CLEAResult

Basically Lighting

Oncor Lighting Workshop

Kyle Hemmi
Senior Energy Engineer

Sameer Desai
Field Energy Engineer

Agenda

- Where the Lighting Market is Heading and When
- Getting on the Same Page
  - Technologies and Terms You Need to Know
- Applying the Best Technologies and Practices
- Case Studies and Demos
  - Linear Fluorescent Troffers
  - Highbay and HID Replacements
  - Incandescent and Halogen Lamp Replacements

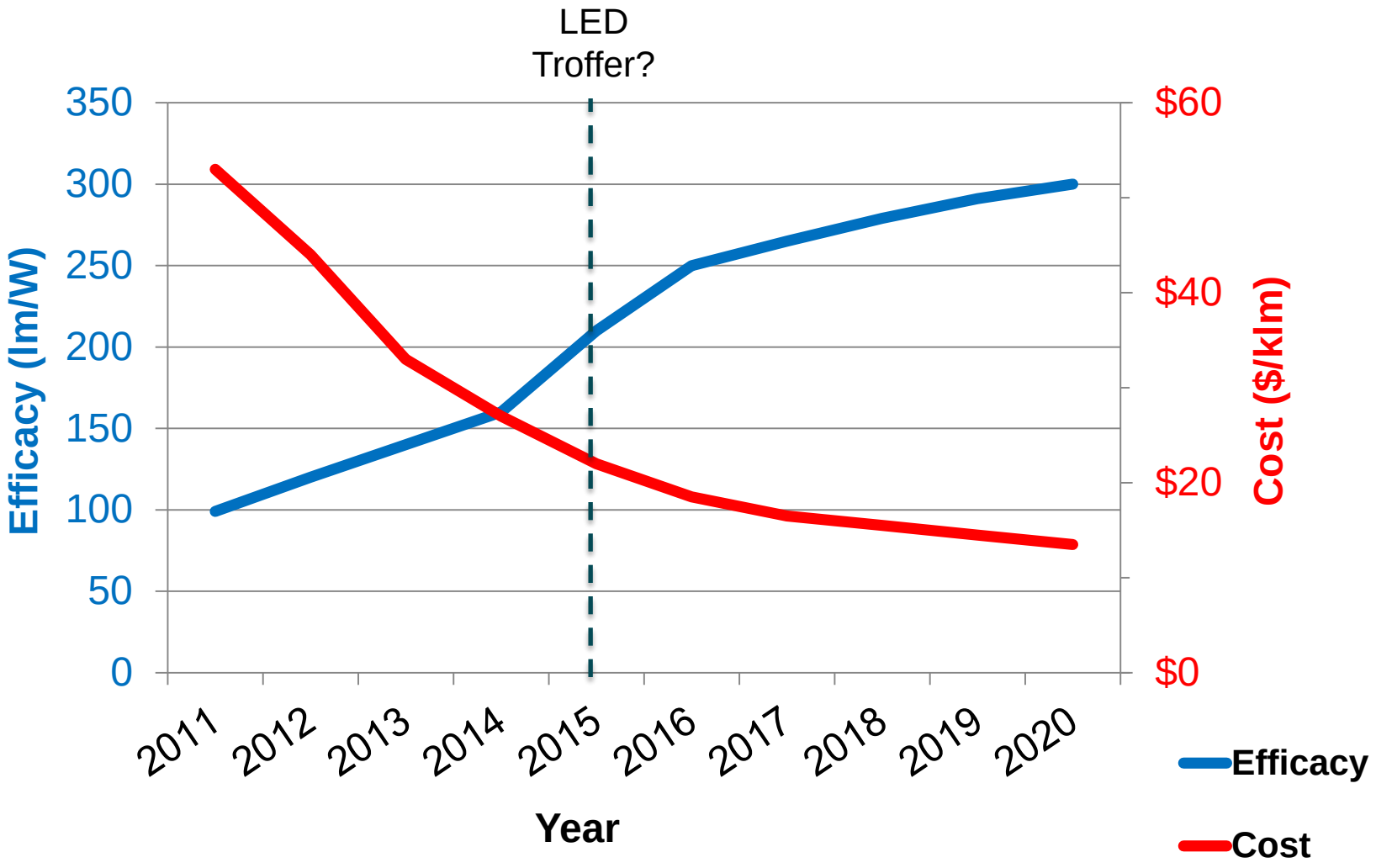
Introductions

Kyle Hemmi and Sameer Desai

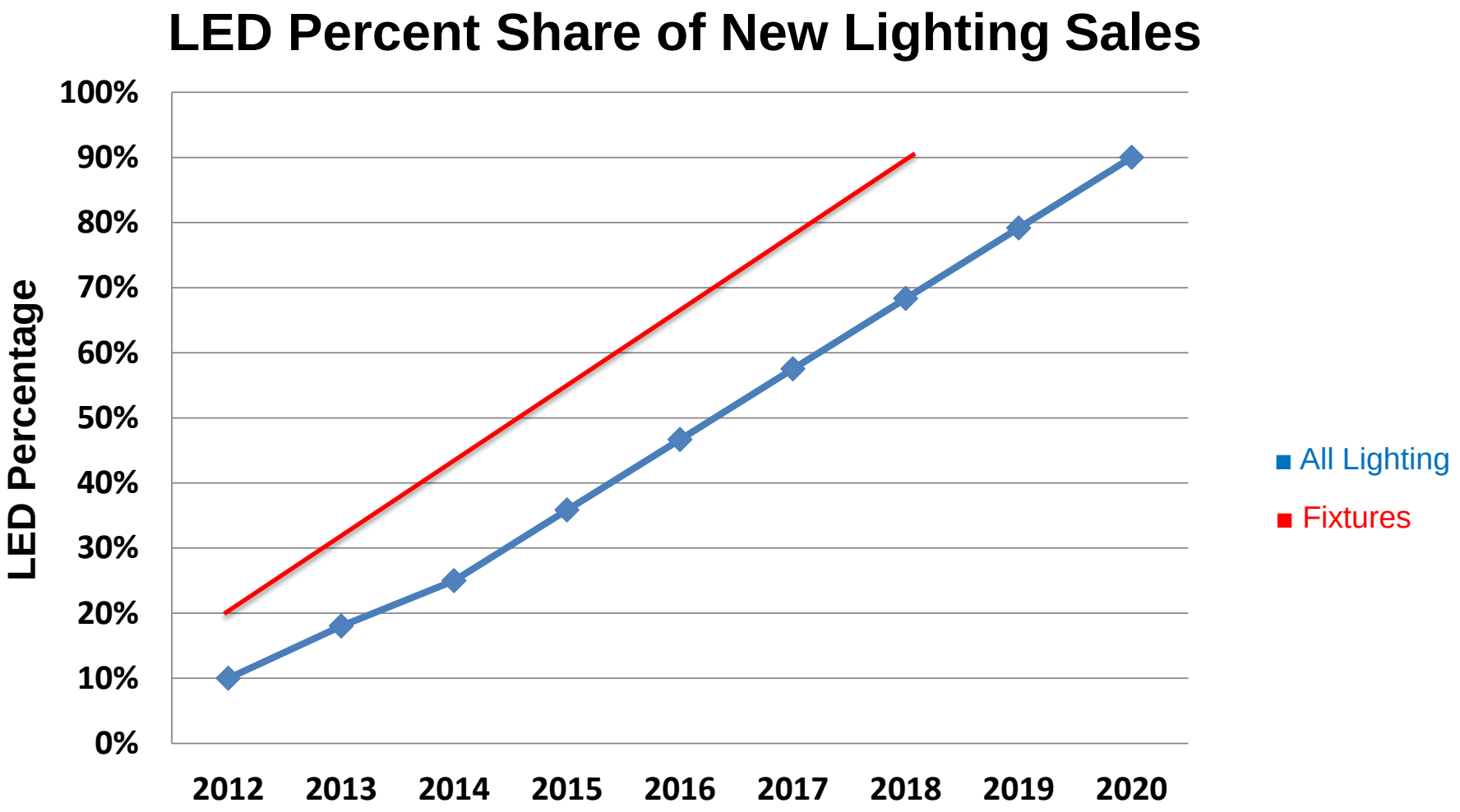
- Engineering support 1,300+ employees in North America implementing 200+ commercial utility programs

- Typical Questions:
  - When should I use LEDs vs. Fluorescent vs. Metal Halide for what application? Are there other technologies I should consider?
  - When will LED pricing come down?
  - How do I know what product is best for my business?
  - Do LEDs really perform as well as reports say they do?
  - Others?

LED Cost and Efficacy: Rapid Improvement



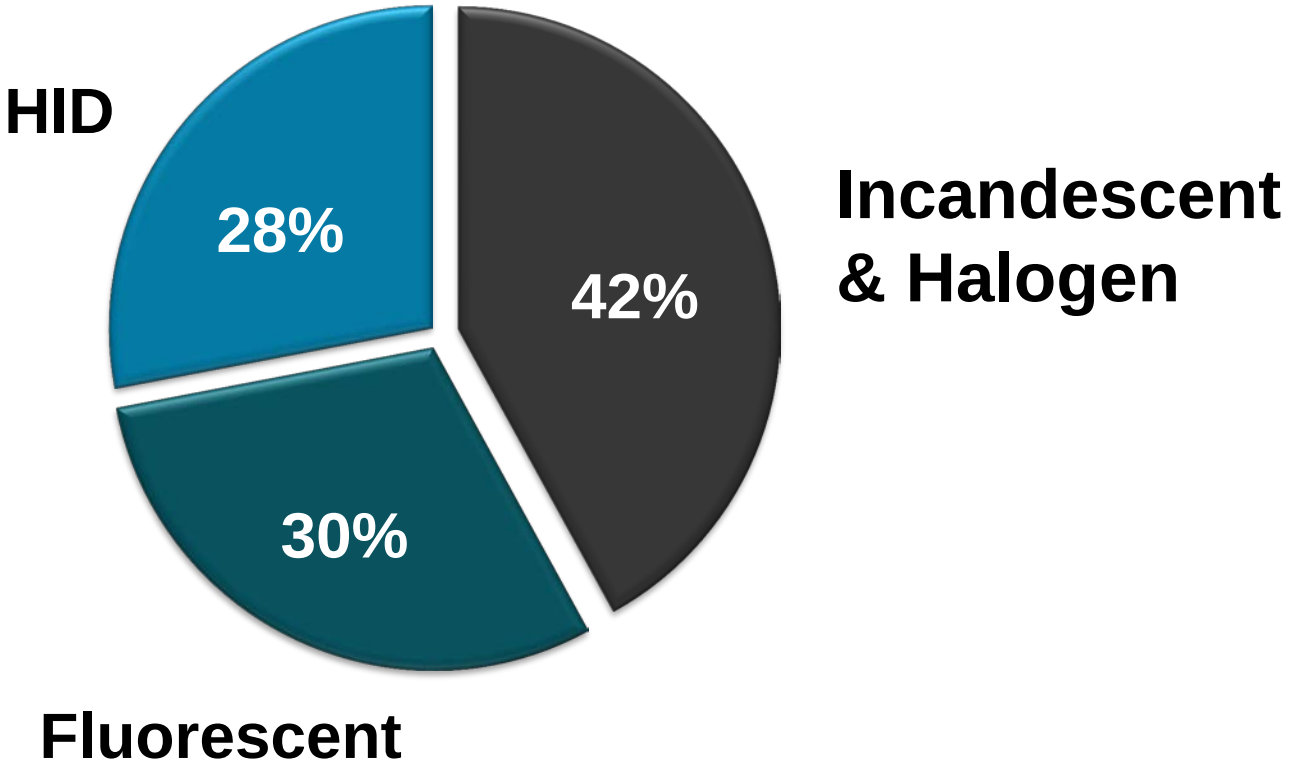
LED Market Share



Lighting Efficiency Fundamentals

Getting on the Same Page with Technology and Terminology

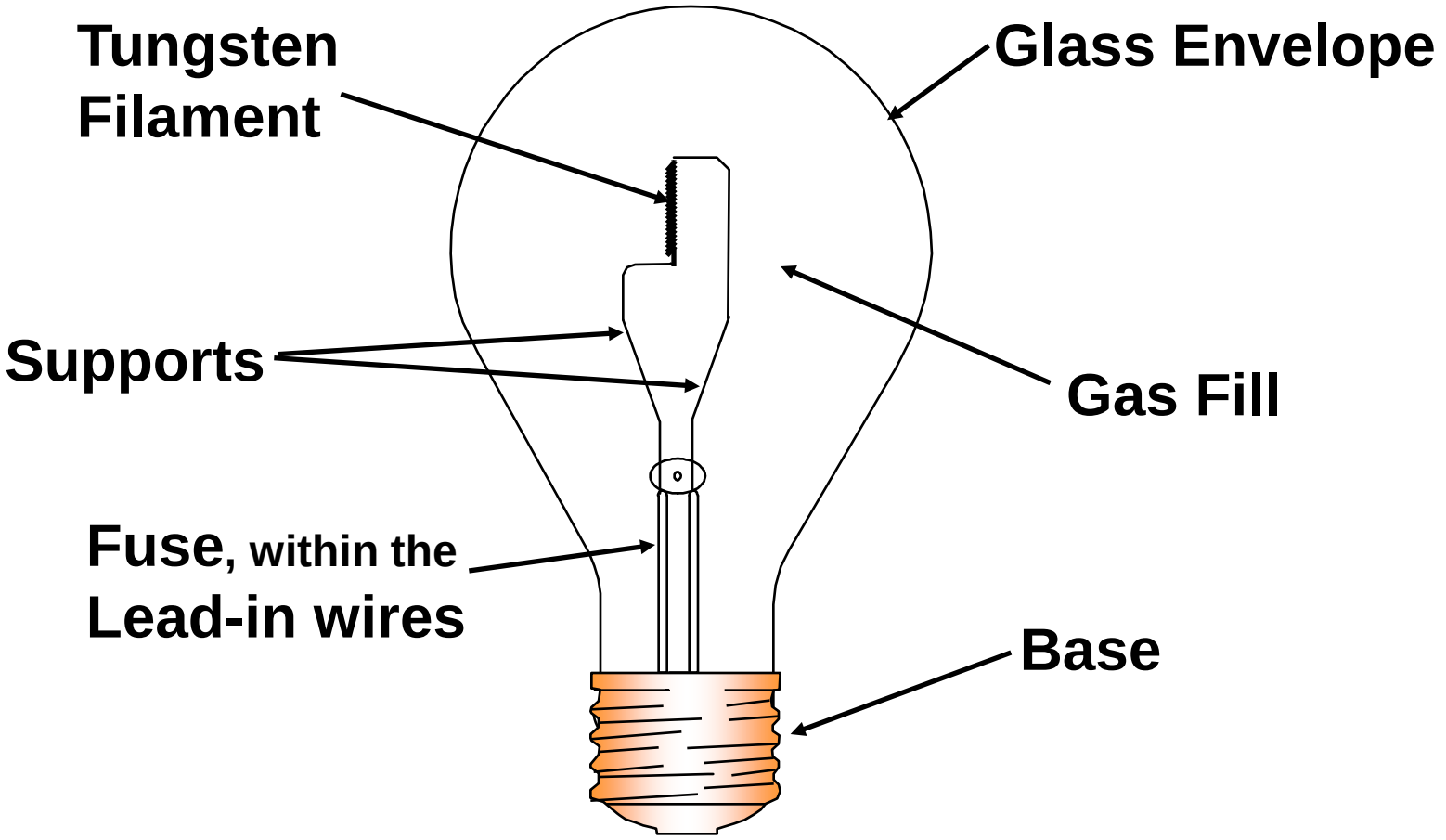
Know Your Enemy: Remaining “Inefficient” Baseline Technologies for Retrofit



Some Definitions

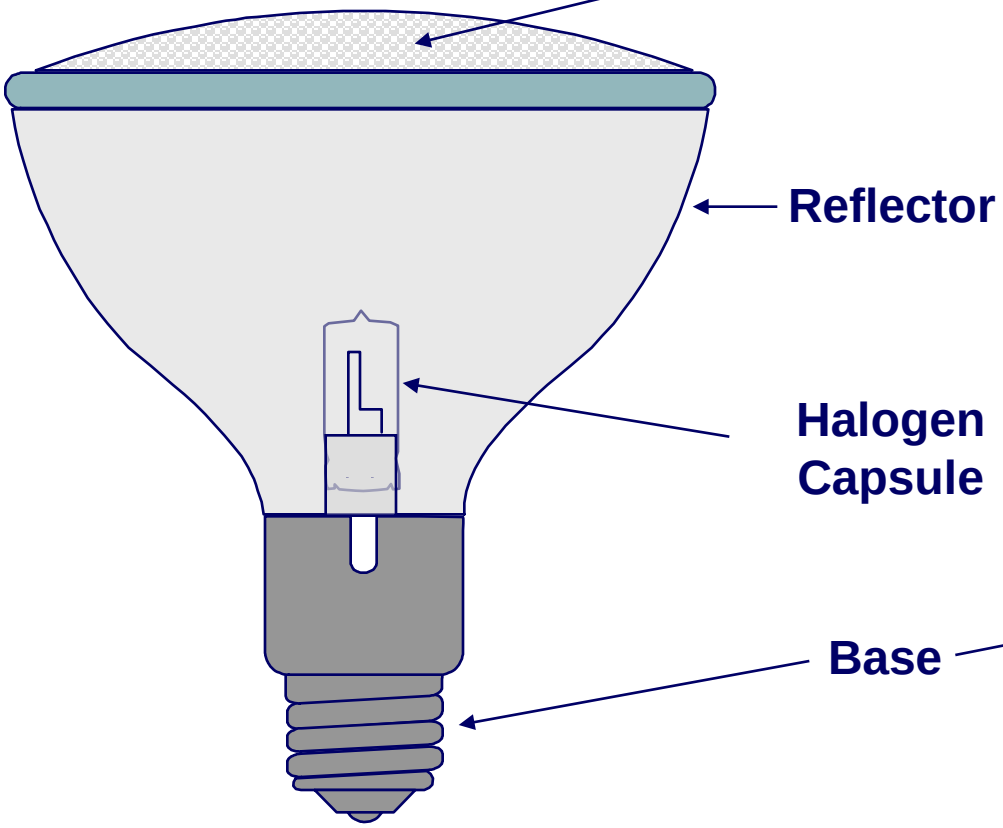
- Incandescent/Halogen
  - Most common residential interior white light source
- Fluorescent
  - Most common interior white light source
  - Office, institutional, retail
- High Intensity Discharge (HID)
  - Metal Halide: Most common high bay white light source
    - Industrial, Warehouse, Gym, big box retail
  - High Pressure Sodium (HPS): Most common exterior
- LED (White)
  - The new kid on the block

Light Sources: Incandescent

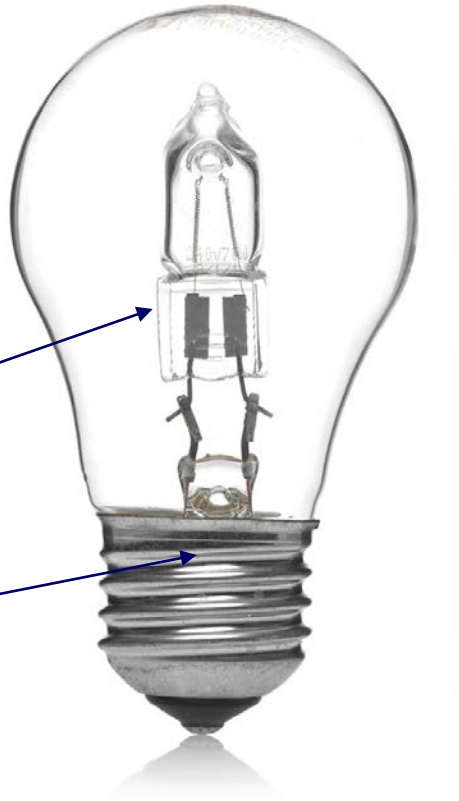


Light Sources: Halogen

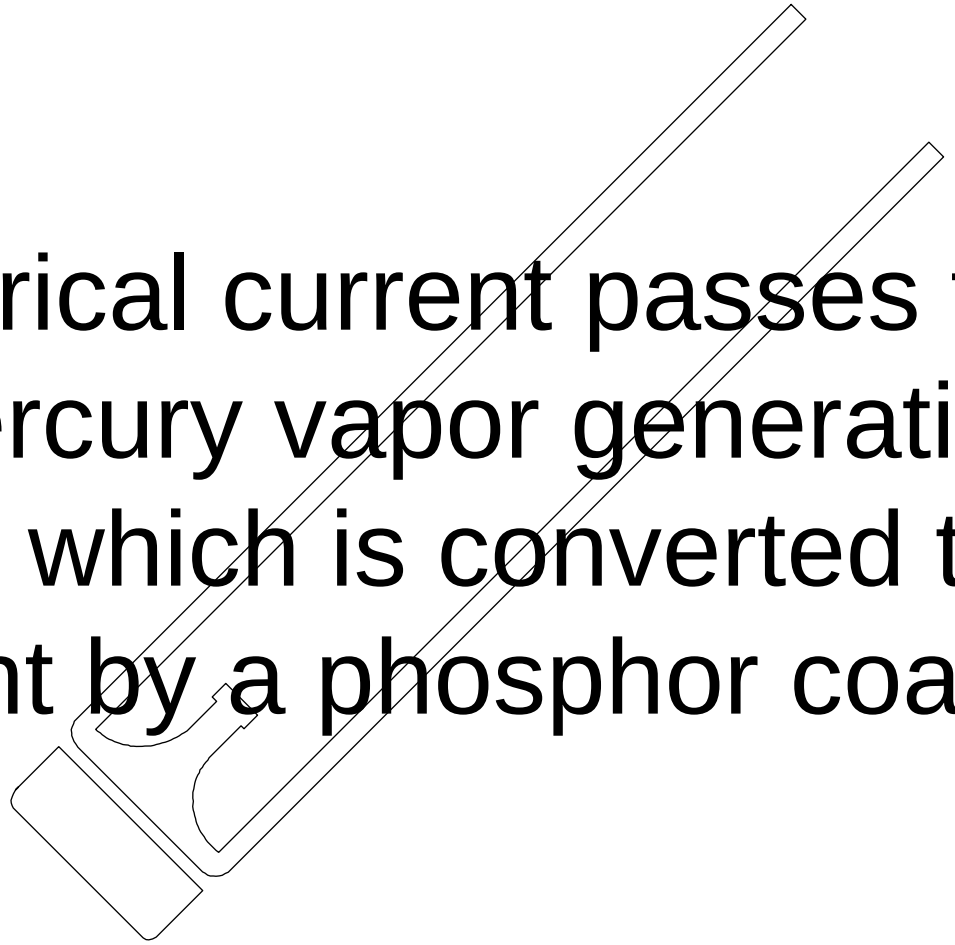
- Directional Lamps



General Illumination Lamps

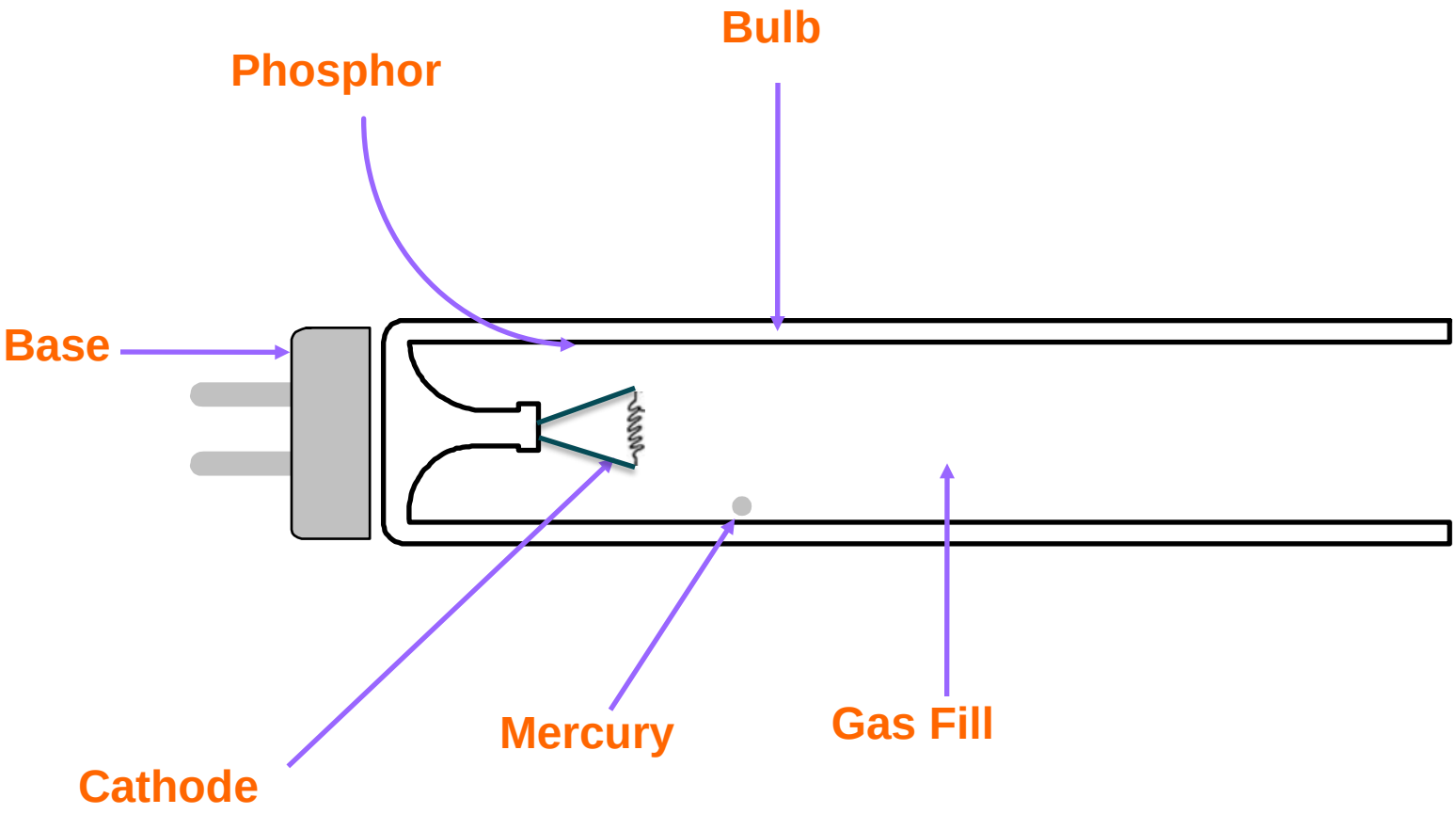


Light Sources: Fluorescent



- Electrical current passes through a mercury vapor generating UV energy which is converted to visible light by a phosphor coating.

Light Sources: Fluorescent



Light Sources: Fluorescent

Linear fluorescent

- Most common for general lighting
- T12 (1.5”) Diameter
- T8 (1”) Diameter
- T5 (5/8”) Diameter

Compact fluorescent

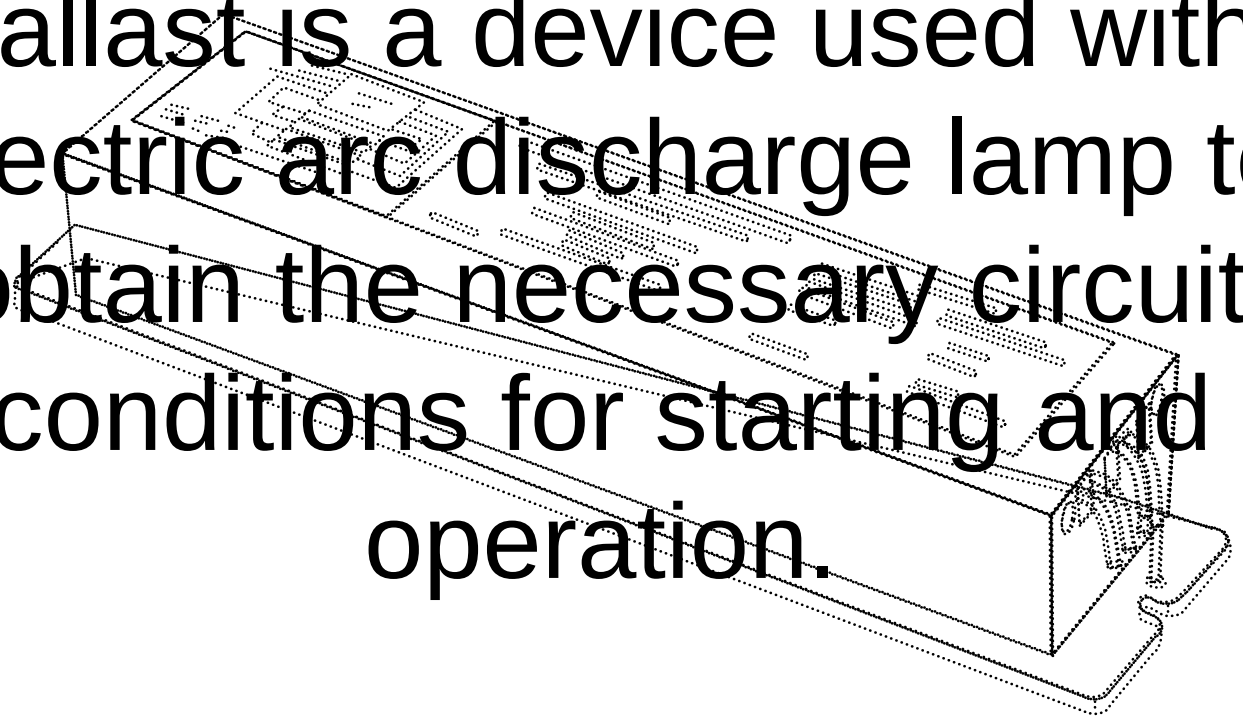
- Commonly used as replacement for incandescent

Electrodeless lamps (Induction)

- More recent development – used as replacement for some HID lamps

Light Sources: Ballasts

- A ballast is a device used with an electric arc discharge lamp to obtain the necessary circuit conditions for starting and operation.



Light Sources: Ballasts

	GOOD Instant Start	GOOD Rapid Start	BEST (occupancy sensors) Programmed Rapid Start
Cathode Voltage			
Starting Voltage			
Start Cycles	Up to 20k	Up to 20k	Up to 50k+
Start Temp	-20° F	50° F	-20° F
Input Power (2 Lamp)	59W	63W	60/58W
Wiring	Parallel	Series	Parallel/Series
Lamp Life* (3hrs/start)	24K	30K	36K

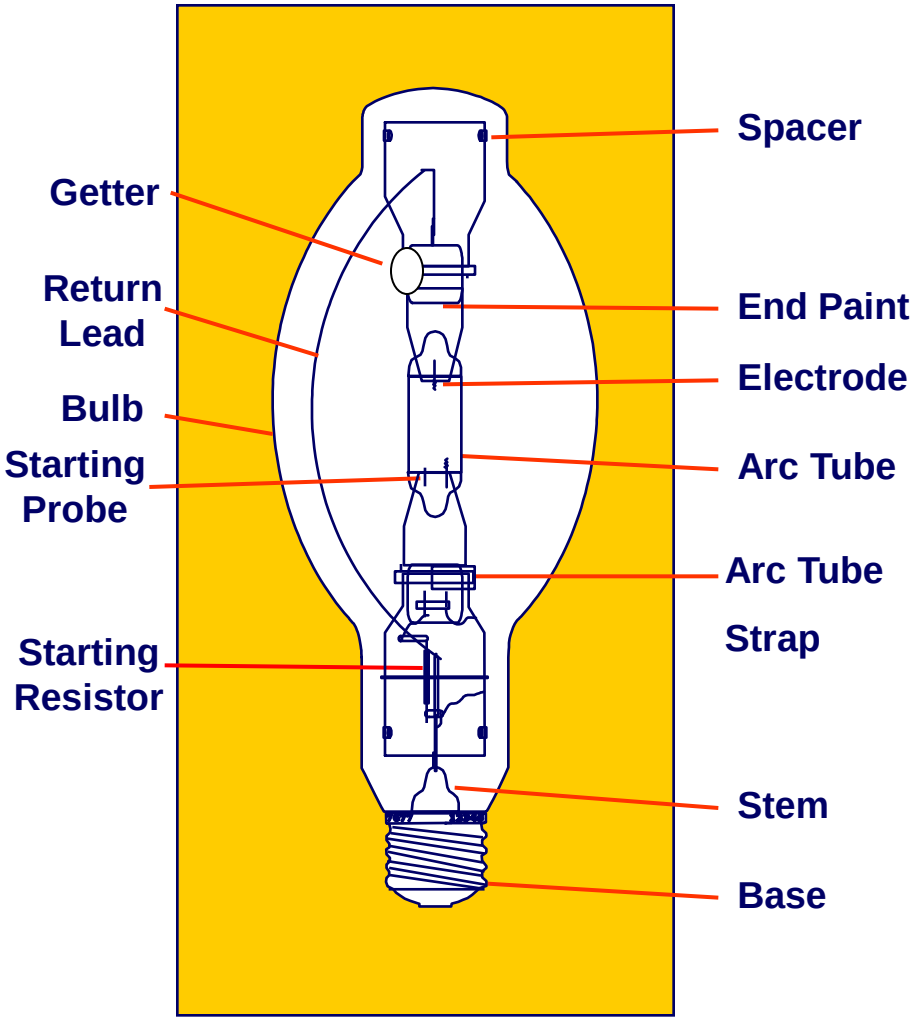
* lamp life 32WT8 800XP series

Light Sources: Metal Halide

- Electrical current passes through a mercury vapor and/or halide vapors under high pressure generating visible light.

Light Sources: Metal Halide

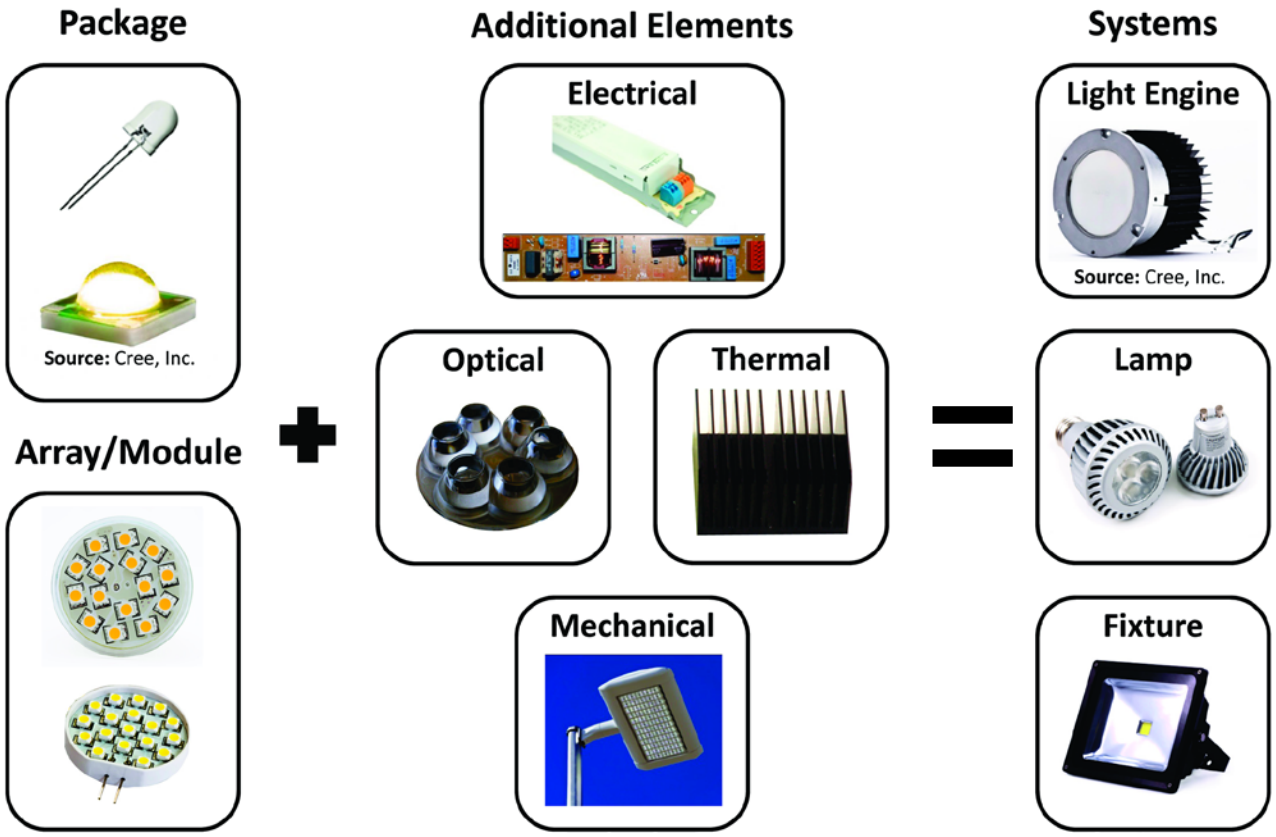
- Metal Halide



Light Sources: Metal Halide and HPS

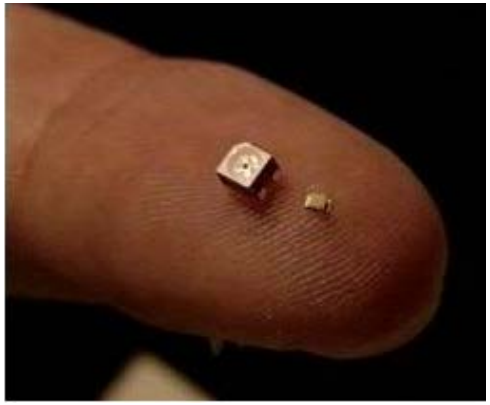
- High Pressure Sodium (HPS)
  - Used mainly for outdoor street and area lighting
  - Higher efficacy than MH
  - Color makes them unacceptable in most application
- Metal Halide
  - Standard lamps
  - Pulse Start (PS) lamps
    - Higher efficacy, longer life with PS ballasts
  - Ceramic Metal Halide (CMH) lamps
    - Higher efficacy, longer life, better Color, improved Color constancy
    - Indoor accent lighting applications

LEDs*: The New Kid on the Block

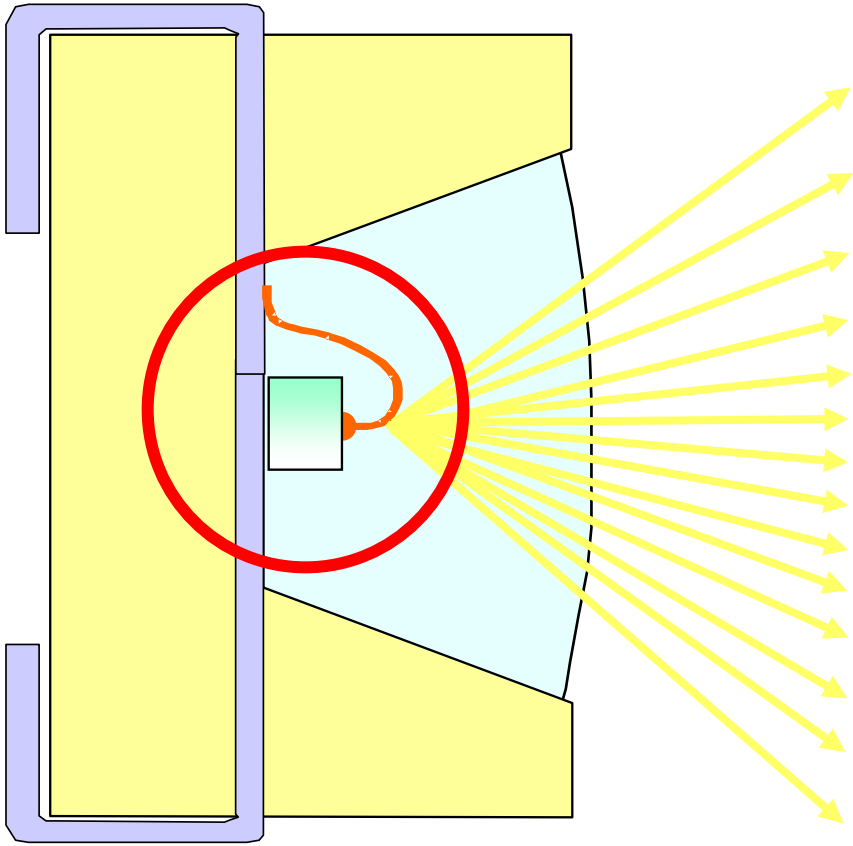


* Sometimes referred to as Solid State Lighting (SSL)

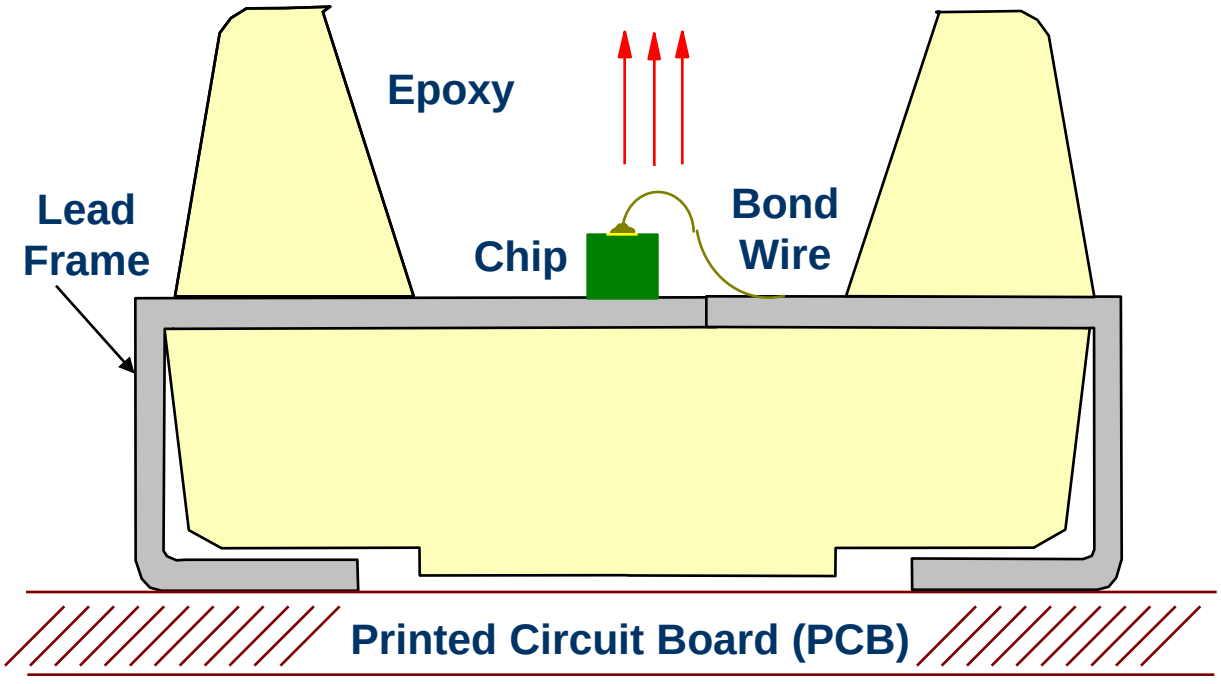
Light Sources: LED

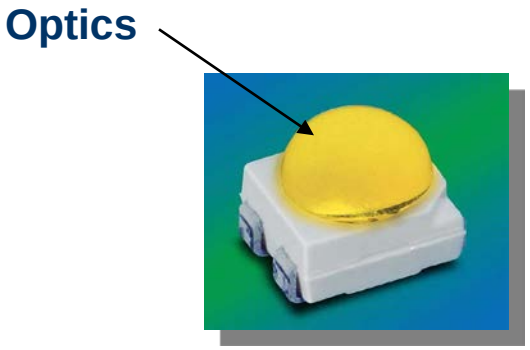


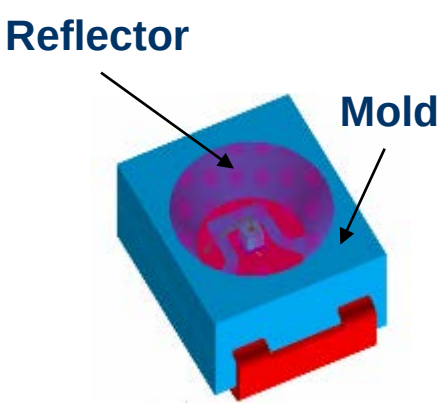
A light-emitting diode is a semiconductor device that emits narrow-spectrum light when electrically biased in the forward direction.



Light Sources: LED

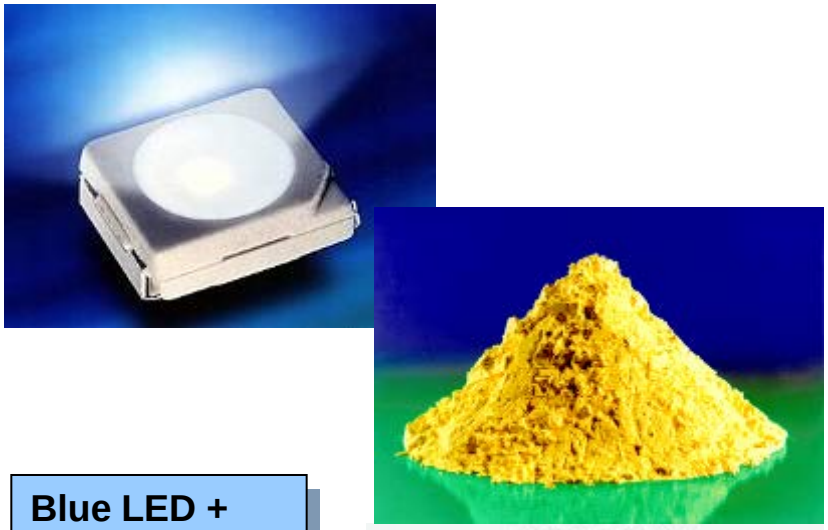


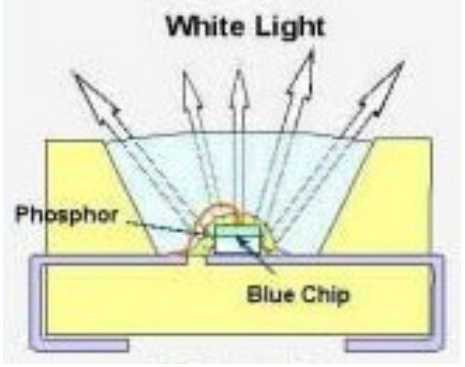




Light Sources: LED

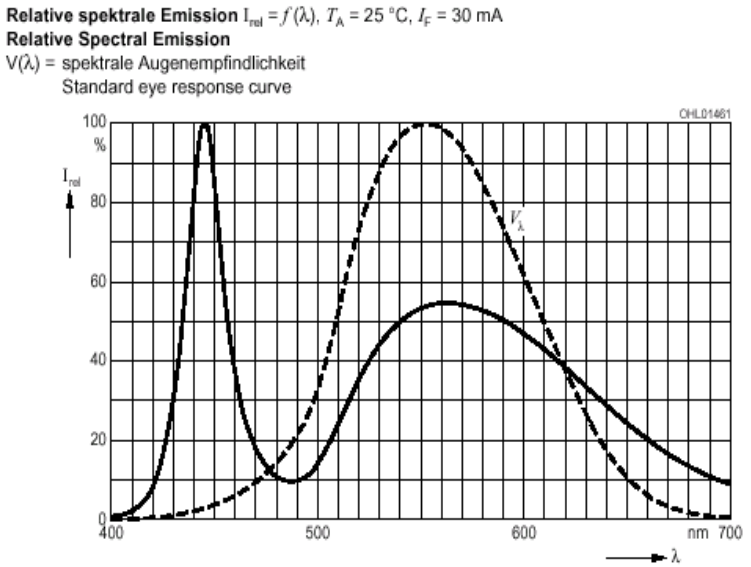
- White Illumination LED – Blue LED with yellow phosphors





Blue LED + Phosphor = White LED

Color rendering: ~ 80
Color temperature: > 6000 K

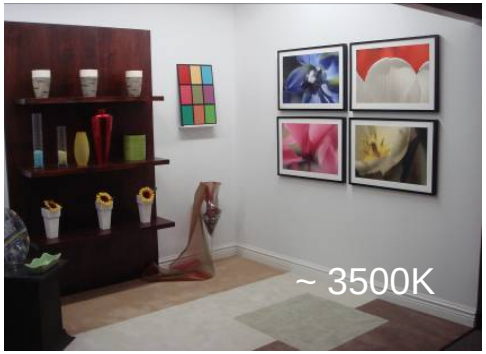


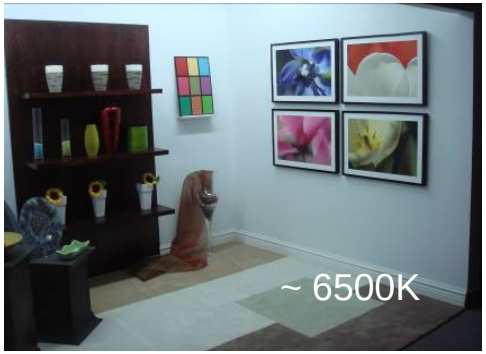
Color Metrics

- Color Temperature
  - Correlated Color Temperature (CCT) measured in Kelvin
  - Applicable to all white light sources

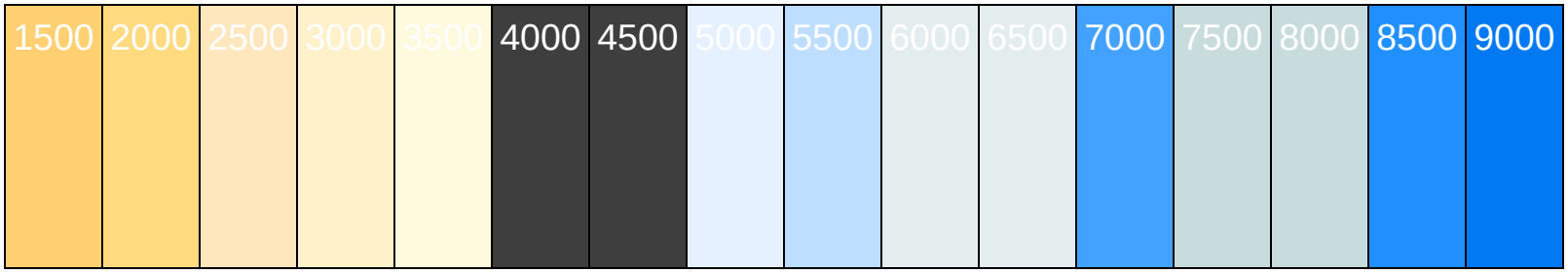
Correlated Color Temperature (CCT)

CCT is a measure of warmth or coolness of the Color of an artificial light source. It is expressed in Kelvin or K.





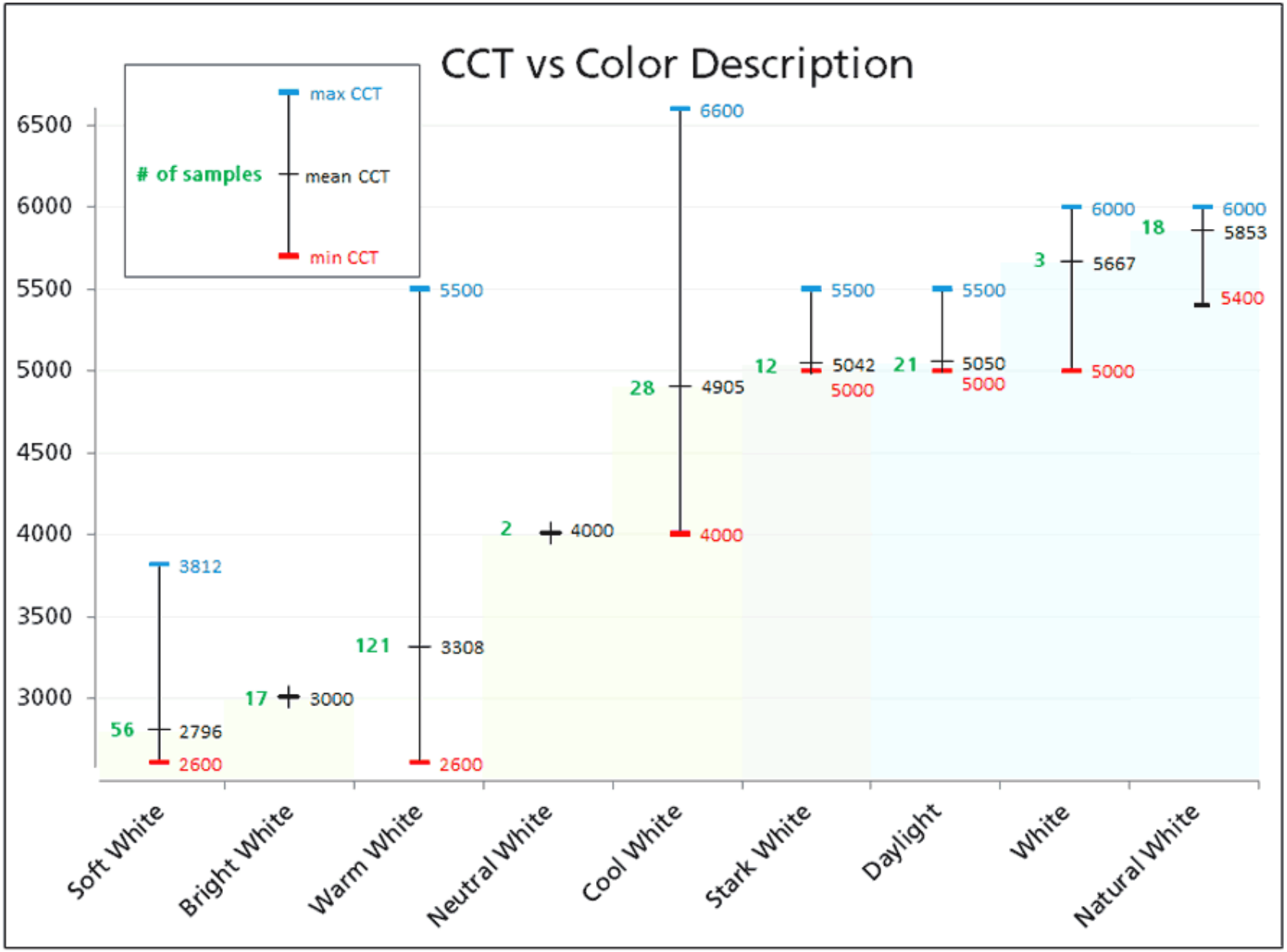
HPS T8 3K T8 4.1 K T8 6.6K



CANDLE INCANDESCENT WHITE LED NORTH LIGHT

Color Metrics

- Color Temperature
  - The next slide shows the results of a study of white light LED A19 lamp replacements
  - This slide compares the actual CCT with the advertized classification of the CCT


CCT vs Color Description
# of samples
max CCT
mean CCT
min CCT
6500
6000
5500
5000
4500
4000
3500
3000
56
3812
2796
2600
17
3000
121
5500
3308
2600
2
4000
28
6600
4905
4000
12
5500
5042
5000
21
5500
5050
5000
3
6000
5667
5000
18
6000
5853
5400
Soft White
Bright White
Warm White
Neutral White
Cool White
Stark White
Daylight
White
Natural White

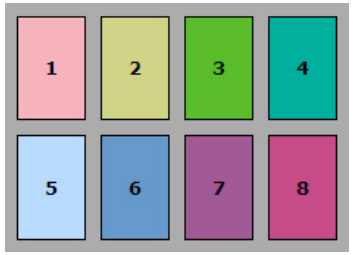
Color Metrics

- Color Rendering
  - CRI of source
  - A faulty metric, but it’s what we have
  - Essentially, compares the relative Color performance of the test lamp with a lab standard lamp, which is halogen (for most common CCT values)
  - Does not work very well for SSL sources

Color Rendering Index (CRI)

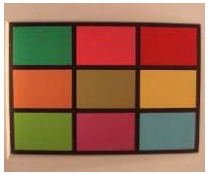
Color Rendering Index (CRI)

is a measure of Color accuracy, expressed as a number on a scale up to 100, with 0 being “poor” and 100 being “excellent”. The higher the number, the more likely the light source will render object Colors well.

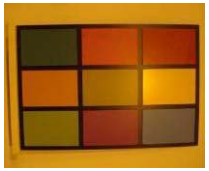


Excellent (100)

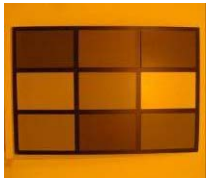
Good (70-90)

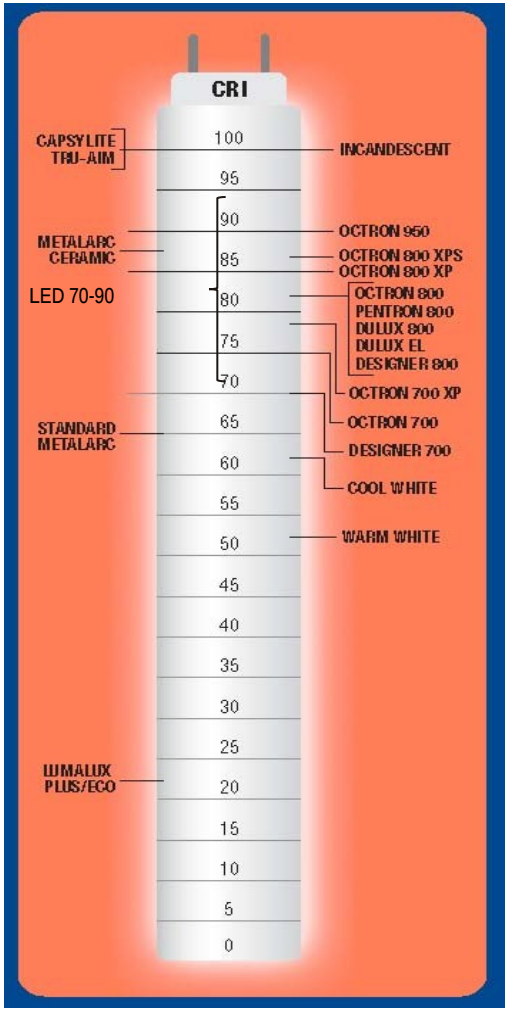


Poor (<70)



Monochromatic

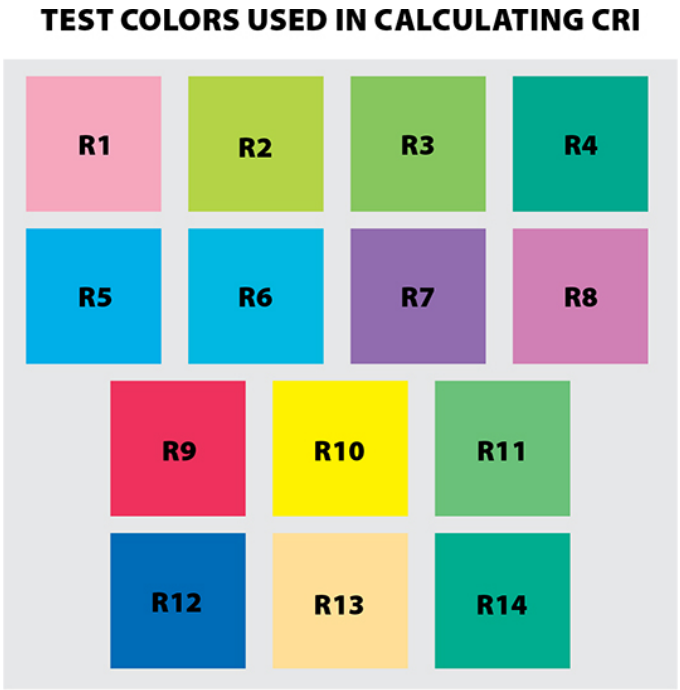




Color Metrics

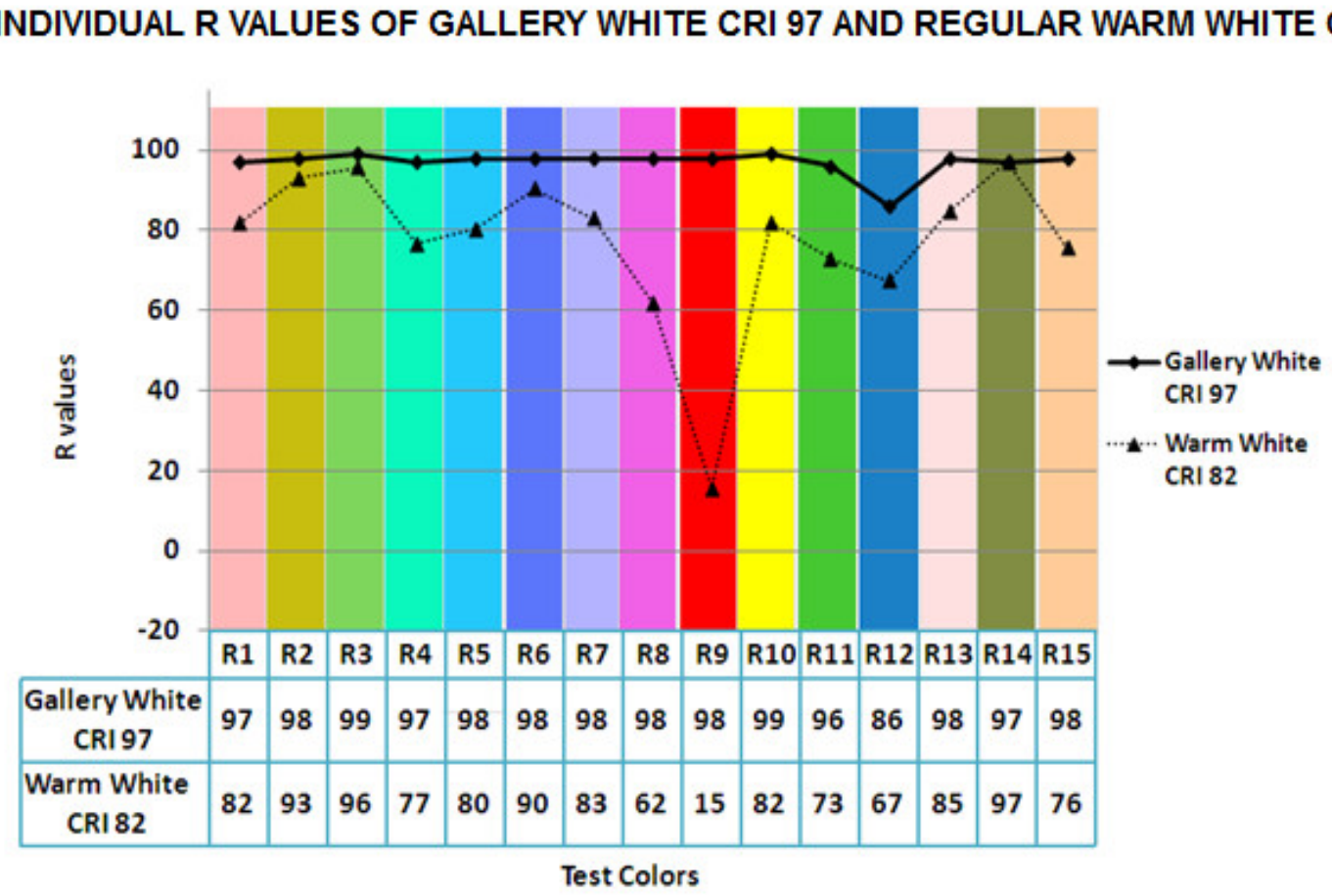
A New Approach to Color Rendering being developed

- A system that builds on the old CRI system
- Accommodates SSL sources
- Test Colors Being Expanded (R9 through R14)



Color Metrics

- LED CRI Comparison



	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
Gallery White CRI 97	97	98	99	97	98	98	98	98	98	99	96	86	98	97	98
Warm White CRI 82	82	93	96	77	80	90	83	62	15	82	73	67	85	97	76

Light Source Efficacy

- Source lumens per Watt
  - Simple:
    - 100W A19 incandescent, 1500 lm
    - Efficacy = 1500/100 = 15 lm/W
  - Complex:
    - F32/T8 fluorescent, 2950 lm
    - Efficacy = 2950/32 = 92 lm/W
    - This does not take the ballast into consideration, so essentially meaningless

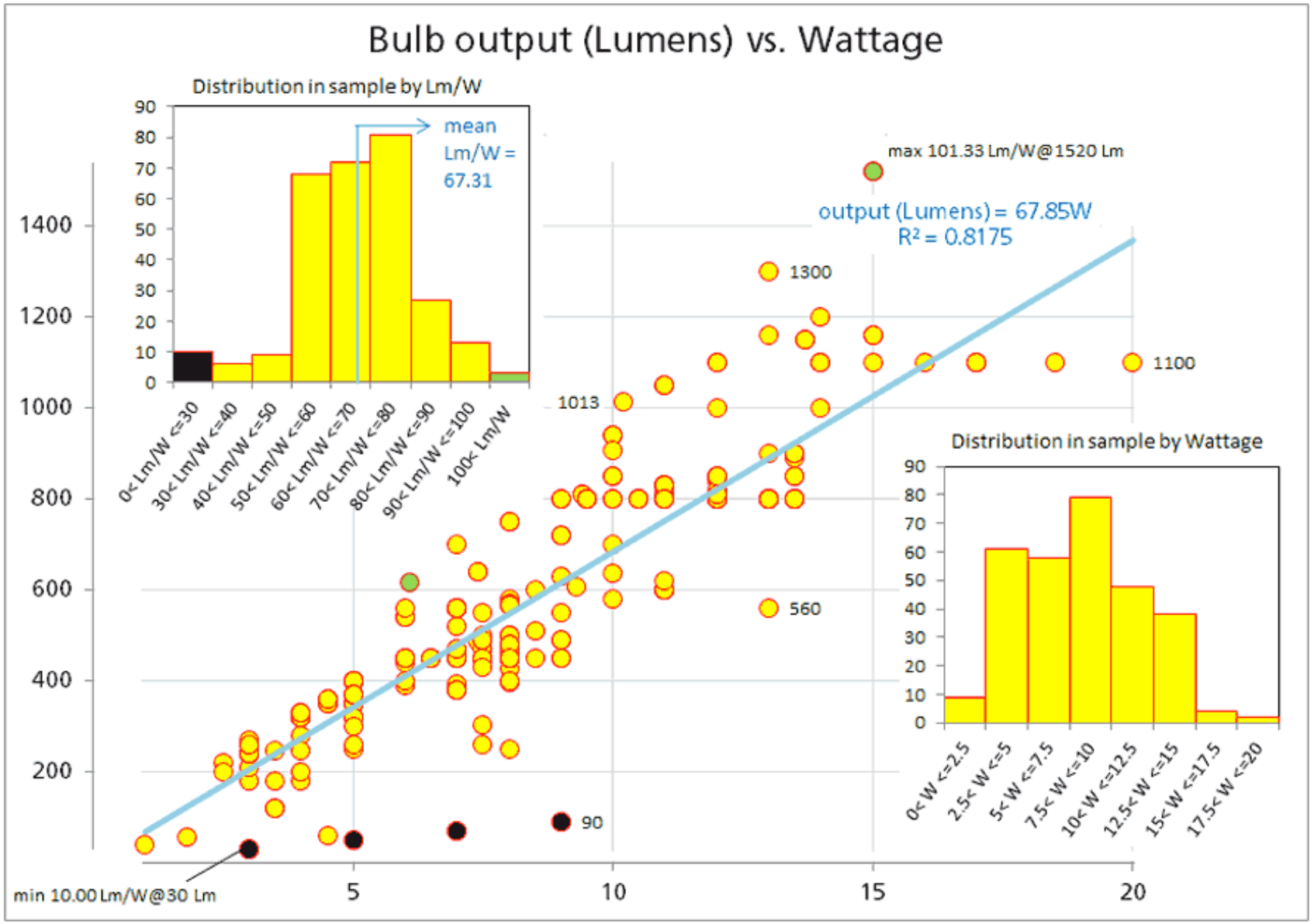
Light Sources: Fluorescent System Efficacy

- Ballast Factor (BF)
  - Use Ballast Factor as a design tool
  - Example – 2 lamp systems, using 3000 lumen F32 T8 lamp

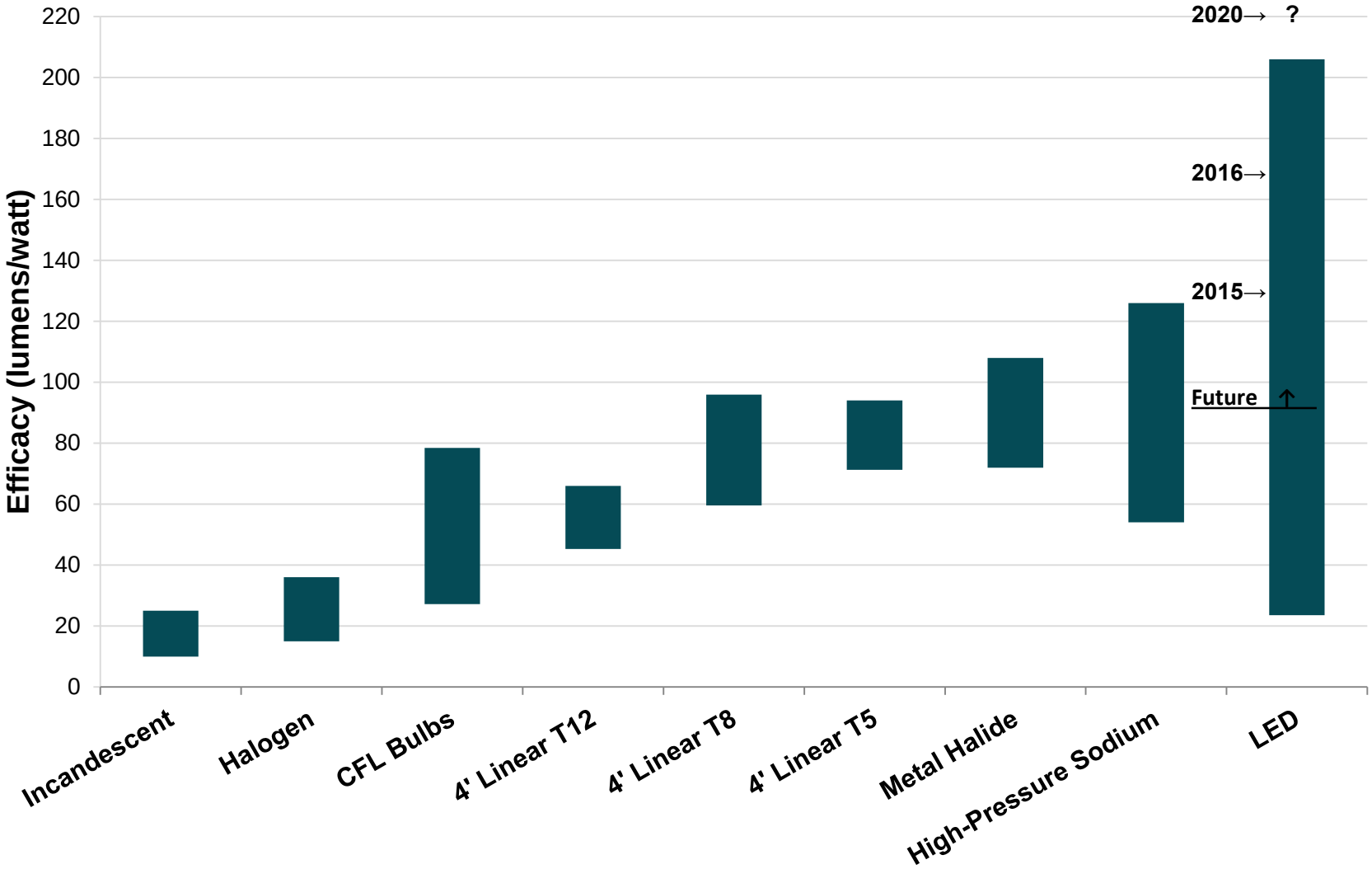
Type	Ballast Factor	Initial Lumens	Watts	Initial lm/W
Low BF	0.78	4,680	48W	98 lm/W
Normal BF	0.88	5,280	55W	96 lm/W
High BF	1.2	7,200	74W	97 lm/W

Light Source Efficacy

- More data from that LED A19 survey
  - Of surveyed LED lamps:
    - The lowest efficacy unit had the lowest price
    - The second lowest had a price 5x higher
- Price is not a reliable indicator of performance


Bulb output (Lumens) vs. Wattage
Distribution in sample by Lm/W
mean Lm/W = 67.31
0< Lm/W <=30
30< Lm/W <=40
40< Lm/W <=50
50< Lm/W <=60
60< Lm/W <=70
70< Lm/W <=80
80< Lm/W <=90
90< Lm/W <=100
100< Lm/W
max 101.33 Lm/W@1520 Lm
output (Lumens) = 67.85W
R² = 0.8175
1300
1100
1013
560
90
min 10.00 Lm/W@30 Lm
Distribution in sample by Wattage
0< W <=2.5
2.5< W <=5
5< W <=7.5
7.5< W <=10
10< W <=12.5
12.5< W <=15
15< W <=17.5
17.5< W <=20

Efficacy (lumens/W) by Technology



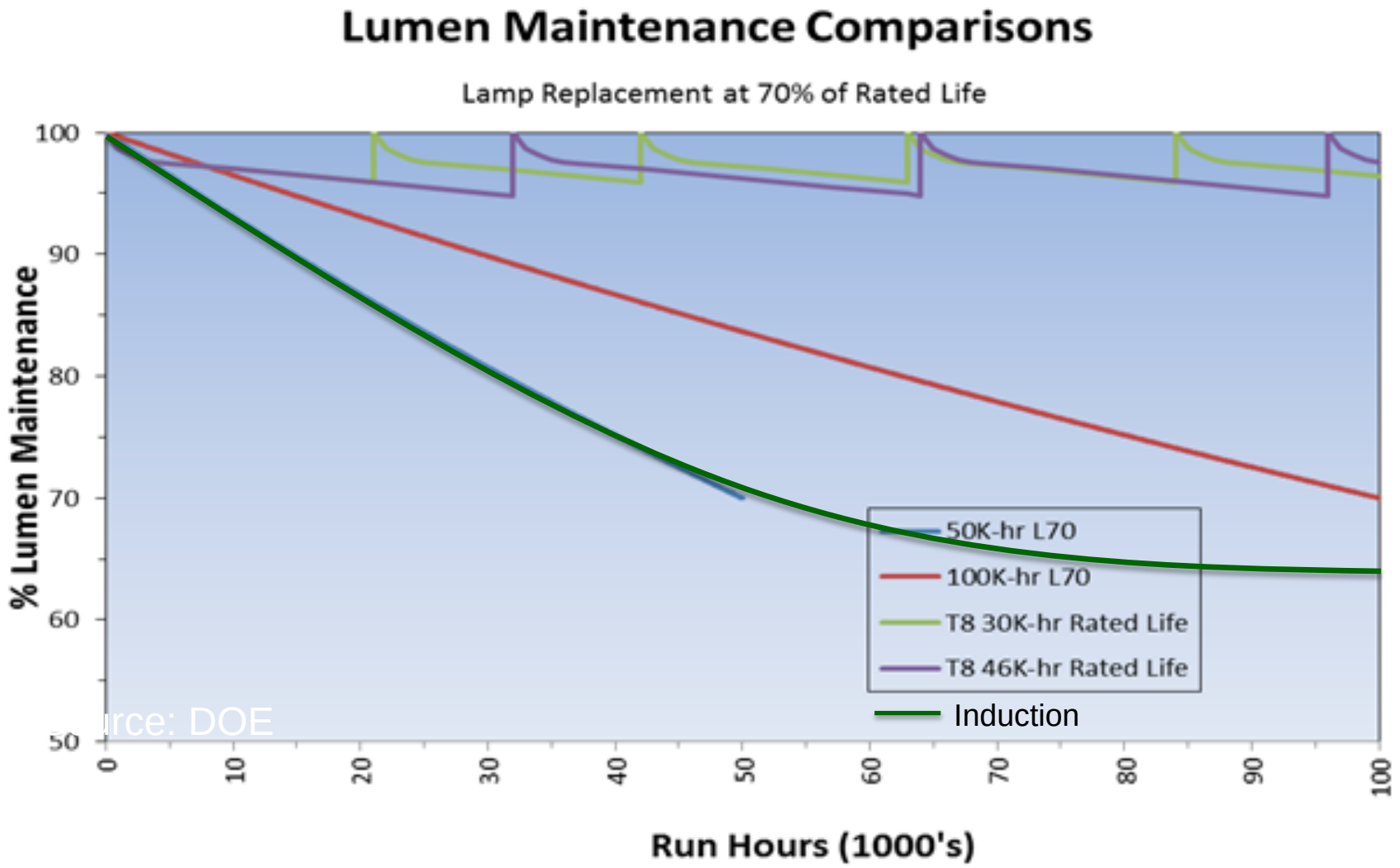
Long Term Performance Metrics

- Lumen Depreciation
  - Typically Measured at 40% of rated life
  - T8 Fluorescent: 0.95
  - Standard Metal Halide: 0.65
  - For LED, lumen depreciation is significant
    - The current practice is L70, the point at which the source has lost 30% of initial lumens (IESNA LM-80)
    - Therefore LLD = 0.70

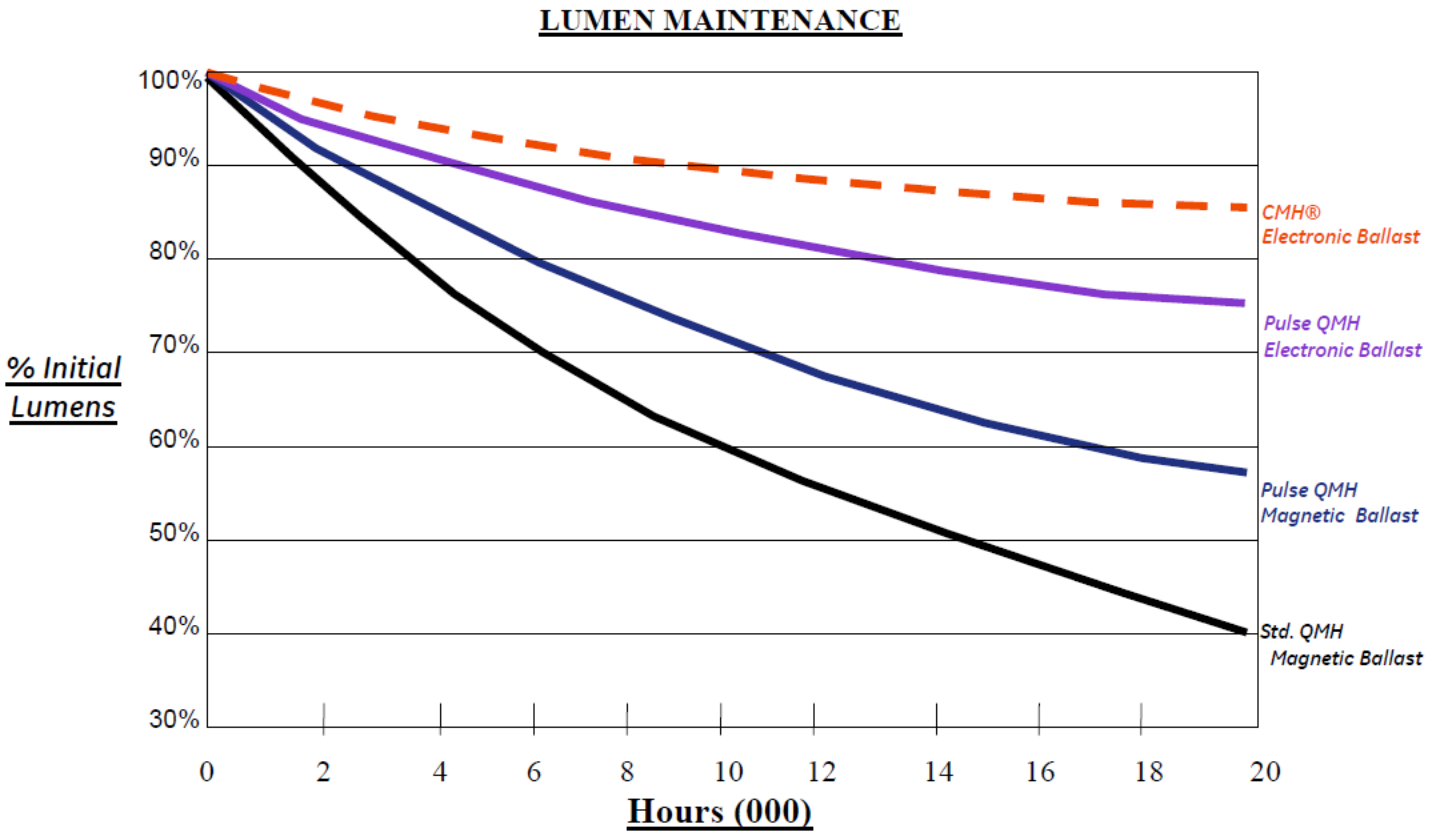
Long Term Performance Metrics

- Lumen Depreciation
  - The next slide shows the long-term performance impact of an LLD of 0.70 with a long-life source
  - From a design specification point of view, the LLD value in calculations must be at least 0.85
  - This is not typically being done properly

Lumen Maintenance: HPT8, LED and Induction



Lumen Maintenance: Metal Halide



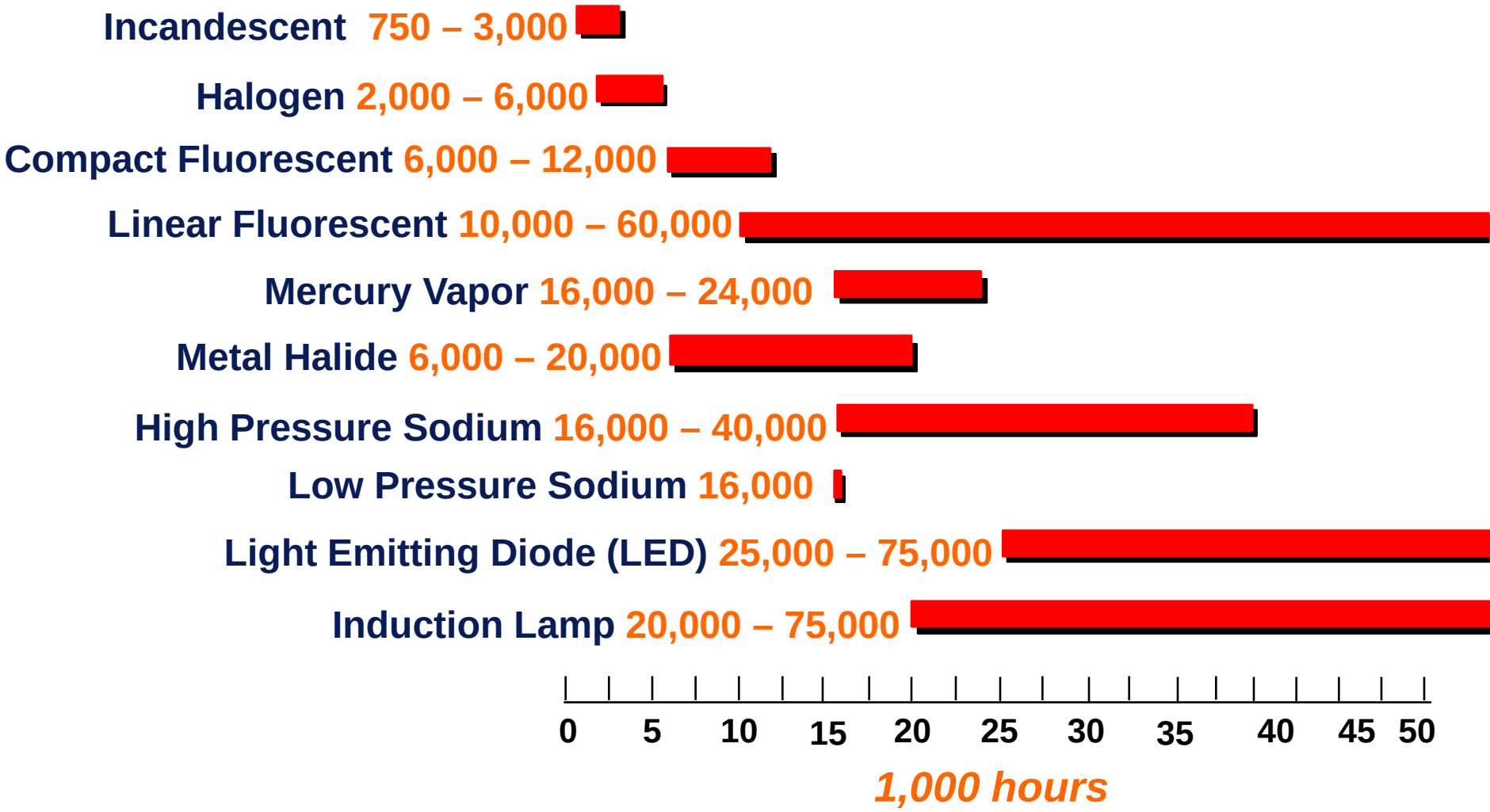
Long Term Performance Metrics

- Life
  - Hours at which 50% of sample is burned out
  - T8 Fluorescent: 20,000 up to 60,000 hrs
  - Metal Halide: 6,000 to 30,000 hrs
  - Induction: 20,000 to 75,000 hrs
  - LEDs: 25,000 to 75,000 hrs
    - Life is defined as the point where the source is no longer producing enough light
    - This uses LM-80 again and L70 is the typical value in use today

Long Term Performance Metrics

- Life
  - The issue for clients is that most common maintenance practice is ‘if it ain’t broke, you can’t fix it’ so lamps are run until they die
  - This has the potential for significant illuminance reduction over time
  - This can influence performance and, more critically, safety

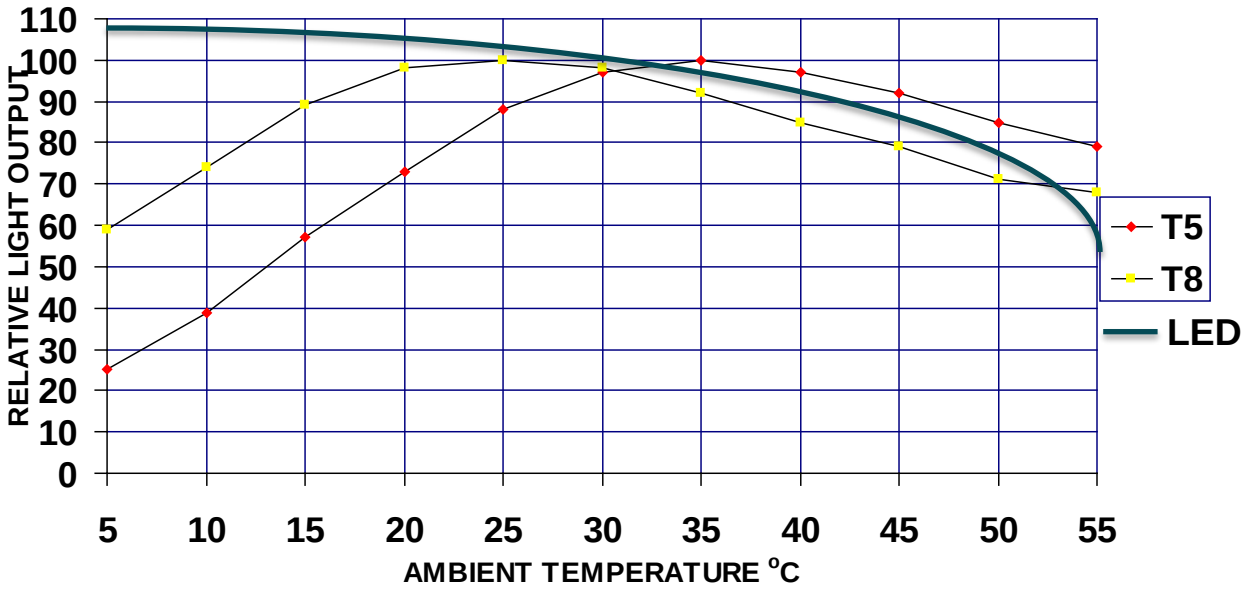
Light Source Life



Potential Performance Issues: Fluorescent/LED

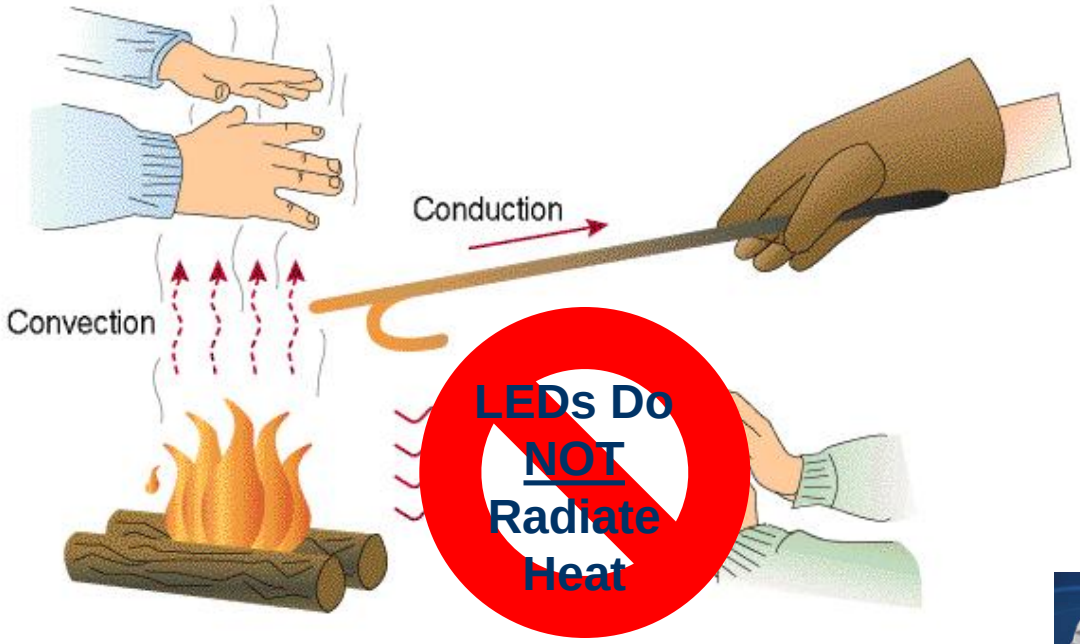
- Ambient Temperature
  - Most sources are influenced by ambient temperature, particularly fluorescent
  - LEDs could see impacts at high temps, but newer (well-designed) products can handle higher temperatures

LUMEN OUTPUT VS. TEMPERATURE T8/T5/LED

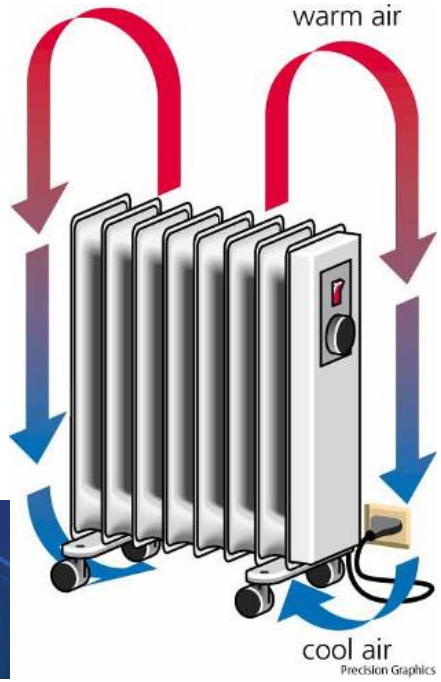


LEDs & Temperature

Thermal management is required for all LEDs.



It must be conducted away from the LEDs by a *heat sink*.



Lighting Energy Codes

- ANSI/ASHRAE/IES 90.1-2007/IECC 2009
  - State Buildings: 90.1-2010/IECC 2012 (expected code in 2015)

Whole Building: Code Allowed Lighting Power Density (W/ft^2)			
Facility Type	**Power Density Factor IECC 2009/ASHRAE 90.1-2007**	**Power Density Factor IECC 2012/ASHRAE 90.1-2010**	**Power Density Factor IECC 2015/ASHRAE 90.1-2013**
Automotive Facility	0.9	0.98	0.8
Convention Center	1.2	1.08	1.0
Courthouse	1.2	1.05	1.0
Dining: Bar/Lounge/Leisure	1.3	0.99	1.0
Dining: Cafeteria	1.4	0.90	0.9
Dining: Family	1.6	0.89	1.0
Dormitory	1.0	0.61	0.6
Exercise Center	1.0	0.88	0.8
Gymnasium	1.1	1.00	0.7
Health Care - Clinic	1.0	0.87	0.9
Hospital	1.2	1.21	0.9
Hotel	1.0	1.00	1.1
Library	1.3	1.18	0.9
Manufacturing	1.3	1.11	1.2
Motel	1.0	0.88	1.2
Motion Picture	1.2	0.83	0.8
Multi-Family	0.7	0.60	0.5
Museum	1.1	1.06	1.0
Office	1.0	0.90	0.8
Outdoor Uncovered Parking Area: Zone 1*	0.15	0.04	0.04

New Technology

- Options & Opportunities
  - Luminaires
    - **Luminaire efficiency will improve system performance**, especially with fluorescent and HID sources
    - High efficiency luminaires tend to be higher priced
    - Higher price is offset by performance
    - Efficiency improvements are centered around reflector design and materials, and thermal management

New Technology

- Options & Opportunities
  - High Performance T8/T5/T5HO
    - Contrary to popular opinion, this is *not* a dead technology
    - **When price and life cycle cost are considered, high performance fluorescent is often still the best alternative**
    - Remember that the LED or Induction systems will most likely need to be replaced or, if possible, upgraded at around 60,000 hours
    - New technologies (e.g. nanophosphors) will also benefit fluorescent sources
    - Fluorescent ballast and control technologies are not standing still

New Technology

- Options & Opportunities
  - **Some LED ‘No Brainer’ Applications**
    - Halogen accent & downlight replacement
    - CFL downlight replacement
    - Cove lighting
    - Roadway, canopy, wallpack and floodlighting
    - Refrigerated cases and warehouses
    - Anything with Color
  - Keep in Mind
    - Ideally, use purpose built LED luminaires
    - With retrofit LED sources, test carefully with the actual fixture
    - Price is not a reliable indicator of performance
    - Performance criteria (lm/W, CCT) are often over-stated

New Technology

- Options & Opportunities
  - **Controls**
    - Get all the juice out of the orange
    - Relatively easy and cost-effective to add to LEDs
  - More Challenging LED Applications
    - Fluorescent troffer replacement
    - High bay applications
  - Potential issues with LEDs
    - Warranty
    - Performance
    - Longevity

An LED Strategy

- Get samples
- Do mock-ups
- Do a life cycle cost
- Caveat emptor (“Buyer Beware”)
  - If it sounds too good to be true, it probably is
- The only constant is change
  - LED efficacies/performance will continue to improve
  - New “nanophosphor” technology will lead to even more efficient LED & fluorescent sources

References

- IESNA Lighting Handbook, 10th edition
- DOE, Energy Efficiency & Renewable Energy
  - http://www1.eere.energy.gov/buildings/ssl/
- A19 LED Bulbs, Blaine Bateman
  - http://www.allledlighting.com/author.asp?section_id=3021&doc_id=560460&print=yes

Lighting Efficiency Best Technologies and Practices

When and Where should I use What?

Downsizing Existing Lighting Systems

“Delamping” in overlit spaces

Best Way to Increase Project Savings

1. Identify current lighting equipment.
2. Interview workers in each area about light levels and effectiveness.
3. Determine existing light levels with light meter.
4. Establish standards using in-house information and industry standards – IES.
5. **Evaluate data for areas of potential lighting reduction**/increase.
6. Choose a qualified product that fits the application
7. Use the standards when changing lighting, verify levels with light meter afterward.
8. Monitor light levels regularly to assess any degradation in levels (Establish then verify/maintain)

Lighting Assessment (Steps 1 – 3): What You Need to Get the Data You Need

Planning and Patience

- Paper survey form(s) or computer-based tools
- Light meter
- Digital camera
- Ballast discriminator
- Handheld counter
- Layouts or drawings of the facility
- Ladder
- Access to facility/storage room – assistance of facility staff
- Contacts and other general information on the facility

Illuminance Selection Procedure

IESNA Illuminance Recommendations for Offices (fc)

Year	Easy	Medium	Difficult
1912	2	4	6
1925	4	6	12
1947	10	30	50
1952	10	30	50
1959	30	70	150
1966	30	70	150
1972	30	70	200
1981	10/15/20	50/75/100	100/150/200
1984	10/15/20	50/75/100	100/150/200
1992	10/15/20	**50/75/100**	100/150/200
2000	5	30	100
2011	10/20/40	**15/30/60**	25/50/100

Schools (fc)

Year	Medium (< 25 yrs)
Pre 2011	**50**
Post 2011	**15**

Compare Current Light Levels with IES Recommendations (Step 4 – 5)

1 Footcandle = 10.76 Lux

Table 30.2 | Industrial Illuminance Recommendations

Applications and Tasks[a]	Notes	Recommended Maintained Illuminance Targets (lux)[b, c, d]									
		Horizontal (E_h) Targets					Vertical (E_v) Targets				
		Visual Ages of Observers (years) where at least half are					Visual Ages of Observers (years) where at least half are				
		Category	<25	25-65	>65	Gauge	Category	<25	25-65	>65	Gauge
BASIC INDUSTRIAL TASKS											
ASSEMBLY											
• Difficult		T	500	1000	2000	Avg	T	500	1000	2000	Avg
• Exacting		W	1500	3000	6000	Avg	W	1500	3000	6000	Avg
• Simple		P	150	300	600	Avg	P	150	300	600	Avg
MATERIALS HANDLING											
• Loading	Inside truck and freight cars	M	50	100	200	Avg	I	15	30	60	Avg
• Picking stock, classifying		M	50	100	200	Avg	K	25	50	100	Avg
• Wrapping, packing, and labeling		P	150	300	600	Avg	N	75	150	300	Avg
WAREHOUSING AND STORAGE											
• Inactive		K	25	50	100	Avg	H	10	20	40	Avg
• Active: bulky items; large labels		M	50	100	200	Avg	K	25	50	100	Avg
• Active: small items; small labels		P	150	300	600	Avg	N	75	150	300	Avg

Recommended light (illuminance) levels

Illuminating Engineering Society of North America (IESNA) publishes guidelines (10th edition) based on:

- Type of task performed
- Size of objects handled
- Duration of task
- Contrast
- Average age of workers in that space

Recommended illuminance examples:

- Offices: 20 and 30 fc
- Schools: 10 to 25 fc

Recent Updates to IES Recommendations

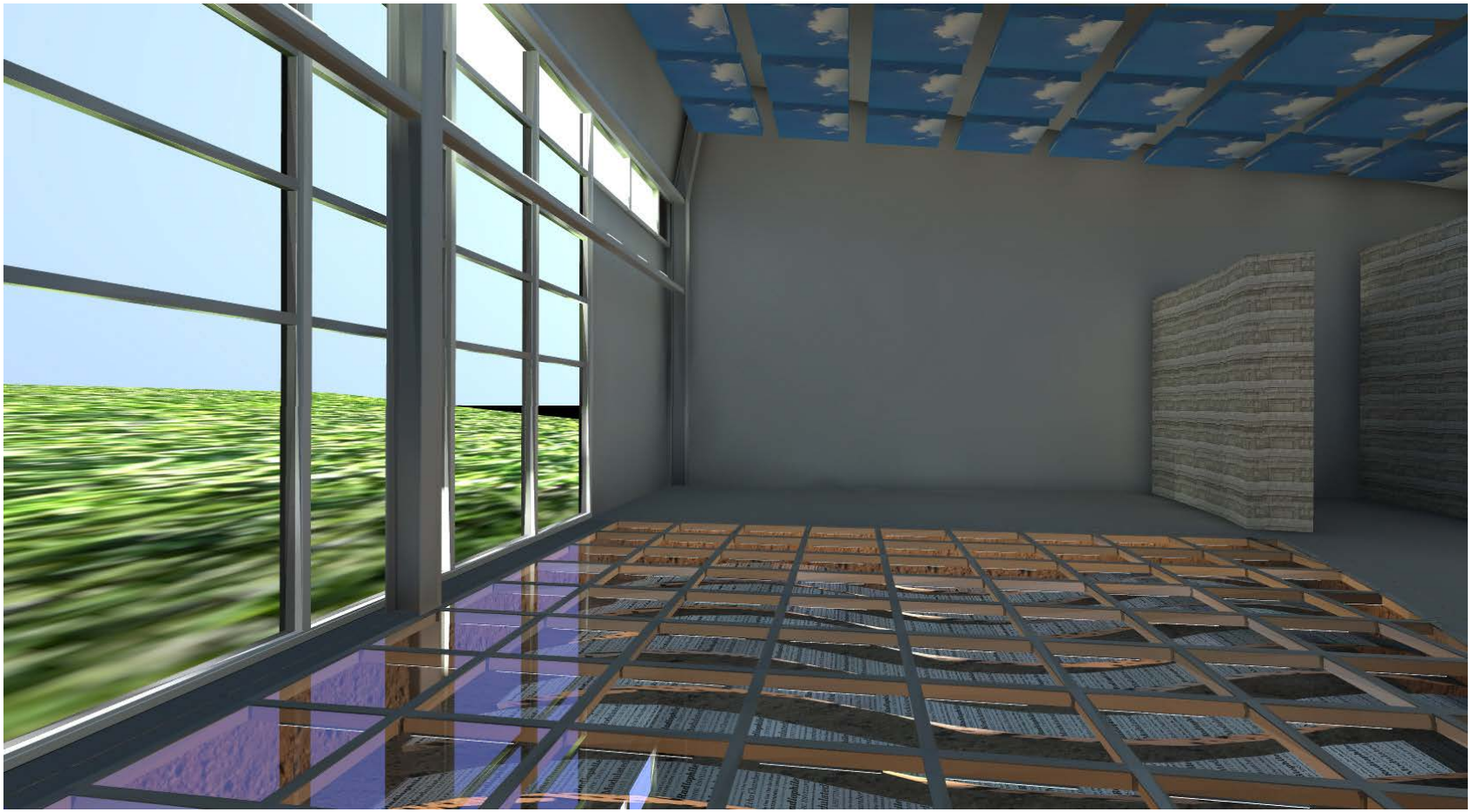
In 2009, the selection procedure was updated

- Increased granularity of illuminance recommendations (by age)
  - Accounts for a younger population (half the anchor value) or an older population (twice the anchor value)
- Localization of illuminance using gauges (min/max/avg) and uniformity (min-max, avg-min)
- Activity Levels
  - Variations are allowed based on the activity within the space
- Includes mesopic multipliers to account for mesopic adaptation
  - Limited to exterior, very low luminance

Lighting Calculation Tools

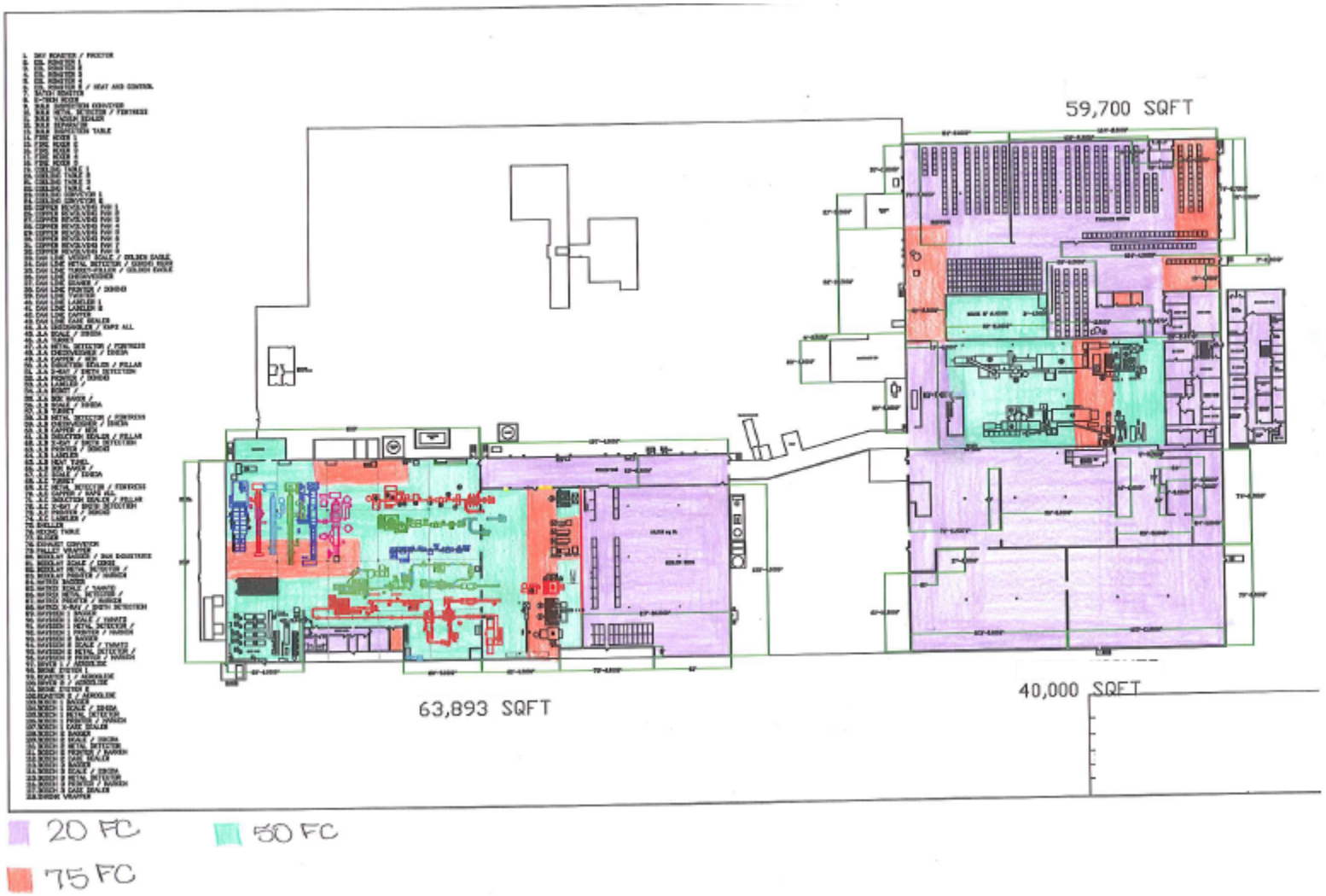
- In a word, software
  - Computer-Aided Design (CAD) software
    - Agi32
    - DIALux
    - Visual
  - Savings Calculation software
    - Available online from many controls companies
    - Lamp manufacturers (GE Lighting, Osram, Philips) all have a number of online and downloadable calculators

Lighting Calculation Tools

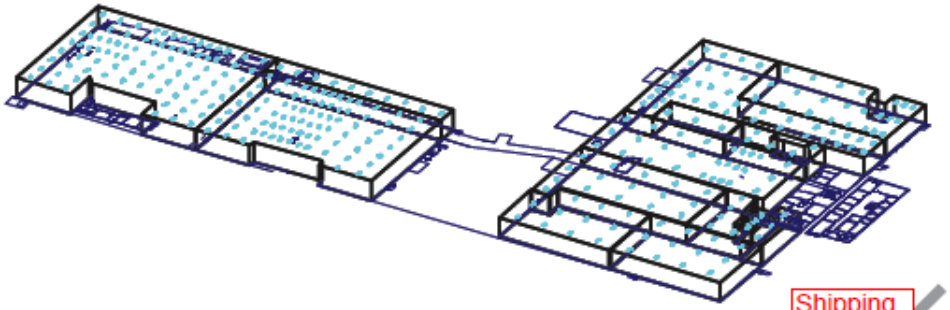


Lighting Calculation Tools

Example Analysis:
Verifying Proposed Solution in Software

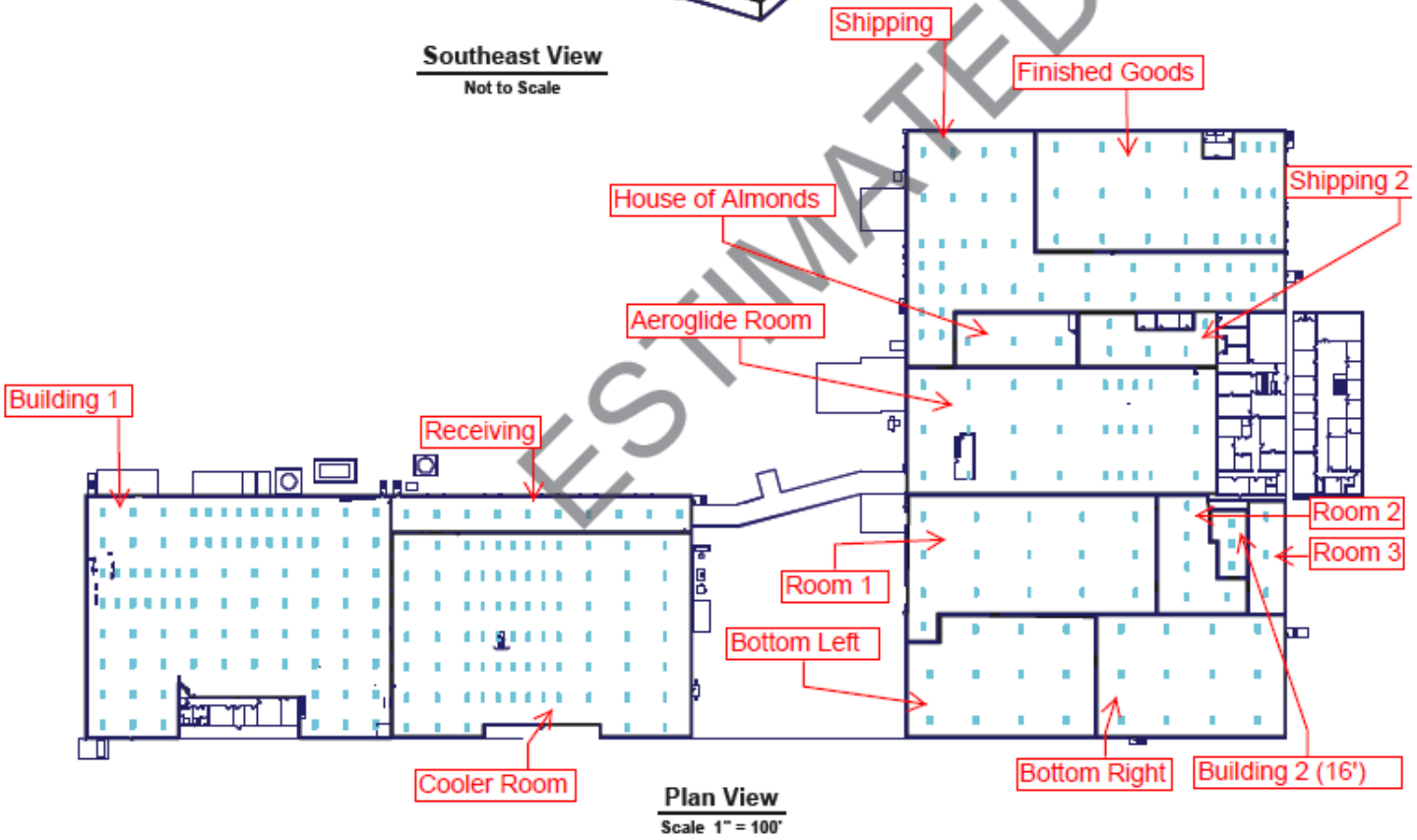


Verifying Proposed Solution in Software



Southeast View

Not to Scale



Plan View

Scale 1" = 100'

Verifying Proposed Solution in Software: Light Level Results

LUMINAIRE SCHEDULE

Symbol	Label	Qty	Catalog Number	Description	Lamp	File	Lumens	LLF	Watts
	A	466	IBZ 632 WD	IBZ, (6) LAMP T8 HIGH BAY WITH WIDE DISTRIBUTION WHITE REFLECTOR	SIX 32-WATT LINEAR FLUORESCENT T8, HORIZONTAL POS.	IBZ_632_WD.ies	2800	1.15	218

STATISTICS

Description	Symbol	Avg	Max	Min	Max/Min	Avg/Min
Aeroglide Rm	+	45.3 fc	87.6 fc	27.2 fc	3.2:1	1.7:1
Cooler Room	+	47.0 fc	78.7 fc	16.6 fc	4.7:1	2.8:1
Finished Goods	+	46.6 fc	86.2 fc	25.2 fc	3.4:1	1.8:1
House of Almonds	+	22.5 fc	34.1 fc	12.5 fc	2.7:1	1.8:1
Leigh Fisher (16' Ceiling)	+	35.6 fc	43.0 fc	28.2 fc	1.5:1	1.3:1
Leigh Fisher (bottom left)	+	31.0 fc	42.9 fc	15.1 fc	2.8:1	2.1:1
Leigh Fisher (bottom right)	+	32.4 fc	44.0 fc	19.9 fc	2.2:1	1.6:1
Leigh Fisher Rm1	+	32.2 fc	45.5 fc	18.8 fc	2.4:1	1.7:1
Leigh Fisher Rm2	+	30.5 fc	43.5 fc	15.7 fc	2.8:1	1.9:1
Leigh Fisher Rm3	+	30.4 fc	35.3 fc	25.0 fc	1.4:1	1.2:1
Receiving	+	22.6 fc	23.9 fc	17.3 fc	1.4:1	1.3:1
Shipping	+	59.2 fc	107.5 fc	23.3 fc	4.6:1	2.5:1
Shipping 2	+	32.0 fc	45.8 fc	16.4 fc	2.8:1	2.0:1
Zane Grey	+	43.1 fc	67.9 fc	19.7 fc	3.4:1	2.2:1

Reasons to increase or decrease the target illuminance

- Age of users
- Life and health issues
- Safety and security issues
- Energy and code requirements
- Historical context
- Reduced visual function
- Melatonin suppression at night
- Mental dysfunction
- Unusual maintenance requirements
- Non-human requirements (plants, animals, cameras)
- Material degradation/ preservation issues
- Unusual client specifications
- Mesopic adaptation

Use your professional judgment and experience

Meeting Target Illuminance Levels

- Energy Codes and Lighting Power Density
  - Many Codes will refer to Lighting Power Density (LPD)
  - Limitations of LPD are used as a method of encouraging more efficient designs
  - LPD is measured as Watts/square foot or square meter
  - A design with an LPD value of 1 W/sf will be 25% more efficient than a design with 1.3 W/sf
  - Note that LPD does not measure glare, appropriateness, or any other lighting quality issues
  - Most designers use the 90.1 definition of determining LPD values

Illuminance Selection Procedure: Meeting LPDs

ANSI/ASHRAE/IESNA 90.1 Lighting Power Density (W/sf)

Sample Lightiing Power Densities Using the Building Area Method					
Occupancy Type	Edition: ASHRAE 90.1 -				
	1989*	2001	2004	2007	2010
Office	1.57	1.30	1.00	1.00	0.90
Retail	2.28	1.90	1.50	1.50	1.40
School/University	1.76	1.50	1.20	1.20	0.99
Hospital	N/A	1.60	1.20	1.20	1.21
Warehouse	0.43	1.20	0.80	0.80	0.66
Multi-family	N/A	1.00	0.70	0.70	0.60
Hotel	N/A	1.70	1.00	1.00	1.00
	*applies to buildings 50,001 to 250,000 sq ft				

Using LPD as a Design Tool

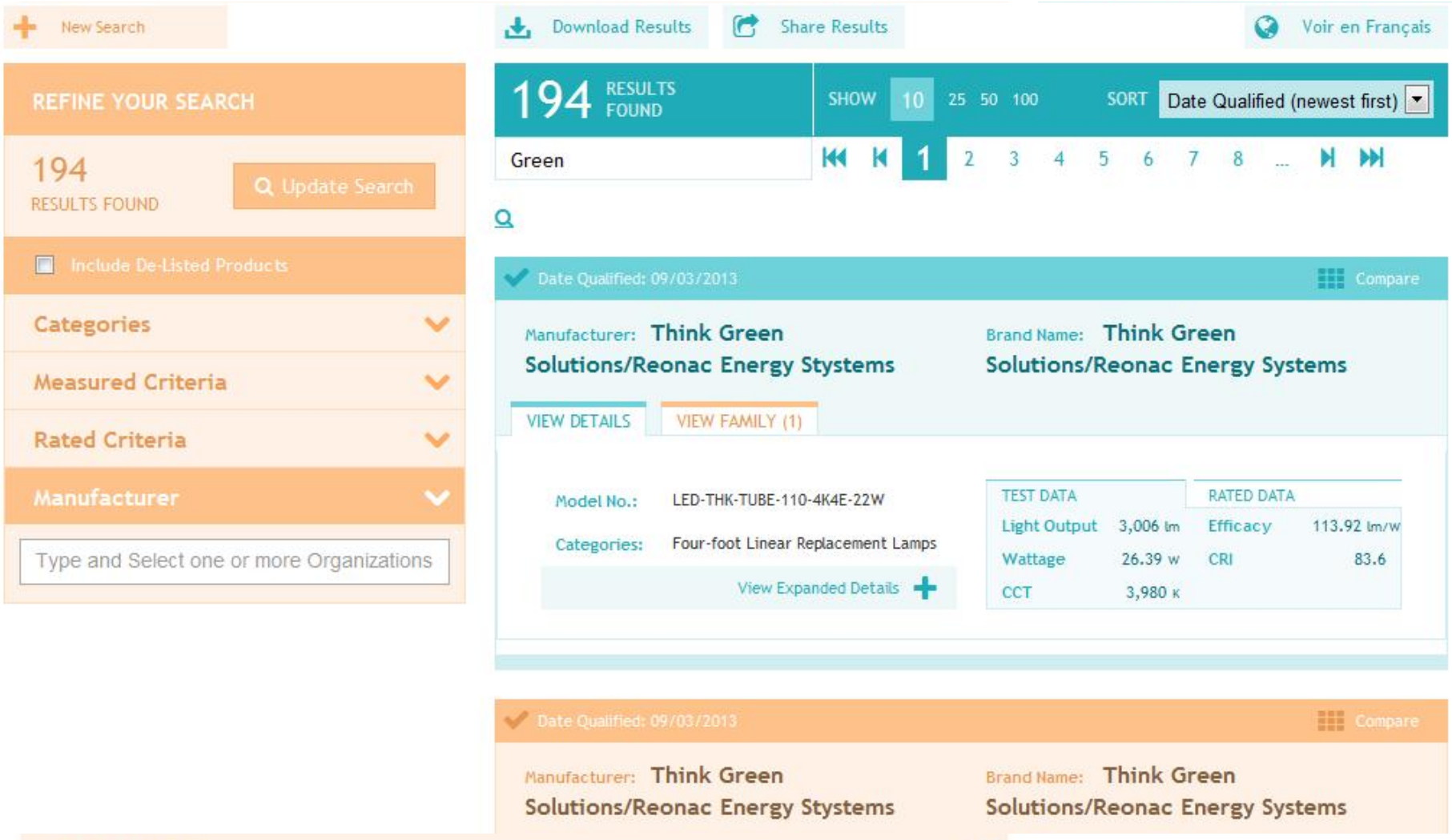
- Energy Codes and Lighting Power Density
  - Example:
    - The LPD for an office space is 0.9 W/sf
    - The space is 10,000 square feet
    - The designer knows the maximum lighting load is 9 kW
      - (10,000 x 0.9 = 9,000W)
    - If a 2 lamp T8 luminaire is rated at 58W, then there will be 155 luminaires
      - (9,000 / 58 = 155)
    - If the designer wants to aim for 20% below 90.1, then she selects a luminaire which will achieve the illuminance with only 124 luminaires required

LED Qualification Standards: DesignLights and ENERGY STAR (Step 6)

Qualified Product Lists - To qualify for Utility incentives, LED Products must be pre-qualified under one of the following options:

- **Energy Star LED Lamps:** http://www.energystar.gov/ → Find Energy Star Products → LED Light Bulbs
  - Integral Lamps – "LED Light Bulbs"
- **Energy Star LED Fixtures:** http://www.energystar.gov/ → Find Energy Star Products → Business & Government → Commercial LED Lighting
  - Recessed Downlights
  - Under-cabinet task lighting
  - Desk task lamps
  - Wall-wash luminaires
  - Bollards
- **Design Lights Consortium (DLC) LED Fixtures:** http://www.designlights.org/ → Solid State Lighting → Qualified Products List (QPL)
  - Outdoor Area/Roadway
  - Outdoor Decorative
  - Outdoor Wall-mount
  - Parking Garage
  - Track and Directional
  - Refrigerated Case
  - Display Case
  - Linear Panels/Troffers (2x2, 2x4, 1x4)
  - Floodlights
  - Retrofit Kits
  - Highbay
  - Lowbay
  - Gas Station Canopy
  - LED Linear T8 Replacement Lamps
  - Linear Ambient

DesignLights: Product Search



What are High Performance and Reduced Wattage T8 Systems? (Step 6)

Using the Consortium for Energy Efficiency (CEE) standards

- Listings for lamps and ballasts on CEE Web site (www.cee1.org)

Lamp +

- Color Rendering Index (CRI)
- Minimal Initial Lumens
- Lamp Life
- Lumen Maintenance

- High Performance (32W High Lumen - XP, SPX, ADV)
- Reduced Wattage (25W; 28W)

Ballast =

- Ballast Efficacy Factor (BEF)
  - Instant Start
  - Programmed Start
  - per Ballast Factor
- Frequency, Power Factor and Harmonic Distortion

- Premium Ballast Lines (Ultramax, Optanium, QHE)
- Most *NEMA Premium*

System

System Efficacy in Mean Lumens per Watt (MLPW)

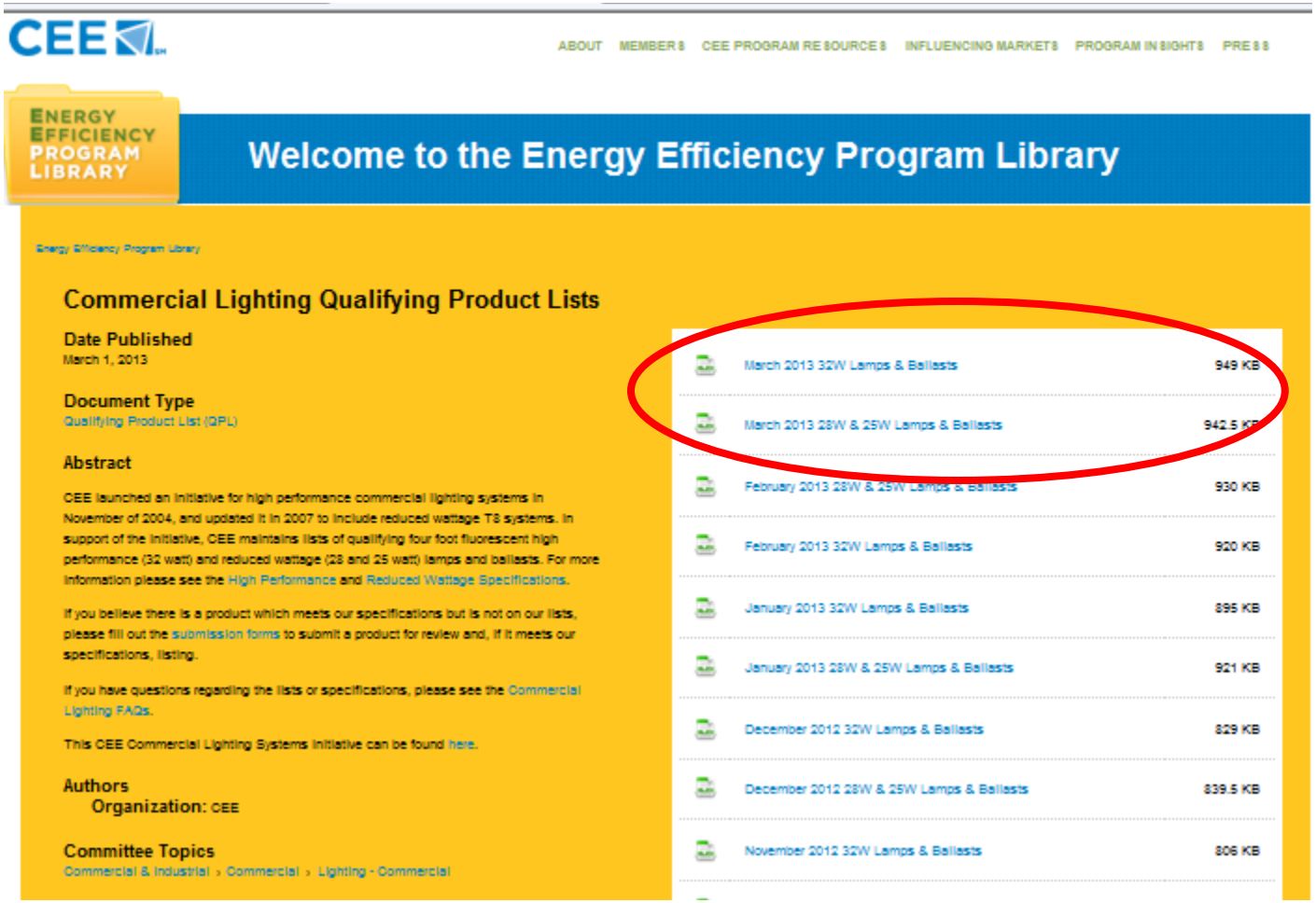
- Countless combinations from many different fixture manufacturers

+

=

CEE listing: Typical Requirements for T8

http://library.cee1.org/content/commercial-lighting-qualifying-products-lists



Tweaking the Solution: Ballast Factors (Step 6)

- Ballast Factor (BF)
  - Designers use Ballast Factor as a design tool
  - Example – 2 lamp systems, using F32 T8 standard lamp

Type	Ballast Factor	Initial Lumens	Watts	Initial lm/W
Low BF	0.78	4,680	48W	98 lm/W
Normal BF	0.88	5,280	55W	96 lm/W
High BF	1.2	7,200	74W	97 lm/W

Tweaking the Solution: Lamp Types (Step 6)

- Lamp Types
  - Designers use Lamp Types as a design tool
  - Example – 2 lamp systems, using F32 T8 lamp
  - Normal Ballast Factor 0.88

Lamp Type	Initial Lumens	System Lumens	Watts	Initial lm/W
Low Watt	2,725	4,800	48W	100 lm/W
Normal	2,850	5,015	52W	96 lm/W
Premium	3,000	5,280	55W	96 lm/W

Lamp Type Considerations

- Reduced Wattage T8 (RWT8) Lamps
  - 25W lamps, no ballast change required
  - Use with caution, especially with existing Instant Start (IS) ballasts
  - Not recommended for short duty cycles or for colder ambient environments

Lighting Redesign

Going beyond 1-for-1 retrofits and getting the most out of your retrofit

Redesign Opportunities and Goals

Why do we care?

- Most spaces are poorly illuminated
  - Changes in tasks and technologies have made older designs dysfunctional
  - In general, spaces tend to be overlit Existing luminaires and layouts may not be appropriate
- Our goals should be
  - Do no harm
  - Improve the lighting quality
  - Save energy
  - If your goal is *only* to save energy, turn off all the lights and send the people home

Design Process

Lighting Redesign Described

- A not-so-new concept that should be revisited
  - Many spaces are overlit
  - Many spaces are lit improperly
- Design with tasks in mind: what luminaire will work the best for this task?
- Design with controls in mind
- *with* redesign, you can achieve **70-90%** energy savings!

Lighting Redesign Practiced

- Place luminaires where needed
- Minimize overhead ambient lighting
- Install task lighting (with controls)
- Highlight vertical surfaces
- Use different luminaires for passageways
- Add additional zones for controllability
- Switch to dimming ballasts/drivers, and tune down to 80%

Redesign Considerations

- Overlit Spaces
  - Perfect candidate for redesign is an overlit space
  - These occur very frequently
  - Difficulty may be getting buy-in from all users
  - Mock-up almost essential
  - If existing luminaires are in excellent condition, delamping and reflectors may be feasible and cost-effective
  - New luminaires may give the best payback

Redesign Considerations

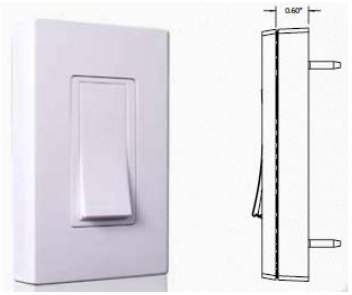
- Renewal Issues
  - It can be counter-productive to stuff new technology into a fixture which is at end-of-life
  - Trade-off is disposal costs for removing old luminaires
  - On fluorescent systems, lamp sockets and lenses usually must be replaced
  - The challenge is the relatively high cost of onsite labour compared to the lower cost of labour for building a new luminaire
  - This can be offset by supplying retrofit or upgrade kits to the site pre-assembled

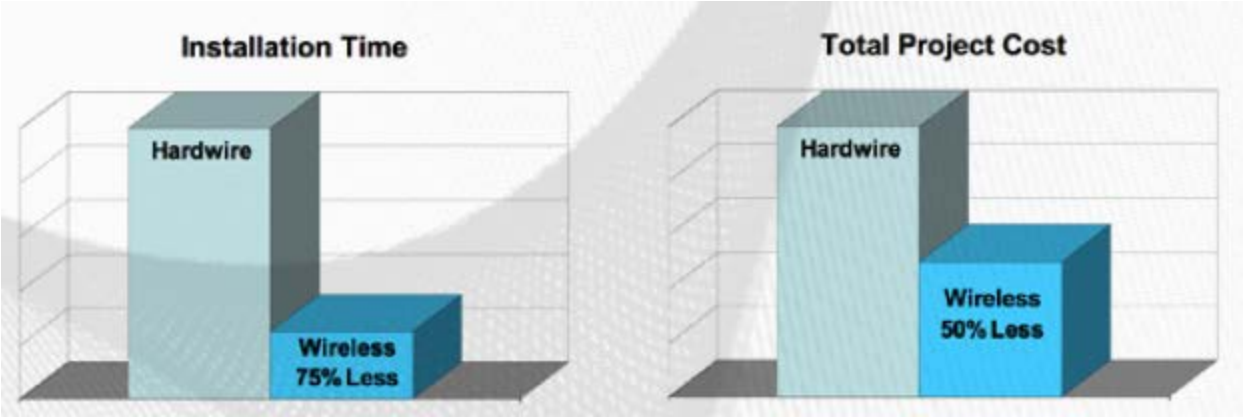
Lighting Controls

Wireless and Integrated Controls are changing the game for retrofits

Wireless (or Low Volt) Controls with LED Retrofits

- **Additional Energy Savings**
- **Flexibility**
- **Scalability**
- **Ease of Installation**
  - low voltage almost as easy





Lighting Controls & Control Strategies

- New controls technologies offer flexibility at reasonable price
- Enables getting all “the juice out of the orange”
- Best candidates
  - Spaces with no local switching
  - Spaces with variable occupancy

Dimming

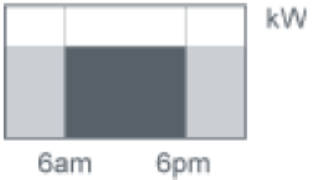
- Technically feasible with all sources
- Difficult cost/benefit due to cost of electricity
- Dimming systems also use some power, so a 50% reduction in illuminance does not translate to a 50% saving
- No-brainer applications:
  - Flexible use spaces such as conference rooms, board rooms
- Challenges
  - Dimming LED can be problematic mostly due to lack of driver standards

Leveraging Multiple Control Strategies

Smart Time Scheduling

In areas of a building where occupancy sensor control is not appropriate, time scheduled switching or dimming of lights can be employed for zones as small as a room or even individual light fixture.

10-40%



Daylight Harvesting

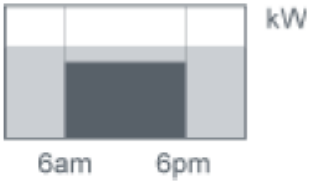
Through the use of photo sensors, light levels are automatically adjusted to take into account ambient natural sunlight entering the building. Appropriate light levels are maintained and artificial lighting is dimmed when necessary.

5-15%

Task Tuning

Setting default (maximum) light levels to suit the particular task or use of a workspace in order to eliminate over lighting.

5-20%

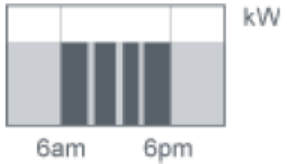


Leveraging Multiple Control Strategies (Cont.)

Occupancy Control

Through the use of occupancy sensors, lights are automatically turned on or off or dimmed based on occupancy detection.

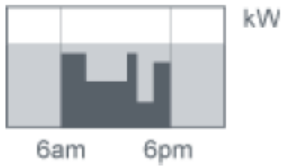
25-50%



Personal Control

Through the Personal Control Software, individuals can control (dim) the light levels in their workspace to suit their personal preferences from their desktop PC.

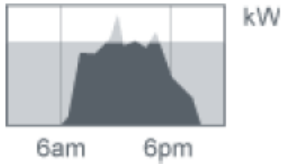
5-15%



Variable Load Shedding

The automatic reduction of electrical demand in a building by shedding lighting loads dynamically (through dimming or switching) either to shave peak demand or to respond to a utility price or demand response signal. Load shedding can be done selectively by lowest priority areas first.

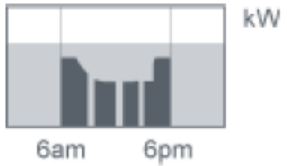
10%



Combined Energy Savings

Potential cumulative savings from above strategies.

Up to 50 - 75%



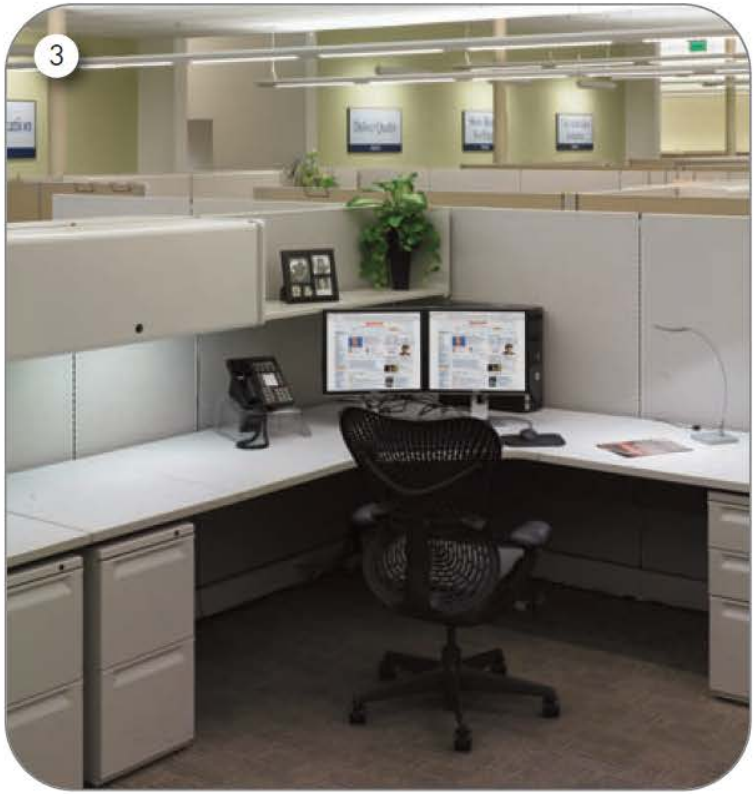
Low Ambient / Task Lighting Strategies

Putting the right amount of light where you need it

Low Ambient/Task Lighting

- In the past, interior lighting systems were designed to light an entire space to the same illuminance with reasonable uniformity
- This approach is wasteful since the highest required illuminance is present throughout the space
- A more intelligent approach is low ambient lighting with task lights as required
- People with task lights generally use them only when necessary
- Today, most office interiors are designed to about 250–300 lx (25–30 fc) ambient illuminance

Low Ambient/Task Lighting



1 Light the task first

Just the PLS task lighting can virtually light the entire work area with only 12 watts.

2 Light the vertical surfaces

Adding a small amount of vertical illumination on the back wall begins to bring balance to the overall brightness in the space.

3 Fill in with ambient lighting at 0.4 w/ft^2

A low ambient approach creates a pleasant and inviting ambience. Illumination levels in the work areas meet task lighting requirements, while allowing for engaged personal interaction. Luminance ratios meet IESNA recommendations of no more than 3:1 in the immediate task area, and no more than 10:1 between the immediate task area and the surrounding visual field of view.

Lowbay Fluorescents Work Well in ...

...<u>Task Lighting</u> to minimize general ambient light

- When upgrading lighting, maximize task lighting and minimize ambient or overhead – put light where needed.

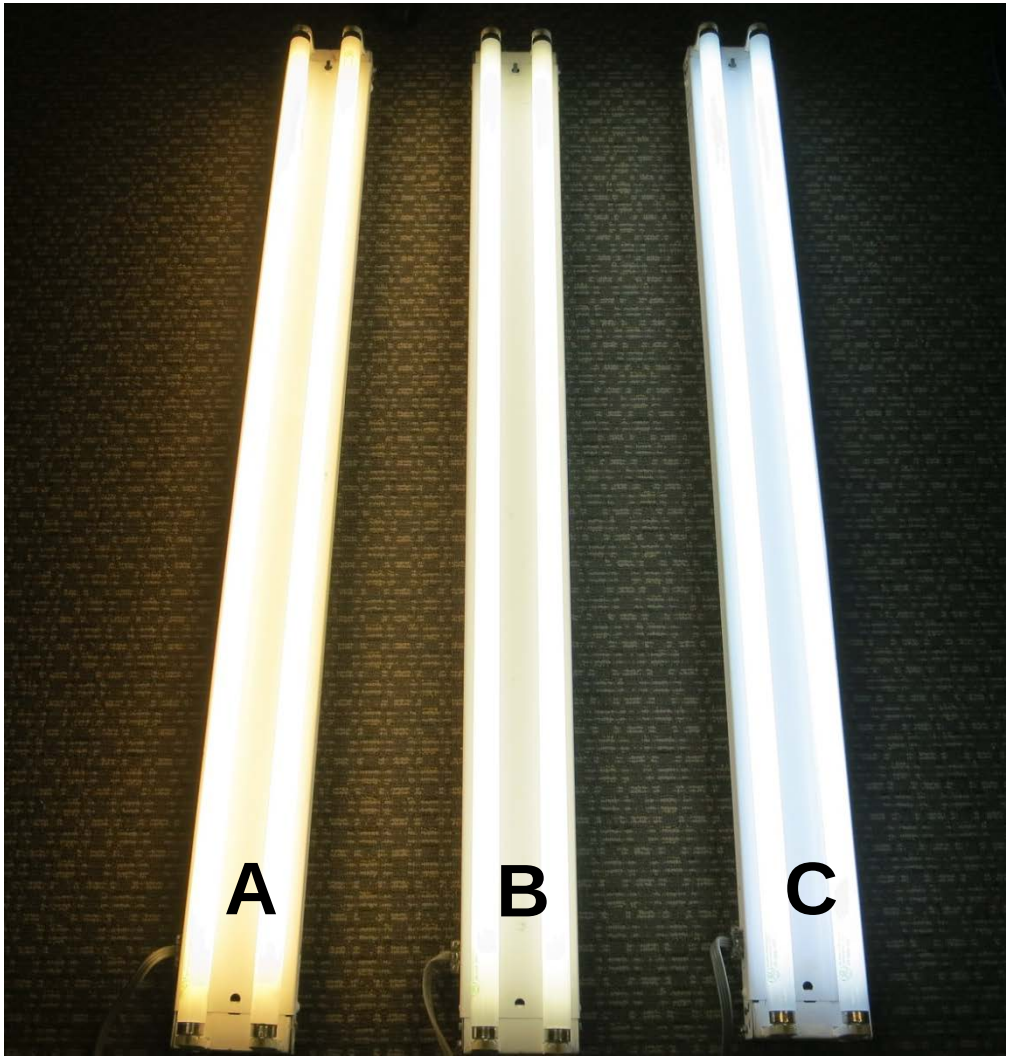
- Combination of area lighting and independently switched task lighting saves up to 20%.

Spectrally Enhanced Lighting (SEL)

Using High CCT Products to Gain Efficiencies

What do you see???

- Which system is brighter?
- Which system is producing more light?
- Which color do you prefer?



A

73W; 40fc; 3000K; High BF

B

54W; 31fc; 4100K; Norm BF

C

48W; 26fc; 6500K; Low BF

What it SEL and how does it work

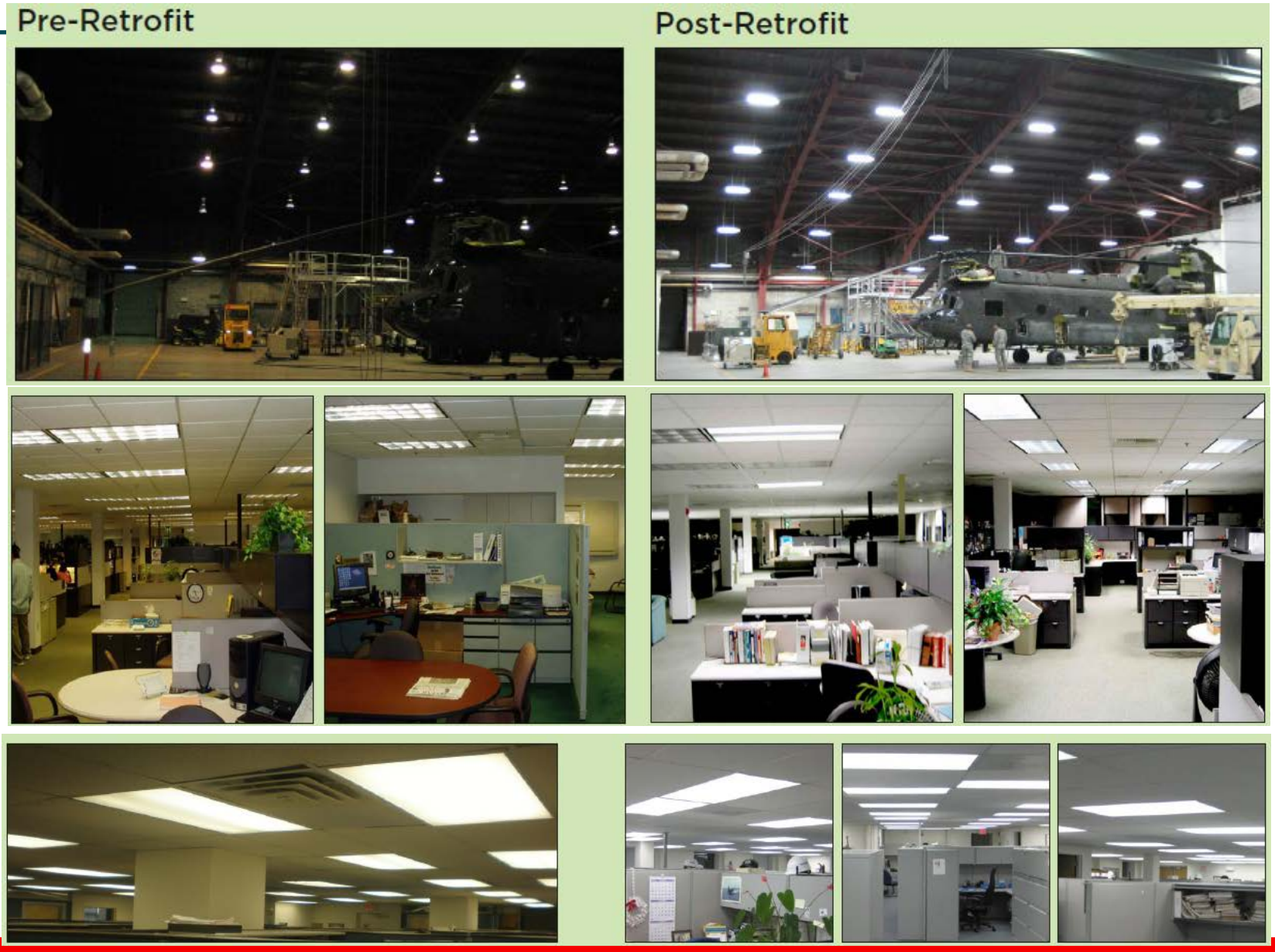
What is Spectrally Enhanced Lighting (SEL)?

- Design method for interior lighting applications where **visual acuity** is important
- Uses higher Color Temperature lamps closer to “Daylight” (≥ 5000K) with a high blue light content (460 to 480 nm), which:
  - Makes the pupil smaller
  - Improves Visual Acuity – ability to resolve fine details
  - Spaces seem brighter – same perceptual effect as increasing light level
  - Affects Circadian Rhythm to a degree
- Cost effective in and of itself; better if part of a broader efficiency job
  - Can produce an additional 15-20% energy savings
  - No special controls or equipment
- IES now has approved factors (EVE factors) to account for this

Illuminance Selection Procedure

- Equivalent Visual Efficiency (EVE) Ratios
  - From IESNA TM-24-13
  - Interior applications when light with high S/P ratio is used
  - The blue component of the light leads to a smaller pupil size
  - This leads to a bigger focus depth
  - This has a positive effect on demanding tasks for instance reading, repairing goods, analyzing goods etc (seeing and recognizing details)
  - More research is required, but this is promising and is beneficial with LED systems which are strong in the blue part of the spectrum

What does that look like?



References

- IESNA Lighting Handbook, 10th edition
- DOE, Energy Efficiency & Renewable Energy
  - http://www1.eere.energy.gov/buildings/ssl/

CLEAResult

Case Studies:

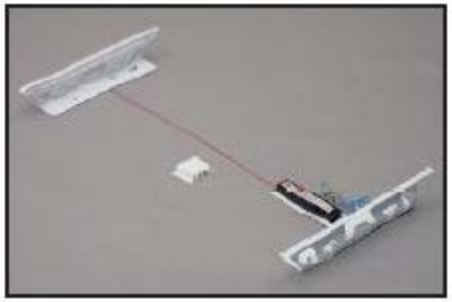
Putting it all together

Case Studies: Interior Troffers

Office Applications

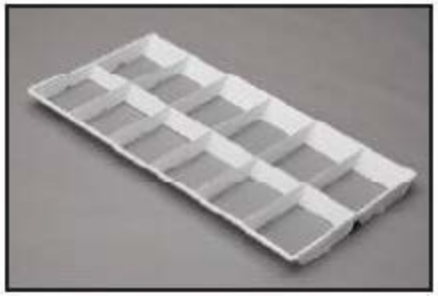
Linear Fluorescent/Troffer Systems & Applications

End Brackets/Splice Box



Reflectors

Louver



Case Studies

- OFFICE/INSTITUTIONAL/HEALTH CARE
  - T8 Vs LED, 30 fc ambient
    - LED luminaires have recently become a valid replacement for T8 recessed troffers

Case Studies

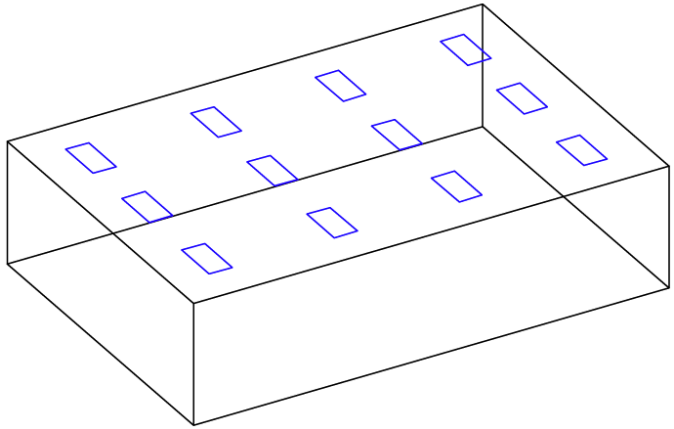
LUMEN METHOD DATA CHART

FACTOR	ITEM	UNITS	3 x T8		LED
SPACE	LENGTH & WIDTH	ft or m	40x60		40x60
	AREA	squ ft or m	2400		2400
	CAVITY HEIGHTS	ft or m	0/6.5/2.5		0/6.5/2.5
	CLG CAVITY RATIO		N/A		N/A
	ROOM CAVITY RATIO		1.4		1.4
	FLOOR CAVITY RATIO		N/A		N/A
	REFLECTANCES	%	50/80/20		50/80/20
	EFFECTIVE REF.	%			
TASK	TASK	A-G	D		D
	REC. ILLUMINANCE	fc or lx	30		30
	TARGET ILLUMINANCE	fc or lx	NA		NA
SOURCE	TYPE		T8		LED
	LAMP LUMENS	lumens	2670		6808
	TOTAL LUMENS	lumens	8010		6808
LUMINAIRE	CU	decimal	0.77		0.99
	ADJUSTED CU		NA		
	LOAD	Watts	64		71
LIGHT LOSS FACTORS	BALLAST FACTOR*	decimal	0.71		1
	LLD*	decimal	0.94		0.8
	Maint. Category	I-VI			
	Room Dirt Cond.				
	Maint. Interval	months			
	LDD*	decimal	0.95		0.95
	Room Dirt Cond.				
	Maint. Interval	months			
	Expected Dirt Dep.	decimal			
	CIE Type				
	RSDD*	decimal	0.95		0.95
	LLF	decimal	0.60		0.72
	NO. REQUIRED		19		15
	ILLUMINANCE	fc or lx	30		30
	DENSITY	sf/luminaire	NA		NA
	LPD	W/sf	0.5		0.4

20% energy saving with LED

Delamping Retrofit Example: Open Office or Classroom (12 fixtures)

- IES Recommended footcandle levels, between **20 and 30 fc for Offices; 10 to 25 for Schools**
  - 97 fc Maximum; 78 fc Average
  - Creates Eye Strain and Glare

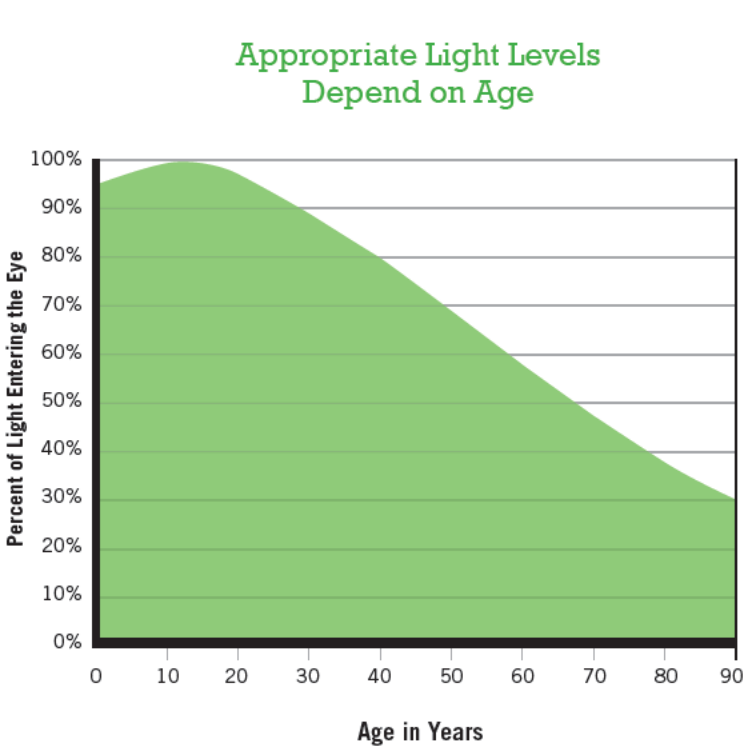


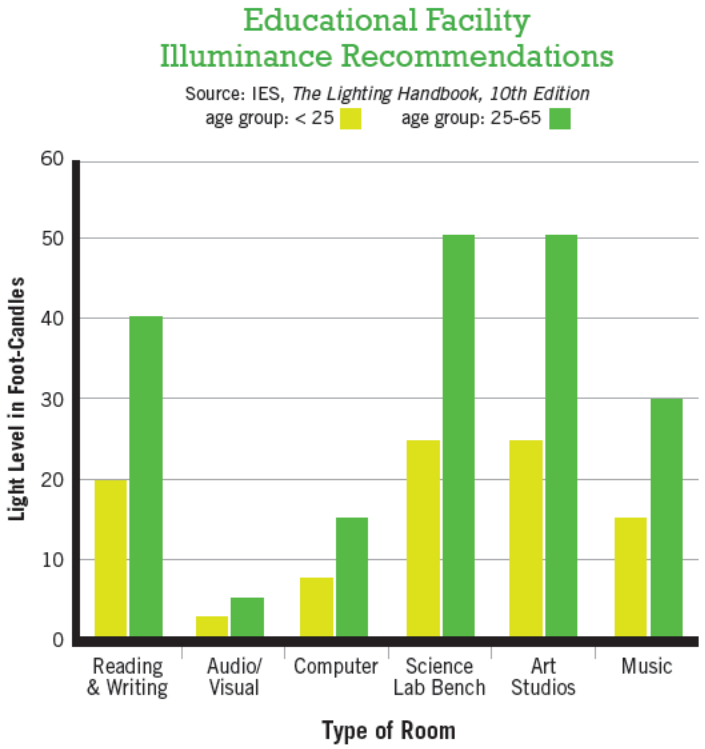
Area	# of Fixt	Fixture Type	Fixture Watts (W)	Total Watts (W)	Area (SqFt)	Power Density (W/SqFt)	Average Maintained Footcandles	Max Footcandles	Savings (%)	
									vs T12	vs Std T8
Baseline (T12 Magnetic)	12	4 lamp, 34W T12 Magnetic	144	1,728	1034	**1.7**	**62**	**77**	NA	NA
Least Cost Option; Newer Baseline (Standard T8)	12	4 lamp, 32W T8 Electronic	112	1,344	1034	**1.3**	**78**	**97**	**22%**	NA
Change Case (Reduced Wattage T8) or LED	12	2-lamp, 28W T8, **Low BF** (or LED)	43 (as low as 34W)	516	1034	**0.5**	**32**	**41**	**70%**	**62%**

IES' School Lighting Recommendations

Schools (fc)

Year	Medium (< 25 yrs)
Pre 2011	50
Post 2011	15





IES Recommendations: Office or Schools

Table 32.2 | Office Facilities Illuminance Recommendations continued from previous page

Applications and Tasks[a]	Notes	Recommended Maintained Illuminance Targets (lux)[b, c, d]									
		Horizontal (E_h) Targets					Vertical (E_v) Targets				
		Visual Ages of Observers (years) where at least half are					Visual Ages of Observers (years) where at least half are				
		<25	25-65	>65			<25	25-65	>65		
		Category			Gauge		Category				Gauge
• Print Media	Digital-printing-press-generated, white paper										
• 6-pt Font											
· Matte paper and ink	E_h @2' 6" AFF; E_v @4' AFF[j]	R	250	500	1000	Avg	L	37.5	75	150	Avg
· Specular paper and ink	E_h @2' 6" AFF; E_v @4' AFF[j]	R	250	500	1000	Avg	L	37.5	75	150	Avg
• 8- and 10-pt Font											
· Matte paper and ink	E_h @2' 6" AFF; E_v @4' AFF[j]	P	150	300	600	Avg	K	25	50	100	Avg
· Specular paper and ink	E_h @2' 6" AFF; E_v @4' AFF[j]	P	150	300	600	Avg	K	25	50	100	Avg
• 12-pt Font											
· Matte paper and ink	E_h @2' 6" AFF; E_v @4' AFF[j]	O	100	200	400	Avg	K	25	50	100	Avg
· Specular paper and ink	E_h @2' 6" AFF; E_v @4' AFF[j]	O	100	200	400	Avg	K	25	50	100	Avg
• VDT Screen and Keyboard											
• CSA/ISO Types I and II	See Figure 12.16 | CSA/ISO Computer Screen Qualities										
· Positive polarity	E_h @2' 6" AFF; E_v @3' 6" AFF[j]	P	150	300	600	Avg	N	75	150	300	Avg
· Negative polarity	E_h @2' 6" AFF; E_v @3' 6" AFF[j]	N	75	150	300	Avg	K	25	50	100	Avg
• CSA/ISO Type III	See Figure 12.16 | CSA/ISO Computer Screen Qualities										
· Positive polarity	E_h @2' 6" AFF; E_v @3' 6" AFF[j]	N	75	150	300	Avg	K	25	50	100	Avg
· Negative polarity	E_h @2' 6" AFF; E_v @3' 6" AFF[j]	L	37.5	75	150	Avg	I	15	30	60	Avg
• White Board											
• Analog or Digital											
· Reading (reference)							N	75	150	300	Avg
· Reading (with presenter)	Presenter at white board						P	150	300	600	Avg

Table 32.2 | Office Facilities Illuminance Recommendations continued next page

What about Troffers and LED Replacement Lamps?

High Performance Fluorescent

Still Most Cost-effective Solution in 2014

LED Troffers and Kits

Best after 2nd QTR 2015

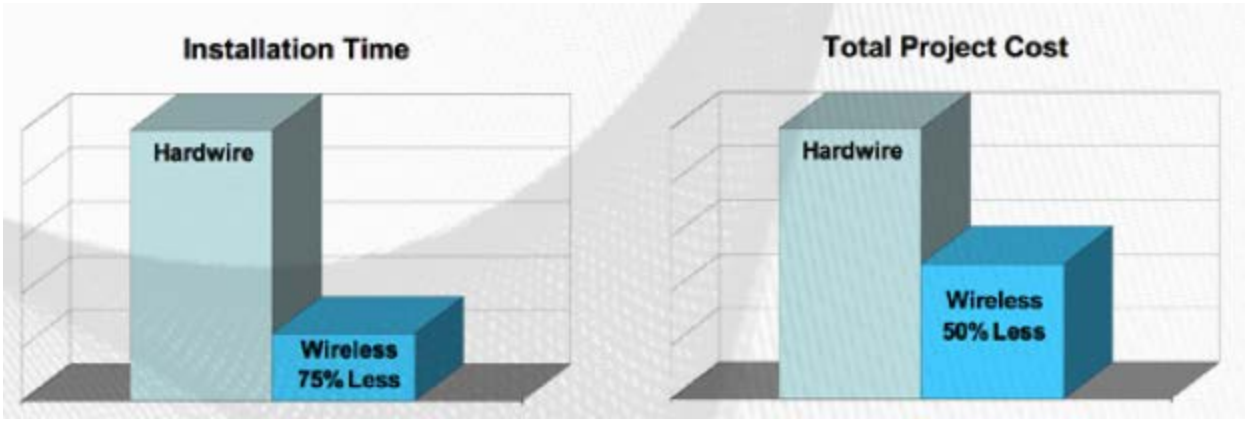
T8 LED Replacement Lamps

Three Types?

Best after 4th QTR 2014

Put Wireless (or Low Volt) Controls on LED Retrofits

- **Additional Energy Savings**
- **Flexibility**
- **Scalability**
- **Ease of Installation**
  - low voltage almost as easy



Case Studies: HID Replacement

Manufacturing, Warehouse and Exterior HID Replacements

What do we do with HID?

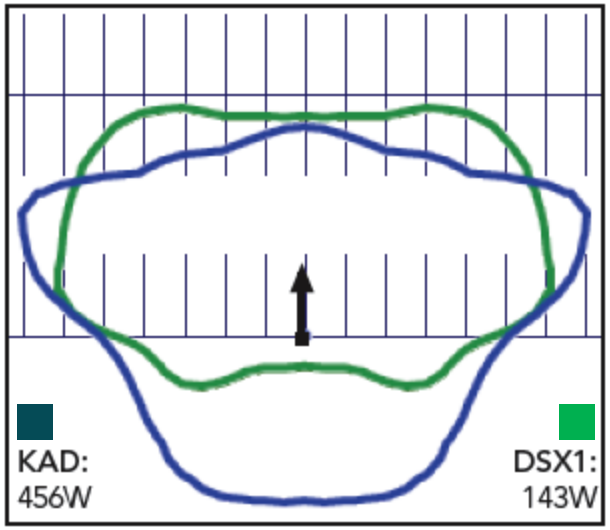
Replace it!

Can’t Compare to Fluorescent and LED

LEDs Put Light Where You Need It

- Half the light
- 1/3 the wattage
- **Same average footcandles!**

456W
Metal Halide



143W
LED

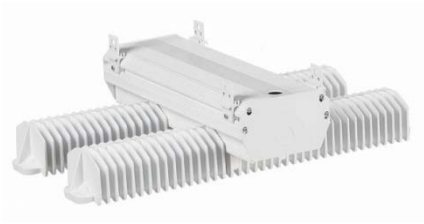
Indoor HID Replacement: LED Highbay

Pro

- Life
- Control
- 40-80% savings

Con

- Initial Cost
  - **LED $** **> $400**
  - Fluorescents < $300



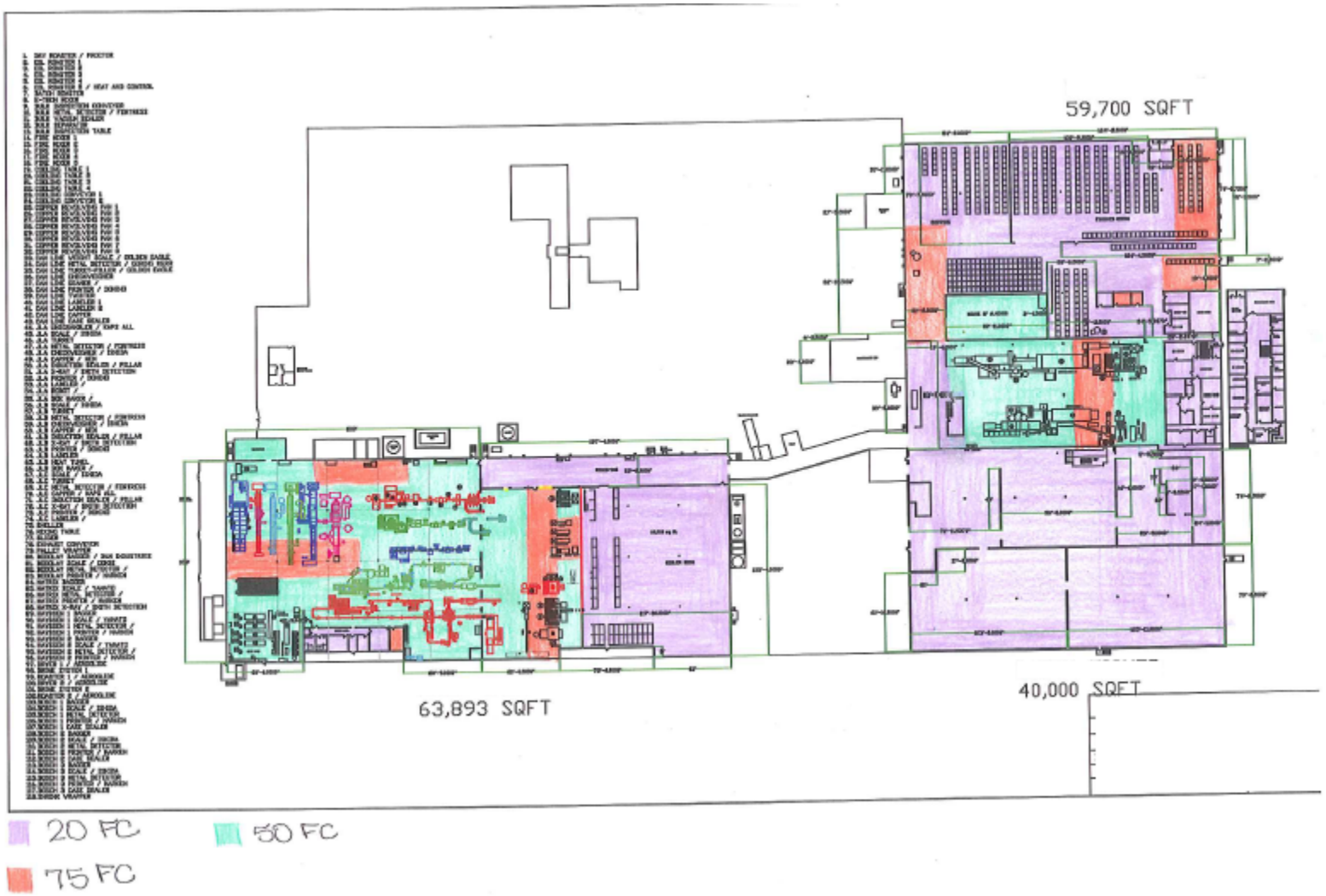
Compare Current Light Levels to Goals and IES Recommendations

1 Footcandle = 10.76 Lux

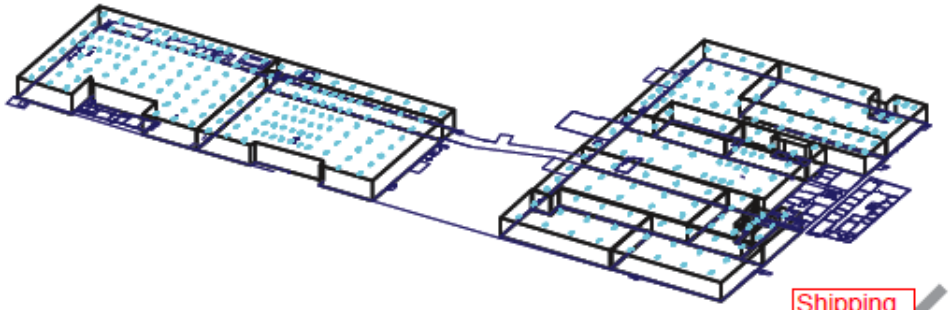
Table 30.2 | Industrial Illuminance Recommendations

Applications and Tasks[a]	Notes	Recommended Maintained Illuminance Targets (lux)[b, c, d]									
		Horizontal (E_h) Targets					Vertical (E_v) Targets				
		Visual Ages of Observers (years) where at least half are					Visual Ages of Observers (years) where at least half are				
		Category	<25	25-65	>65	Gauge	Category	<25	25-65	>65	Gauge
BASIC INDUSTRIAL TASKS											
ASSEMBLY											
• Difficult		T	500	1000	2000	Avg	T	500	1000	2000	Avg
• Exacting		W	1500	3000	6000	Avg	W	1500	3000	6000	Avg
• Simple		P	150	300	600	Avg	P	150	300	600	Avg
MATERIALS HANDLING											
• Loading	Inside truck and freight cars	M	50	100	200	Avg	I	15	30	60	Avg
• Picking stock, classifying		M	50	100	200	Avg	K	25	50	100	Avg
• Wrapping, packing, and labeling		P	150	300	600	Avg	N	75	150	300	Avg
WAREHOUSING AND STORAGE											
• Inactive		K	25	50	100	Avg	H	10	20	40	Avg
• Active: bulky items; large labels		M	50	100	200	Avg	K	25	50	100	Avg
• Active: small items; small labels		P	150	300	600	Avg	N	75	150	300	Avg

Example Analysis

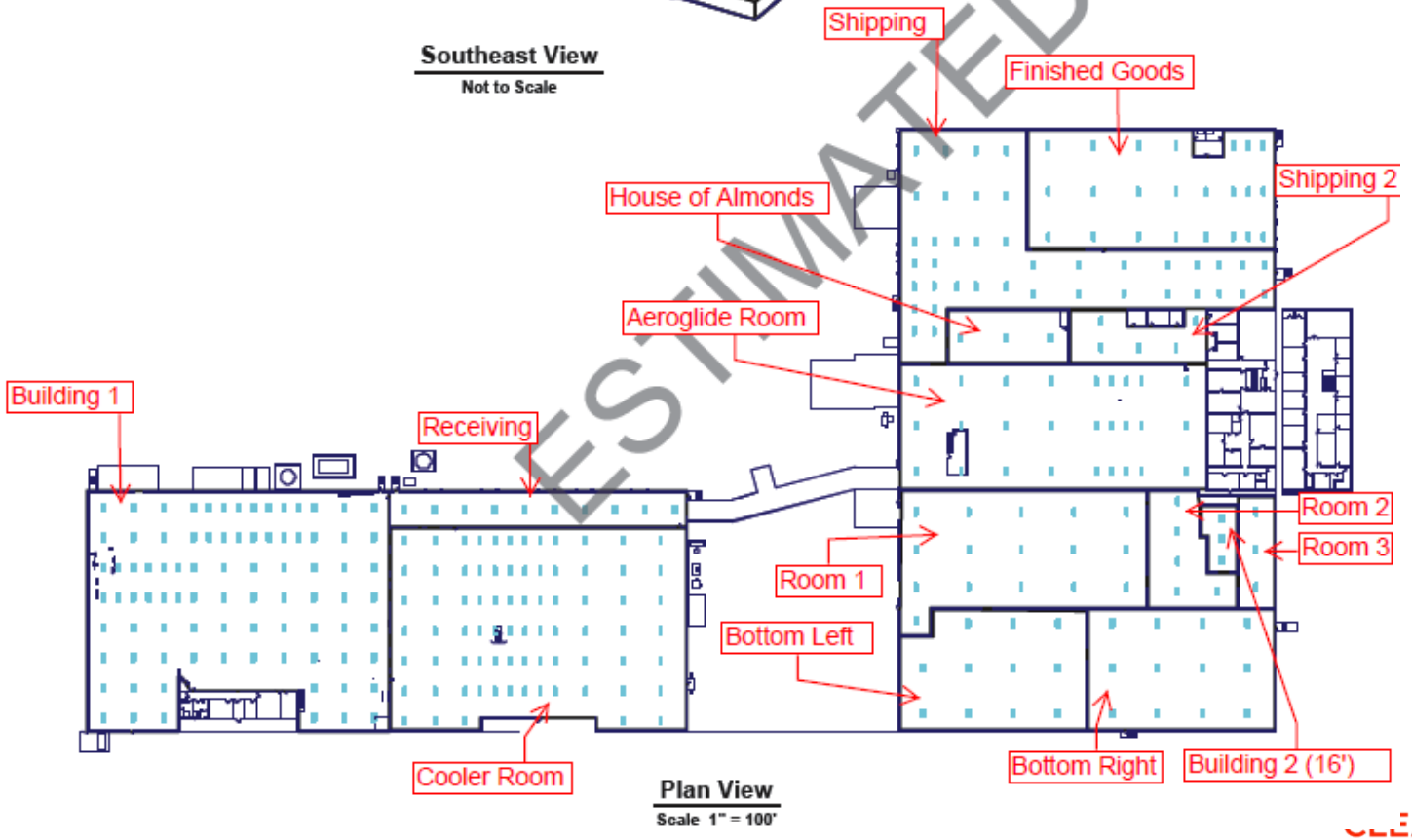


Example Analysis: Proposed Solution



Southeast View

Not to Scale



Plan View

Scale 1" = 100'

Example Analysis: Light Level Results Insufficient

LUMINAIRE SCHEDULE

Symbol	Label	Qty	Catalog Number	Description	Lamp	File	Lumens	LLF	Watts
	A	466	IBZ 632 WD	IBZ, (6) LAMP T8 HIGH BAY WITH WIDE DISTRIBUTION WHITE REFLECTOR	SIX 32-WATT LINEAR FLUORESCENT T8, HORIZONTAL POS.	IBZ_632_WD.ies	2800	1.15	218

STATISTICS

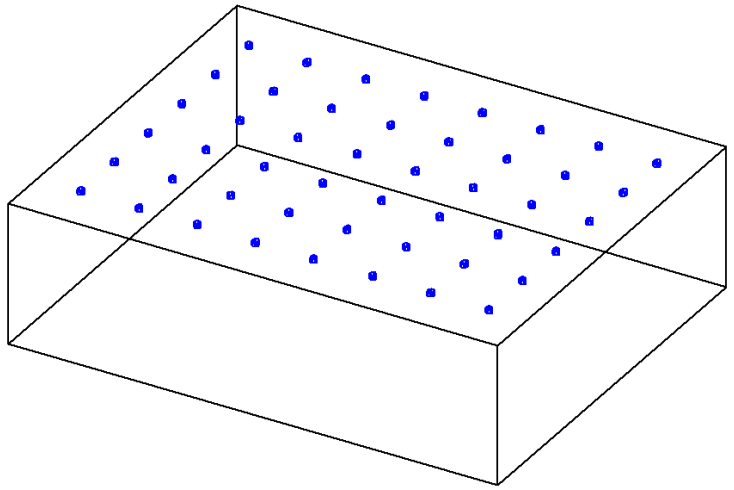
Description	Symbol	Avg	Max	Min	Max/Min	Avg/Min
Aeroglide Rm	+	45.3 fc	87.6 fc	27.2 fc	3.2:1	1.7:1
Cooler Room	+	47.0 fc	78.7 fc	16.6 fc	4.7:1	2.8:1
Finished Goods	+	46.6 fc	86.2 fc	25.2 fc	3.4:1	1.8:1
House of Almonds	+	22.5 fc	34.1 fc	12.5 fc	2.7:1	1.8:1
Leigh Fisher (16' Ceiling)	+	35.6 fc	43.0 fc	28.2 fc	1.5:1	1.3:1
Leigh Fisher (bottom left)	+	31.0 fc	42.9 fc	15.1 fc	2.8:1	2.1:1
Leigh Fisher (bottom right)	+	32.4 fc	44.0 fc	19.9 fc	2.2:1	1.6:1
Leigh Fisher Rm1	+	32.2 fc	45.5 fc	18.8 fc	2.4:1	1.7:1
Leigh Fisher Rm2	+	30.5 fc	43.5 fc	15.7 fc	2.8:1	1.9:1
Leigh Fisher Rm3	+	30.4 fc	35.3 fc	25.0 fc	1.4:1	1.2:1
Receiving	+	22.6 fc	23.9 fc	17.3 fc	1.4:1	1.3:1
Shipping	+	59.2 fc	107.5 fc	23.3 fc	4.6:1	2.5:1
Shipping 2	+	32.0 fc	45.8 fc	16.4 fc	2.8:1	2.0:1
Zane Grey	+	43.1 fc	67.9 fc	19.7 fc	3.4:1	2.2:1

Leveraging High Performance T8
Comparing 4-lamp Systems

System Type	Watts	Mean Lumens of Fixture	Maintained Efficacy (MLPW)	CRI	Rated Lamp Life (hrs)
400W Metal Halide	453	18,300	40	65	15,000 – 20,000
High Performance (HP) Ballast – Six High Lumen 32W Lamps (Normal BF)	162	14,890	92	85	> 24,000
Four Reduced Wattage T5HO 47W Lamps	206	17,360	84	85	30,000
LED Highbay Fixture	130 to 175	12,000 to 20,000	80 to 100	70 to 80	50,000 to 75,000

Warehouse-Maintenance Facility Design

- This Warehouse-Maintenance facility design proposed
  - (36) 400W Metal Halides – 24ft height
- IES Recommended footcandles:
  - 5 - 30 fc Warehouse
  - 50 fc for Maintenance Work
  - 30 – 75 fc Gymnasium



Area	# of Fixt	Fixture Type	Fixture Watts (W)	Total Watts (W)	Area (SqFt)	Power Density (W/SqFt)	Average Maintained Footcandles	Max Footcandles	Savings (%) vs MH 400
Baseline (400W MH)	36	400W MH	453	16,308	8700	1.9	**86**	**121**	NA
High Performance T8 (HPT8) 6-lamp Highbay or LED	36	6-lamp, 32W HPT8 **(or LED)**	162 **(as low as 130W)**	5,832	8700	0.67	48	61	**64%**
T5HO 4-lamp 47W Highbay	36	4-lamp, 47W T5HO	206	7,416	8700	0.85	61	74	**55%**

High Bay Lighting: Comparing 400W MH with Linear Fluorescent Side by Side

400 W Metal Halide

6-Lamp High Lumen 32W T8s

CLEAResult

Lowbay Fluorescents Work Well in ...

...<u>Task Lighting</u> to minimize general ambient light

- When upgrading lighting, maximize task lighting and minimize ambient or overhead – put light where needed.

- Combination of area lighting and independently switched task lighting saves up to 20%.

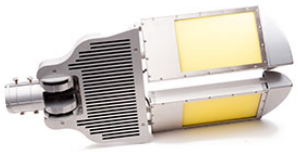
Outdoor LED Applications: Parking Lots

Pro

- Life
- Control
- Aesthetics
- 50-80% Savings

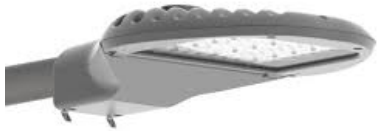
Con

- Initial Cost

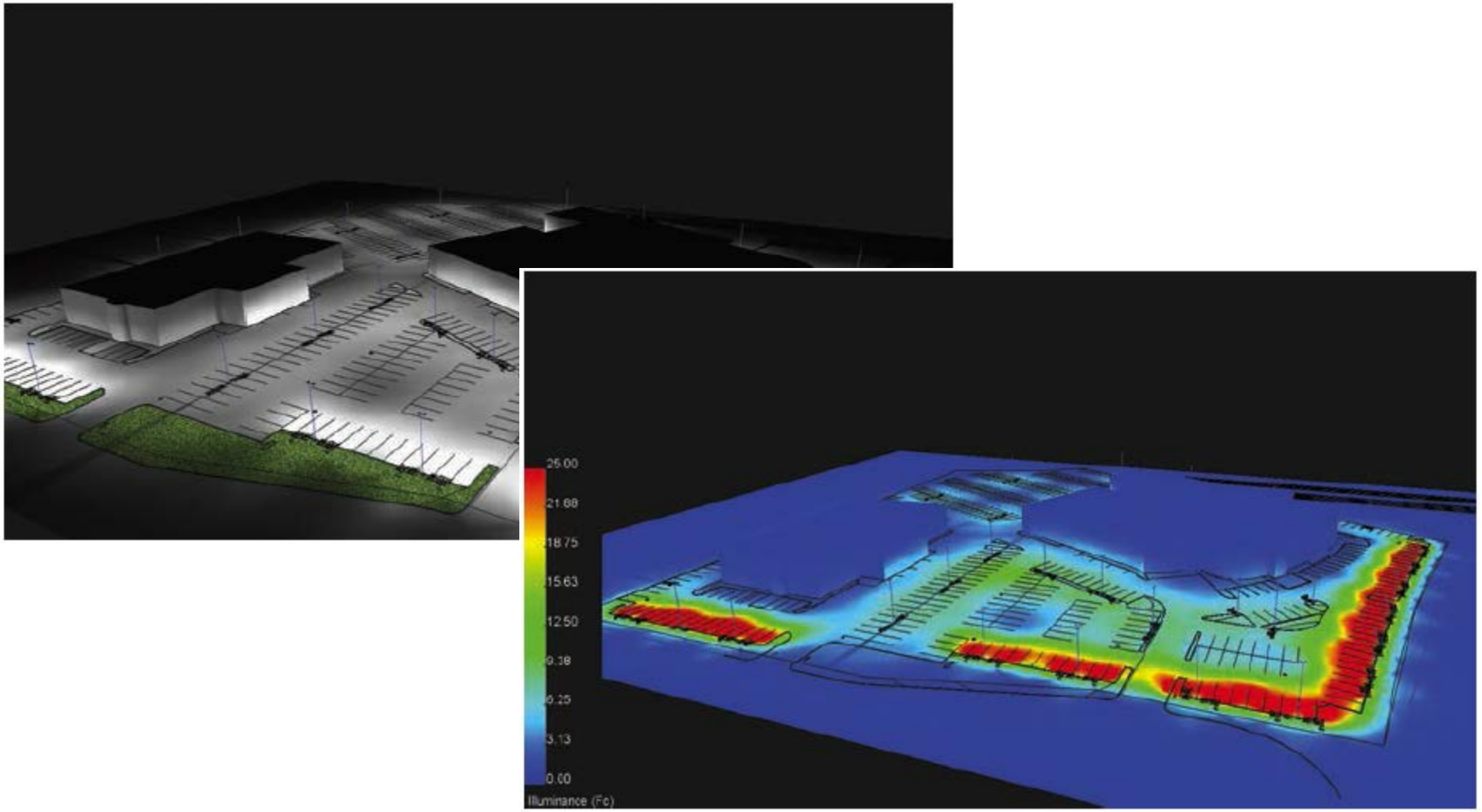


Auto Dealer Example

Car Dealership Case Study		
	Savings Impacts	
No. of Fixtures	kW (winter Peak)	kWh
160	83.0	545,957



LED Automotive Dealership: The Possibilities of Occupancy Controls



Source: Cree automotive dealership brochure

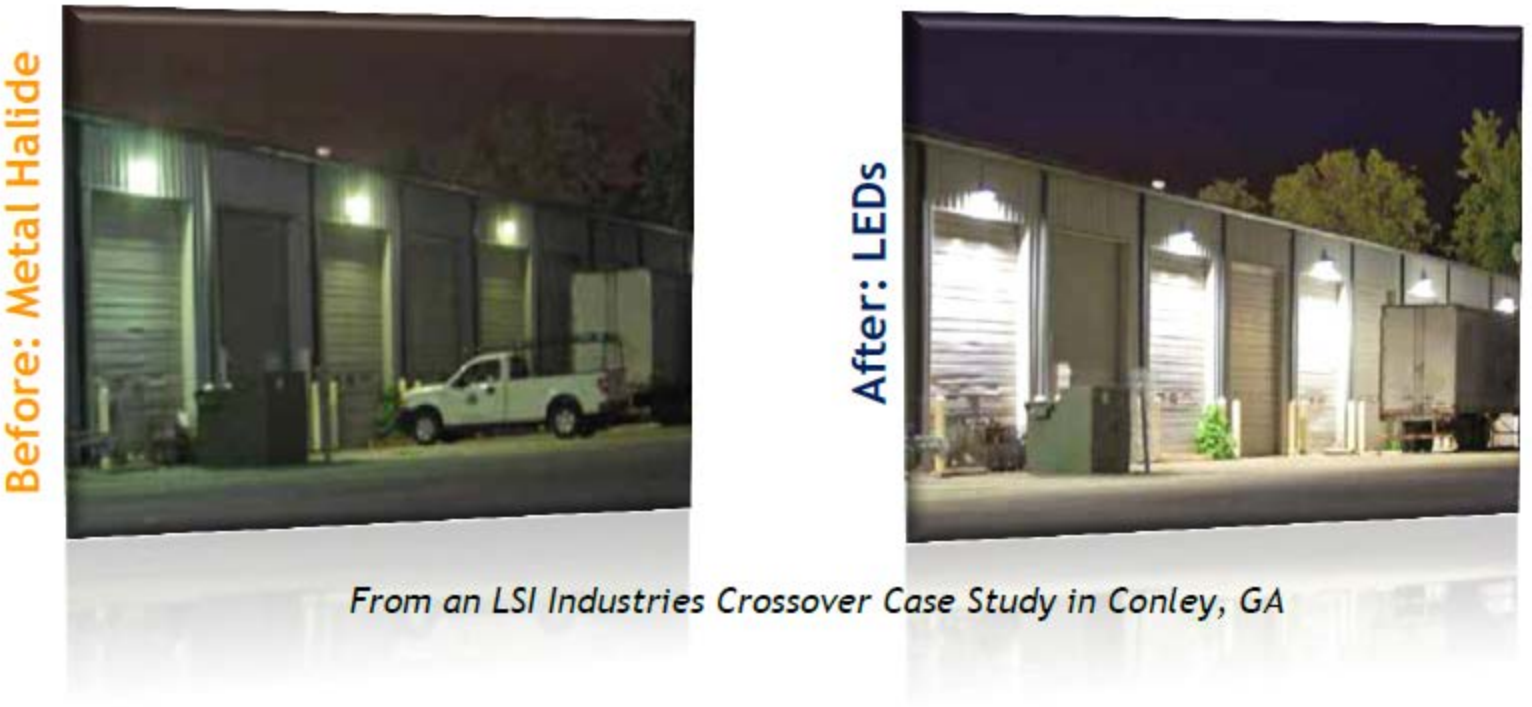
Wallpacks Demo

- Typical Wallpack

- DLC-Qualified Wallpack (full cutoff)

Wallpacks: Exterior Lighting Applications

- **Note:** DLC-approved Wallpacks will not light perimeter; don't expect them to throw light out and up as far



Other Outdoor LED Applications

Convenience Stores

Floodlights

Streetlights

Parking Garages

Case Studies: Lamps

Lamps are EVERYWHERE!

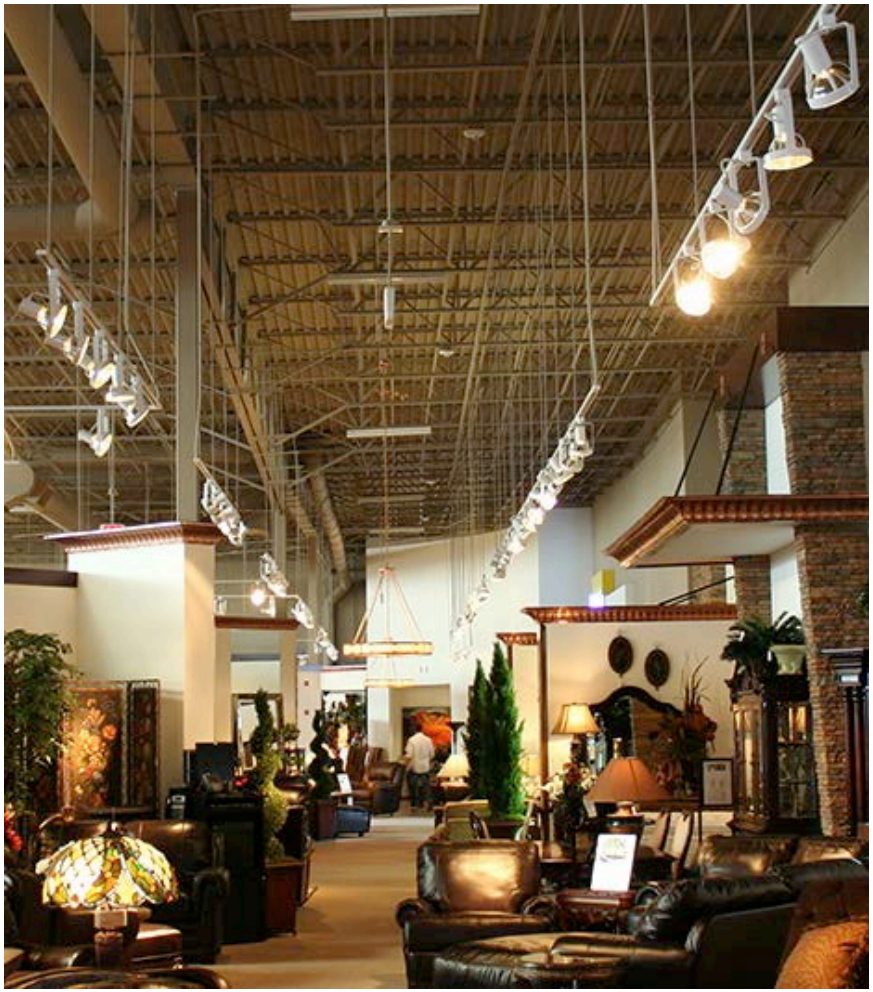
Reflector Lamps and Downlights: Retail, Hospitality and Everywhere

Pro

- Life - 25K vs. 3K
- Maintenance Savings
- 50-80% savings
  - Interactive AC savings

Con

- Initial Cost
  - $30+ vs. $10 halogen



Retail – Furniture Store Example

Furniture Store Example		
	Savings Impacts	
No. of Lamps	kW	kWh
1,032	47.0	198,000

Contact

Kyle Hemmi

Senior Energy Engineer, CLEAResult

khemmi@clearesult.com

512.416.5966

Case Studies: Educational Facilities

Changing needs, changing technologies and changing what you know about light levels

Courtesy of Rod Heller of EPL

Kids Today!

- Totally technology driven
- Schools are being driven to keep up
- Oh and kids still have good eyesight!
- What does this mean?

Schools Today

- Existing are built for a paper-based task
- Typically illuminated at 60-70 footcandles
  - Some as high as 120+ footcandles
- Very few classrooms have capability of controlling the lights at the front
- Normally Inboard/Outboard
- Only a few have daylight harvesting!

The Problem

- Bright lights just do not mix well with today's primary learning tool - computer screens!
- Where should we be with illumination?[1]
  - Horizontal plane – 20 to 30 fc
  - AV vertical plane – 2.5 fc
  - White Board vertical plane – 15 fc

IES Recommendations[1]

Applications and Tasks[a]	Notes	Recommended Maintained Illuminance Targets (lux)[b, c, d]										
		Horizontal (E_h) Targets					Vertical (E_v) Targets					
		Visual Ages of Observers (years) where at least half are					Visual Ages of Observers (years) where at least half are					
		Category	<25	25-65	>65	Gauge	Category	<25	25-65	>65	Gauge
• Print Media	Digital-printing-press-generated, white paper											
• 6-pt Font												
· Matte paper and ink	E_h @2' 6" AFF; E_v @4' AFF[j]	R	250	500	1000	Avg	L	37.5	75	150	Avg
· Specular paper and ink	E_h @2' 6" AFF; E_v @4' AFF[j]	R	250	500	1000	Avg	L	37.5	75	150	Avg
• 8- and 10-pt Font												
· Matte paper and ink	E_h @2' 6" AFF; E_v @4' AFF[j]	P	150	300	600	Avg	K	25	50	100	Avg
· Specular paper and ink	E_h @2' 6" AFF; E_v @4' AFF[j]	P	150	300	600	Avg	K	25	50	100	Avg
• 12-pt Font												
· Matte paper and ink	E_h @2' 6" AFF; E_v @4' AFF[j]	O	100	200	400	Avg	K	25	50	100	Avg
· Specular paper and ink	E_h @2' 6" AFF; E_v @4' AFF[j]	O	100	200	400	Avg	K	25	50	100	Avg
• VDT Screen and Keyboard												
• CSA/ISO Types I and II	See Figure 12.16 | CSA/ISO Computer Screen Qualities											
· Positive polarity	E_h @2' 6" AFF; E_v @3' 6" AFF[j]	P	150	300	600	Avg	N	75	150	300	Avg
· Negative polarity	E_h @2' 6" AFF; E_v @3' 6" AFF[j]	N	75	150	300	Avg	K	25	50	100	Avg
• CSA/ISO Type III	See Figure 12.16 | CSA/ISO Computer Screen Qualities											
· Positive polarity	E_h @2' 6" AFF; E_v @3' 6" AFF[j]	N	75	150	300	Avg	K	25	50	100	Avg
· Negative polarity	E_h @2' 6" AFF; E_v @3' 6" AFF[j]	L	37.5	75	150	Avg	I	15	30	60	Avg
• White Board												
• Analog or Digital												
· Reading (reference)							N	75	150	300	Avg
· Reading (with presenter)	Presenter at white board						P	150	300	600	Avg

Need Illumination Flexibility But...

- How can we cost-effectively adjust lighting to accommodate computer screens and paper-based tasks?
  - Financial realities limit options
  - Focus on energy or demand savings (less on maintenance or productivity)

Problem Solving

- Leaves us with:
  - Existing fixtures & wiring
  - Occupancy & daylight sensors
- Need to get the hard energy savings, so start with light fixtures (luminaires)
- Calculate energy savings from sensors after we figure out lighting solution

Fixtures (Luminaires)

- Are they in ok condition?
  - Can replace lens and gussy up
- Got a good Grid pattern?
  - Key to getting good even lighting
- Run photometrics on existing grid pattern
  - Try different kits to increase efficiency of existing fixture
  - Get illumination to RP for task and age
  - Classroom 20 footcandles when under age 25

Existing Fixture – 4 lamp, 32 watt T8

Photometrics

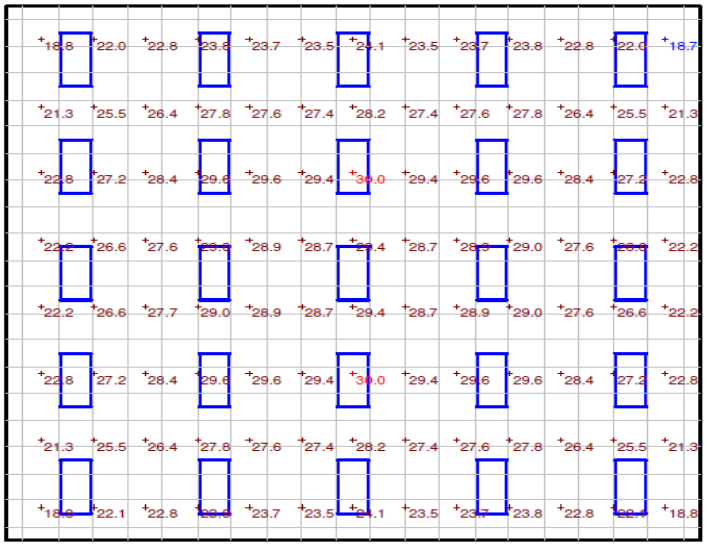
1 lamp 32W kit with a very low (.71) ballast factor gets us 26 fc maintained

STATISTICS

Description	Symbol	Avg	Max	Min	Max/Min	Avg/Min
Workplane	+	26.0 fc	30.0 fc	18.7 fc	1.6:1	1.4:1

LUMINAIRE SCHEDULE

Symbol	Label	Qty	Catalog Number	Description	Lamp	File	Lumens	LLF	Watts
	LM-1	25		K-24-12525-WR132	Fluor. 32W 4' T8	2x4 GTWR 1x32 Prismatic.ies	3000	0.67	25



Proposed Solution

Interior of fixture with 1 lamp kit

Proposed Solution

New lens in the door!

Results on Fixture Replacement

- T8 to T8 with low BF = 79% energy savings
- LPD = .39 watts/sq. ft.
- Average Illumination = 26 fc (maintained)
- Min/Max = 1.6:1
- 4.2 year payback based on 2100 hours/year
- While lowering light levels, went with higher kelvin color temperature (5000K)
  - Higher CCT => Greater Alertness[2]
  - Higher CCT => Greater Visual Acuity[3]

Scene Control Problem

How do we adjust lighting to accommodate computer screens, smart boards, paper-based tasks and the teacher who is 50 years old?

- Teacher is 50 years old (needs 40 fc)
  - Task light for paper work, most of the work is performed on a computer
- For Smart Board and AV presentations, light control put at front to switch off lighting in front 1 or 2 rows
- Vacancy controls would offer additional control/savings but...LPD is now so low, it creates a Catch 22
- Daylighting experiences numerous constraints in retrofits

Light Control at Front

References

1. Lighting Handbook, 10th edition, section 24.8. majority of occupants under age of 25
2. Blue-enriched white light in the workplace improves self-reported alertness, performance and sleep quality by Antoine U Viola, PhD, Lynette M James, Luc JM Schlangen, PhD, Derk-Jan Dijk, PhD
3. IES TM-24-13