Introduction to Lighting Systems and Controls

Course No. ENRG 54

Outline

A. Introduction to fundamentals of lighting
- Lighting terminology
- Physics and principles of lighting
- Units of measurement
- Vision and colors
- Ambient, directional and task lighting
- Over- and under-illuminance

B. Lighting systems
- Components
- Types of lamps
- Ballasts
- Lamp comparison matrix
- Types of lighting luminaires and intensities
- Energy efficiency measures (EEMs)

C. Lighting controls
- Basic concepts of effectiveness of lighting control
- Types and appropriate applications of lighting controls
- Lighting control equations
- Energy efficiency measures (EEMs)

D. Additional EEMs
- De-lamping
- Scotopic lighting
- Task and ambient light levels
- Circadian rhythms

E. Lighting measurements
- Tools
- Data loggers and applications

F. Lighting calculations
- Equation and method of calculating lumens (zonal cavity formula)
- Equation and method of calculating energy savings
- Method of calculating skylight energy savings

G. Lighting standards, codes and regulations
- Underwriters' Laboratory (UL)
- Uniform Building Code (UBC)
- Americans with Disabilities Act (ADA)
- Title 24 applications

H. O&M measures to assure optimal performance

B. Lighting systems

1. Components
2. Types of lamps
3. Ballasts
4. Lamp comparison matrix
5. Types of lighting luminaires and intensities
6. Energy efficiency measures (EEMs)

B. Lighting systems

1. Components
2. Types of lamps
3. Ballasts
4. Lamp comparison matrix
5. Types of lighting luminaires and intensities
6. Energy efficiency measures (EEMs)

1. Components
    a. Luminaire
    b. Lamp
    c. Ballast
    d. Reflector
    e. Diffuser, lens or louver

Luminaire

- A complete lighting unit
- Including lamps, ballast/power drive, reflector, diffuser/lens/louver, other accessories
- Consider luminaire efficiency not just lamp efficacy
- Spacing of luminaires is a factor
- High efficiency systems reduce cooling loads.

© designsenselighting.com

Luminaire

Fluorescent troffer (lowes.com)

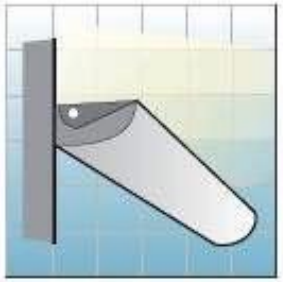
CFL downlighting (amazon.com)

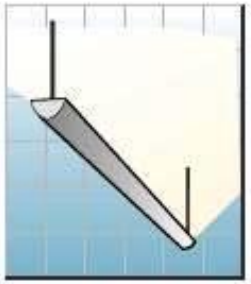
LED accent lighting (zap.com)

LED tunnel lighting (zap.com)

Luminaire


Cove-mounted Uplighting


Wall-mounted Uplighting


Suspended Linear Fluorescent Luminaire


Recessed Round Downlight


Open HID High-bay (Metal Reflector) Luminaire


Recessed Round Wall-washers

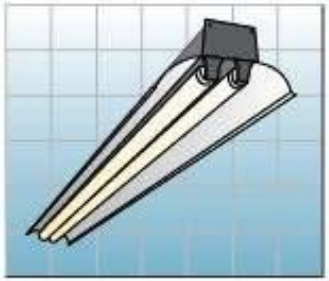

Decorative Pendant Downward Light


Portable Task Lighting


Track Lighting (Metal Halide)


Track Lighting (Incandescent)


Functional Wall Sconce


Open Fluorescent Luminaire, Refl. Industrial


Portable Torchiere Uplight


Task Lighting, Fixed and Furniture Integrated


Decorative Wall Sconce

Lamp: lighting source

- Incandescent
- Halogen
- Fluorescent
- High Intensity Discharge
  - Metal halide
  - Mercury vapor
  - High Pressure Sodium
  - Low Pressure Sodium
- Induction lamps
- Light Emitting diodes (LEDs)
- Neon

Ballast

- Power regulator required for all discharge lamps: HID and fluorescent
- Preheat the electrodes (for rapid start lamps) to make it easier to start the arc
- Apply high voltage to start the arc
- Limits current in an electric circuit
- Types:
  - Electromagnetic (magnetic)
  - Electronic

Frontierlighting.com

Fluorescent lamp ballast

- Instant start:
  - starts lamps w/o heating the cathodes
  - energy efficient but reduces lamp life
  - good for lamps not turned on/off very often
- Rapid start:
  - applies voltage and heats cathodes simultaneously
  - superior lamp life and more cycle life, but uses more energy
- Programmed start:
  - advanced version of rapid start
  - gives the best life
  - good for frequent power cycling

Reflector

- directs/distributes light
- common types:
  - spherical, short-sided, broad spread
  - parabolic, providing a tighter and parallel beam of light

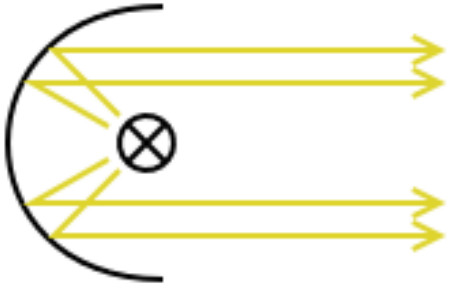


Diagram of a lamp reflector, showing path that light typically takes from a light source. © wikipedia

© supplierlist.com

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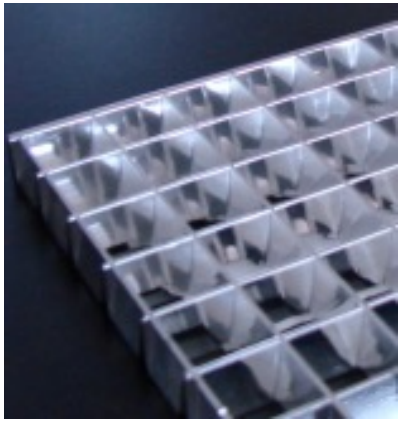
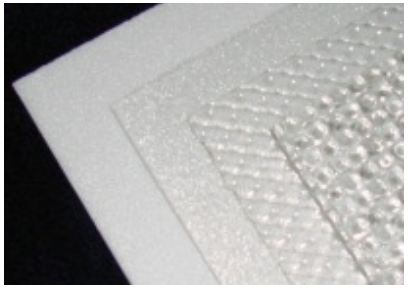
Diffuser, lens or louver

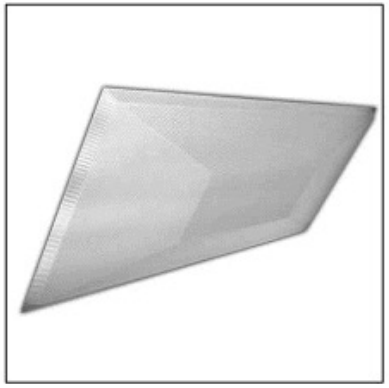
- Lenses use a clear material and redirect light
- Diffusers diffuse light in all directions
- Louvers eliminate glare on vertical surfaces



Parabolic louvers @ mclightingsupply.com



Flat lamp lenses @ mclightingsupply.com



Maximizer diffuser @liteandlamps.com

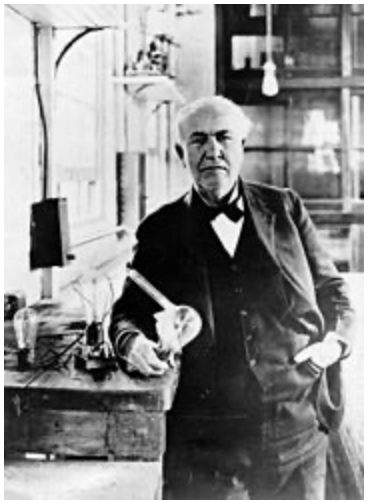
B. Lighting systems

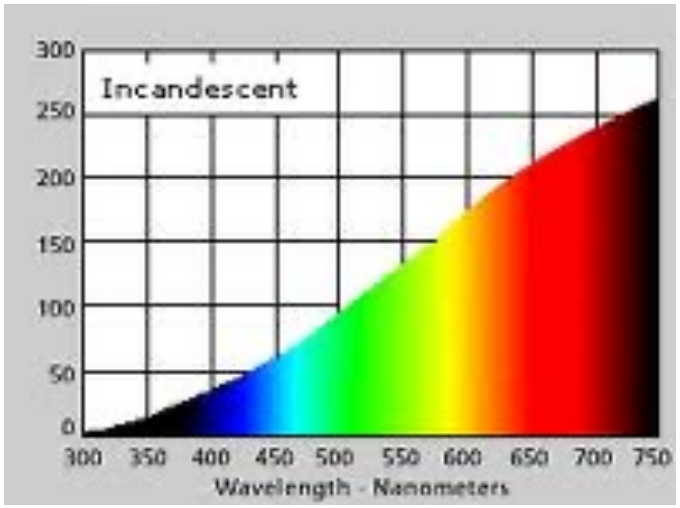
1. Component
2. Types of lamps
3. Ballasts
4. Lamp comparison matrix
5. Types of lighting luminaires and intensities
6. Energy efficiency measures (EEMs)

2. Types of lamps
    a. Incandescent
    b. Halogen
    c. Fluorescent
    d. High intensity discharge
        - Metal halide
        - Mercury vapor
        - High pressure sodium
        - Low pressure sodium
    e. Induction lamps
    f. Light emitting diodes (LED)
    g. Neon

Incandescent

- With a filament wire
- Produces light when filament glows
- Protected by filling with inert gas or evacuated.
- Halogen lamp is one type of incandescent





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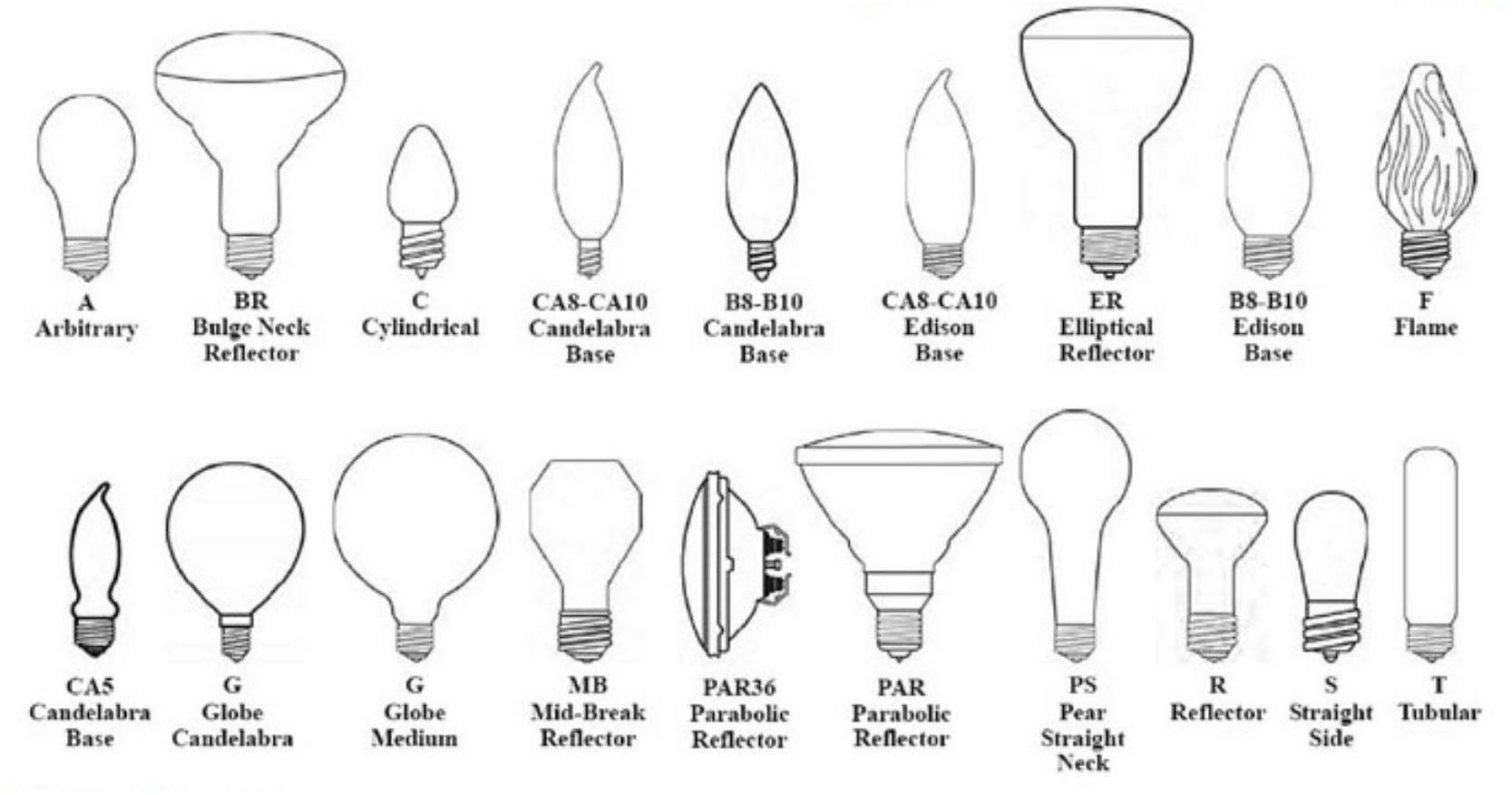
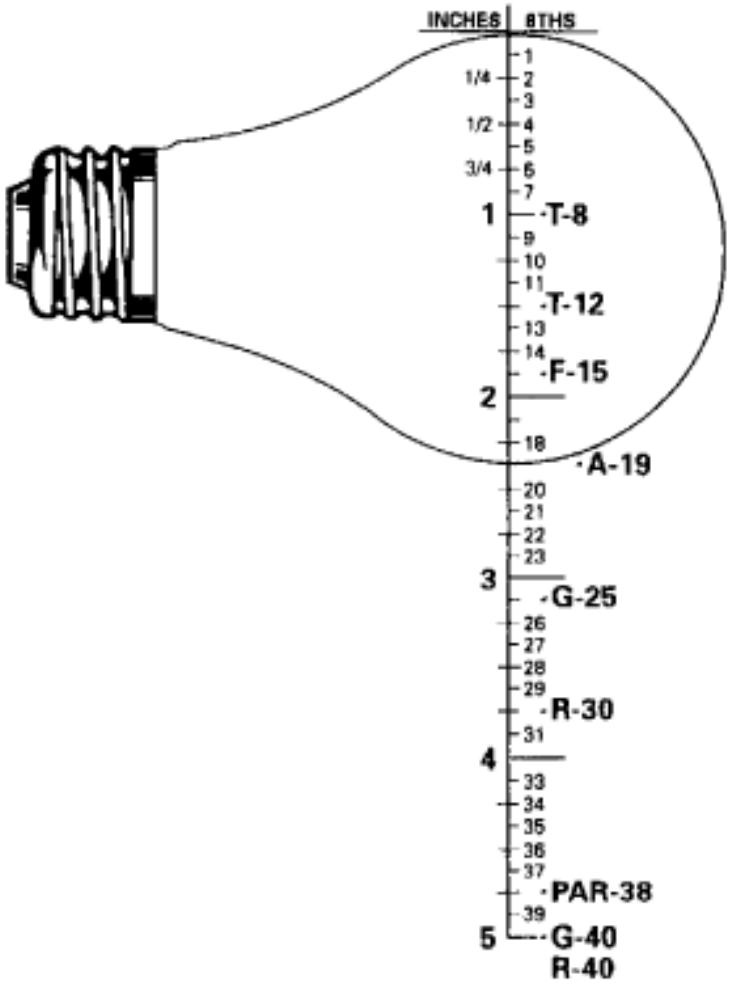
Incandescent: bulb shapes



Incandescent: size of bulb



EEM opportunities to replace incandescent bulb by CFL and/or LED

Lamp Comparison Matrix

Lamps	Source Type	Efficacy (lm/W)	Lamp Life (rated hrs)	Color Temp.[1]	CRI	Dimm -able [2]	Voltage Sensitive [2]	Temp. Sensitive[2]
Incandescent	Point	6-24	750-2000	W	100	Y	Y	N

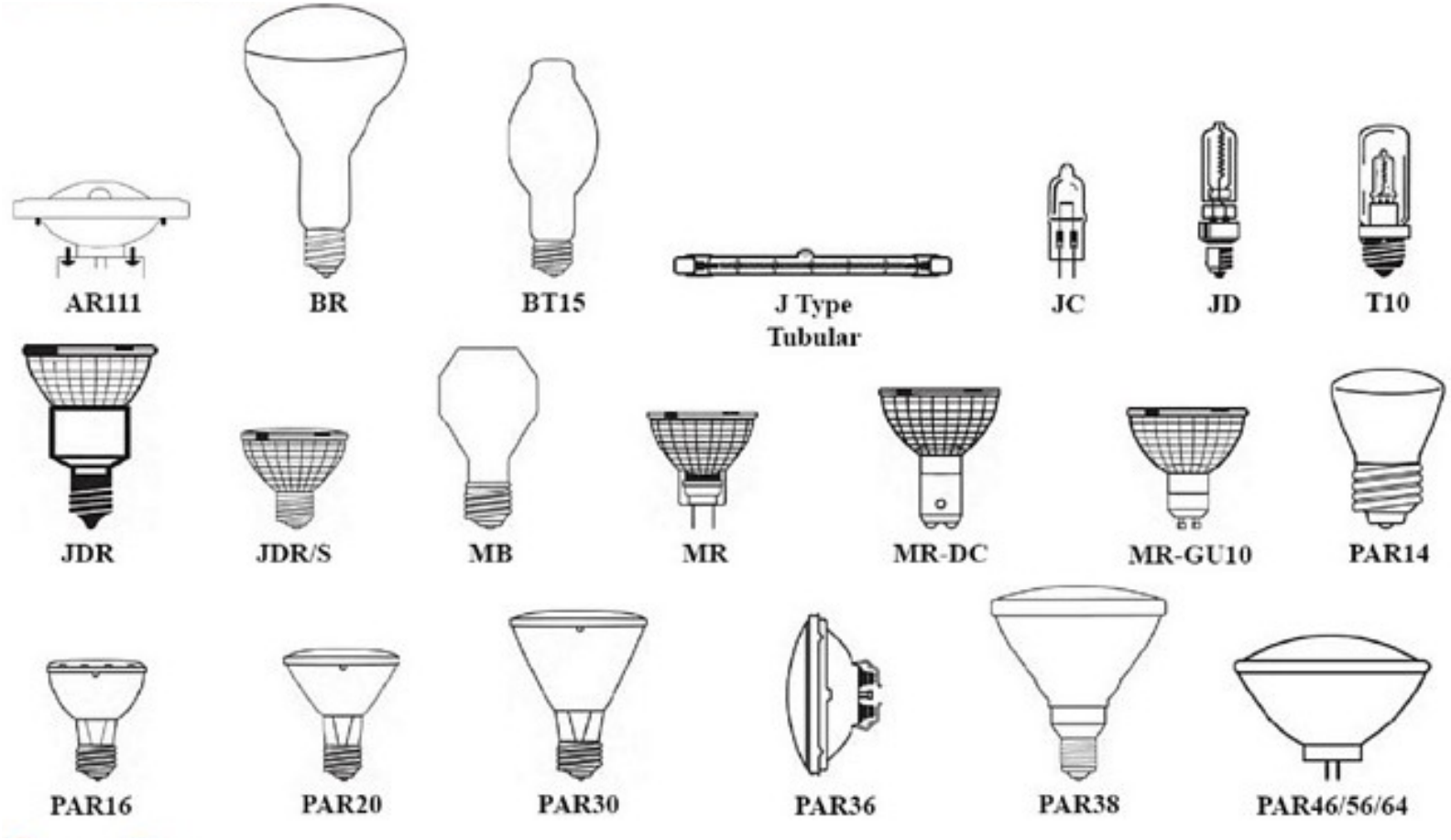
1: W (Warm), M (Mid-range), C (Cool); 2: Y (Yes), S (Special cases), N (No)

Halogen lamp

- Known as tungsten halogen lamp or quartz iodine lamp
- Is an incandescent lamp with halogen gas
- Halogen cycle chemical reaction increases lamp life
- Operated at higher temperature
- higher luminous efficacy and color temperature

© wikipedia

Halogen



Multifaceted Reflector (MR) light bulb

- a format for halogen bulbs
- directional lighting
- MR 16 is a popular lamp
- CFL and LED lamps interchangeable with some sizes of MR halogen lamps

Left to right: MR16 with GU10 base and with GX5.3 base, MR11 with GU4 or GZ4 base

© wikipedia

LED MR11, LED MR16

EEM opportunities to replace halogen bulbs by CFL and/or LED

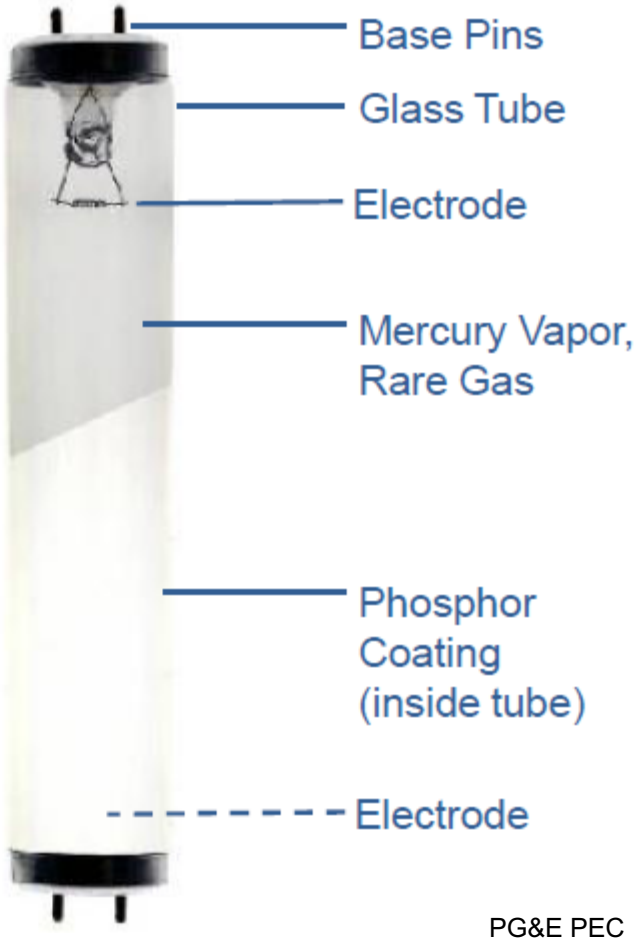
Lamp Comparison Matrix

Lamps	Source Type	Efficacy (lm/W)	Lamp Life (rated hrs)	Color Temp.[1]	CRI	Dimm -able [2]	Voltage Sensitive [2]	Temp. Sensitive[2]
Incandescent	Point	6-24	750-2000	W	100	Y	Y	N
Halogen	Point	8-35	2000-6000	W	100	Y	Y	N

1: W (Warm), M (Mid-range), C (Cool); 2: Y (Yes), S (Special cases), N (No)

Fluorescent

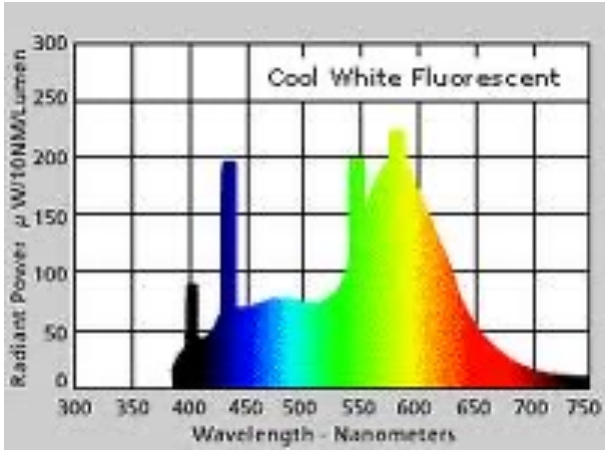
- Mercury vapor arc stream emits UV energy
- Phosphors convert UV into visible light
- Phosphors & Coatings
  - Color & Light output
- Cathodes/Electrodes
  - Life & Lumen maintenance
- Gas Pressure & Composition
  - Power Consumption & life



PG&E PEC

Fluorescent

- requires a ballast to regulate the current through the lamp
- Fluorescent tube lamp
- Compact Fluorescent Lamp (CFL)
- need recycling to avoid hazardous waste



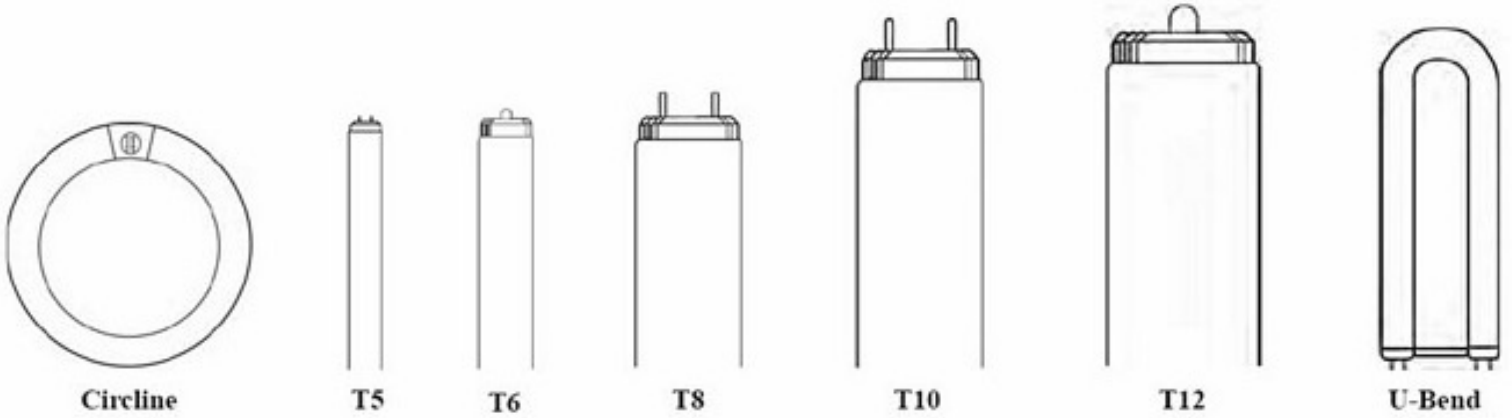
Rapid Start: warming circuit; two pins

Instant Start: high voltage pulse to start; single pin

Not to be confused with Ballast Terminology

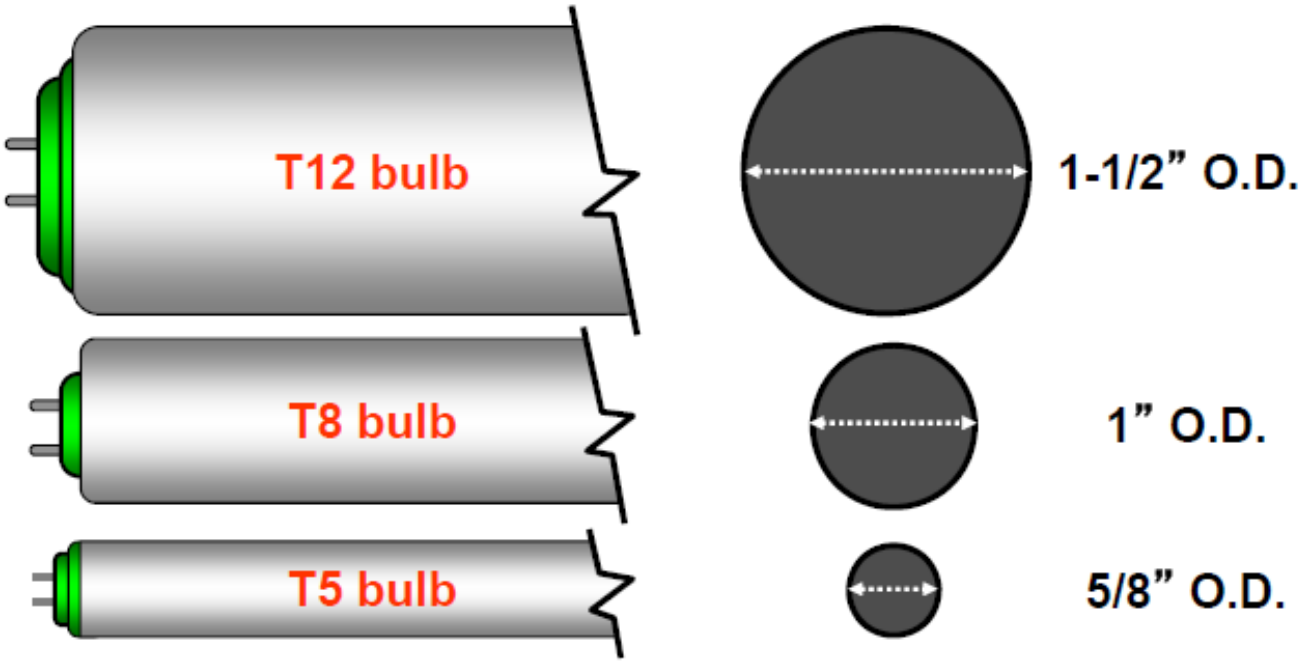
Fluorescent: tube

Bulb Shapes



Base Types

Fluorescent: tube



Example: F32T8/835

F = fluorescent

T = tubular bulb shape

/ = separator

32 = 32 lamp watts

8 = 8/8" diameter (1")

8 = CRI in the 80s

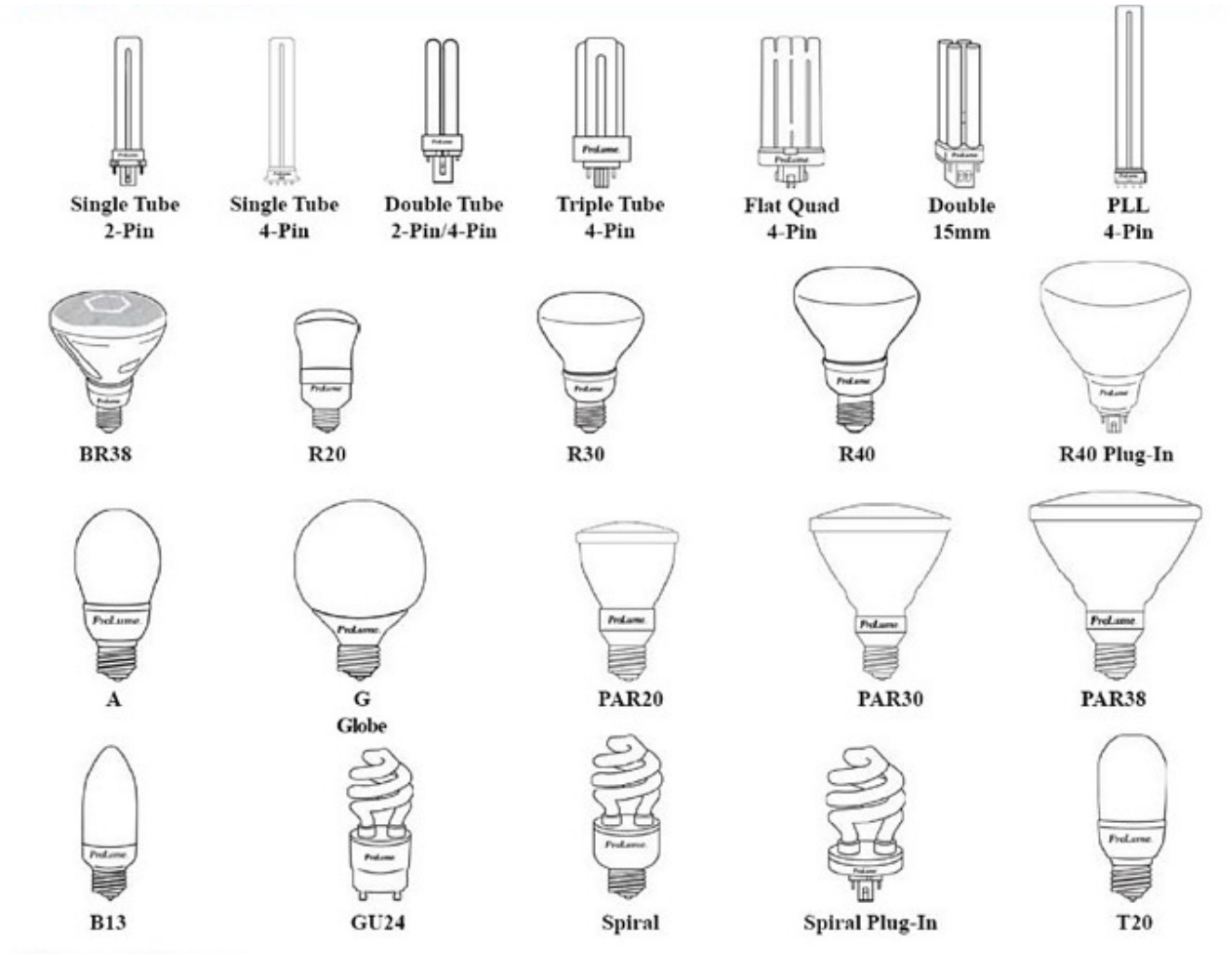
35 = apparent color temperature = 3500° Kelvin

Lamp Comparison Matrix

Lamps	Source Type	Efficacy (lm/W)	Lamp Life (rated hrs)	Color Temp.[1]	CRI	Dimm -able [2]	Voltage Sensitive [2]	Temp. Sensitive[2]
Incandescent	Point	6-24	750-2000	W	100	Y	Y	N
Halogen	Point	8-35	2000-6000	W	100	Y	Y	N
Fluorescent	Linear	60-100	7500-30,000	WMC	50-98	Y	N	Y

1: W (Warm), M (Mid-range), C (Cool); 2: Y (Yes), S (Special cases), N (No)

Fluorescent: CFL



Fluorescent - Summary

Advantage:

- High efficacy
- Long life
- Low initial cost
- High CRI
- Broad range of color temps
- High frequency operation
- Excellent lumen
- Workhorse for general lighting

Design Issues:

- Thermally sensitive
- Requires ballast
- Special ballast required for dimming
- Not a point source

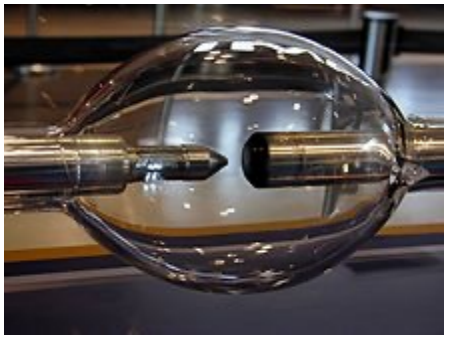
Lamp Comparison Matrix

Lamps	Source Type	Efficacy (lm/W)	Lamp Life (rated hrs)	Color Temp.[1]	CRI	Dimm -able [2]	Voltage Sensitive [2]	Temp. Sensitive[2]
Incandescent	Point	6-24	750-2000	W	100	Y	Y	N
Halogen	Point	8-35	2000-6000	W	100	Y	Y	N
Fluorescent	Linear	60-100	7500-30,000	WMC	50-98	Y	N	Y
CFL	Area	28-84	10,000-20,000	WMC	82-86	S	N	Y

1: W (Warm), M (Mid-range), C (Cool); 2: Y (Yes), S (Special cases), N (No)

HID – High-intensity discharge lamp

- A type of electrical gas-discharge lamp
- Produces light by an electric arc between tungsten electrodes inside a fused quartz or fused alumina arc tube
- The tube is filled with both gas and metal salts
- Types



xenon short-arc lamp
© wikipidia

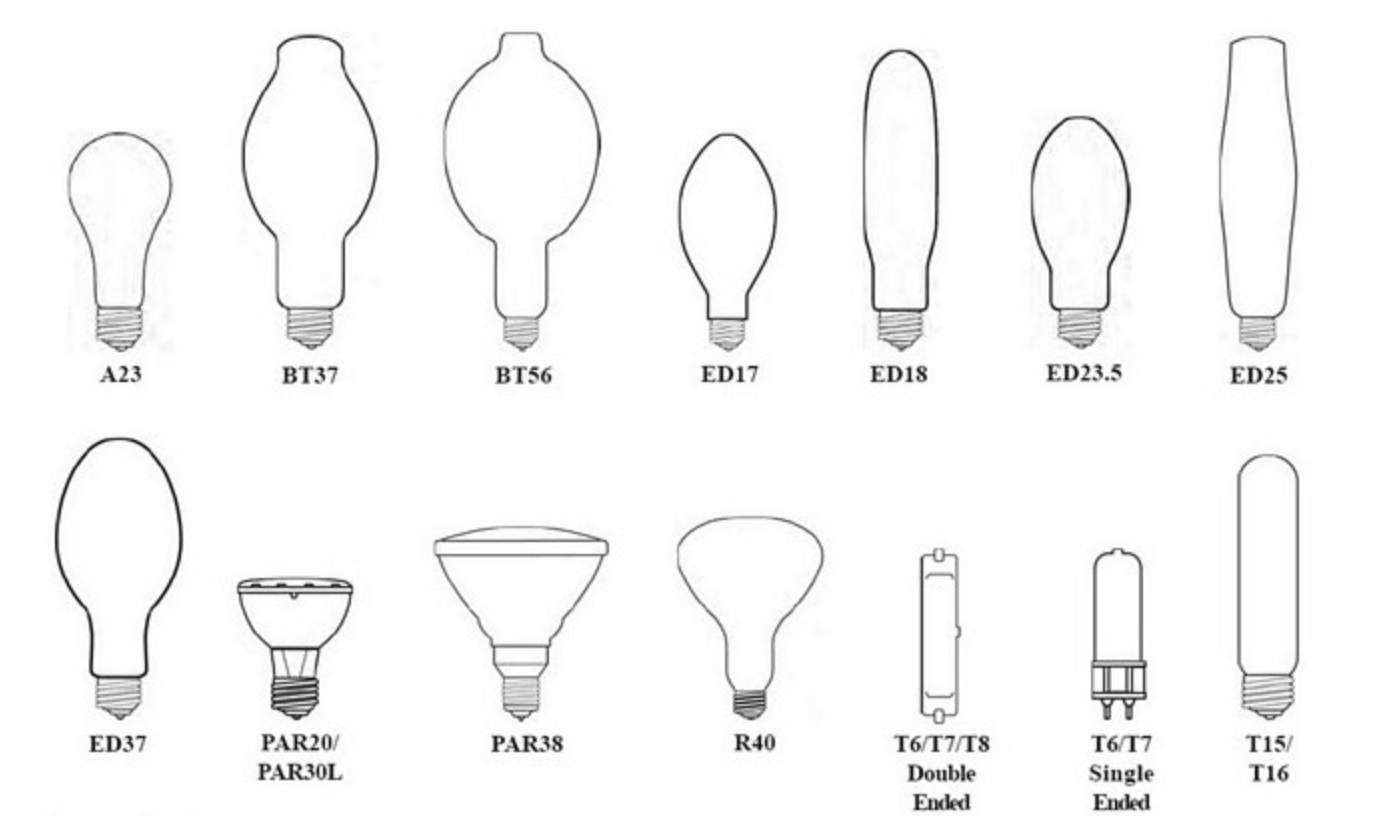
HID – High-intensity discharge lamp

- Used to light surfaces some distance

from source

- applications:
  - Street lights
  - Exterior lighting of buildings
  - Warehouse lighting
  - High-bay retail

HID – shapes


A23
BT37
BT56
ED17
ED18
ED23.5
ED25
ED37
PAR20/
PAR30L
PAR38
R40
T6/T7/T8
Double
Ended
T6/T7
Single
Ended
T15/
T16

HID – Metal halide

- produces light by an electric arc through a gaseous mixture of vaporized mercury and metal halides.
- Strengths:
  - High efficacy
  - Long lamp life
  - Good lumen maintenance
  - Good color rendering for HID source
- Weaknesses:
  - Warm-up time: 2-10min to full brightness
  - Long re-strike time: 3-20 min
  - Color shifts with age
  - Expensive to dim

© wikipedia

Lamp Comparison Matrix

Lamps	Source Type	Efficacy (lm/W)	Lamp Life (rated hrs)	Color Temp.[1]	CRI	Dimm -able [2]	Voltage Sensitive [2]	Temp. Sensitive[2]
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Halogen	Point	8-35	2000-6000	W	100	Y	Y	N
Fluorescent	Linear	60-100	7500-30,000	WMC	50-98	Y	N	Y
CFL	Area	28-84	10,000-20,000	WMC	82-86	S	N	Y
Metal Halide	Point	50-110	6000-20,000	WM	65-92	S	N	N

1: W (Warm), M (Mid-range), C (Cool); 2: Y (Yes), S (Special cases), N (No)

HID – Mercury vapor

- Uses an electric arc through vaporized mercury to produce light.
- Long lamp life
- Application: large area overhead lighting, such as in factories, warehouses, sports arenas, and streetlights
- Weaknesses:
  - Warm-up: 3-5min to full brightness
  - Long re-strike time: 5 min
  - Poor color rendering

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Lamp Comparison Matrix

Lamps	Source Type	Efficacy (lm/W)	Lamp Life (rated hrs)	Color Temp.[1]	CRI	Dimm -able [2]	Voltage Sensitive [2]	Temp. Sensitive[2]
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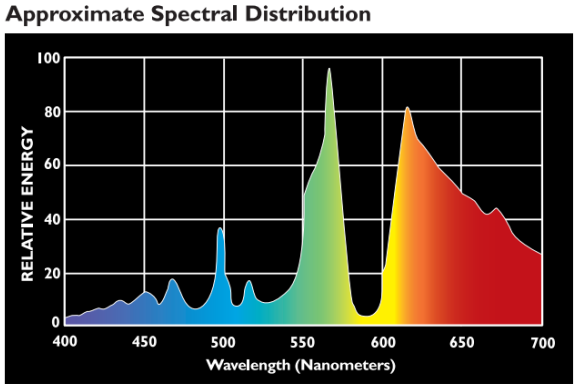
Halogen	Point	8-35	2000-6000	W	100	Y	Y	N
Fluorescent	Linear	60-100	7500-30,000	WMC	50-98	Y	N	Y
CFL	Area	28-84	10,000-20,000	WMC	82-86	S	N	Y
Metal Halide	Point	50-110	6000-20,000	WM	65-92	S	N	N
Mercury Vapor	Point	30-65	16,000-24,000	WMC	15-40	S	Y	N

1: W (Warm), M (Mid-range), C (Cool); 2: Y (Yes), S (Special cases), N (No)

HID – High pressure sodium

© wikipidia

- Uses sodium in an excited state to produce light
- High Efficacy/Long lamp life
- Produces warm white light
- Exterior, industrial, and street lighting
- Weaknesses:
  - Warm-up: 4-6min to full brightness
  - Re-strike time: 1 min
  - Poor color rendering



Philips High Pressure Solium White Son®

HID – High pressure sodium

Reading Material:

Factsheet for HID
http://www.lightingassociates.org/i/u/2127806/f/tech_sheets/High_Pressure_Sodium_Lamps.pdf

Lighting for agriculture

http://homeharvest.com/lightingmain.htm

Lamp Comparison Matrix

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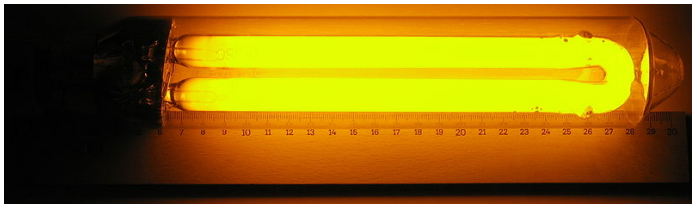
Fluorescent	Linear	60-100	7500-30,000	WMC	50-98	Y	N	Y
CFL	Area	28-84	10,000-20,000	WMC	82-86	S	N	Y
Metal Halide	Point	50-110	6000-20,000	WM	65-92	S	N	N
Mercury Vapor	Point	30-65	16,000-24,000	WMC	15-40	S	Y	N
High Pressure Sodium	Point	50-120	16,000-24,000	W	25	N	N	N

1: W (Warm), M (Mid-range), C (Cool); 2: Y (Yes), S (Special cases), N (No)

HID – Low pressure sodium

- most efficient electrically powered light source
- Long lamp life
- Produces monochromatic light
- highway and security lighting; astronomical observatory parking
- Weaknesses:
  - Poor color rendering



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Astronomers love LPS

Lamp Comparison Matrix

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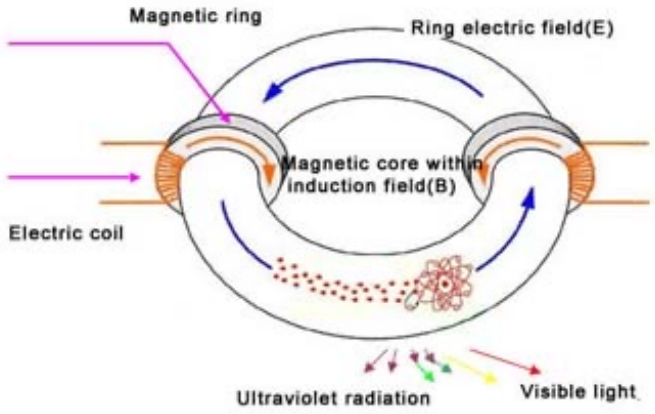
Fluorescent	Linear	60-100	7500-30,000	WMC	50-98	Y	N	Y
CFL	Area	28-84	10,000-20,000	WMC	82-86	S	N	Y
Metal Halide	Point	50-110	6000-20,000	WM	65-92	S	N	N
Mercury Vapor	Point	30-65	16,000-24,000	WMC	15-40	S	Y	N
High Pressure Sodium	Point	50-120	16,000-24,000	W	25	N	N	N
Low Pressure Sodium	Point	60-150	12,000-18,000	W	5	N	N	N

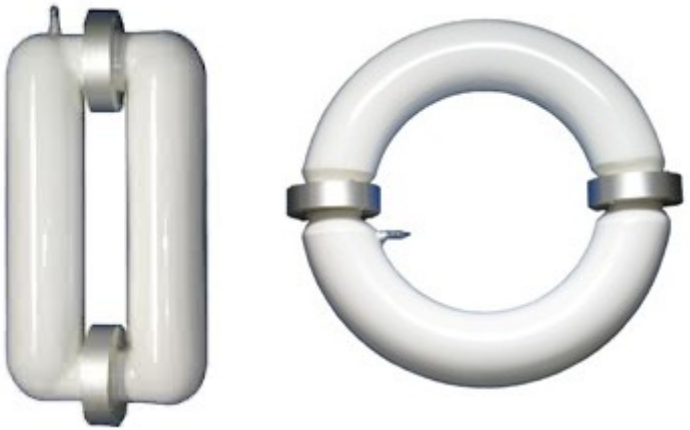
1: W (Warm), M (Mid-range), C (Cool); 2: Y (Yes), S (Special cases), N (No)

Induction lamps

- Electrode-less, fewer failures
- Induction coil generates magnetic field within lamp
- Mercury vapor generates UV energy, converted to visible light by phosphor coating, similar to fluorescent lamp.



www.lvd.cc



Induction lamps

- Long lamp life: up to 100k hr
- High CRI and good efficacy
- low maintenance
- Best uses: where maintenance is difficult.
- Expensive first cost
- Qualifies for PG&E incentives
- Reading Link: http://www.lightsoftherockies.net/Induction_Main.html

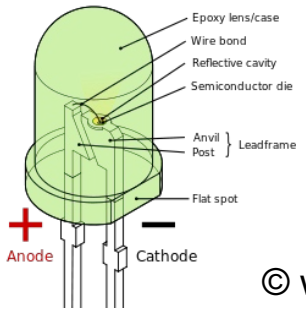
Lamp Comparison Matrix

Lamps	Source Type	Efficacy (lm/W)	Lamp Life (rated hrs)	Color Temp.[1]	CRI	Dimm-able [2]	Volt. Sen-sitive[2]	T. Sen-sitive[2]
Incandescent	Point	6-24	750-2000	W	100	Y	Y	N
Halogen	Point	8-35	2000-6000	W	100	Y	Y	N
Fluorescent	Linear	60-100	7500-30,000	WMC	50-98	Y	N	Y
CFL	Area	28-84	10,000-20,000	WMC	82-86	S	N	Y
Metal Halide	Point	50-110	6000-20,000	WM	65-92	S	N	N
Mercury Vapor	Point	30-65	16,000-24,000	WMC	15-40	S	Y	N
High Pressure Sodium	Point	50-120	16,000-24,000	W	25	N	N	N
Low Pressure Sodium	Point	60-150	12,000-18,000	W	5	N	N	N
Induction	Area	60-80	100,000	WM	80	N	N	N

1: W (Warm), M (Mid-range), C (Cool); 2: Y (Yes), S (Special cases), N (No)

Light emitting diodes (LED)

- A semiconductor light source
- Produce light by electro-luminescence
- Available across the visible, UV and infrared wavelengths
- Developing rapidly
- High brightness
- Low energy consumption
- Long life time
- Need heat management



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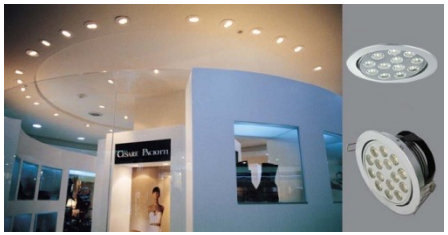
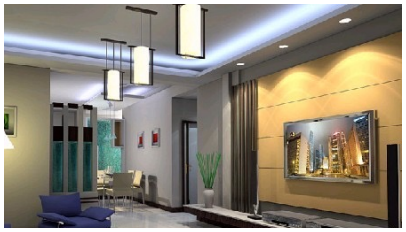
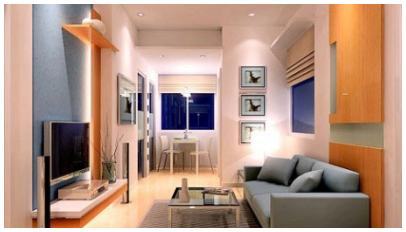
Light emitting diodes (LED)

- Applications:
  - indoors/outdoors
  - Exit signs, safety lights
  - Traffic lights/street lamps
  - Advertising
  - General lighting

- Qualify PG&E incentives
- Retrofit opportunity






Light emitting diodes (LED) -- more examples

© sielement.com

© japantrends.com

Lamp Comparison Matrix

Lamps	Source Type	Efficacy (lm/W)	Lamp Life (rated hrs)	Color Temp.[1]	CRI	Dimm-able [2]	Volt. Sen-sitive[2]	T. Sen-sitive[2]
Incandescent	Point	6-24	750-2000	W	100	Y	Y	N
Halogen	Point	8-35	2000-6000	W	100	Y	Y	N
Fluorescent	Linear	60-100	7500-30,000	WMC	50-98	Y	N	Y
CFL	Area	28-84	10,000-20,000	WMC	82-86	S	N	Y
Metal Halide	Point	50-110	6000-20,000	WM	65-92	S	N	N
Mercury Vapor	Point	30-65	16,000-24,000	WMC	15-40	S	Y	N
High Pressure Sodium	Point	50-120	16,000-24,000	W	25	N	N	N
Low Pressure Sodium	Point	60-150	12,000-18,000	W	5	N	N	N
Induction	Area	60-80	100,000	WM	80	N	N	N
White LEDs	Projec-tion	27-92	50,000-100,000	WMC	75	Y	N	Y

1: W (Warm), M (Mid-range), C (Cool); 2: Y (Yes), S (Special cases), N (No)

Reading materials:

http://www.greenbiz.com/blog/2012/08/14/bright-idea-how-led-technology-key-future-smart-buildings?utm_source=E-News+from+GreenBiz&utm_campaign=c8af7dd6c7-GreenBuzz-2012-08-16&utm_medium=email

Bright idea: How LED technology is key to future smart buildings

By **Casey Talon**
Published August 15, 2012
Tags: Big Data, Buildings, More...

Email | Print | Single Page View

http://www.greentechmedia.com/articles/read/LED-Fixture-Prices-Fall-24-in-Two-Years-How-Much-Lower-Can-They-Go/

LED Fixture Prices Fall 24% in Two Years—How Much Lower Can They Go?

Enterprise LED pricing could soon use dollars per footcandle as a performance metric.

Neon Lighting

- Electrified glass tubes/bulbs containing rarefied neon or other gases
- The color of light depends on the gas in the tube:
  - neon: red
  - helium: yellow
  - carbon dioxide: white
  - mercury: blue
- Now ‘competing’ with LEDs

© wikipidia

Homework 1

Visit a local home improvement or lighting store

1. Locate and identify at least 5 types of lamps

2. Record 2 lamp codes selected from each lamp type. Interpret and record the meaning of the codes (eg. F32T8/835 and F34T12/830)

3. check ballasts, reflectors, and diffusers

B. Lighting systems

1. Component
2. Types of lamps
3. Ballasts
4. Lamp comparison matrix
5. Types of lighting luminaires and intensities
6. Energy efficiency measures (EEMs)

3. Ballasts

a. Electro-magnetic (magnetic) ballast
   - Made of wire coiled to create a magnetic field
   - Secondary freq. = primary frequency (60Hz)

b. Electronic ballast
   - Up to 40% efficiency improvement over magnetic ballasts
   - Secondary freq. 20000-40000Hz
   - No ballast "hum"
   - Can drive up to 4 lamps/ballast
   - High Power Factor
   - Light weight
   - No flicker

EEM opportunities to replace magnetic ballast by electronic ballast

Ballast factor

- Lamp lumen ratings are determined under controlled test conditions on a reference ballast with a default ballast factor of 1.0
- used to describe ballast that under- or over-drive lamps
- Options (w/Electronic Ballasts)
  - Reduced Light Output (RLO): $0.75 \leq BF < 0.87$
  - Normal Light Output (NLO): $0.87 \leq BF < 0.95$
  - High Light Output (HLO): $0.95 \leq BF < 1.20$

B. Lighting systems

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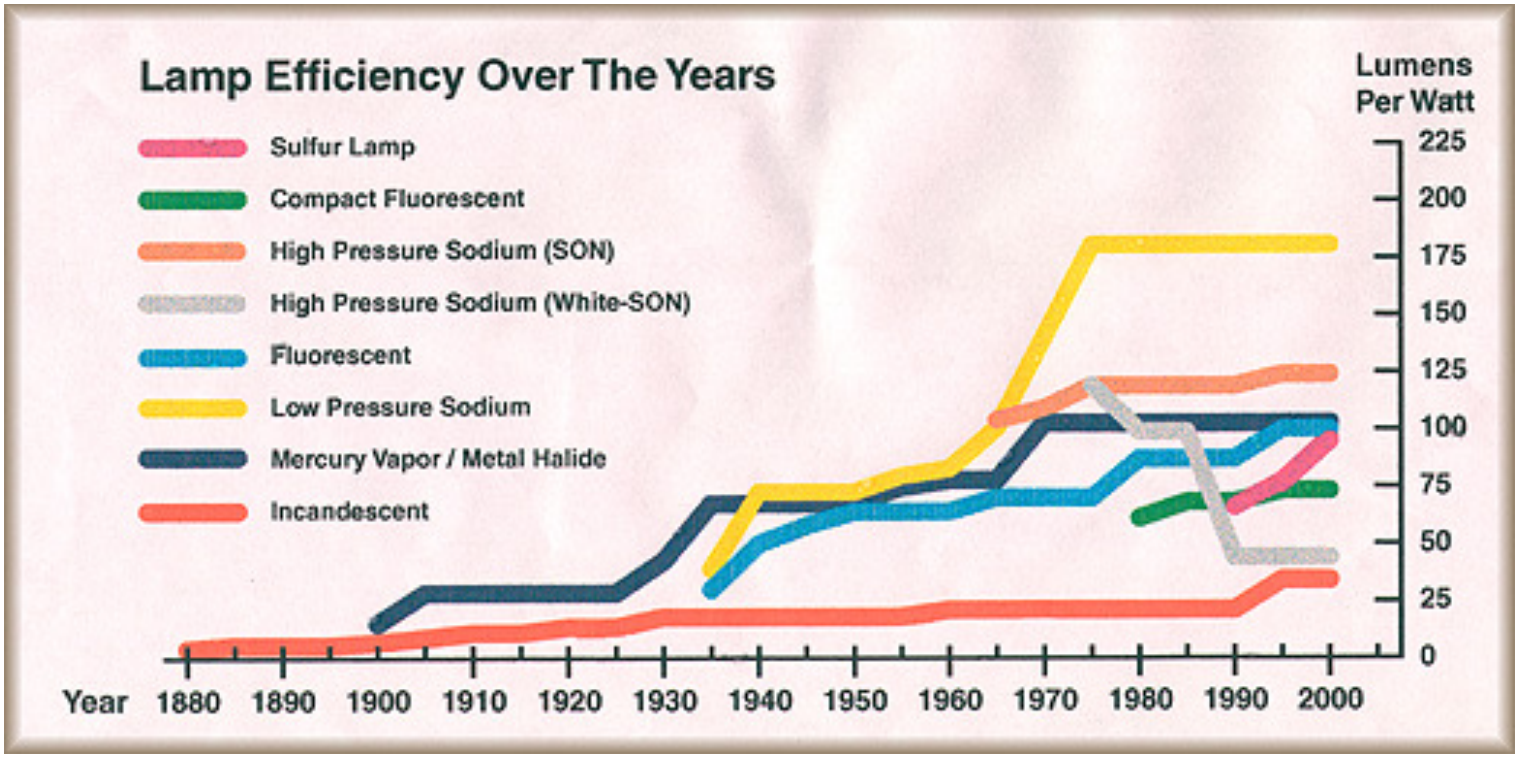
Efficacy



http://americanhistory.si.edu/lighting/tech/chart.htm

Lamp Comparison Matrix

Lamps	Source Type	Efficacy (lm/W)	Lamp Life (rated hrs)	Color Temp.[1]	CRI	Dimm-able [2]	Volt. Sen-sitive[2]	T. Sen-sitive[2]
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Halogen	Point	8-35	2000-6000	W	100	Y	Y	N
Fluorescent	Linear	60-100	7500-30,000	WMC	50-98	Y	N	Y
CFL	Area	28-84	10,000-20,000	WMC	82-86	S	N	Y
Metal Halide	Point	50-110	6000-20,000	WM	65-92	S	N	N
Mercury Vapor	Point	30-65	16,000-24,000	WMC	15-40	S	Y	N
High Pressure Sodium	Point	50-120	16,000-24,000	W	25	N	N	N
Low Pressure Sodium	Point	60-150	12,000-18,000	W	5	N	N	N
Induction	Area	60-80	100,000	WM	80	N	N	N
White LEDs	Projec-tion	27-92	50,000-100,000	WMC	75	Y	N	Y

1: W (Warm), M (Mid-range), C (Cool); 2: Y (Yes), S (Special cases), N (No)

http://www.eleekinc.com/eleekchart.pdf

Incandescent | E26 Medium & E12 Candelabra Base

This is the traditional "Edison" light bulb. It emits light in a warm, broad spectrum; however, approximately 90% of all the power consumed by an incandescent light bulb is emitted as heat rather than visible light. Given far more efficient alternatives, some governments are mandating a phase-out or ban of its use.

Halogen | T3 Bi-Pin, G4 Base & MR16, GU5.3 Base

Halogen is a form of incandescent. It has the truest color rendering of any light source other than the sun and is therefore often used to illuminate works of art. In the MR16 format, this long-lasting, low-voltage spot is amplified by an integrated reflector, greatly increasing its apparent efficacy.

Ceramic Metal Halide | E26 Medium Base

Metal Halide is an efficient, high-output lamp commonly used to illuminate large outdoor areas, in part because its output is unaffected by environmental temperature changes. Due to high intensity and slow start-up, it is best suited for outdoor and commercial applications. MHs contain mercury, requiring special disposal measures.

Light-Emitting Diodes [LEDs]

LEDs are a promising technology currently undergoing rapid development. Their warmth and color rendering can be comparable to incandescent in certain applications. Their small size makes them highly versatile. Given their long life, high efficiency and low toxicity, their cost is likely to be justified over time.

Compact Fluorescent [CFL] Integrated Ballast | GU-24 Pin & E26 Medium Base

CFLs use less energy than incandescents and can last up to eight times longer (if not overheated) while generating light that is becoming increasingly comparable. CFLs contain trace amounts of mercury, requiring special disposal measures. The ballast must be discarded along with this type of lamp.

CFL non-Integrated ballast Twin & Quad Tube | 2G11 & GX24Q, 2 & 4 Pin Base

These CFLs utilize separate, reusable electronic ballasts; they are slightly more efficient and can last longer compared to integrated-ballast CFLs. One ballast will often run multiple wattages and permit dimming. Lamp disposal issues are the same.

High Pressure Sodium (HPS) & White "SON"

These lamps are typically used for streetlights and security lighting, where color rendering is not critical. HPS lamps contain trace amounts of mercury, making disposability an issue, and they decline in lumen output as they age. White "SON" is a higher cost HPS variant with a high CRI but reduced life and efficacy.

Fluorescent Tube | T5, T5 HO Mini Bi-Pin, T8

The "new and improved" flicker-free fluorescent tube offers good color rendering, long life and low cost. Like all fluorescents, special disposal measures are required due to mercury content.

ELEEK LAMPING COMPARISON CHART

WWW.ELEEK.COM

	ENERGY watts	OUTPUT lumens ❶	EFFICACY lumens per watt ❷	CO2 lbs ❸	CO2: lumen ratio ❹	LAMP COST ❺	LIFE (hours)	RUN COST per 1000 hrs ❻	CRI 1—100 ❼	CCT kelvin ❽
	25	170	07	33	.194			$3.60		
	40	495	12	46	.105	$0.60	1000	$5.40	100	2700
	60	830	14	78	.093			$7.80		
BI-PIN	20	320	16	26	.081	$3.30	2K to 4K	$3.40	100	2850
	20	320	16	26	.081	$2.00		$3.06		
MR16	35	600	17	46	.077	$5.00	2K to 4K	$5.80	100	2950 to 6000
	50	900	18	65	.072	$9.79		$9.26		
	22	1155	53	27	.023	$88		$9.94		
	70	4500	64	91	.020	$32	12K	$11.06	81—96	2900 to 4100+
	150	9800	65	195	.020	$31		$20.50		
	02	200	100*	03	.015	$20		$0.71		
	05	500	100*	07	.014	$38	35K to 50K	$1.49	40—90	2900 to 6100
	10	1000	100*	13	.013	$80		$3.06		
	13	850	65	17	.020	$3.20		$1.88		
	18	1100	61	23	.020	$4.40	10K	$2.60	82—90	2700 to 4100
	23	1600	69	30	.018	$4.00		$3.16		
	26	1800	69	34	.019	$7.40		$3.58		
	32	2400	75	42	.018	$10.00	12K to 20K	$4.47	82—90	2700 to 6500
	36	2800	78	47	.016	$10.60		$4.98		
	80	6000	75	104	.017	$28.00		$11.35		
HPS	35	2250	64	46	.020	$23.70	16K 24K	$5.68	22	1900
	70	6400	91	91	.014			$9.38		
SON	50	2000	40	65	.032	$79.50	10K	$13.95	85	2500 to 2700
	100	4170	42	130	.031			$19.95		
T5	28	2900	104	31	.015	$9.74	25K to 35K	$3.68	82—85	3000 to 6500+
	35	3450	99	70	.014			$4.52		
T8	17	1260	80	22	.017	$4.84	20K to 46K	$2.18	78—96	3000 to 6500
	32	2800	80	46	.016	$2.54		$3.91		

❶ Lumens are a measurement of the perceived power of light. All ratings approximate. ❷ Efficacy = lumens/watts. The higher the number, the more efficient. ❸ Approximate CO2 emission per 1,000 hours of use assuming coal generated electricity. ❹ CO2 output per lumen is a finer gauge of sustainability. ❺ Costs are collected averages. ❻ Includes electricity at national average of 12c/kwh, and average lamp cost. ❼ CRI = Color Rendering Index. 100 = full color range incandescent. ❽ CCT = Correlated Color Temperature in degrees Kelvin. Low temps are "warm" colors, high: "cool". *Actual efficacies measured in application are generally between 40—60. This is rapidly improving. For resources, references and more, go to http://www.eleek.com/lampguide.html

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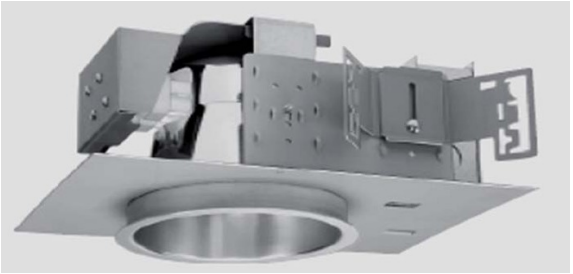
5. Types of lighting luminaires and intensities

By distribution:

- Direct (downlight)
- Semi-direct (mostly downlight)
- General/ambient
- Semi-indirect (mostly uplight)
- Indirect (uplight)



CFL downlight

By function:

- Ambient
- Wall wash
- Ceiling wash
- Accent
- Decorative

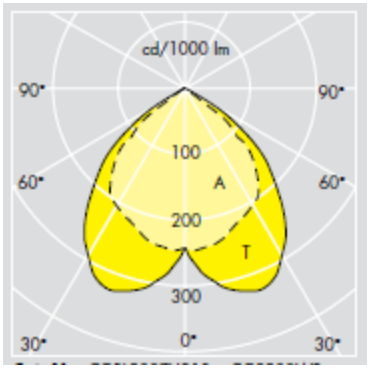
Decorative @ houzz.com

LED accent light

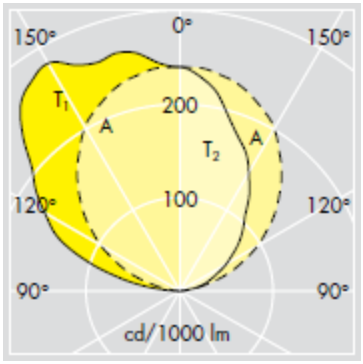
Photometric distribution

The diagrams illustrate the distribution of luminous intensity of the luminaire, in candelas.

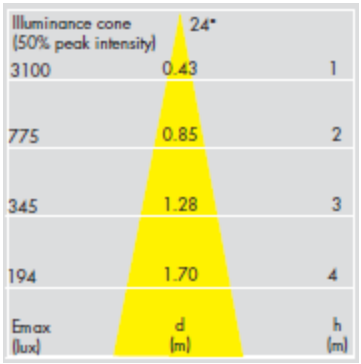
The curves provide a visual guide to the type of distribution expected from the luminaire, e.g. wide, narrow, direct, indirect, etc.



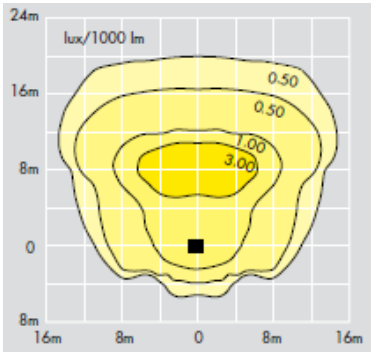
Downlight



Uplight



Spotlight



Floodtlight

www.thornlighting.co.uk

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6. Energy Efficiency Measures (EEMs)

a. Lamp replacement

b. Ballast replacement

Lamp replacement

- Replace inefficient lamps with efficient lamps
- Replace incandescent lamps with CFL or LED
- Replace T12 lamps with T8, T5 or T5/HO
- Replace mercury vapor lamps with MH or other sources

Lamp replacement

Replace incandescent lamps with CFL or LED

- Screw-in CFLs are good for general service

- LEDs are good candidates for directional lamp retrofit.

Exercise: A hotel has 50 rooms, and each room has 10 60W incandescent bulbs. If the average working time is 1500hrs, and average electricity cost is $0.10/kWh. Calculate the annual savings to replace these incandescent bulbs with 15W CFL.

Lamp replacement

Exercise: A hotel has 50 rooms, and each room has 10 60W incandescent bulbs. If the average working time is 1500hrs, and average electricity cost is $0.10/kWh. Calculate the annual savings to replace these incandescent bulbs with 15W CFL.

Answer:

single bulb: ΔP=60W-15W=45W

Δ Annual Energy Usage=45W * 1500h/1000

=67.5kWh/yr

No. of bulbs= 50 *10=100

Total annual energy saving = 67.5 *100 = 6750 kWh

Total money saving = $0.1/kWh *6750 kWh = $ 675

Besides, CFL good for 20k hrs while incandescent only ~2k hrs. ----More savings on bulb changing cost and labor.

Lamp replacement

Replace T12 lamps

Diameter	Watts	Lumens	Lumens/Watt
T5	28	2900	104
T8 (super)	32	3100	97
T5/HO	54	5000	93
T8/741	32	2850	89
T12/WM	34	2650	78
T12/CW	40	3050	76

Following PG&E incentives expires after 12/31/2012

- Upgrade from T12 to a T8 lamp and electronic ballast
- De-lamp T12s
- Upgrade T12 fixtures to more efficient interior fixtures

Ballast replacement

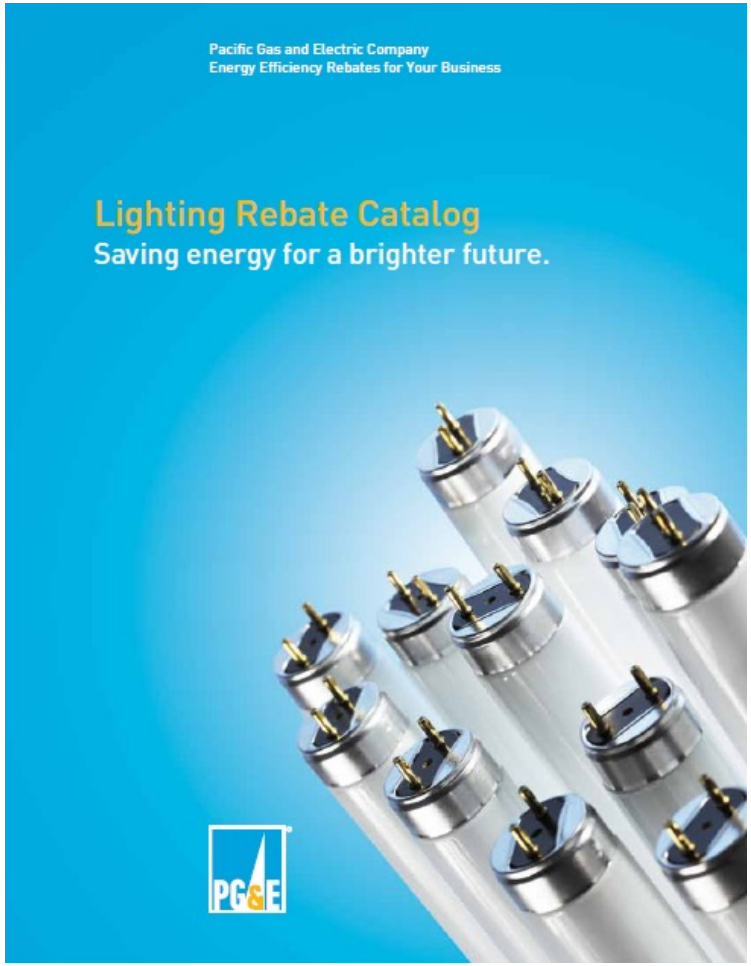
Replace magnetic ballast with electronic ballast :

- for fluorescent lamps, 10-25% efficiency improvement
- for HID lamps, lower ballast losses and light depreciation, meaning lamps produce more light over their entire lifespan.

Frontierlighting.com

PG&E lighting rebates

http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/lighting_catalog_final.pdf



Case study : http://sfenvironment.org/article/case-studies/sf-energy-watch-success-story-chloe-fine-arts-gallery

SF Energy Watch Success Story: Chloe Fine Arts Gallery

Topics

- Energy
  - > Energy Efficiency
    - > Home
    - > Commercial and Multifamily Properties
  - > Renewable Energy
- Transportation
- Zero Waste
- Toxics & Health
- Buildings & Environments
- Education & Equity
- Climate Change

Newsletter

Email

First Name

Last Name

Submit

Chloe Fine Arts Gallery

Locally owned and operated, with over 23 years in gallery management, Chloe Fine Arts Gallery represents national and international fine artists while exploring the inter-relationship and influences between fine art from the 18th to 21st centuries.

Chloe Fine Arts Gallery was approached by a City representative during the SF Energy Watch Neighborhood Campaign. After learning about the Program, the management signed up for a free energy assessment. Upon learning of their potential energy savings and the high incentives offered by the Program, Chloe Fine Arts Gallery decided to follow through on the recommendations, using one of the Program's participating lighting contractors.

The Gallery replaced 120 dimmable 75-watt halogen PAR30s with 13-watt dimmable LED lights for artwork display. In addition, a total of 13 T12 linear fluorescents light fixtures with magnetic ballasts were upgraded with efficient T8 lamps with electronic ballasts, (eight fixtures were de-lamped from 3 lamps to 2). To maximize savings throughout the gallery, the incandescent exit signs were also upgraded with LEDs. Chloe Fine Arts Gallery is the first art gallery in San Francisco to install LED lighting through SF Energy Watch.

Case study : http://sfenvironment.org/article/case-studies/sf-energy-watch-success-story-chloe-fine-arts-gallery

Benefits:

- Significant energy and financial cost saving
- Improvement of the lighting on the artwork
- Contribution to Chloe Fine Art's commitment to going green

Chloe Fine Arts Gallery Profile

Location	645 Beach St in San Francisco
Square Footage	4,000
Number of Employees	5
Types of Space	Art gallery presenting fine paintings and sculptures
Energy Efficiency Upgrades	Lighting Retrofits

Savings Snapshot

Total Project Cost	$8,343
Program's Incentive	$6,829
Customer's Co-Pay	$1,514
Annual Savings	**$ 4,473**
kW Reduction	6.92
Payback	4 months

Useful links:

DOE energy savers info for lighting:
http://www.energysavers.gov/your_home/lighting_daylighting/index.cfm/mytopic=11985

Lighting glossary
http://www.mbm.net.au/uss/lighting_glossary.html

Industry resources
http://www.lightingassociates.org/industry_resources

BEST Center Curricula, Resources & Recordings

Academic Programs
Georgia Piedmont Technical College - Building Automation Systems
Milwaukee Area Technical College - Sustainable Facilities Operations
Laney College - Commercial HVAC Systems
City College San Francisco - Commercial Building Energy Analysis & Audits

Professional Development Materials, Presentations & Videos
National Institutes
Building Automation Systems Instructor Workshops
Webinars (e.g., BEST Talks)

Faculty Profile Videos
Reports & Case Studies
Marketing Resources

BEST
Building Efficiency for a Sustainable Tomorrow

NSF National Science Foundation