General Lighting Recommendations

Design Guidelines for Energy Efficient Lighting Systems

Thank you for your interest in energy efficiency! According to the US Department of Energy, 51% of the energy used in commercial buildings is consumed by lighting systems. The guidelines presented in this document have been organized to support building designers and owners selecting efficient lighting technologies and practices. This document provides both general technology recommendations as well as example specifications that can be copied and pasted into project specifications. These recommendations are based on those of the Illumination Engineering Society of North America (IESNA), the Consortium for Energy Efficiency (CEE) and other non-profit third-party industry groups that promote cost-effective energy efficiency in lighting. The most current IESNA Handbook should be consulted for more specific design recommendations.

Through your electric utility's energy efficiency programs, CLEAResult helps building owners, architects and engineers evaluate the benefits of energy efficiency. Building owners are encouraged to assess and address their energy use through a variety of program-related services, including energy performance benchmarking, energy master planning, technical assistance and even public relations support. This document offers objective, third-party recommendations on best practices in the areas of energy usage and energy efficiency. These services are provided free of charge through your electric utility and are not intended to substitute for the services of paid professionals.

CLEAResult

UNLEASHING THE VALUE OF ENERGY

LIGHT QUALITY CONCERNS

Color Rendering Index (CRI)

CRI is a quantitative measure of a light source's ability to reproduce colors of various objects in comparison to an ideal or natural light source. Simply put, it determines how "true" colors appear. Higher CRI lamps can better reproduce the visible light spectrum and can potentially reduce needed footcandle levels. Product specifications for any lamp will list the CRI of that lamp. With natural light having a CRI of 100, ***we recommend a CRI greater than 80.***

Note: Lamp sources of different color temperatures can all have a CRI greater than 80. Color temperature is a measure of the color of a light source in degrees Kelvin. Lower color temperatures (~3000K) are more golden while higher color temperatures (~6000K) have more of a blue tint. Choice of color temperature depends on individual preferences, but ***we recommend that all light sources in a facility utilize the same color temperature.***

Illumination Levels

IESNA provides detailed horizontal and vertical illumination level recommendations for thousands of specific space types in their Handbook. These light levels are most commonly expressed in "footcandles" (fc). Lighting designers should reference the IESNA Handbook as the authority for maximum and minimum footcandle levels in each applicable space type. This ensures appropriate light levels will be maintained while also minimizing energy consumption of the lighting system.

Many existing facilities have much higher than recommended footcandle levels, and this problem is amplified when combined with the visual discomfort of "glare". This is often dramatically experienced when working on computers. Glare from overhead lights can actually make it difficult to read most computer screens or monitors since those devices are already backlit. In cases where higher light levels are needed or desired for a specific task or usage type, appropriate illumination is better achieved by moving the light source closer to the task or through supplementary task lighting, as opposed to simply increasing the light output from an overhead fixture.

IESNA recommends the following light levels for various tasks:

RECOMMENDED LIGHT LEVELS	
Orientation and Simple Tasks These tasks occur in public spaces where reading and visual inspection are only occasionally performed. Visual performance is largely unimportant.	
Public Spaces	3 fc
Simple Orientation for Short Visits	5 fc
Working Spaces for Simple Visual Tasks	10 fc
Common Visual Tasks Visual performance is important for these. Higher light levels are recommended for visual tasks involving low contrast or small size.	
Tasks with High Contrast and Large Size	30 fc
Tasks with High Contrast and Small Size	50 fc
Tasks with Low Contrast and Large Size	50 fc
Tasks with Low Contrast and Small Size	100 fc
Special Visual Tasks These tasks are very specialized, including those with very small or very low contrast critical elements. Visual performance is of critical importance. Recommended illuminance levels should be achieved with supplementary task lighting.	
Critical Visual Tasks	300 - 1000 fc

Lighting Power Density (LPD)

LPD is the power used by luminaires (including lamps, ballasts, transformers and control devices) per unit area of a building in watts per square foot. For new construction buildings, local building codes dictate the maximum allowed LPD. Energy efficiency incentives for new construction lighting are paid based on comparing the project's actual LPD with the code requirement.

The table below lists the current maximum allowed LPD for various building types according to International Energy Conservation Code 2009 (IECC 2009), along with maximum LPD levels we recommend.

RECOMMENDED LIGHTING POWER DENSITIES		
Facility Type	**IECC 2009 Allowed LPD**	**Recommended LPD (30% Savings)**
Automotive Facility	0.90	0.63
Convention Center	1.20	0.84
Courthouse	1.20	0.84
Dining: Bar/Lounge/Leisure	1.30	0.91
Dining: Cafeteria	1.40	0.98
Dining: Family	1.60	1.12
Dormitory	1.00	0.70
Exercise Center	1.00	0.70
Gymnasium	1.10	0.77
Health Care - Clinic	1.00	0.70
Hospital	1.20	0.84
Hotel	1.00	0.70
Library	1.30	0.91
Manufacturing	1.30	0.91
Motel	1.00	0.70
Motion Picture	1.20	0.84
Multi-Family	0.70	0.49
Museum	1.10	0.77
Office	1.00	0.70
Parking Garage	0.30	0.21
Penitentiary	1.00	0.70
Performing Arts	1.60	1.12
Police/Fire Stations	1.00	0.70
Post Office	1.10	0.77
Religious Buildings	1.30	0.91
Retail	1.50	1.05
School/University	1.20	0.84
Sports Arena	1.10	0.77
Town Hall	1.10	0.77
Transportation	1.00	0.70
Warehouse	0.80	0.56
Workshop	1.40	0.98

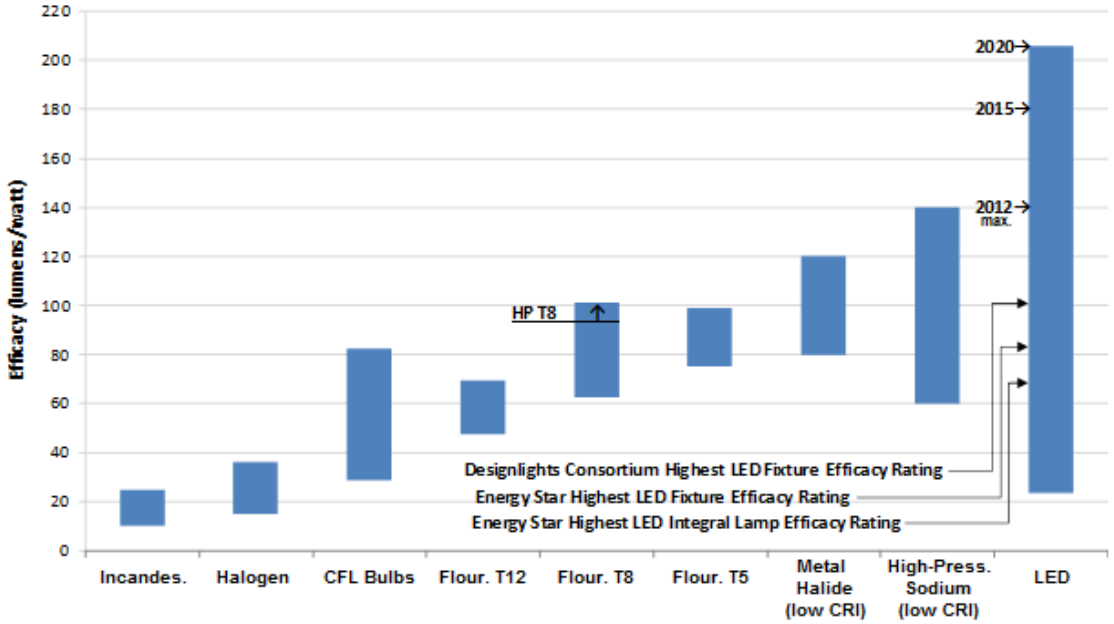
LIGHTING CONTROLS

Lighting controls reduce energy use from lighting by dimming or turning off luminaires in day lit or unoccupied spaces. Lighting controls include dimming controls, daylight controls and occupancy controls. Multiple controls may be appropriate for a single building space. ***We recommend installing lighting controls wherever appropriate.*** See the table below for a more detailed description of each control type.

LIGHTING CONTROL TYPES	
Dimming Controls	Dimming controls lower light levels in order to reduce the energy consumed. Dimming can be continuous or involve step controls.
Daylight Controls	Daylight controls dim or turn off lights when ambient light is sufficient. Daylight sensors can be indoor or outdoor.
Occupancy Controls	Occupancy controls sense occupancy or vacancy in order to turn lights on or off. There are two main types: infrared and ultra-sonic. Controls that use both technologies are the most reliable.

LIGHTING TECHNOLOGIES

Lighting technologies have various ranges of efficacies (light output per watt input), with incandescent lamps being the least efficacious lighting technology. LED efficacies are improving every year. See the graph below for a comparison of efficacies of different lighting technologies. ***For indoor lighting, both high- and low-bay, we recommend high performance fluorescent fixtures and ENERGY STAR or DesignLights qualified LED fixtures.***



ENERGY STAR and DesignLights LED Fixtures

LEDs are quickly becoming the premier lighting technology and have the potential to save significant energy and maintenance costs. ***We recommend that any LED fixture purchased be qualified under ENERGY STAR or DesignLights Consortium programs.*** These two industry groups rate the best and most reliable LED products on the market. This is the easiest way to choose an LED product that will not fade out or change color before its time. For more information, see the following websites:

http://www.energystar.gov/index.cfm?c=manuf_res.pt_lighting
http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php
http://www.lightingfacts.com/

High Performance T8 Fixtures

For most indoor new construction and retrofit applications, we recommend high performance T8 lamp and ballast systems. High performance T8s provide increased light output along with longer lamp life and lumen maintenance at the same wattage as traditional T8s. Improvements to traditional T8s include enhanced rare Earth phosphors, improved gas fill compositions and more robust cathodes, enabling superb color quality (CRI ≥80) at any color temperature. Premium-efficiency ballasts save energy compared to standard ballasts. The Consortium for Energy Efficiency (CEE) is a non-profit industry group that qualifies high-performance T8 and reduced-wattage T8 lamp and ballast systems. For more information, visit the following website: http://library.cee1.org/content/commercial-lighting-qualifying-products-lists

COMPARISON OF TYPICAL INDOOR FIXTURES

Typical 2x4 Fixture Type	Lumens/ Lamp	Lumen Maint - enance	CRI	Rated Life (hrs)	System Wattage	System Lumen Output
ENERGY STAR LED 2x4 Troffer	N/A	≥70%	≥80	≥25000	50	3,600
2-Lamp High Performance T8 (F32T8)	3,100	95%	≥80	≥24000	54	6,200
2-Lamp Reduced Wattage T8 (F25T8)	2,400	95%	≥80	≥24000	48	4,300
2-Lamp Standard T8 (F32T8)	2,850	90%	75	20,000	58	5,700
2-Lamp Standard T12 (F34T12)	2,482	88%	60	20,000	72	4,964

An important thing to consider when choosing a T8 lamp and ballast system is the ballast factor (BF). This factor is a measure of the lumen output of a ballast relative to a reference ballast. High, low and normal ballast factors are all available as premium ballasts for every type of T8 lamp. This way, you can modify the power input and light output of a T8 fixture by changing the ballast factor in new designs and retrofits. The following chart gives a few examples for a high-performance T8 system.

BALLAST FACTOR COMPARISON					
Typical 2-Lamp High Performance T8 System	Initial Lamp Lumens	Ballast Factor (BF)	Mean Fixture Lumens	System Wattage	Mean Lumens per Watt
Low Ballast Factor	3,100	0.77	4543	48	94.6
Normal Ballast Factor	3,100	0.87	5133	53	96.8
High Ballast Factor	3,100	1.00	5900	62	95.2
Very High Ballast Factor	3,100	1.18	6962	73	95.4

OUTDOOR LIGHTING

Because LED lamps tend to provide directional light in a more even spread than other technologies, ***we recommend ENERGY STAR or DesignLights qualified LED fixtures for outdoor illumination.*** The directional quality of LEDs means that outdoor areas can be adequately lit using less light output and therefore less energy. In addition, LED fixtures can last up to ten years and require far lest maintenance than conventional outdoor lighting. In areas where maintenance is a challenge (such as pole lights) the reduced maintenance for the LED fixtures helps balance the up-front cost of the LEDs. Make sure that the LED product is rated for high temperatures if the fixture is to be installed in a warm climate.

EXAMPLE LIGHTING SPECIFICATIONS

NEW CONSTRUCTION AND RETROFITS

A. Average lighting levels and measurements must comply with the most current Illuminating Engineering Society of North America (IESNA) recommended practices.
B. Final light levels must meet the requirements of the end user and meet the satisfaction of all approving authorities having jurisdiction for specific applications.
C. The Engineer, Contractor or Supplier must confirm that the lighting levels will meet the illumination range stated in this document, or most current IESNA recommendations, for the applicable space type.
D. Retrofit designs should consider the recommended practice of:
    a. Reducing the number of lamps in the retrofit fixture.
    b. Reducing the number of fixtures in a room or space.
    c. Conversions from 2-lamp, 8' T12 high output lamps to 2-lamp, 4' high-performance (or "super") T8 lamps with low ballast factor ballasts.
    d. Uniform lamp and ballast types to facilitate a consistent and economical equipment stock.

I. LINEAR FLUORESCENT T8 LIGHTING SYSTEMS

A. FOUR-FT LAMPS
    a. For all possible fluorescent lighting applications, 4-ft high-performance T8 fixtures to be chosen for maximum efficiency. T8 lamps and ballasts to meet the Consortium for Energy Efficiency (CEE) High Performance criteria

(www.cee1.org). High-performance lamps to be chosen as one of the following wattage levels: 32W, 28W, or 25W.

b. 32W lamps to be CEE-Qualifying High-Performance 4-ft T8 lamps installed in conjunction with CEE-Qualifying High-Performance ballasts. A qualifying 32W lamp is rated at ≥ 3,100 initial lumens, ≥ 80 CRI, ≥ 24,000-hour life (at 3 hours per start), and ≥ 94% lumen maintenance.
c. 28W lamps to be CEE-Qualifying Reduced-Wattage 4-ft T8 lamps, installed in conjunction with CEE-Qualifying Reduced-Wattage ballasts. A qualifying 28W lamp is rated at ≥ 2,585 initial lumens, ≥ 80 CRI, ≥ 20,000-hour life (at 3 hours per start), and ≥ 94% lumen maintenance.
d. 25W lamps to be CEE-Qualifying Reduced-Wattage 4-ft T8 lamps, installed in conjunction with CEE-Qualifying Reduced-Wattage ballasts. A qualifying 25W lamp is rated at ≥ 2,400 initial lumens, ≥ 80 CRI, ≥ 20,000-hour life (at 3 hours per start), and ≥ 94% lumen maintenance.
e. Ballasts for all 4-ft T8 fluorescent lighting to be CEE-Qualifying High Performance and/or Reduced-Wattage Ballasts (www.cee1.org).

B. LAMPS (all other types) – Prior written approval must be obtained from the owner for use/specification of any lamp type other than 4-ft. T8 as listed above.
   a. 2' lamps to be F17T8, nominal lamp of 17 watts or lower (high efficiency, premium lamps)
   b. 3' lamps to be F25T8, nominal lamp of 25 watts or lower (high efficiency, premium lamps)
   c. Color Rendering Index (CRI) to be a minimum of 80. For color critical applications, Color Rendering Index (CRI) to be a minimum of 86.
   d. Minimum lamp life for all 2ft, 3ft and 4ft T8 lamps to be a minimum of 20,000 hours, @ 3 hours per start, but recommended to be 24,000 hours or more @ 12 hours per start regardless the type of electronic ballast

II. LINEAR FLUORESCENT T5 LIGHTING SYSTEMS

A. T5HO LAMPS - 49W T5HO lamps are preferred over 54W T5HO in most high bay applications for increased energy savings with comparable lumen output.

B. T5 LAMPS (2', 3', 4') – For standard applications such as classrooms, offices, hallways, etc., T5 systems are generally not recommended. Rather, high-performance (or "super") T8 systems are recommended for the following reasons:
   a. High-performance T8 lamps have a longer operating life than T5 lamps.
   b. High-performance T8 systems are more energy-efficient than T5 systems.
   c. High-performance T8 lamps have a lower purchase cost than T5 lamps, resulting in lower maintenance costs.
   d. High-performance T8 lamps are a more direct retrofit into existing T12 fixtures than T5 lamps.

III. HIGH INTENSITY DISCHARGE LIGHTING

High intensity discharge (HID) lamps are rarely appropriate for indoor use due to their low CRI, high energy usage and rated life expectancy. Because HID fixtures can be replaced by more-efficient high bay fluorescent (HBF) fixtures, induction lamps or compact fluorescent lamps, HID lamps should not be used for indoor lighting.

IV. HIGH BAY FLUORESCENT LIGHTING

High bay fluorescent (HBF) fixtures are to be installed in areas with high ceilings such as gymnasiums. The three primary types of HBF fixtures are as follows; refer to lamp criteria above:

1. 6-lamp 4-ft T8 fixture (with ballast factor of ≥ 1.0) – typical 400W HID replacement
2. 4-lamp 4-ft T5HO fixture – typical 400W HID replacement
3. 6-lamp 4-ft T5HO fixture – typical 400W HID replacement, but with reduced fixtures so that lighting-level requirements are met

V. LIGHTING LEVEL REQUIREMENTS

Lighting to be designed such that illumination levels fall within a given range, according to the space type. Average lighting levels are not to fall below the range's lower limit and not to exceed the range's upper limit. This is to assure all spaces are adequately lit but are not over-lit. The ranges apply to all working areas in a space, and should be sustained throughout lamp life. The following footcandle (fc) ranges are derived primarily from IESNA recommended levels and NCAA gymnasium lighting best practices.

Space Type *	Lighting Level Range (fc)
Classroom	30 – 50
Science Lab	50 – 70
Library	30 – 50
Office	30 – 50
Computer Lab	3 – 30
Corridor / Common Space	10 – 20
Gym (recreational)**	30 – 50
Gym (competition)**	50 – 100
Gym (NCAA broadcasting)**	100 – 150
Cafeteria	10 – 20
Kitchen	30 – 50
Pool	5 – 50
Parking Garage	10 – 20
Restroom	5 – 15
Mechanical Room	20 – 50

* IESNA recommended lighting levels to be used for other space-types not listed above.
** "Gym" refers only to the lighting levels on the actual court, not the adjacent general circulation and seating.

VII. LIGHTING CONTROLS

A. INTERIOR – All interior spaces to be controlled via occupancy sensors; infrared, ultrasonic, or dual technology as applicable to the space.
B. EXTERIOR – Exterior light fixtures to be controlled via photocell or time-clock for energy conservation.