Lighting Efficiency

Lighting efficiency is a measure of how much visible light is given off from a light source per unit of energy. It is measured in lumens per watt (lumens/watt). Energy not converted into visible light is radiated as heat or beyond the ends of the visible spectrum, such as ultraviolet or infrared.

Lighting efficiency is important because electrical energy accounts the overwhelming cost of lighting.[1] Lighting uses 20-25% of electrical energy, costing $75 billion annually.

There is substantial potential for energy efficient lighting, as only 10% of America's floor space has been upgraded to efficient lighting. Upgrading lamps, ballasts, or fixtures can pay back in a year or less, especially when considering the potential for less maintenance, such as cleaning and lamp replacement. Additional energy savings from reduced heat and air conditioning is also likely.

Lighting terms and conversion factors

A candela is a lumen per steradian, or "beam candlepower".
Photopic – pertaining to the human visual system and its response to light.
One lux is lumens per square meter. [2]
Lux is a measure of irradiance.
A lumen is defined as 1/680 watt at 540 x 10^{12} Hz (550 nm. wavelength)
Conversions: (lumen abbr. = lm)

1 footcandle (candela) =	1 lumen per square foot
1 footcandle =	10.76 lumen / sq-m
1 footcandle =	10.76 lux
1 lumen =	1/680 watts @ 550nm
1 lux =	1 lumen / sq-m

Natural Lighting Levels and Required Lighting Levels

The following table[3] lists natural outdoor light levels:

Type	**Illuminance (lux)**
Bright sun	50,000 to 100,000
Hazy day	250,000 to 50,000
Cloudy bright	10,000 to 25,000
Cloudy dull	2,000 to 10,000
Very dull	100 to 2,000
Sunset	1 - 100
Full moon	0.01 - 0.1
Starlight	0.001 - 0.001

[1] http://www.tristarlighting.com/page4.htm
[2] http://www.sunriseinstruments.com/terminology.html
[3] http://www.electro-optical.com/whitepapers/candela.htm

The Illuminating Engineering Society of North America (IESNA) establishes required lighting levels for various work and other environments. Here is a sample of some lighting levels required[4]:

Type	**Illuminance (lux)**
Average Reading and Writing	500
Offices with Computer Screens	500
Task Lighting	250
Ambient Lighting	250
Hallways	100
Stockroom Storage	300
Loading and Unloading	100
High-Volume Retail	1000
Low-Volume Retail	300
Roadway Lighting	3 – 16
Parking Lots	8 – 36
Building Entrance	50

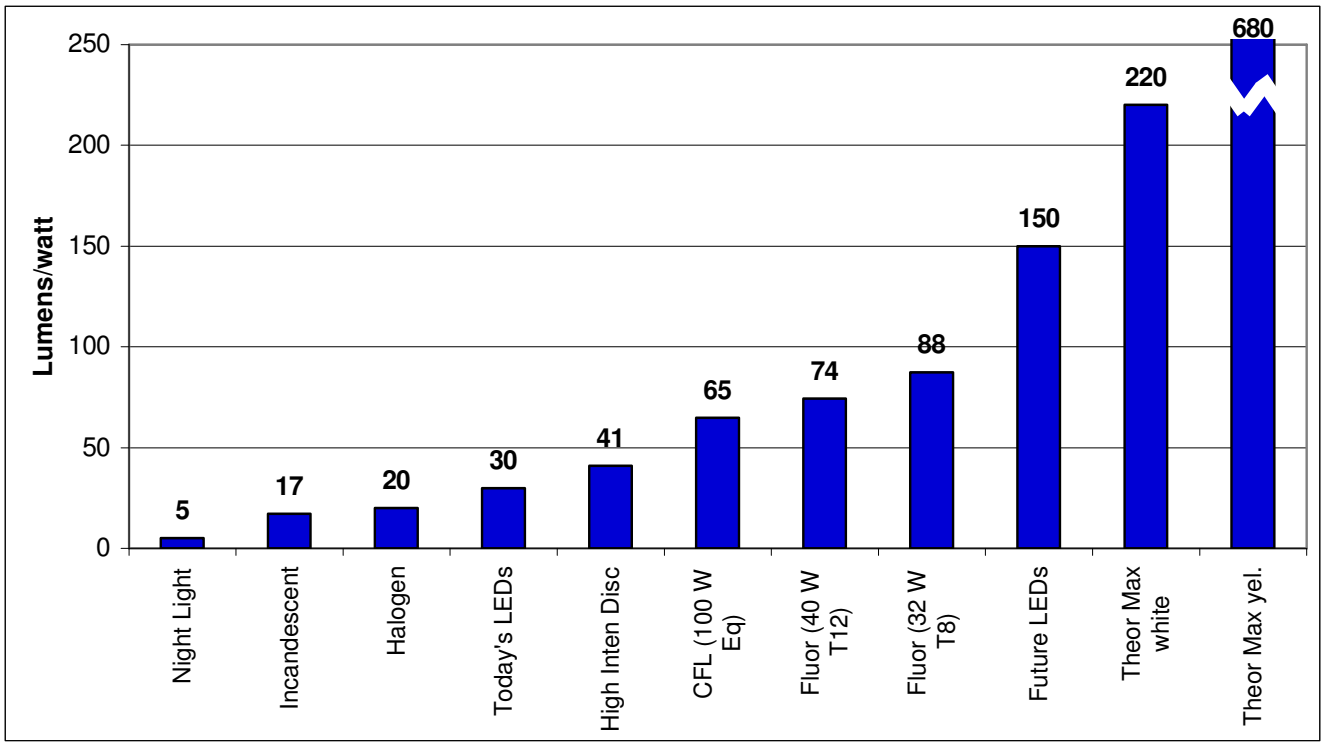
IESNA handbooks document the many other lighting attributes that must be considered for each application.

[4] IESNA Lighting Handbook

Efficiency of Lamps

The efficiency of lamp types varies greatly as shown in the following table and chart of example lamp efficiencies and theoretical efficiency: [5]

Type	Lumens/watt	Wattage	Lumens	Life-Hrs	Usage
Night Light	5	7	35	2000	Night Light
Incandescent	17	100	1740	1000	Room light[6]
Halogen	20	100	2000	2000	Room light
Today's LEDs	30	4	120	20000	Spec Light
High Intensity Discharge	41	150	6150	20000	Industrial
Cold Cathode Compact Fl	60	5	300	25,000	Candelabra
CFL (100 W Equivalent)	65	27	1750	10000	Room light
Fluor (40 W T12)	74	40	2970	20000	
Fluor (32 W T8)	88	32	2800	30000	
Future LEDs	150-200			100000	Future LEDs[7]
Theoretical Max white	220			N/A	Full Spectrum
Theoretical Max yellow	680			N/A	at 550 nm



CFL (compact fluorescent lamps) should be used to replace incandescent and halogen lamps to greatly improve efficiency and lamp life. Similarly, higher efficiency / longer life T-8 (1") and T-5 (1.625") fluorescent lamps should replace T-12 (1.5") fluorescent lamps. (Size in parentheses is the diameter of the tube.[8])

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[5] http://en.wikipedia.org/wiki/Lighting_efficiency
[6] http://demo.apogee.net/res/relinca.asp
[7] http://lighting.sandia.gov/XlightingoverviewFAQ.htm#efficiency
[8] http://www.aceee.org/ogeece/ch2_lamps.htm

The maximum efficiency of yellow light is high because the eye is more sensitive at 550 nm wavelength (yellow light) than at other wavelengths. Low-pressure sodium lamps selectively emit yellow light to achieve efficiencies of up to 200 lumens / watt. However, because yellow light provides a distorted view of people and objects, these types of lamps are only usage for some outdoor security lighting.

The usual modern white LEDs (as of early 2006) produce about 29-37.6 lumens per watt by converting a blue LED to white using special phosphors. Future LEDs are projected to provide efficiencies of up to 150.[6]

Overall Lighting Efficiency

There are several other factors besides lamp efficiency that must be considering when ensuring that adequate lighting reaches the objects being viewed at lowest energy use. These include:

- Efficient fixtures, with specular reflectors and efficient (or no) diffusers
- Cleaning and maintenance of lamps and fixtures
- Maintenance includes schedules to replace lamps before they burn out, as lamps emit less light as they age.
- Task lighting (getting effective light to the work piece)
- Ballasts
- Wall color
- Opportunities for daylighting
- Losses out of dark windows at night (no shades)
- Reducing lighting levels or turning off lights when a space is not occupied.
- Providing adequate but not excessive lighting