


Sustainable Cities Network

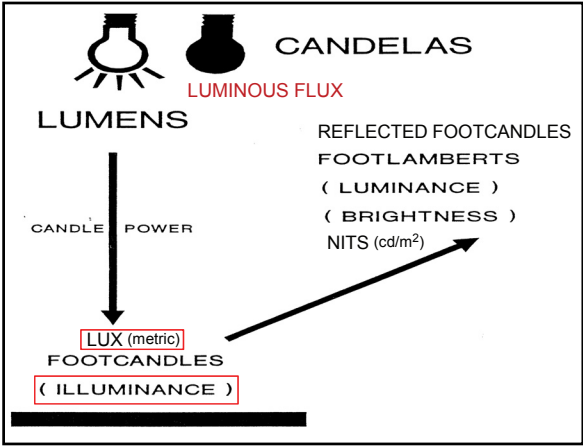
New Street Lighting Opportunities and Challenges

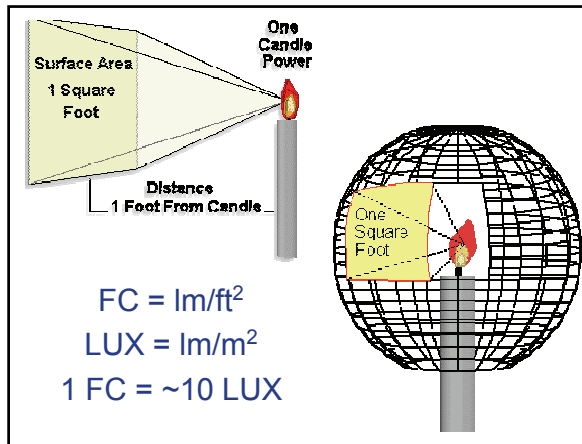
Don Happ
D.H. Lighting Solutions

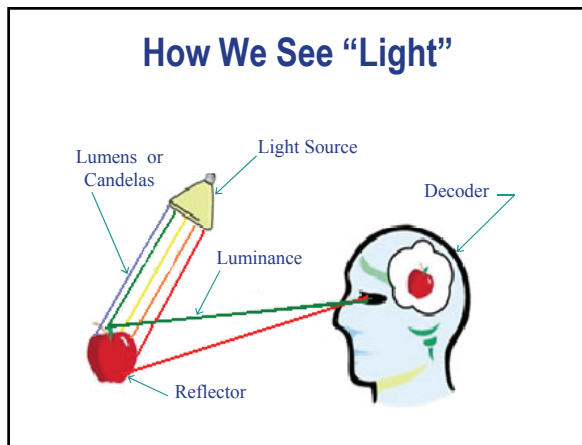


Presentation Topics

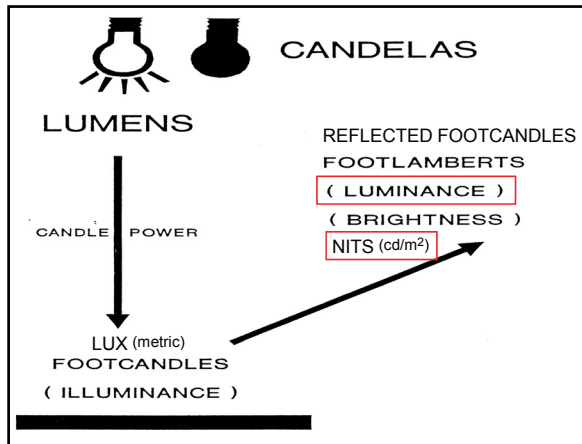
- Terminology & Fundamentals
- Technology Alternatives











Illuminating Engineering Society of North America

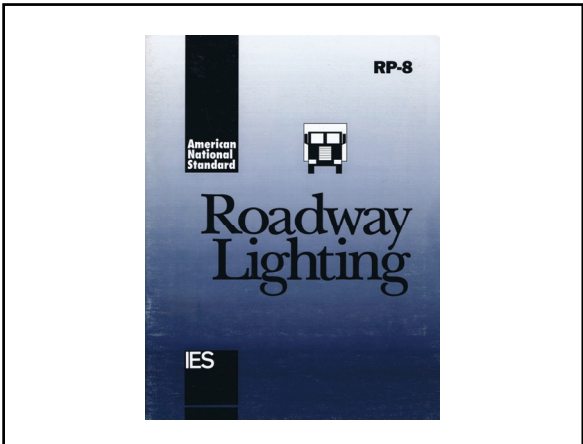


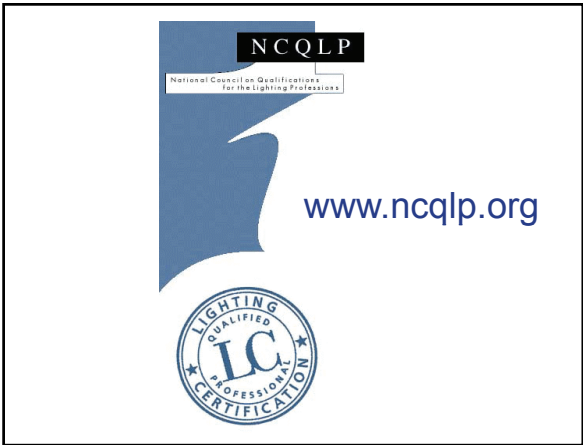
- Founded in 1906 to establish scientific lighting recommendations and to disseminate this information.
- Mission Statement: *"To advance knowledge and disseminate information for the improvement of the lighted environment to the benefit of society".*
- Works with such entities as ASHRAE, ANSI and OSHA. **The recognized authority on lighting in North America.**

Recommended Practices



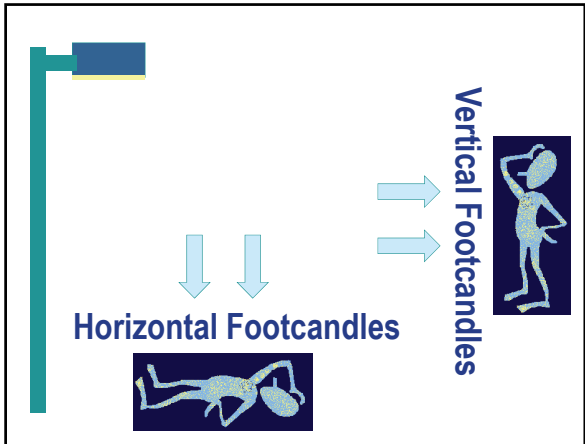
- illuminance / Footcandles
- Uniformity Ratios
- Luminaire Types
- Aiming Angles
- Color

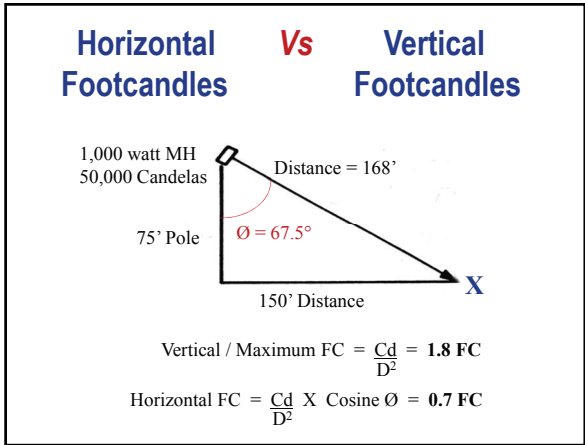


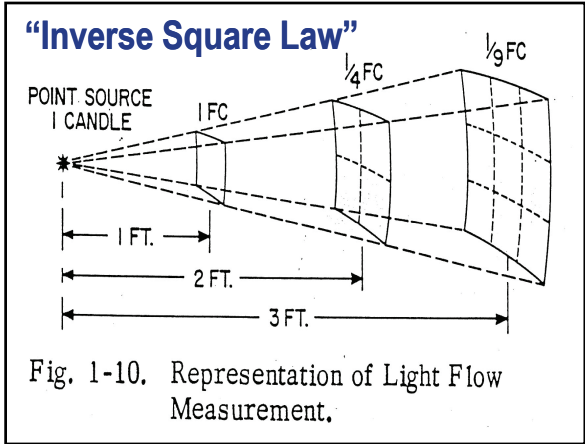


IESNA RP-8 Recommended Practice

Road and Area Classification		Pavement Classification				Illuminance Uniformity Ratio (E_{avg} to E_{min})
		R1	R2 and R3	R4		
Freeway Class A		6	9	8		3 to 1
Freeway Class B		4	6	5		
Expressway	Commercial	10	14	13		3 to 1
	Intermediate	8	12	10		
	Residential	6	9	8		
Major	Commercial	12	17	15		3 to 1
	Intermediate	9	13	11		
	Residential	6	9	8		
Collector	Commercial	8	12	10		4 to 1
	Intermediate	6	9	8		
	Residential	4	6	5		
Local	Commercial	6	9	8		6 to 1
	Intermediate	5	7	6		
	Residential	3	4	4		



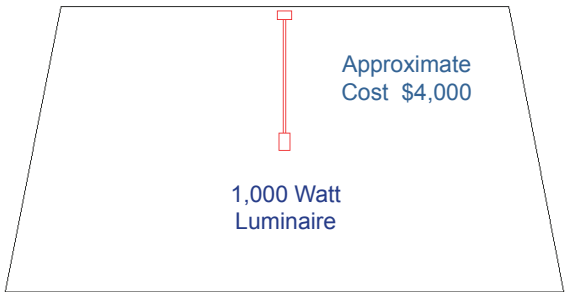


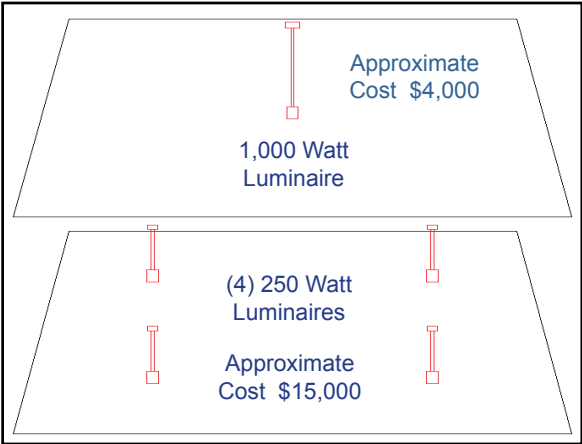


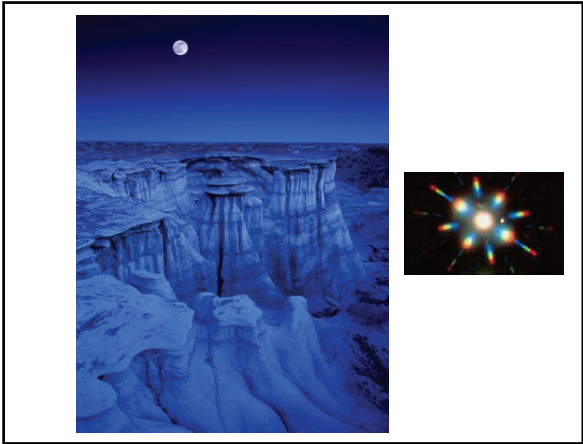
Uniformity / Uniformity Ratio

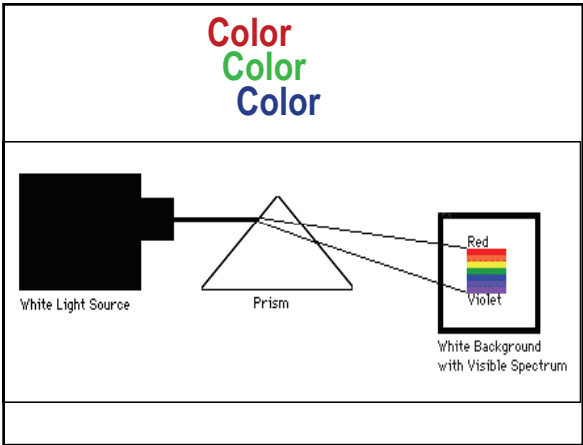
- Even Distribution of Light throughout the space
- Maximum / Min (sportslighting)
- Average / Min (most lighting projects)
- Example: 4 : 1 Uniformity Ratio
Avg 1.0 FC
Min 0.25 FC

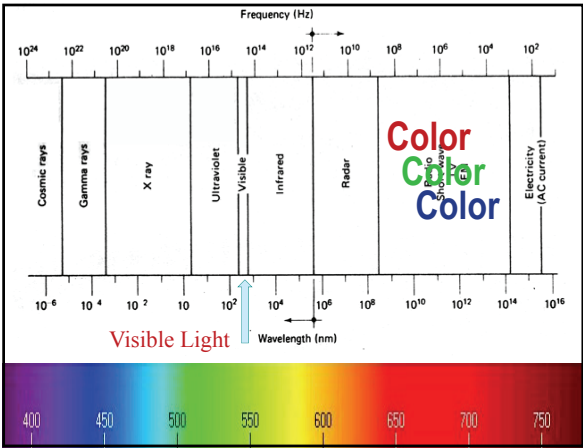
Parking Lot Uniformity Example









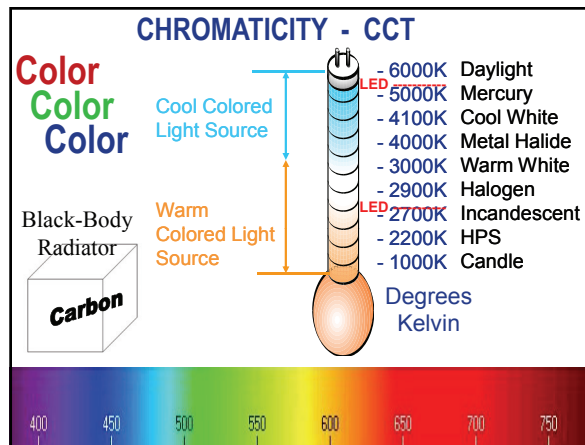


Chromaticity / Correlated Color Temperature (CCT)

Color or Hue of the luminous flux produced by a light source. Lower number values are “warm” colors, while higher values are “cool” colors.

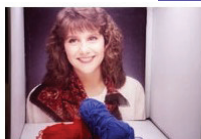
Color Rendering Index (CRI)

The light source’s ability to make colors of things appear correctly, based on a scale of 0 to 100, with 100 being the best (sun light).

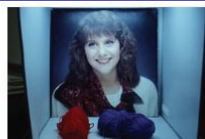


Cool color on a warm background.

Warm color on a cool background.




warm white light




cool white light


Effects of Color Temperature



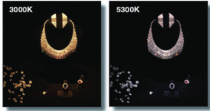
4100K "Cool" T8




3500K "Neutral" T8




4100K "Cool" Induction
Vs
2200K "Warm" HPS




Specialty Halogen



4100K "Cool" CFL
Vs
2700K "Warm" CFL

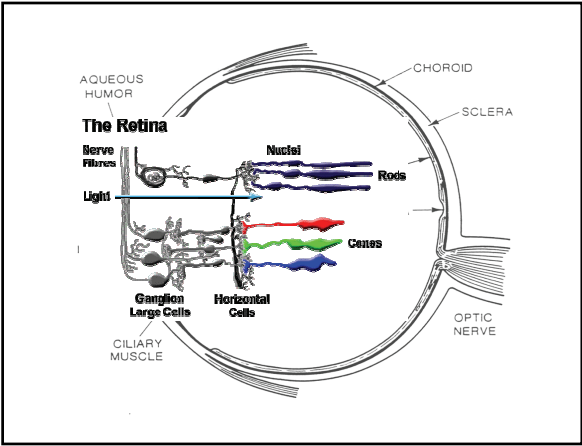


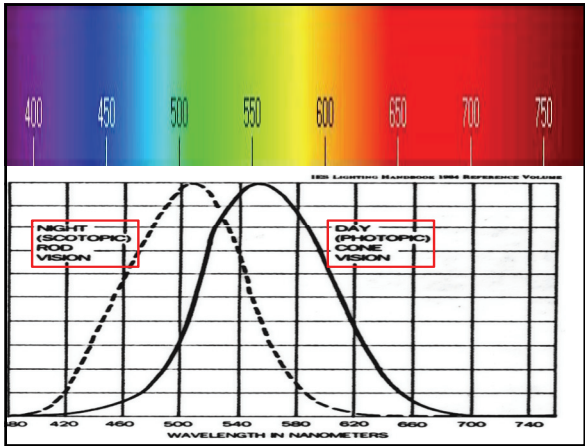
5500K "Cool" LED

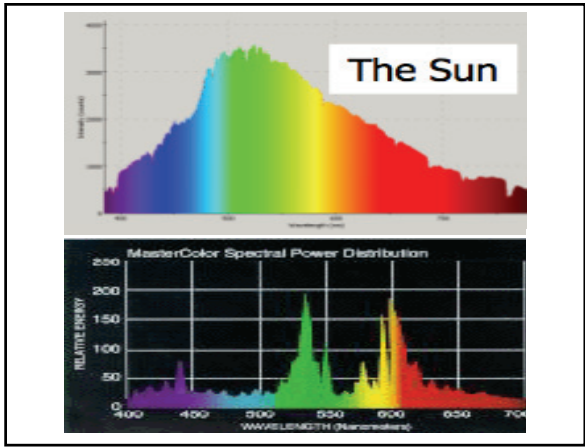


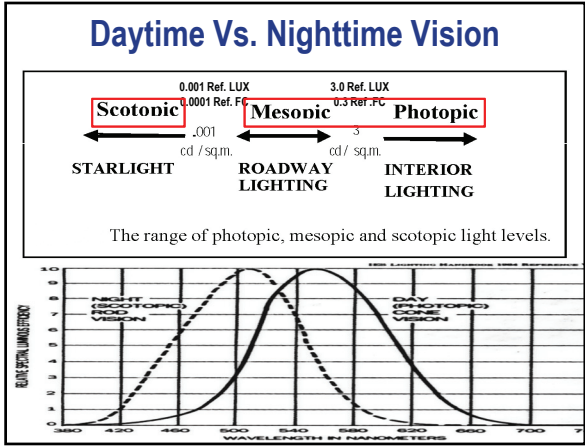
3000K "Warm" LED

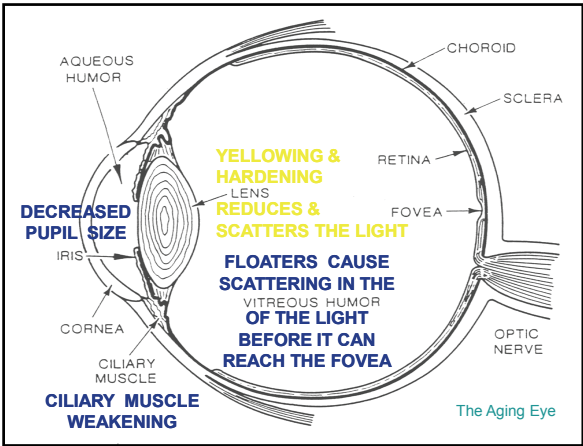






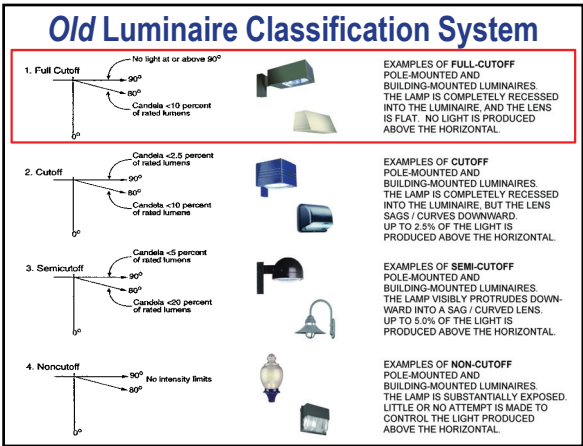


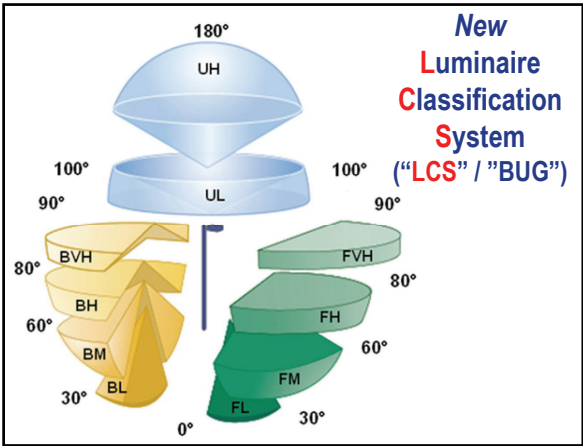




The Aging Eye

- Can't reshape the lens enough to see close objects ("arms aren't long enough anymore").
- Can misidentify deep shadows as solid objects.
- Needs ~3 X the illuminance.
- Needs ~2.5 X the contrast.
- Is ~3.5 X as sensitive to glare.
- Takes longer to adapt to low light levels.
- Needs higher temperature (CCT) lighting in order to compensate for the yellowing Lens.





BUG / LCS Rating System

Backlight, which creates light trespass onto adjacent sites. The B rating takes into account the amount of light in the BL, BM, BH and BVH zones, which are direction of the luminaire OPPOSITE from the area intended to be lighted.

Uplight, which causes artificial sky glow. Lower uplight (zone UL) causes the most sky glow and negatively affects professional and academic astronomy. Upper uplight (UH) is mostly energy waste. The U rating accounts the amount of light into the upper hemisphere with greater concern for the lower uplight angles in UL.

Glare, which can be annoying or visually disabling. The G rating takes into account the amount of frontlight in the FH and FVH zones as well as BH and BVH zones.

Secondary Solid Angle	B0	B1	B2	B3	B4	B5
BH	110	500	1000	2500	5000	>5000
BM	220	1000	2500	5000	8500	>8500
BL	110	500	1000	2500	5000	>5000

Secondary Solid Angle	U0	U1	U2	U3	U4	U5
UH	0	10	100	500	1000	>1000
UL	0	10	100	500	1000	>1000
FVH	10	75	150	>150		
BVH	10	75	150	>150		

Secondary Solid Angle	G0	G1	G2	G3	G4	G5
FVH	10	250	375	500	750	>750
BVH	10	250	375	500	750	>750
FH	660	1800	5000	7500	12000	>12000
BH	110	500	1000	2500	5000	>5000

BUG / LCS Rating System

Backlight, which creates light trespass onto adjacent sites. The B rating takes into account the amount of light in the BL, BM, BH and BVH zones, which are direction of the luminaire OPPOSITE from the area intended to be lighted.

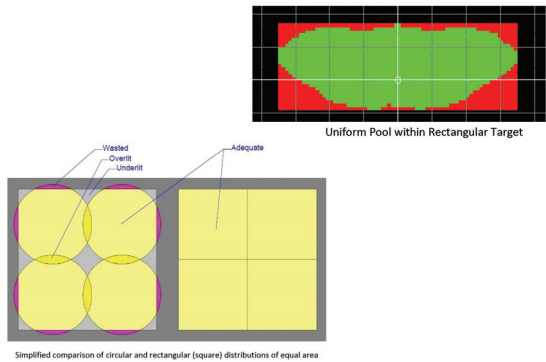
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“Fitted Target Efficiency” System

- Developed by DOE as part of Energy Star program.
- Was developed to in order to quantify the performance of pole-mounted luminaires more accurately than was available from existing metrics.
- Based upon two key assumptions:
 - Relatively rectangular distribution patterns cover most areas more efficiently than overlapping rounded patterns.
 - A luminaire's approximate area of coverage can be defined as the area illuminated in conformance with IESNA-recommended uniformity ratios.

“Fitted Target Efficiency” System

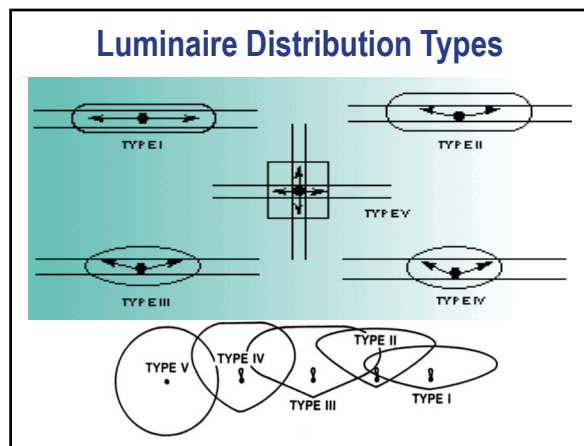
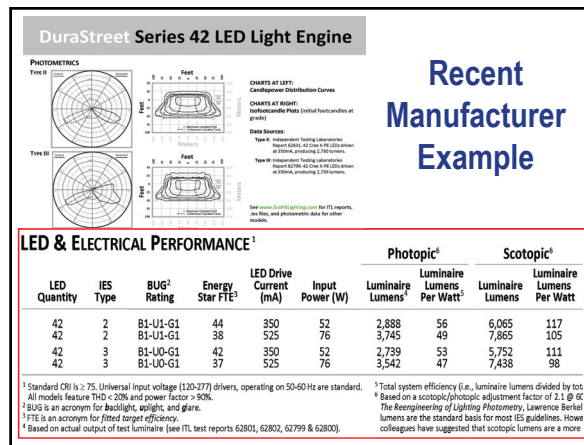
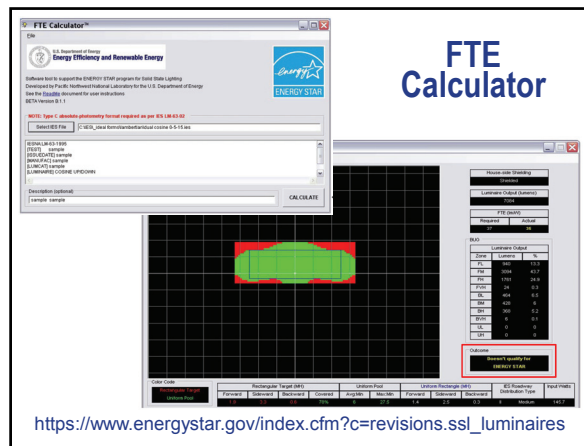


“Fitted Target Efficiency” System

$$FTE = \frac{(\text{flux in uniform pool}) (\text{percentage of rectangular target covered by uniform pool})}{(\text{luminaire input power})}$$

FTE results are expressed in standard efficacy terms of lumens per watt.

ENERGY STAR Draft – July 01, 2009			
Minimum Fitted Target Efficacy (FTE) for Outdoor Pole-Mounted Area and Roadway Luminaires			
Shielded (< 1.5 MH house-side)		Unshielded (≥ 1.5 MH house-side)	
Low Output < 9,500 lumens	High Output ≥ 9,500 lumens	Low Output < 13,300 lumens	High Output ≥ 13,300 lumens
37 lm/W	48 lm/W	53 lm/W	70 lm/W



Luminaire Photometry

- Graphical and numerical representation of a luminaire's light distribution.
- Aids designers in selecting the most appropriate luminaire.
- Available electronically from the manufacturer.
- Details the light “cut-off” angle of a luminaire.
- Some designers consider this a minimum requirement for considering a new luminaire.
- Understand “Relative” Vs “Absolute” photometry.

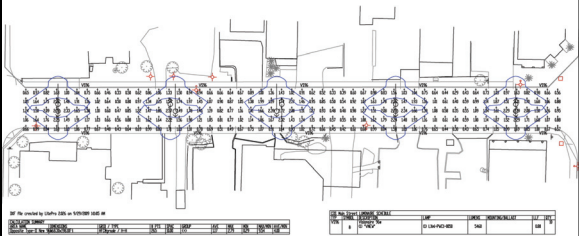
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TESNA:LM-63-2002
[TEST] GL-8429
[TESTLAB] XXXXXXXXXXXX
[ISSUEDATE] 12/10/2008
[MANUFAC] XXXXXXXXXXXX

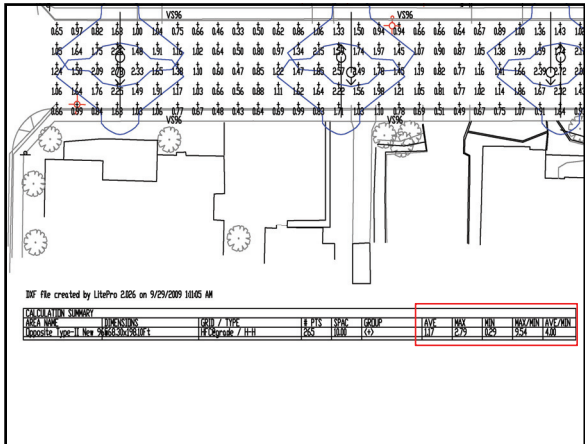
[LUMCAT] RL-3-85LA-CW

[LUMINAIRE] XXXXXXXXXX
[LAMP] (1) LIGHT ARRAY OF 54 LEDs DRIVEN AT 520mA
[OTHER] DATA SHOWN IS ABSOLUTE PHOTOMETRY AT RATED INPUT

TABLE ONE
1 5907 1 73 30 1 1 0 0 0
1 5907
0 2.5 5 7.5 10 12.5 15 17.5 20 22.5 25 27.5 30 32.5 35
37.5 40 42.5 45 47.5 50 52.5 55 57.5 60 62.5 65 67.5 70
72.5 75 77.5 80 82.5 85 87.5 90 92.5 95 97.5 100 102.5
105 107.5 110 112.5 115 117.5 120 122.5 125 127.5 130
132.5 135 137.5 140 142.5 145 147.5
150 152.5 155 157.5 160 162.5 165 167.5 170 172.5 175
177.5 180
0 5 15 25 35 45 55 60 62.5 65 67.5 70 72.5 75 77.5 80
82.5 85 87.5 90 95 105 115 125 135 145 155 165 175 180
758.60 789.10 823.30 846.50 840.20 777.60 726.60 682.90
640.70 608.40 581.70 564.40 555.70 567.10 594.70 624.50
660.50 689.60 701.00 691.30 707.70 781.80 881.30 991.30
1030.10 992.70 875.00 696.80 560.90 439.20 311.30
170.40 102.10 59.10 25.70 3.60 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00
758.60 805.30 828.90 832.80 802.70 747.00 702.40 657.30
620.20 589.50 566.70 554.30 555.30 578.80 607.50 641.20
674.10 699.50 710.70 733.80 778.90 844.30 950.70
1034.70 1088.60 1037.60 905.30 728.20 553.30 408.00
276.80 156.80 82.80 52.00 19.40 2.50 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00
758.60 803.20 824.20 827.00 811.00 759.70 709.30 666.70
622.80 588.80 566.80 557.90 559.90 584.50 618.00 655.50
```

Photometric Study for a Collector Roadway with LED Luminaires





Presentation Topics

- Terminology & Fundamentals
- Technology Alternatives

Street Lighting Technologies

HID
(HPS, LPS, & MH)

Induction

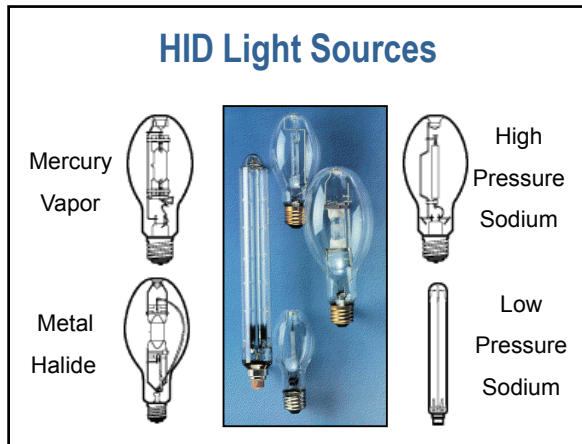


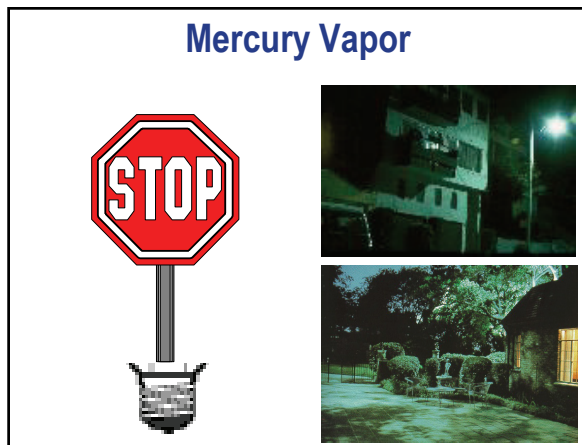
Photovoltaic
(Solar)

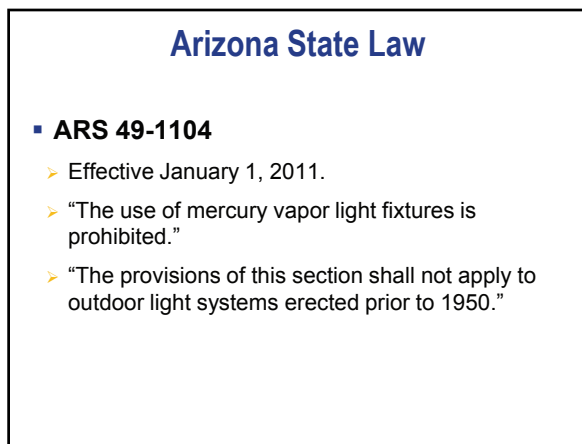


Fluorescent

LED



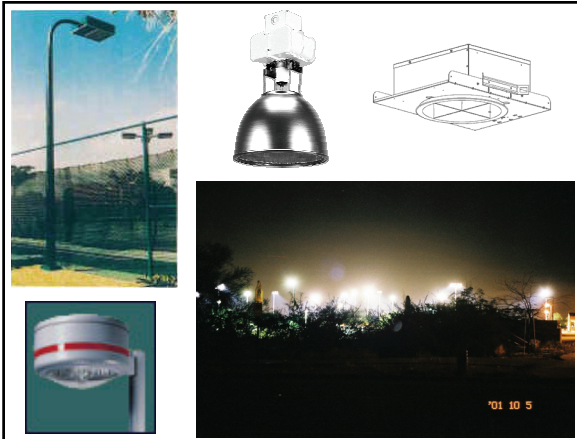




Metal Halide



- Descendant of MV
- Balanced white light
- Position sensitive
- Moderate life
- Good efficacy
- Poor lumen maint.
- Poor color shift



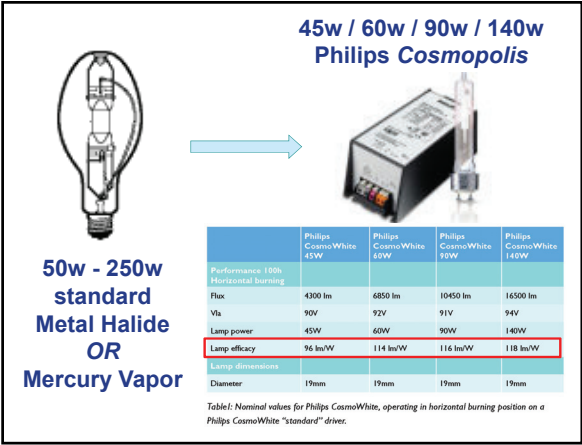
Metal Halide

- Probe-Start being replaced by Pulse-Start
 - ARS 44-1375: Metal halide lamps & ballasts from 150 – 500 watts must be pulse-start as of January 1, 2008.
 - 2007 Energy Independence And Security Act, effective January 1, 2009.
 - Watch the in-rush current with magnetic PSMH ballasts!
- New ballast efficiency standards
 - Increased minimum efficiency ratings will likely eliminate the use of most magnetic ballasts by the summer of 2011.

Advances In Metal Halide Technology



MH400/U Quartz Switch Start MP350/BU/PS Quartz Pulse Start CDM320 Pulse Start CDM/E 210 Electronic



**45w / 60w / 90w / 140w
Philips CosmoPolis**

**50w - 250w
standard
Metal Halide
OR
Mercury Vapor**

	Philips CosmoWhite 45W	Philips CosmoWhite 60W	Philips CosmoWhite 90W	Philips CosmoWhite 140W
Performance: 100h Horizontal burning				
Flux	4300 lm	6850 lm	10450 lm	16500 lm
Via	90V	92V	91V	94V
Lamp power	45W	60W	90W	140W
Lamp efficacy	96 lm/W	114 lm/W	116 lm/W	118 lm/W
Lamp dimensions				
Diameter	19mm	19mm	19mm	19mm

Table 1: Nominal values for Philips CosmoWhite, operating in horizontal burning position on a Philips CosmoWhite "standard" driver.

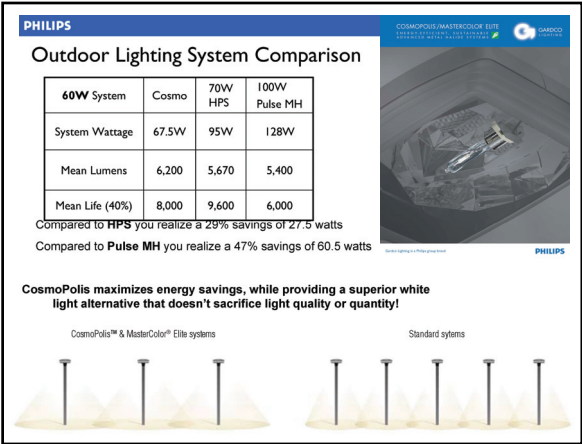
PHILIPS Outdoor Lighting System Comparison

	60W System	Cosmo	70W HPS	100W Pulse MH
System Wattage		67.5W	95W	128W
Mean Lumens		6,200	5,670	5,400
Mean Life (40%)		8,000	9,600	6,000

Compared to **HPS** you realize a 29% savings of 27.5 watts
Compared to **Pulse MH** you realize a 47% savings of 60.5 watts

CosmoPolis maximizes energy savings, while providing a superior white light alternative that doesn't sacrifice light quality or quantity!

CosmoPolis™ & MasterColor® Elite systems Standard systems



Kirlin, Targetti, Lumca, LAM, Delray, SPI,
US Pole, Lumec, Schreder, Spaulding,
DesignPlan, Stonco, and Exceline.



LEI
Infrastructure
A Company with a Smart Plan



ALTMAN
Lighting
1-800-4-ALTMAN



Widelite
VISIONAIRE LIGHTING
PERFORMANCE IN A WHOLE NEW LIGHT



architectural
arealighting



SISTEMALUX.com



INSIGHT
MISSION



AccuLite
Commercial and Industrial Lighting



KIM LIGHTING



HOLOPLANE
LIGHTS TO LIGHTING SOLUTIONS



HUBBELL
Hubbell Lighting, Inc.



LITHONIA LIGHTING
A National Light and Color Company



AMERLUX



COOPER Lighting

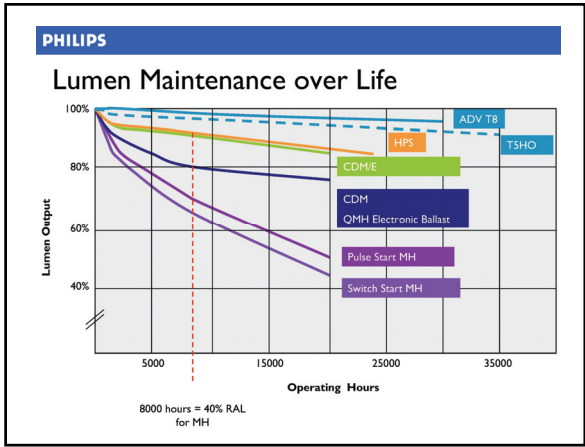


HABCO



Spectrum Lighting


58



Metal Halide General Recommendations

- Ceramic arc tubes instead of Quartz
 - Higher CRI
 - Reduced color shift
 - Reduced lumen depreciation (equals energy savings)
- Vertical-oriented lamp instead of Horizontal
 - Increased lamp life
 - Reduced color shift
 - Higher initial lumens, and reduced depreciation
 - Better uniformity of the illumination

High Pressure Sodium



- Designed from scratch
- Yellow-white light
- Long-life
- High efficacy
- Good lumen maint.
- No color shift
- “Cycles” at EOL

www.sylvania.com

LUMALUX PLUS® AND LUMALUX PLUS® ECO®

Non-Cycling, Lead-Free and Reduced Mercury High Pressure Sodium Lamps




Key Features & Benefits

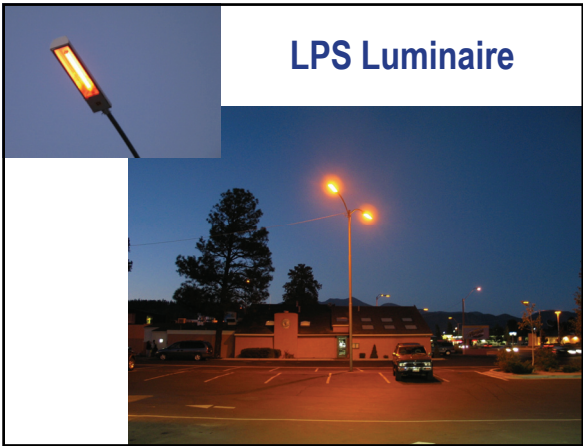
- Average rated lamp life is 40,000 hours***
~ 85% survival at 24,000 hours
~ 50% survival at 40,000 hours
- Over 65% longer life than comparable HPS lamps
- Same initial lumens as a standard HPS lamp with a 15% higher maintained light output at end of rated life
- Non-cycling lamps mean quicker identification of outages, fewer repeat trips and provides less stress to the ignitor**
- Same warm-up and hot restrike time as standard HPS
- Lamp design eliminates voltage rise (standard high pressure sodium lamps may exhibit voltage rise of 50 or 60 volts)
- Passes Federal TCLP test. Lead-free and up to 90% less mercury than standard HPS lamps
- Lead-free base allows a higher maximum base temperature of 250°C, 40°C higher than ANSI specification for lead soldered bases
- Direct replacements for standard HPS; operates on ballasts of similar wattage
- New 6 digit code showing the month, day and year the lamp was manufactured

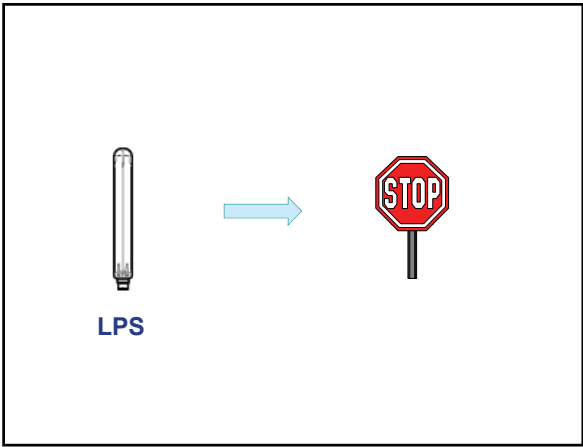
The SYLVANIA LUMALUX PLUS and LUMALUX PLUS ECO lamps incorporate the latest technology to eliminate the end-of-life cycling of HPS lamps. They remain off at end-of-life. LUMALUX PLUS/ECO lamps are constructed with lead-free welded bases and pass the existing Federal TCLP test.

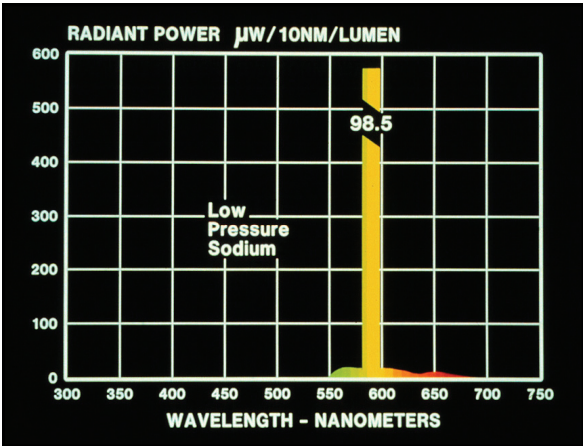
Low Pressure Sodium

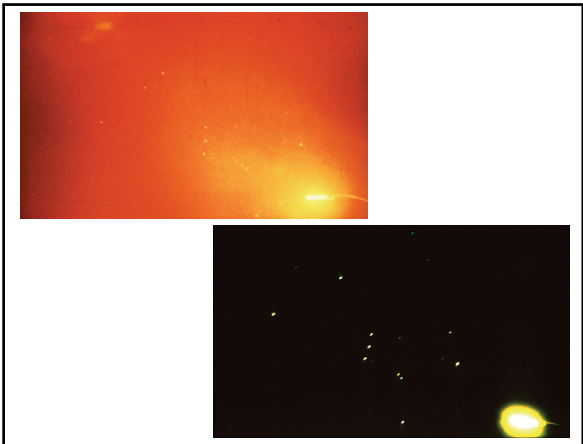


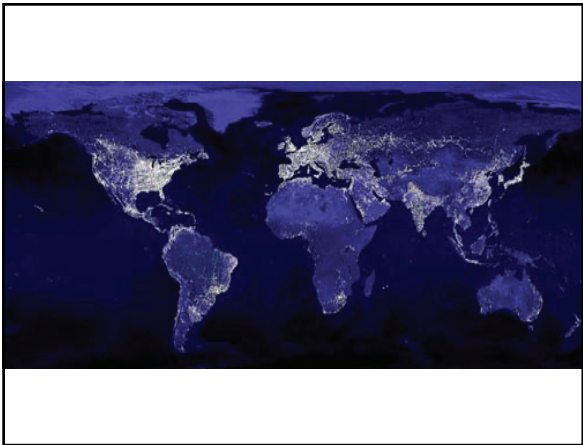
- Originated in Europe
- Deep-yellow, mono-chromatic light
- Long-life
- Highest efficacy
- Best lumen maint.
- Astronomer preferred



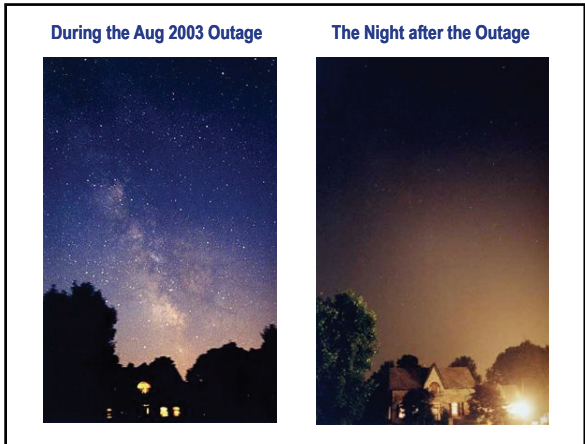


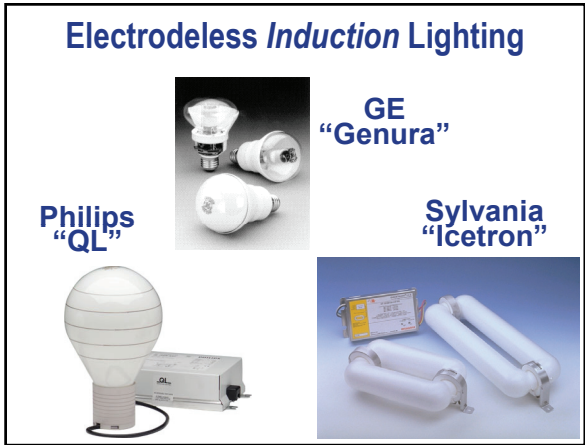






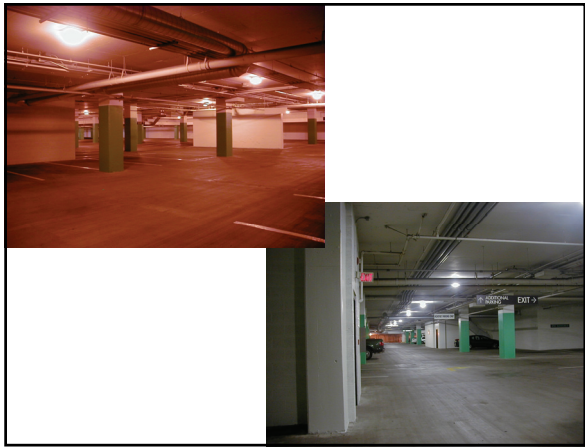




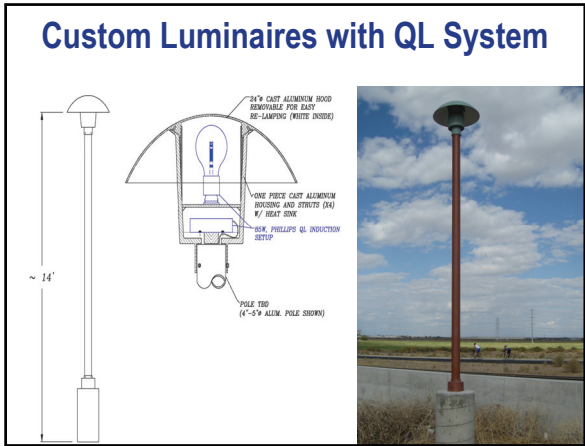


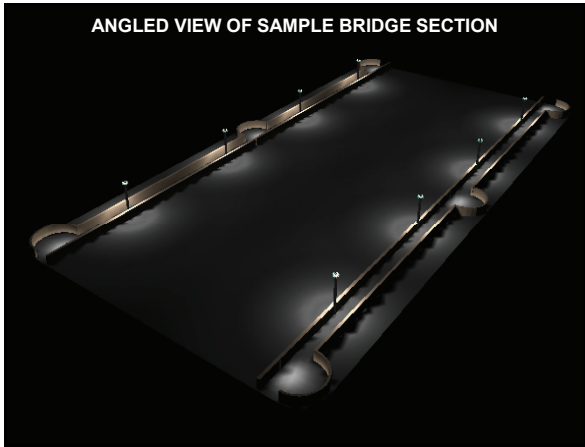


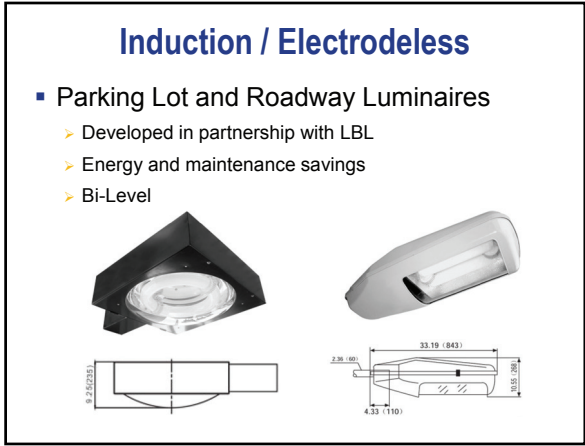













Induction Performance Comparisons


EverLast® Induction Technology Compared to Beta LED Lighting
50% higher efficiency and 25% better light distribution equals unsurpassed performance

Call us today for pricing
888-383-7578

[Request Quote](#)



Everlast® 70w Type III Cobra



Beta Type III Cobra

System Watts 277v	78.9	80.3
Lumen Output	5900	3200
Luminance Efficacy Rating (LER)	52	28
Advised Distribution	Type III	Type III
IES Distribution	Type III, Med. Throw	Type III, Short Throw
Lumens Per Watt	75	39

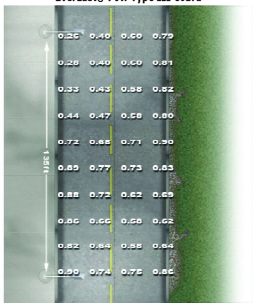
Roadway Comparison: 135 ft. pole spacing; 25ft. mounting height; 24 ft. 2-lane R3 asphalt surface

Warranty	10 years	5 years "One night stand" click here to see pdf
Illuminance Avg.	1.08 fc	0.65 fc
Illuminance Max.	2.13 fc	0.96 fc
Illuminance Min.	0.62 fc	0.39 fc
Luminance Avg.	0.83 cd/m²	0.46 cd/m²
Luminance Max.	1.07 cd/m²	0.78 cd/m²
Luminance Min.	0.64 cd/m²	0.29 cd/m²

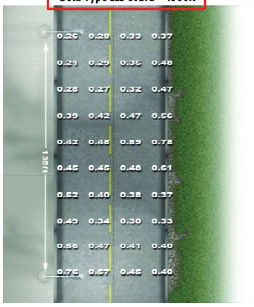
Induction Performance Comparisons

Roadway Photometrics

EverLast® 70w Type III Cobra




Beta Type III Cobra - 4300K



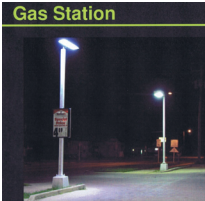
Fluorescent (T5HO)

Columbia Lighting

Orion Energy Systems

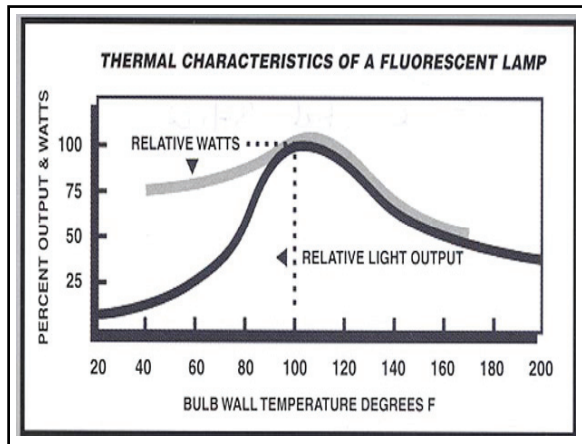


Gas Station

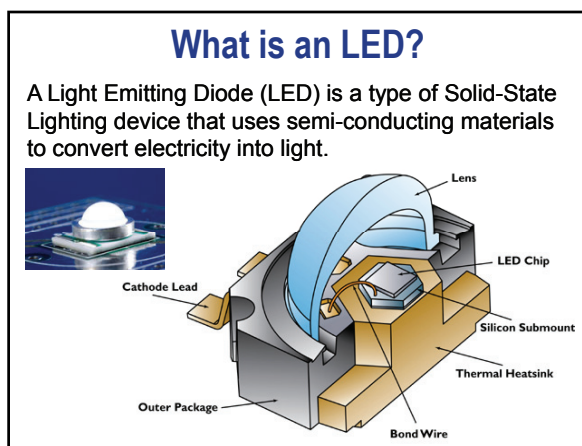


Superior Performance
Fluorescent lighting with compact fluorescent tubes provides superior performance in the roadway and industrial areas.

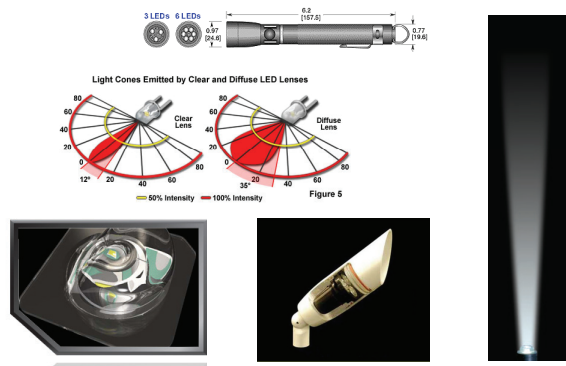
Best Value
Superior lighting is what you expect.







LEDs Are Inherently Directional



LEDs Are Inherently Colored

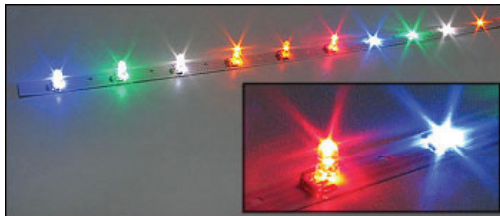


Table 3: Luminous Efficacy of Production Run 1-watt LEDs (as of 2004)

Color	Wavelength (nm)	Efficacy (lm/W)
White (5500 K)		25
Warm white (3200 K)		22
Green	530	30
Blue	470	10
Red	625	44
Red-Orange	617	55
Amber	590	36

Gallium Nitride Compounds

Indium-Gallium Phosphide Compounds

Creating The “White” LED

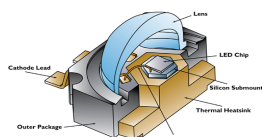
White
Phosphor
Coating

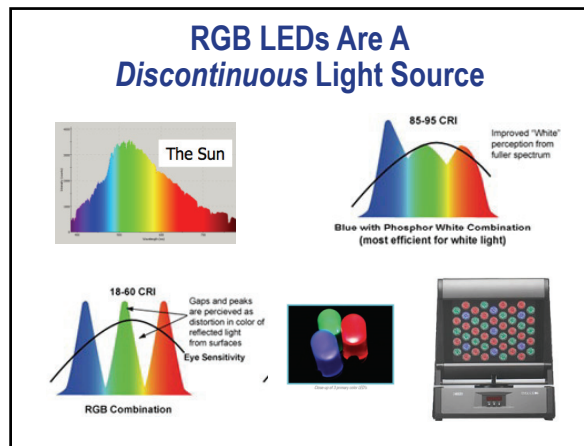


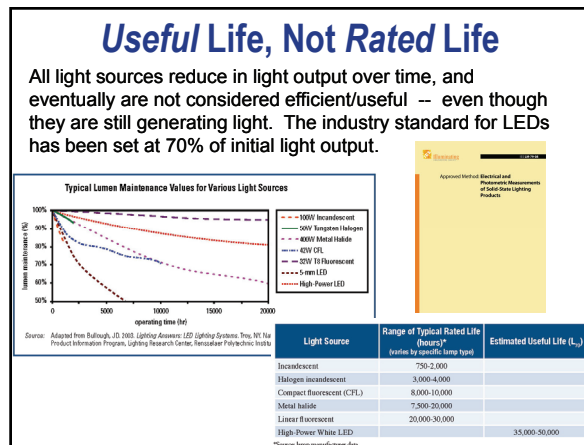
“Dichroic” Phosphor Coating



Combine
Red/Green/Blue

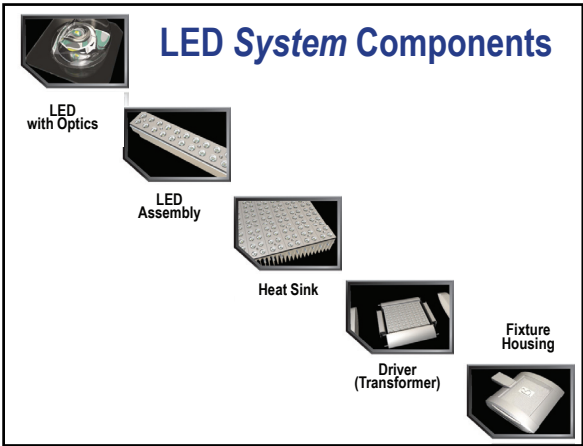


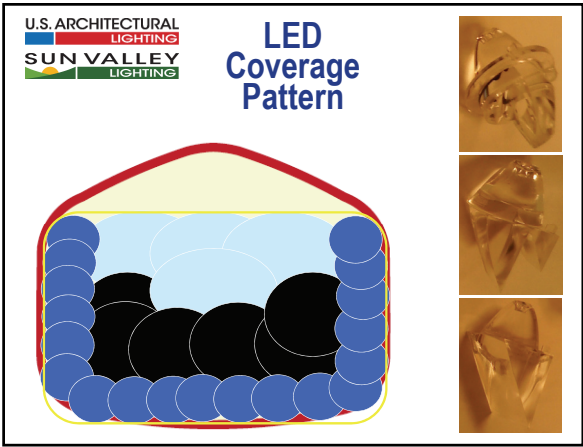


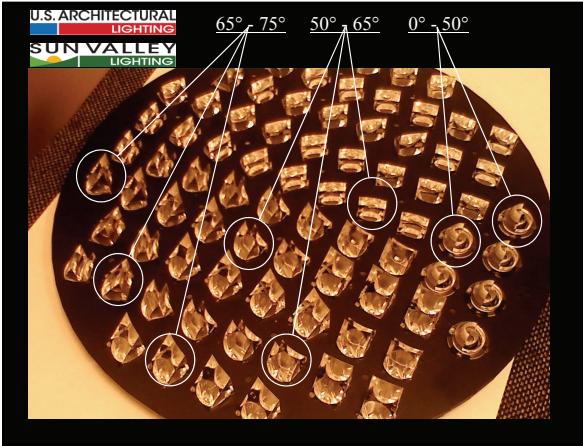


White LED Efficiency

- ~3 X the efficiency of halogen
(6 watts of LED ≈ 20 watts of halogen)
- ~2/3 the efficiency of CFL, and
~1/2 that of linear fluorescent.
- Efficiency and life are permanently reduced by excessive heat.
- LED luminaires should be designed from "scratch" in order to maximize efficiency.





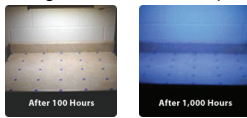


LED

- Most significant remaining issues
 - Quality and Color Consistency (binning)
 - CRI
 - Heat removal
 - Efficiency
 - Cost / Payback

LED

- Quality and Color Consistency (binning)
 - About 90% of available product is sub-standard.
 - Variations in initial color, and as LEDs age.
 - ❖ (proper "binning" methods increase product cost)



- Require independent testing or documented verification (including IES photometric files).
- Remember, most jurisdictions require a UL listing.

LED Color Inconsistency

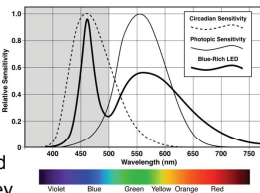


An example of poor Thermal Management, or poor "Binning".

These are two of the several reasons why some LED luminaires are half the cost of others.

CRI and Color Temperature (CCT)

- LEDs can range from 16 – 92 CRI, and the same color of lamp (CCT) may look different from each manufacturer.
- The International Dark-Sky Association (IDA) has issued advisories about “blue” light and its affect on human health. They advise against any outdoor lighting with a CCT of > 3000K.



LED

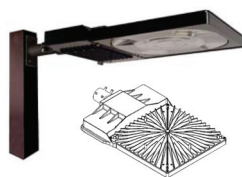
Efficiency

- Efficiency and Photometrics should be based upon the assembled luminaire, not the separate LED module.



- Currently about 60 LPW getting out of the luminaire.
- DOE “Bright Tomorrow Lighting Competition”
 - CRI ≥ 90
 - \$10,000,000
 - A Lamp: ≥ 900 lumens, ≥ 90 LPW, ≤ 10 watts
 - \$5,000,000
 - PAR38: $\geq 1,350$ lumens, ≥ 123 LPW, ≤ 11 watts

Exterior LED
luminaires should
be heat tested to
at least 40° C.

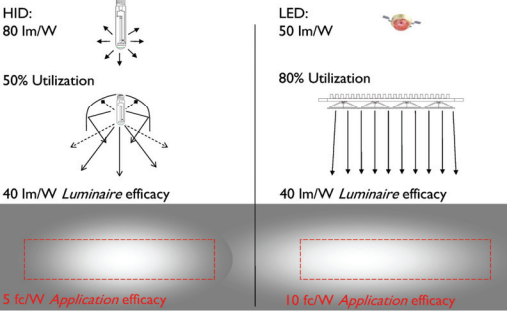


EVOLVE™ LED SERIES
AREA LIGHT
Medium Thin Profile

GE LIGHTING SYSTEMS
85 – 214 WATTS

The Theory Behind LED Outdoor Lighting

Application Efficacy – Hypothetical Data

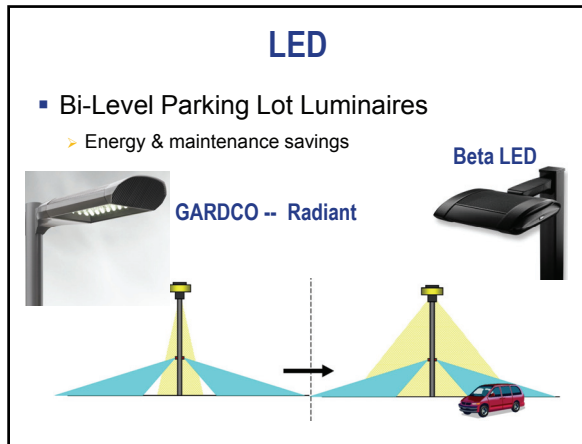


Examples of LED Roadway Luminaires
(60 – 80 LPW)



Examples of LED Roadway Luminaires
(60 – 80 LPW)





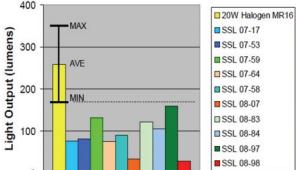
DOE CALiPER PROGRAM

- *Commercially Available LED Product Evaluation and Reporting.*
- Specifiers “consumer reports” of LED systems.
- Independently tests and provides unbiased information on the performance of commercially-available LED products.
- The test results guide DOE planning for ENERGY STAR and technology procurement activities, & provide objective produce performance information to the public.

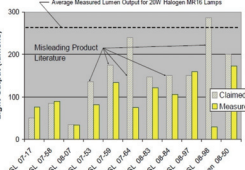
<http://www1.eere.energy.gov/buildings/ssl/caliper.html>

DOE CALiPER PROGRAM

- In the latest round of CALiPER testing, 10 different MR16 replacement lamps were evaluated.
- The output of most of the lamps fell well short of the manufacturer’s claims.
- All produced less light than the lowest output 20W MR16.



Light Output (lumens)



Light Output (lumens)

DOE “Fact Sheets”

www.netl.doe.gov/ssl/publications/publications-factsheets.htm

LED Basics

LED technology continues to develop rapidly as a general light source. As more LED products and light fixtures are introduced on the market, it is important to know how to use them to their best advantage.

LED Application Series: Using LEDs to Their Best Advantage

Using LEDs to Their Best Advantage

LEDs are often touted for energy efficiency and long life. While these are important considerations, lighting selection is based on many other factors as well. This fact sheet reviews some of the critical attributes of LEDs, which include:


- Thermal Management of White LEDs
- Light Output
- Color Accuracy
- Color Rendering Index (CRI)
- Correlated Color Temperature (CCT)

Thermal Management of White LEDs

LEDs aren't like your home's incandescent light bulbs, but they do produce heat. In fact, thermal management is arguably the most important aspect of commercial LED system design. This fact sheet reviews the role of heat in LED performance and methods for managing it.

All light sources convert electric power into radiant energy and heat to various degrees. Incandescent lamps emit generally 90% heat and 10% light. LEDs emit much less heat.

Building Technologies Program



www.netl.doe.gov/ssl/publications/publications-factsheets.htm

DOE “Lighting Facts” Labels

Light Output/Lumens
Measures light output. The higher the number, the more light is emitted.
Reported as “Total Integrated Flux (Lumens)” on LM-79 test report.

Watts
Measures energy required to light the product. The lower the wattage, the less energy used.
Reported as “Input Power (Watts)” on LM-79 report.

Lumens per Watt/Efficacy
Measures efficiency. The higher the number, the more efficient the product.
Reported as “lm/Watt” on LM-79 test report.

IESNA LM-79-2008
Industry standardized test procedure that measures performance qualities of LED luminaires and integral lamps. Follows for true comparison of luminaires regardless of the light source.

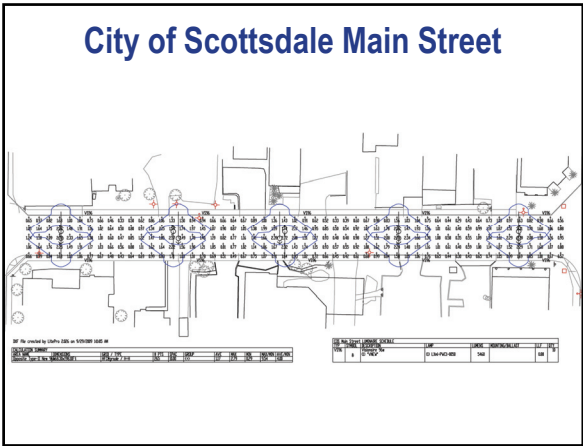
Lighting Facts™

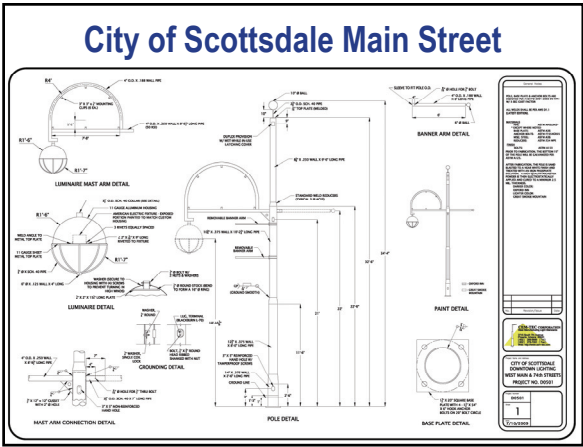
LED Product

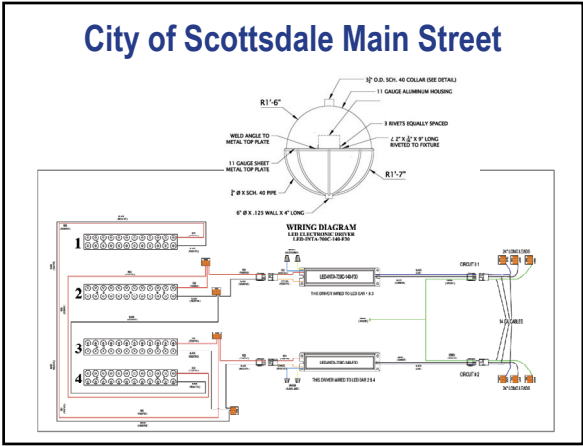
Light Output (Lumens)	840
Watts	9
Lumens per Watt (Efficacy)	93
Color Accuracy Color Rendering Index (CRI)	87
Light Color Correlated Color Temperature (CCT)	2900 (Warm White)

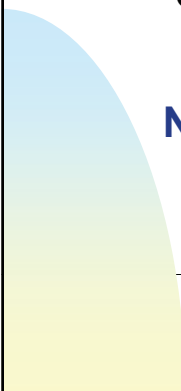
Visit www.lightingfacts.com for the Label Reference Guide.

All results are according to IESNA LM-79-2008. Approved Method for the Electrical and Photometric Testing of Solid-State Lighting. Based on IESNA E-90-01/02/03/04/05/06/07/08/09/10/11/12/13/14/15/16/17/18/19/20/21/22/23/24/25/26/27/28/29/30/31/32/33/34/35/36/37/38/39/40/41/42/43/44/45/46/47/48/49/50/51/52/53/54/55/56/57/58/59/60/61/62/63/64/65/66/67/68/69/70/71/72/73/74/75/76/77/78/79/80/81/82/83/84/85/86/87/88/89/90/91/92/93/94/95/96/97/98/99/100/101/102/103/104/105/106/107/108/109/110/111/112/113/114/115/116/117/118/119/120/121/122/123/124/125/126/127/128/129/130/131/132/133/134/135/136/137/138/139/140/141/142/143/144/145/146/147/148/149/150/151/152/153/154/155/156/157/158/159/160/161/162/163/164/165/166/167/168/169/170/171/172/173/174/175/176/177/178/179/180/181/182/183/184/185/186/187/188/189/190/191/192/193/194/195/196/197/198/199/200/201/202/203/204/205/206/207/208/209/210/211/212/213/214/215/216/217/218/219/220/221/222/223/224/225/226/227/228/229/230/231/232/233/234/235/236/237/238/239/240/241/242/243/244/245/246/247/248/249/250/251/252/253/254/255/256/257/258/259/260/261/262/263/264/265/266/267/268/269/270/271/272/273/274/275/276/277/278/279/280/281/282/283/284/285/286/287/288/289/290/291/292/293/294/295/296/297/298/299/300/301/302/303/304/305/306/307/308/309/310/311/312/313/314/315/316/317/318/319/320/321/322/323/324/325/326/327/328/329/330/331/332/333/334/335/336/337/338/339/340/341/342/343/344/345/346/347/348/349/350/351/352/353/354/355/356/357/358/359/360/361/362/363/364/365/366/367/368/369/370/371/372/373/374/375/376/377/378/379/380/381/382/383/384/385/386/387/388/389/390/391/392/393/394/395/396/397/398/399/400/401/402/403/404/405/406/407/408/409/410/411/412/413/414/415/416/417/418/419/420/421/422/423/424/425/426/427/428/429/430/431/432/433/434/435/436/437/438/439/440/441/442/443/444/445/446/447/448/449/450/451/452/453/454/455/456/457/458/459/460/461/462/463/464/465/466/467/468/469/470/471/472/473/474/475/476/477/478/479/480/481/482/483/484/485/486/487/488/489/490/491/492/493/494/495/496/497/498/499/500/501/502/503/504/505/506/507/508/509/510/511/512/513/514/515/516/517/518/519/520/521/522/523/524/525/526/527/528/529/530/531/532/533/534/535/536/537/538/539/540/541/542/543/544/545/546/547/548/549/550/551/552/553/554/555/556/557/558/559/560/561/562/563/564/565/566/567/568/569/570/571/572/573/574/575/576/577/578/579/580/581/582/583/584/585/586/587/588/589/590/591/592/593/594/595/596/597/598/599/600/601/602/603/604/605/606/607/608/609/610/611/612/613/614/615/616/617/618/619/620/621/622/623/624/625/626/627/628/629/630/631/632/633/634/635/636/637/638/639/640/641/642/643/644/645/646/647/648/649/650/651/652/653/654/655/656/657/658/659/660/661/662/663/664/665/666/667/668/669/670/671/672/673/674/675/676/677/678/679/680/681/682/683/684/685/686/687/688/689/690/691/692/693/694/695/696/697/698/699/700/701/702/703/704/705/706/707/708/709/710/711/712/713/714/715/716/717/718/719/720/721/722/723/724/725/726/727/728/729/730/731/732/733/734/735/736/737/738/739/740/741/742/743/744/745/746/747/748/749/750/751/752/753/754/755/756/757/758/759/760/761/762/763/764/765/766/767/768/769/770/771/772/773/774/775/776/777/778/779/780/781/782/783/784/785/786/787/788/789/790/791/792/793/794/795/796/797/798/799/800/801/802/803/804/805/806/807/808/809/810/811/812/813/814/815/816/817/818/819/820/821/822/823/824/825/826/827/828/829/830/831/832/833/834/835/836/837/838/839/840/841/842/843/844/845/846/847/848/849/850/851/852/853/854/855/856/857/858/859/860/861/862/863/864/865/866/867/868/869/870/871/872/873/874/875/876/877/878/879/880/881/882/883/884/885/886/887/888/889/890/891/892/893/894/895/896/897/898/899/900/901/902/903/904/905/906/907/908/909/910/911/912/913/914/915/916/917/918/919/920/921/922/923/924/925/926/927/928/929/930/931/932/933/934/935/936/937/938/939/940/941/942/943/944/945/946/947/948/949/950/951/952/953/954/955/956/957/958/959/960/961/962/963/964/965/966/967/968/969/970/971/972/973/974/975/976/977/978/979/980/981/982/983/984/985/986/987/988/989/990/991/992/993/994/995/996/997/998/999/1000/1001/1002/1003/1004/1005/1006/1007/1008/1009/1010/1011/1012/1013/1014/1015/1016/1017/1018/1019/1020/1021/1022/1023/1024/1025/1026/1027/1028/1029/1030/1031/1032/1033/1034/1035/1036/1037/1038/1039/1040/1041/1042/1043/1044/1045/1046/1047/1048/1049/1050/1051/1052/1053/1054/1055/1056/1057/1058/1059/1060/1061/1062/1063/1064/1065/1066/1067/1068/1069/1070/1071/1072/1073/1074/1075/1076/1077/1078/1079/1080/1081/1082/1083/1084/1085/1086/1087/1088/1089/1090/1091/1092/1093/1094/1095/1096/1097/1098/1099/1100/1101/1102/1103/1104/1105/1106/1107/1108/1109/1110/1111/1112/1113/1114/1115/1116/1117/1118/1119/1120/1121/1122/1123/1124/1125/1126/1127/1128/1129/1130/1131/1132/1133/1134/1135/1136/1137/1138/1139/1140/1141/1142/1143/1144/1145/1146/1147/1148/1149/1150/1151/1152/1153/1154/1155/1156/1157/1158/1159/1160/1161/1162/1163/1164/1165/1166/1167/1168/1169/1170/1171/1172/1173/1174/1175/1176/1177/1178/1179/1180/1181/1182/1183/1184/1185/1186/1187/1188/1189/1190/1191/1192/1193/1194/1195/1196/1197/1198/1199/1200/1201/1202/1203/1204/1205/1206/1207/1208/1209/1210/1211/1212/1213/1214/1215/1216/1217/1218/121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Sustainable Cities Network

New Street Lighting Opportunities and Challenges

Don Happ
D.H. Lighting Solutions

