

D. LIGHTING AND POWER SYSTEMS

1. General

- a. The design of a building's lighting system has direct bearing on the performance of the occupants. The ability to perform visual tasks is strongly impacted by the type and quality of the lighting systems implemented. Lighting strategies that reduce glare while still producing the required lumen levels are essential components of a high performance energy efficient building.
- b. Lighting represents 25%-40% of a typical building's energy costs. An energy-efficient lighting system can save thousands of dollars annually in just one building, because improving the efficiency of the overall lighting system reduces the energy requirements for both lighting and air conditioning. The use of automated controls in daylit spaces can automatically decrease or increase light levels as needed, and occupancy sensors can automatically turn off lights in unoccupied spaces.

2. Lighting Design Strategies

- a. The design team should create an energy-efficient, high-quality lighting system by typically following these three strategies.
 1. Select efficient lamps, ballasts, lenses and fixtures that address the needs of each space and achieve the highest output of lumens per input of energy.
 2. Provide occupancy sensors, electric timers, and other controls that limit the time the lights are on to only those hours when the space is occupied and the light is needed.
 3. Provide automated daylighting controls that reduce or dim the electrical lighting when sufficient natural light is present.
- b. Review current ASHRAE Standard to establish lighting power densities (LPDS) for each space within the facility. ASHRAE 1999-90.1 was used to prepare these guidelines.
- c. In naturally lit spaces, the artificial lighting design should be compatible with the objectives of the daylighting. In non-daylit spaces, the objective should be to implement the most energy-efficient system possible that minimizes glare while providing the proper level of quality light. These objectives can be achieved by:
 1. Maximizing illumination by considering the geometry and reflectances of finishes in each space.
 2. Consider indirect lighting strategies as a way to complement daylighting.
 3. Consider fixtures that are designed to minimize glare, particularly in rooms with computers.
 4. Consider providing low-level ambient lighting supplemented by task lighting.

5. Consider photovoltaic lighting systems for remote exterior applications such as greenways, parking lots, and walkways. It is often more cost-effective to use a localized photovoltaic system with its own battery storage than to provide underground electrical service to a building located more than 100 yards away.
- d. Consider daylighting that could reasonably be incorporated in the overall design.
1. If significant daylighting is to be incorporated and the space is typically unused at night, consider standard back-up lighting systems in the daylight spaces. Because the amount of time that the electrical lighting is on will be minimal, it may be difficult to justify the more energy efficient, state-of-the-art, lighting strategies.
 2. If daylighting is not possible within well-used spaces, compare various lighting and ballast combinations to determine the optimum design.
 3. In conjunction with daylighting analyses, evaluate staged and dimable controls, staged lighting levels tied to a photocell that operates banks of lights in one to four stepped increments, and dimmable lighting, individually controlled by dedicated photocells.
- e. Minimize glare and eyestrain by:
1. evaluating the location of the lighting sources and the occupant's field of view;
 2. avoiding glare problems commonly experience when viewing computer screens;
 3. minimizing situation of "transient adaptation" where the eye can not properly adjust when going from one space to another with drastically different light levels; and
 4. considering indirect lighting systems.

3. High-Efficacy Lamps

1. Efficacy is an important measure for energy-efficiency in light output per unit of energy used. High-efficacy lamps can provide the same illumination and color rendition as standard lamps, but at two to six times the efficiency.
2. To maximize efficacy, minimize the use of incandescent fixtures.

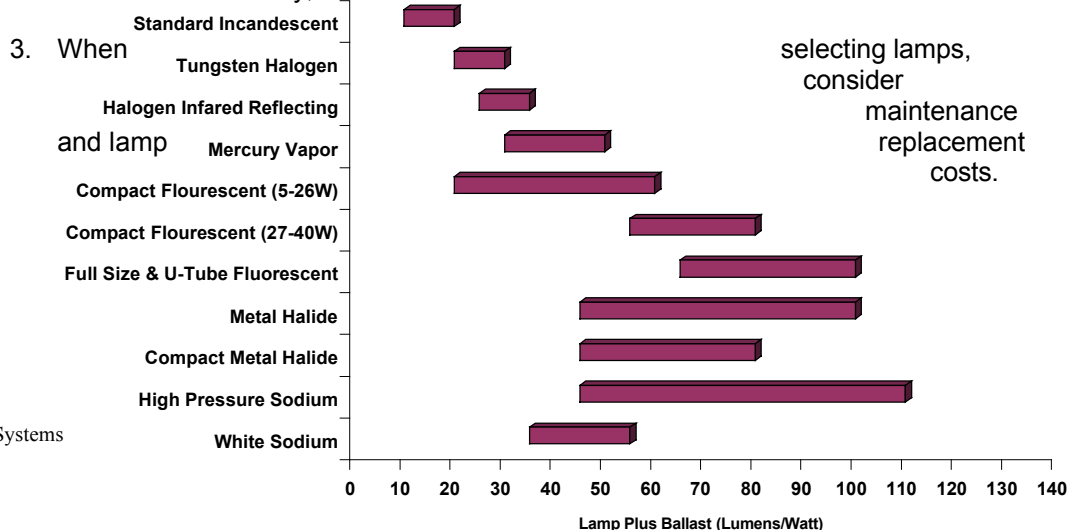


Figure illustrates different lamp efficiencies

4. Select the lamps with the highest lumens of output per Watt input that addresses the specific need.

4. Fluorescent Lamps

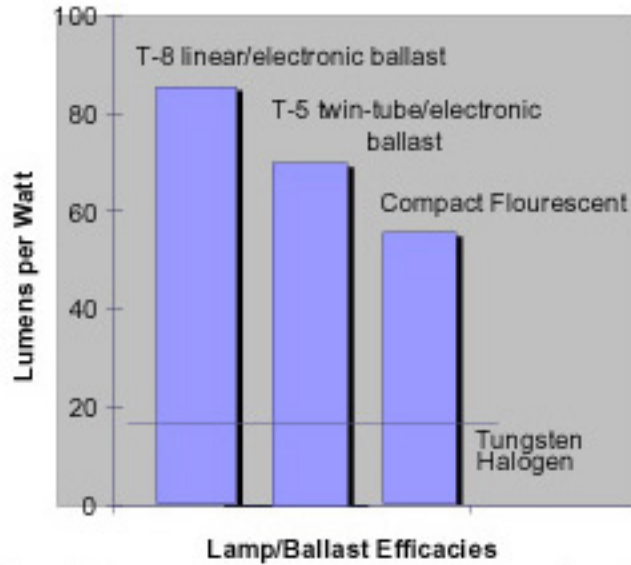
Fluorescent Lamp Technologies-Efficacy Comparisons						
Lamp Type	Lamp Life	Lumen /Watt	C.R.I.	Lumen Maint.*	Ballast Factor	Description and comments
T-5 Fluorescent (28Watts/4Ft)	20000	104	85	0.95	1	5/8" dia. Tube; high lamp and ballast efficiency, high CRI, similar output to T-8 with a 12% reduction in power usage
T-5 HO Fluorescent (54Watts/4Ft)	20000	93	85	0.95	1	5/8" dia. Tube; high lumen output, high CRI, 88% higher lumens than standard 4 Ft. T-8
T-8 Fluorescent (32Watts/4Ft)	20000	92	82	0.92	0.9	1" dia. Standard for efficient fluorescent lamps 23% efficiency improvement over T-12
T-12* Fluorescent (34Watts/4Ft)	20000	69	72	0.89	0.88	1 1/2" dia. Tube, still being used where efficiency is not being considered**

Developed by Padia Consulting from manufacturer's literature (Philips, Osram Sylvania, General Electric)

* The lumen maintenance percentage of a lamp is based on measured light output at 40% of that lamp's rated average life. For T-5, after 8,000 hours of life time, the lumens/Watt will be 98.8 lumen/Watt (104x0.95)
 Fluorescent lamp selection should be based on the illumination needs of the area and lamp replacement frequency and cost.

**Note: T-12 should not be specified for County and School Projects.

- a. Consider the smaller diameter T-8 and T-5 fluorescent tubes over the traditional T-12s because they have a higher efficacy. The T-8 system produces 92 lumens per Watt as compared to 69 lumens per Watt for the T-12 system. The T-5 system produces 33% more lumens per Watt than the T-12 system.
- b. Consider fixtures that are designed to enhance the efficacy of the T-8 and T-5 lamps by incorporating better optics in the luminaire design.



The graph compares efficacies of common fluorescent lamp/ballast combinations with the efficacy of a tungsten halogen lamp.

5. Compact Fluorescent Lamps

- a. Consider compact fluorescent lamps that are energy efficient and long lasting. A 13-Watt compact fluorescent lamp (about 15 Watts with an electric ballast) provides the same illumination as a 60-Watt incandescent lamp and lasts up to 10 times longer. Additionally, have excellent color rendering.
- b. In larger daylight spaces like gymnasiums or meeting rooms, consider ganged compact fluorescents as a practical means of addressing the need for dimmable lights.
- c. Consider fixtures with effective reflector design.

6. Metal Halide and High-Pressure Sodium Lamps

- a. Consider metal halide and high-pressure sodium lamps for exterior lighting applications.
- b. Use metal halide and high-pressure sodium lamps only in areas where the long warm up and restrike time after a power outage will not affect the safety of students, visitors, and staff.

7. LED Exit Lights

- a. Select light-emitting diode (LED) exit lights. Exit signs operate 24 hours a day, 365 days a year. LED exit signs offer energy savings between 80 kilowatt-hour/year and 330 kilowatt-hour/year per fixture with little maintenance. LED exit lights have a projected life ranging from 700,000 hours to more than 5 million hours and the standby battery requires replacement about every 80,000 hours. Typical fluorescent lamps will last only 15,000 hours.

8. High Efficiency Reflectors

- a. High-efficiency fixtures employ two main strategies to minimize the blockage or trapping of light within the fixture housing. These two strategies are high-efficiency lensed troffers and fixtures with parabolic reflectors.
 1. Incorporate well-designed troffers that use the shape and finish of the inner housing to minimize inter-reflections and maximize lumens per Watt. A high-efficiency troffer with two or three lamps can produce the same illumination as a standard four-lamp fixture.
 2. Selected fixtures with parabolic reflectors as an alternative means to improve optics and increase the performance of the light fixture.

9. Ballasts

- a. Solid state electronic ballasts are available in both rapid-start and instant-start models. The instant-start ballasts have a very high efficiency but should be avoided in applications where sensors are used. Electronic and magnetic ballasts are identical in shape, size, and external wiring, but electronic ballasts can each operate up to four lamps.
- b. While selecting a dimmable ballast, consider that magnetic ballasts will only dim to about 40% of full power before the flicker becomes problematic, whereas electronic ballasts may be dimmed to near zero output with no perceptible flicker. Electronic ballasts also have a higher lumen output at reduce power levels than magnetic ballasts.
- c. Select high-efficiency electronic ballasts because they save energy, have a low propensity to attract dust, and incorporate a minimum of hazardous materials. These also operate at a cooler temperatures.
- d. Select electronic ballasts because they minimize the characteristic humming from fluorescent lamps.
- e. Consider that conventional ballasts cycle at 60 Hertz and create a perceptible flicker, whereas electronic ballasts cycle faster, reducing eye strain.

10. Lumen Maintenance

- a. The output of a fluorescent lamp decreases over its rated life. The strategy used for maintained light level calculations is the initial light output of the luminaires multiplied by factors for lamp depreciation, luminaire depreciation, and room surface dirt depreciation. This will reduce the calculated output by at least 25%–30%.
- b. The better strategy is to measure the light output at the work surface using a light sensor in an “open loop” control. This will save power initially, extend the life of the lamps, and compensate for dirt on luminaires and room surfaces. It is important to establish a program of group lamp replacement because this will ensure that overall lighting levels are even and maintenance labor costs by are reduced by 88% over “spot” replacement.

11. Lighting Controls

- a. Evaluate switching versus dimming strategies. The following comparison is offered as a guide for such evaluations.

Switching	Dimming
<ul style="list-style-type: none"> • Inexpensive • Abrupt light changes • HID lamp restrike time • May reduce lamp life • Increases service life • “Burnt out” lamp appearance • Better used for indirect lighting 	<ul style="list-style-type: none"> • More expensive • Added flexibility • Gradual level change • May reduce lamp life • Increased incandescent lamp life • Reduces efficacy • Check dimming range and residual power use • May give color shift • Square law dimming effect

- b. Consider switching where daylight levels are consistently high and tasks are non-critical (atriums, walkways, warehouses, etc)
- c. Consider dimming where daylight levels are close to target, tasks are critical and tolerance for controls is low (office areas, classrooms, etc.)
- d. From an energy-savings perspective, switching typically outperforms dimming if daylight levels are consistently higher than target; dimming typically outperforms switching if daylight levels are close to or less than target.
- e. Consider infrared, ultrasonic, or a combination of infrared and ultrasonic motion detectors in all major spaces to turn off the lights when the space is not occupied.
- f. In daylit spaces, consider staged or dimmable lighting controls tied to photocells located within each space and capable of reading light levels at the work surface
- g. Incorporate override switches for automatic daylight dimming controls only where the need to manually control lighting levels is necessary to function the space.
- h. Consider photocell on outdoor lights to ensure that they are off during daytime hours.

12. Power Systems

An inefficient electrical distribution system in a building can result in degraded power quality, the introduction of wasteful harmonics, and line losses up to 4%.

- a. Evaluate the merits of a high-voltage distribution system, taking into consideration the initial cost and operational savings due to reduced line losses. Analyze the costs of delivering power at 208/120 volts versus 480/277 volts.
- b. Consider more efficient transformers that operate at lower temperatures
- c. Consider using K-rated transformers to serve non-linear equipment.
- d. Wherever possible, minimize long runs of wire from power distribution panels to electrical equipment. Where equipment would be likely to operate at a low voltage due to distance from the distribution panel, install a larger size wire to reduce the voltage drop.
- e. Consider high-efficiency motors and, where appropriate, variable frequency drives for motors. Compare motors using No. 112, Method B, developed by the Institute of Electrical and Electronic Engineers (IEEE).
- f. Consider fans and pumps for the highest operating efficiency at the predominant operating conditions.
- g. Consider energy-efficient, ENERGY STAR-rated food-service appliances; washers, dryers, and other similar equipment.
- h. Consider providing a grounding conductor in all raceways for the primary grounding path.
- i. Segregate motor, equipment and lighting loads from other more sensitive equipment loads throughout the distribution system, as is practical.
- j. Evaluate and specify the appropriate K-ratings for the distribution transformer where harmonics may be an issue.
- k. Consider problems that may arise when equipment shares receptacles on the same circuit. Determine the number of circuits, the layout of receptacles on the same circuit, and equipment that will require dedicated circuits.
- l. Evaluate and provide the following for computer circuits, sensitive equipment and panelboards, as required:
 - m. Dedicated Circuits
 - n. Isolated grounds and ground receptacles
 - o. Transient surge suppressors
 - p. Power conditioning
 - q. Uninterruptible power supplies for critical loads
- r. Provide distribution class surge arrestors on the building power main.

- s. In some cases, transient surge protection in the branch circuit panelboards might be required. The focus should be on panels with dedicated circuits that have isolated grounding provisions.
- t. Apply Transient Voltage Surge Suppression as needed at loads.
- u. Implementation of Variable Speed Drives (VSD_ should be evaluated for PQ issues and should include auto restart and manual bypass on critical loads. The inclusion on line reactors to mitigate harmonics should be evaluated on an individual drive, based on its location in the distribution system.
- v. Consider using Uninterruptible Power Supplies (UPS) to include online and line interactive only. Do not use standby or offline UPS on critical loads.