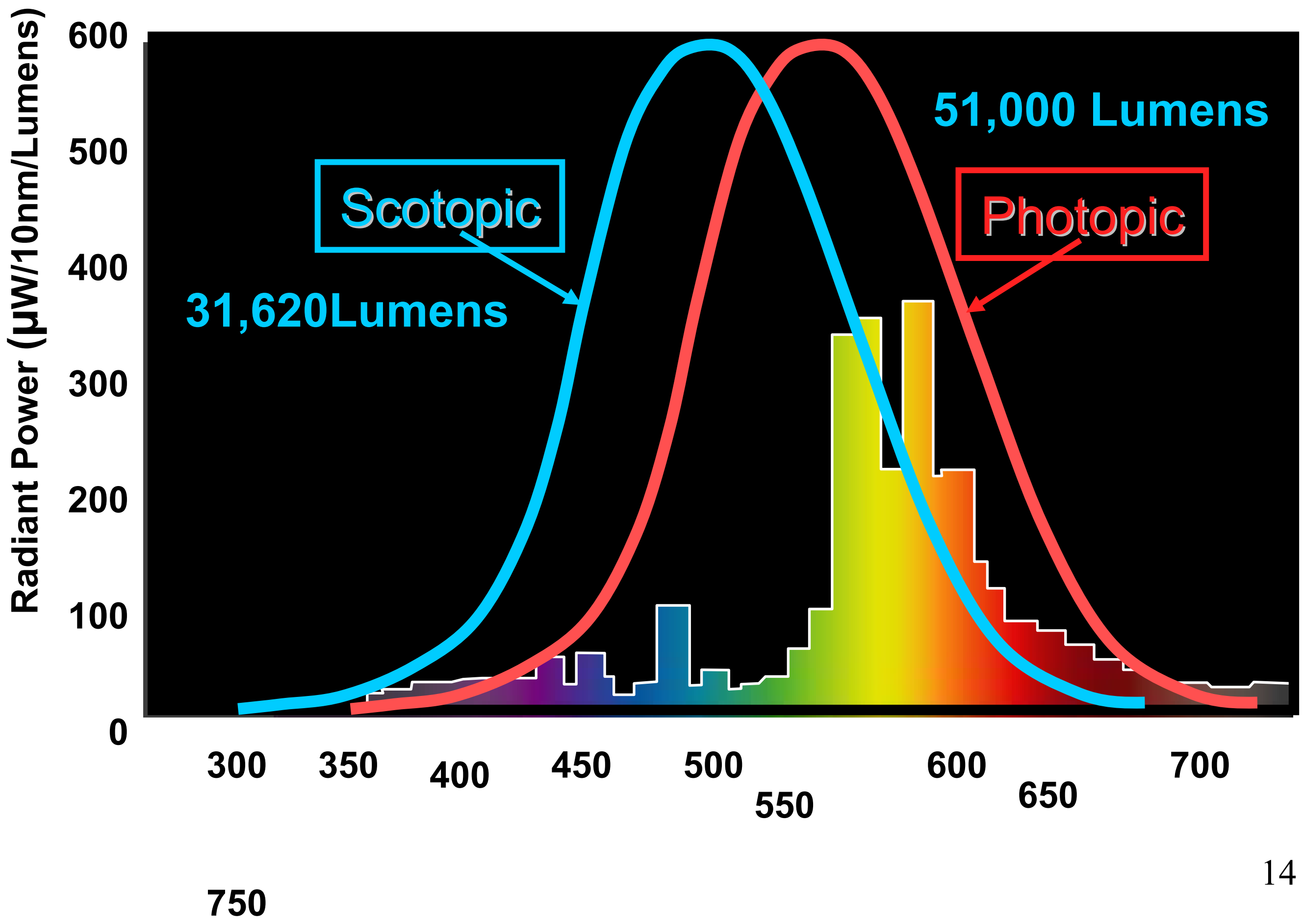
Calculating "Lumens"

Spectral Power Distribution - Lucalox



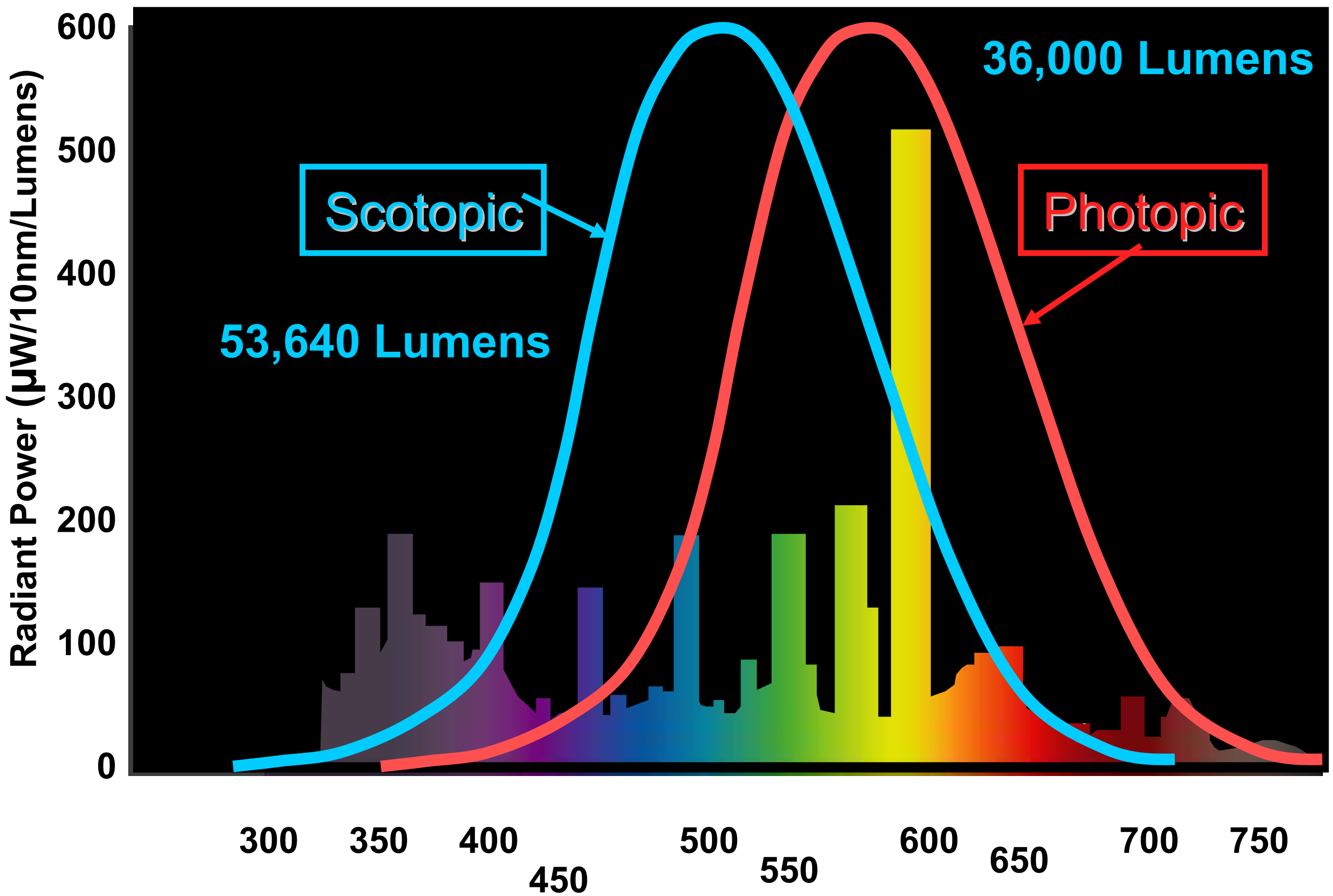
COLOR ISSUES

Spectral Power Distribution - Lucalox



COLOR ISSUES

Spectral Power Distribution - MultiVapor



Some Examples:

Lamp	Photopic Lumens	Scotopic Lumens	S/P Ratio
400 Watt Lucalox	51,000	31,620	0.62
400 Watt MultiVapor	36,000	53,640	1.49
F32T8/SPX50	2,750	5,500	2.0

The **S/P Ratio** is the Scotopic Lumens Divided by The Photopic Lumens for any Lamp

For Ease of Understanding – the Higher the S/P Ratio, The More “Bluish” the Lamp Appears

$$\text{S/P Ratio} = \frac{\text{Scotopic Lumens}}{\text{Photopic Lumens}}$$

High S/P Ratio (>1.0) Indicates More Radiant Energy in the Blue End of the Spectrum

Many Lighting Designers today say they won't use a lamp with less than 1.4 S/P ratio Indoors!

Ex: HPS - .4 MH – 1.5 SP30 – 1.3 SP35 – 1.4 SP41 – 1.6 SPX50 – 2.0 SPX65 – 2.3

Lighting Efficiency S/P Ratio Method

(Credited to Dr. Sam Berman – LBL)

- Obtain Scotopic/Photopic Ratios from lamp manufacturers.
- These ratios can be used to determine more accurate visual efficiencies for these tasks:

Std. Lumens	Ratio	Brightness Perception	Reading Paper	Computer Tasks
P	(S/P)	$P \times (S/P)^{0.5}$	$P \times (S/P)^{0.78}$	$P \times (S/P)$

- *This method is not yet recognized by IESNA*

Courtesy of Stan Walerczyk, Brian Liebel

S/P Ratio Example

Compare SP35 to SPX50 fluorescent lamps

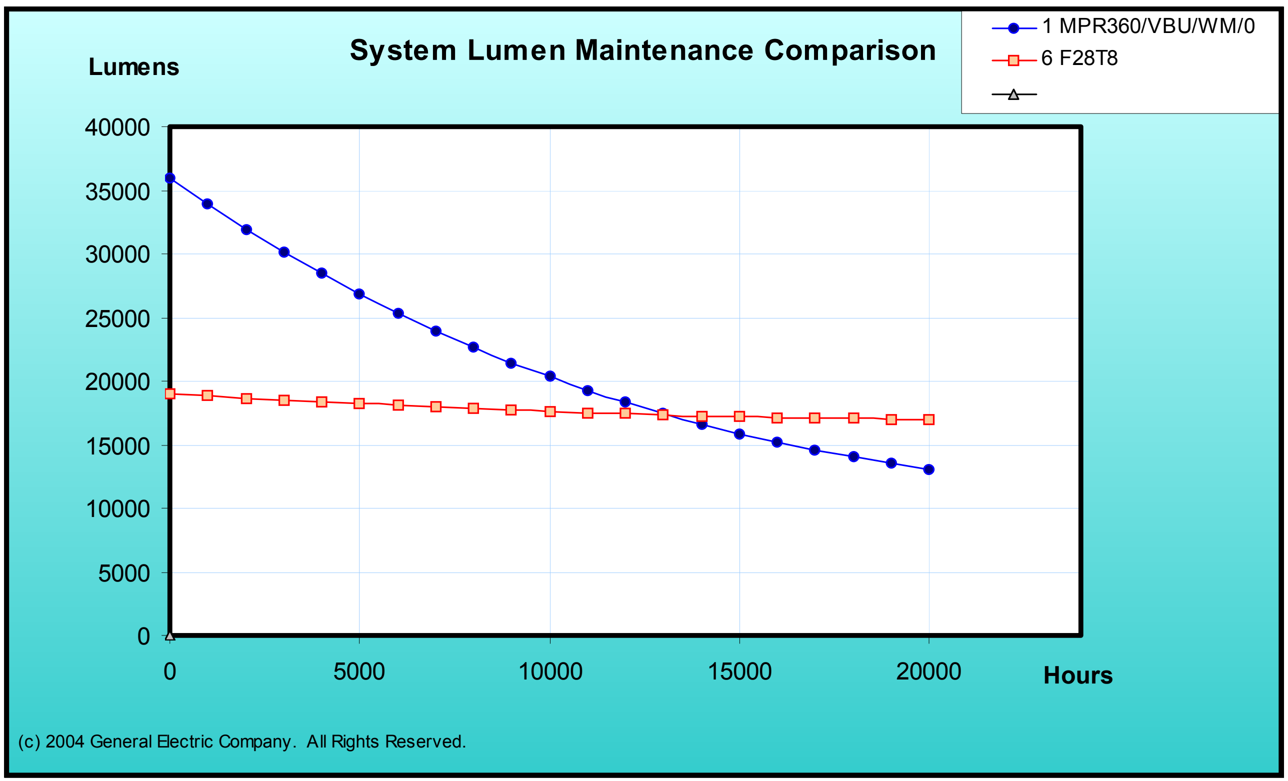
Lamp	Efficacy (P)	S/P Ratio	Brightness $P(S/P)^{0.5}$	Paper $P(S/P)^{0.78}$	Computer Tasks $P(S/P)$
SP35	89	1.39	104.9	115.1	123.7
SPX50	93	2.0	131.5	159.7	176.7
The Scotopic Benefit: *Increase in energy efficiency when considering full field visual effect*			+ 25%	+ 38%	+ 50%

This method is not yet recognized by IESNA

Courtesy of Stan Walerczyk, Brian Liebel

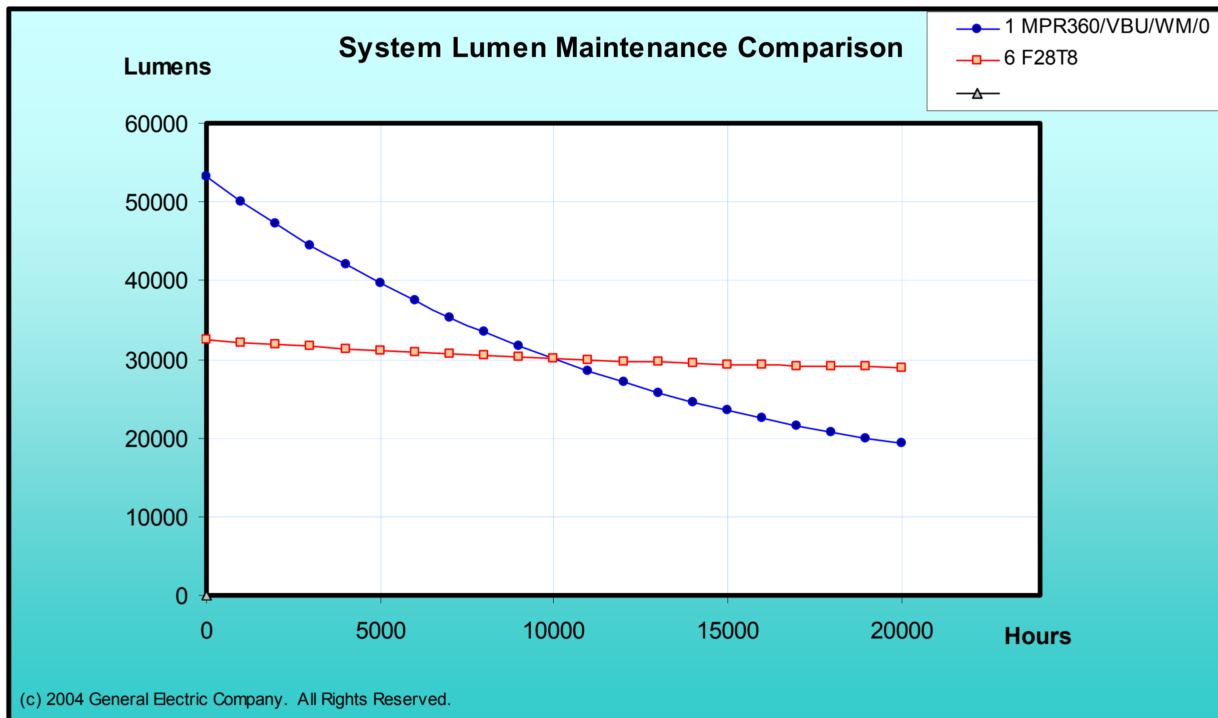
360 W MVR vs 6 lamp F28T8 Standard Lumen Comparison (The old way.)

# lamps /fixture		Lamp	Rated Initial Lumensr	Mean Lumens (%)	Life (hr.)	Brallast Factor
System 1:	**1**	**MPR360/VBU/WM/0**	**36000**	**62%**	**20,000**	**1**
System 2:	**6**	**F28T8**	**2750**	**94%**	**20,000**	**1.15**



360 W MVR vs 6 lamp F28T8 S_P Lumen Comparison (The new way)

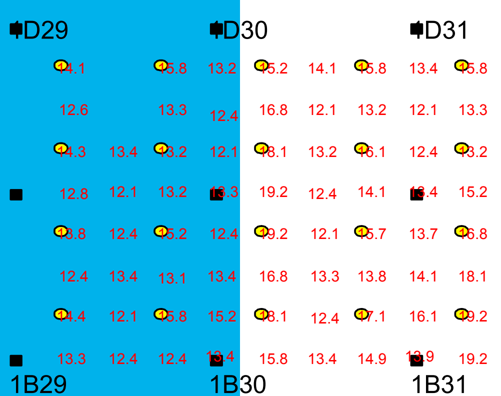
# lamps /fixture		Lamp	Rated Initial Lumensr	Mean Lumens (%)	Life (hr.)	Brallast Factor
System 1:	**1**	**MPR360/VBU/WM/0**	**53200**	**62%**	**20,000**	**1**
System 2:	**6**	**F28T8**	**4700**	**94%**	**20,000**	**1.15**



TMMI Measured Result (Standard Lumens)

Before

Area bounded by 1B29-1D31 is presently lit with 360W HID lamps using 400W ballasts.



Average lumens in area bounded by 1B29-1D31

13.8

Average photopic-scotopic lumens in area bounded by 1B29-1D31

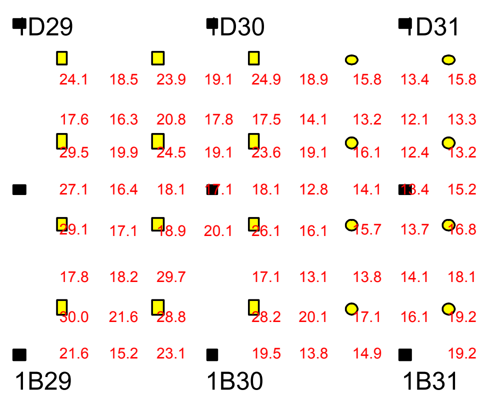
18.6

After

Install energy saving 6 lamp HIFs. Calculate energy savings and measure foot candles in the re-lamped area (1B29-1D30.5).

Calculated energy savings of 47%.

Measured light levels in relamped area greatly exceed levels in adjacent area.



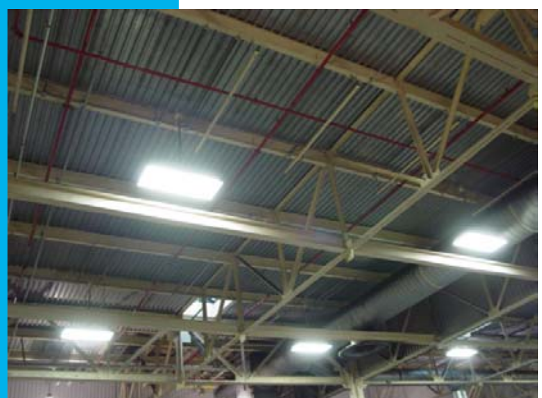
Average lumens in area bounded by 1B29-1D31

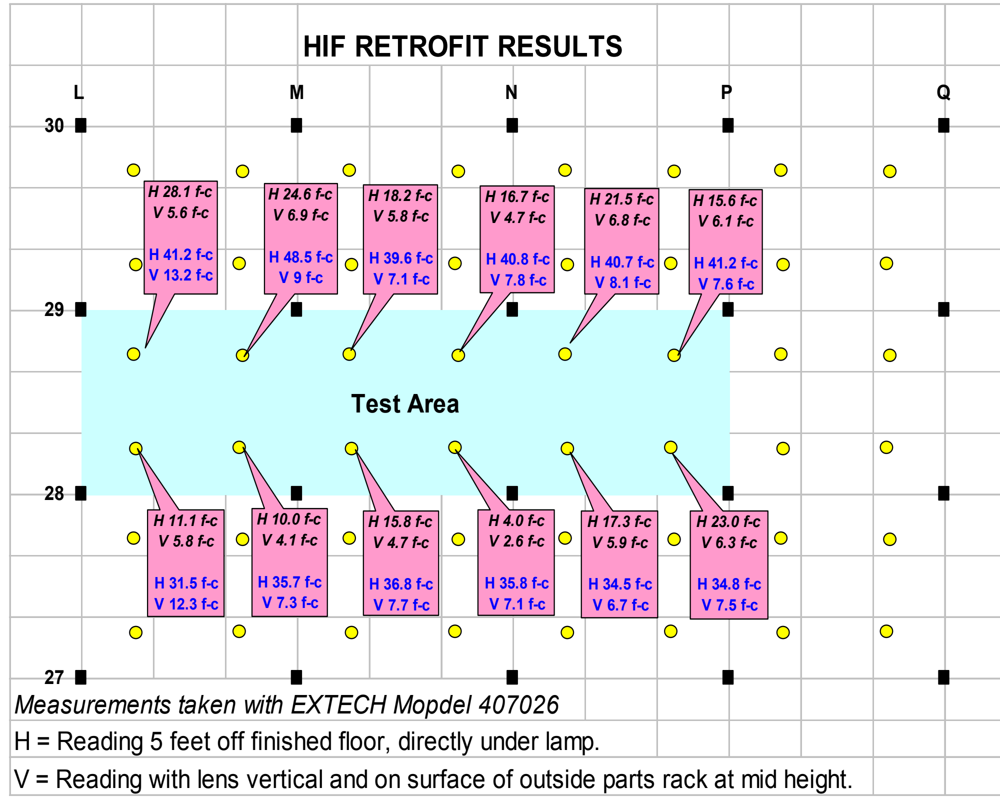
20.4

Average photopic-scotopic lumens in area bounded by 1B29-1D31

34.1

NUMMI T8-HIF Demo





- 6-Lamp T8 HIF fixture test bank has been installed in PC
- Before Avg. FC = 17   After Avg. FC = 38
- Overall Light Quality Improved
- T/Ms in area are very satisfied – stated kanban cards are much easier to read

TMMNA Lighting Improvement Results

- Space Lighting
  - Reduce energy consumption – identified savings
    - F32T8 > 36,920,000 kWH
    - F28T8 > 38,500,000 kWH
  - Improve lighting quality
    - CRI 65 ⇒ 83
  - Set standard building lighting illuminance level
    - 15 lumens
  - Reduce new construction cost
    - $33/fixture
  - Eliminate or minimize lumen depreciation
    - 60%+ ⇒ 8% maximum
  - Maintain or increase lamp life
    - No change

TMMNA Lighting Improvement Results

- Task lighting
  - Reduce energy consumption
    - F32T8 ⇒ F28T8 = 4,000,000 kWH
  - Maintain or improve lighting conditions
    - Maintained
  - Improve lighting quality
    - Color Temp 4100k ⇒ 5000k
    - CRI 83 ⇒ 83
  - Minimize lumen depreciation
    - 9% ⇒ 8%
  - Maintain or increase lamp life
    - Maintained
  - Evaluate safety concerns over broken lamp tubes
    - Evaluated shatterproof lamps

Questions

Scotopic Photopic Meter

- Solar Light PMA2200
  - Reads:
    - Photopic Light
    - Scotopic Light
  - Calculates and measures
    - Brightness
    - S/P Ratio

Questions & Comments

Change A Light

- ENERGY STAR Change A Light Day – October 4, 2006
- Corporate pledge drive planned
- Great employee outreach activity!
- Specialized web resources will be developed for employee pledge campaigns
  - Sample E-mails for employees
  - Materials Employees
  - Programs & material for schools
- Web based mechanism for tracking pledge drives/
- Campaign web site coming this spring!

Upcoming Web Conferences

April 19 – Leading Energy Management Programs

May 17 – High Performance HVAC

Download past web conference presentations at:
www.energystar.gov/networking

Thank you for participating!