Lighting Efficiency

Units

- Lighting quantity is primarily expressed in three types of units.
  - Watts – measure of electrical power that defines the rate of energy consumption.
  - Lumens – output of a lamp, how much light is being produced by the lighting system.
  - Foot candles – shows how much light is actually reaching the work plane or task (lumens/SqFt)

Light Levels

Building Area and Task Lighting Level	Foot Candles
Auditoriums	14
Bank Teller Stations	70
Barber Shops	70
Bathrooms	28
Building Entrances	5
Cashiers	28
Cleaning	14
Conference Rooms	28
Corridors	14
Dance Halls	7
Drafting - high contrast	70
Drafting - low contrast	139
Elevators	14
Exhibition Halls	14
Floodlighting	28
Hospitals - Examination rooms	70
Hospitals - Operating rooms	139
Kitchen	70
Laundry	28
Lobbies	28
Offices - general	70
Parking Areas – covered	5
Parking Areas - open	2
Reading - Writing	70
Restaurant - Dining	7
Restaurant - food display	70
Stairways	14
Stores - sales areas	70
Street lighting - highways	1
Street lighting - roadways	1
Utility Rooms	28
Warehouses*- inactive, bulky storage	7
Warehouses*- active, medium storage	14
Warehouses*- small item storage	28
Warehouses*- shipping and receiving	28

* In warehouses, this is the recommended level at document reading height

*** Source - The Illuminating Engineering Society of North America

Factors in successful Lighting Applications

- Amount of light required in FC
- Efficacy*
- Lumen output of lamps and fixtures
- Color rendition – Color Rendering Index (CRI)
- Color temperatures in Kelvin
- Types of light source
- Lighting Quality

- Efficacy – similar to efficiency, efficacy describes an output/input ratio, the higher the output (while input is kept constant) the greater the efficacy. Measured as lumens/watt.

Lamp family	Lamp type	Watts	Efficacy
Incandescent	Incandescent	3 – 1,500	4 – 23
	Halogen	42 – 1,500	14 – 22
CFL	Screw-base	9 – 85	40 – 65
	Twin-tube	5 – 13	50 – 69
Linear Fluorescent	T2	6 – 13	52 – 66
	T5	14 – 35	96 – 104
	T8	32	53 – 88
	T8 reduced wattage	30	94 – 95
	T12 HO reduced wattage	95	81 – 92
Mercury Vapor	Standard	50 – 1,000	32 – 58
	Self ballasted	160 – 750	14 – 19
Metal Halide	Standard Probe Start	50 – 1,500	69 – 115
	Pulse –Start	50 – 1,000	69 – 110
High Pressure Sodium	Standard	35 – 1,000	64 – 150
Low Pressure Sodium		18 – 180	100 – 175

Color Rendition (CRI)

Indicates the effect of a light source on the color appearance of objects for a given color temperature.

75- 100 CRI = Excellent color rendition

65 – 75 CRI = Good color rendition

55 – 65 CRI = Fair color rendition

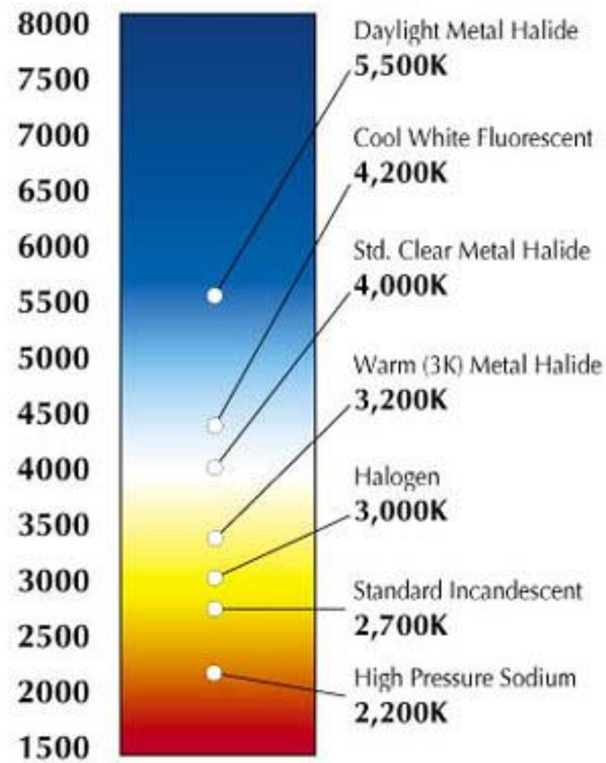
0 – 55 CRI = Poor color rendition

Color Temperature

A measure of the “warmth” or “coolness” of a light source. Also effects color appearance of objects.

< 3,200K = warm or red side of spectrum

>4,000K = cool or blue side of spectrum



Amount of light required for specific applications

We often use more light than is needed for many applications and tasks. Light levels are measure in foot-candles using an luminance meter.

FC = lumens/SqFt

Consensus standards for light levels are set by the *Illuminating Engineering Society of North America (IESNA.org).*

Lighting Maintenance Principles

- Light output of all lighting systems decreases over time
- Lighting systems are over-designed to compensate for future light loss
- Improving maintenance practices can reduce light loss and can either:
  - Allow reductions in energy consumption, or
  - Improve light levels
- Group maintenance practices save money

What to look for in Lighting Audit

- Lighting Equipment Inventory
- Lighting Loads
- Room dimensions
- Illuminating levels
- Hours of Use
- Lighting Circuit Voltage

Potential Lighting ECMs

- Fluorescent Upgrades
- Delamping
- Incandescent Upgrades
- HID Upgrades
- Controls Upgrades
- Daylight compensation (daylight harvesting)

Three major areas for lighting improvement

Much of the cost savings from new retrofit lighting can be achieved in three major areas:

1. Replace incandescent lamps with fluorescent or CFLs
2. Upgrade fluorescent fixtures with improved components
3. Install lighting controls to minimize energy costs

Not all lighting needs to be changed

- Lowering lights can also yield great results with existing lighting where feasible and possible.
- Fundamental Law of Illumination (or Inverse Square Law)

$$E = \frac{I}{d^2}$$

- E = Illuminance in Foot Candles
- I = Luminous intensity in lumens
- d = Distance from light source to surface area of interest

Let's look at an example:

Another method:

A high bay facility has their lights located at a height of 40’, there is no use of the space between 20’ and 40’. The current light levels are 50 FC at the floor.

What will the approximate FC be if lowering the lights to the 20’ level?

Answer:

$$50\left(\frac{40^2}{20^2}\right) = 200\text{FC}$$

LIGHTING AUDIT WORKSHEET

	A	B	C	D	E	F	G	H	I
Lighting	**Type of Lamp** *(incandescent/ halogen/CFL)*	**# of Lamps**	**Lamp Wattage**	**# of hours used per yr** *(hrs per day x 365 days)*	**kWh USED per year** ([C x D]/1000)	**Wattage of energy efficient Equivalent CFL**	**Watts saved after retrofit** *(C - F)*	**kWh SAVED per year** *([G x D]/1000)*	**Notes** (are any lamps are either too dim/bright for their application, is shade/cover size adequate, are lamps in room necessary?
Overhead/Ceiling Fixture									
Table/Desk Fixture									
Floorlamp/Torchier Fixture									
Other Fixture Type:									
Other Fixture Type:									
Other Fixture Type:									
Other Fixture Type:									
Other Fixture Type:									
Other Fixture Type:									
TOTAL yearly kWh for using all lamps before retrofit	----	----	----	----		----	----	----	
TOTAL yearly kWh SAVED from switching to CFLs	----	----	----	----	----	----	----		

Notes: "Lamp" is actually the light bulb itself, which is screwed into the "light fixture."
Wattage Equivalents for energy efficient lamps are as follows:

Incandescent
100-watt = 27-watt CFL
75-watt = 20-watt CFL
60-watt = 15-watt CFL

Halogen
150-watt = 39-watt CFL

TIPS: *When selecting replacement lamps, choose CFLs that have electronic ballasts instead of magnetic*

Energy Savings Potential with Occupancy Sensors

Offices (private)	25 – 50%
Offices (open spaces)	20 – 25%
Rest Rooms	30 – 75%
Corridors	30 – 40%
Storage Areas	45 – 65%
Meeting Rooms	45 – 65%
Conference Rooms	45 – 65%
Warehouses	50 – 75%

Lighting Example:

Assumptions –

1. 2 x 4 troffer with 4 lamps
2. Average energy cost = $0.07/kWh
3. Annual fixture operation = 3,500 hrs.
4. Lamp life = 28,860 hrs.
5. Labor to replace lamps = $6.00/lamp
6. System life = 15 years

A. Case "A" – fixture power = 144W
lamp cost = $1.50 each

B. Case "B" – fixture power = 101W
lamp cost = $3.00 each

Find the following:

AEC (Annual Energy Cost)

AMC (Annual Material Cost)

ALC (Annual Labor Cost)

AOC (Total Annual Operating Cost)

Lighting Example Solution:

AEC = Fixture Power (kW) x Operation (hrs/yr) x energy cost ($/kWh)

AEC (A) = .144 x 3,500 x 0.07 = $35.28/yr

AEC (B) = $24.74/yr

AMC = lamps/yr x cost ($/lamp)

AMC (A) = (4 x (3,500 / 28,860)) x 1.5 = $0.73/yr

AMC (B) = $1.46/yr

ALC = lamps/yr x labor ($/lamp)

ALC (A) = 0.485 x 6 = $2.91/yr

ALC (B) = $2.91/yr

AOC = AEC + AMC + ALC

AOC (A) = 35.28 + 0.73 + 2.91 = $38.92/yr

AOC (B) = $29.11/yr

*lamps/yr = # of lamps x (operation (hrs/yr)/Lamp life (hrs/lamp))

High Bay cost analysis:

A 244,000 SqFt high bay facility is presently lit with 800 twin 400W mercury vapor fixtures (455 watts per lamp including ballast). What are the annual savings of replacing the existing lighting system with 800 single 400W high pressure sodium fixtures (465 watts per lamp including ballast)? Assume 8,000 hrs. operation per year, an energy cost of $0.05/kWh, and a demand cost of $6.00/kW per month.

Solution is ....

………but first let's look at a couple of things.

What does a ballast do?

- Conditions the lamp to start
- Applies a high voltage spike to start the gas discharge process
- Applies a current limiter to reduce the lamp current to a safe operating level

What is Demand Charge?

- Let's look at the handout.

………now let's look at the answer……..

CFL Example

For retrofit applications in task lights, wall sconces, downlights, wallwashers, and outdoor fixtures, a wide variety of lamp shapes and types are available. These include globes, capsules, floods, and twin/quad-tube units. The most common retrofit applications are in open fixtures with mounting heights less than 12’. In some applications, users may prefer to hardwire the ballast in the fixture to prevent replacement with incandescent lamps. Lamps with excellent color rendition capabilities (80 – 95 CRI) are recommended for most indoor applications.

Wattages: 5 – 26W

Replaces: 25 – 100W Incandescent

Energy Savings: 60 – 75%

Efficacy: 26-58 lm/W

Lamp Cost: $3 – 6

Ballast Cost: $9 – 24

Demand charge - $4/kW/mo

Rated Lamp Life: 10,000 hrs

Color Quality: 60 – 85 CRI

Dimming: Not in retrofit applications

Qualifications: These lamps can have starting limitations in freezing temperatures and operation. In enclosed fixtures may shorten lamp and ballast life and reduce light output. Because CFL’s are not point sources; other technologies may be more suitable in applications such as retail display lighting where good beam control is required. Some conventional fixture types may not be large enough to accept the larger size of the fluorescent lamp/ballast package. Check manufacturer data to determine impacts of ballast use on power factor and power quality.

- **Old System**

  Incandescent hallway recessed downlighting in 12' hallway. 100 fixtures @ 75 watts. 15hrs/day operating hours, 6 days a week (4,680 hrs./yr.).

- **New System**

  Screw-in fluorescent lamps (82 CRI) with integrated magnetic ballasts, downlighting reflectors. 100 fixtures @ 22 watts (including ballast operation).

- **Results**

  71 % energy savings, virtually unchanged light level and appearance. 10 times longer lamp life.

- **Savings**

  kW savings – 100 fixtures (.075 kw/fixture - .022 kw/fixture) = 5.3 kW

  kWh savings – (5.3 kW)(4680 hrs/yr) = 24,804 kWh

  Demand $ savings – (5.3 kW)($4/kW/mo)(12 mo/yr) = $254.40/yr

  Energy $ savings – (28,804kWh/yr)($0.08/kWh) = $1,984.32/yr

  Total dollar savings – ($254.40 + $1,984.22)/yr = $2,239/yr

T8 Example

Old System

Office lighting consisting of 360 fluorescent 2' x 4' fixtures. Operating hours are 14hrs/day, 5 days a week (3,640 hrs/yr). Each fixture draws 188 watts with 4 standard cool white 40 watt fluorescent lamps and 2 standard magnetic ballasts. $4 kW monthly demand charge. Energy rate is $0.08/kWh.

New System

Each fixture now draws 112 watts with 4 tri-phosphor F40T8 32 watt fluorescent lamps and 1 electronic T-8 instant-start mode ballast. Material costs are $612/yr and labor costs are $437/yr

Results

40% energy savings, 2% reduction in light level, improved color rendering, 50% fewer ballasts to replace, 25% less lamp life using instant-start mode ballasts.

Savings

kW saving = ? 360 fixtures (.188kW/fixture - .112kW/fixture) = 27.4 kW

kWh savings = ? (27.4 kw)(3,640 hrs/yr) = 99,736 kWh/yr

Demand savings = ? (27.4 kW)($4/kW/mo)(12 mo/yr) = $1,315.20/yr

Energy Savings = ? (99,736 kWh/yr)($0.08/kWh) = $7,978.88/yr

Total dollar savings = ? $1,350.20 + $7,978.88 - $612 - $437 = $8,280.08

- **Cost of Material**

  Material: 1440 F32T8 fluorescent lamps @ $3.25 ea.; 360 T-8 instant-start mode electronic ballasts @ $31 ea.; labor to install 360 fixtures @ $20 ea.

  Total project cost: $23,040

- **Payback**

  $23,040 / $8,280.08/yr = 2.8 years

- One more thing to remember:

The amount of carbon dioxide greenhouse gas generated during electricity production ranges from 1.4 lbs. to 2.8 lbs per kWh. Depending upon the production method used, coal, nuclear, or hydro power this also needs to be accounted for when considering the environment.