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IES LEM-3-13

IES Guidelines for **Upgrading Lighting Systems in Commercial and Institutional Spaces**

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IES Guidelines for Upgrading Lighting Systems in Commercial and Institutional Spaces

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**Prepared by:
The IES Energy Management Committee**

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1.0 INTRODUCTION

Increasing lighting efficiency is often the most cost effective energy efficiency improvement that can be made to an existing building. There are two basic approaches for improving the energy efficiency of an existing lighting system: *retrofit* or *redesign*. Retrofitting the existing luminaires will be the more common approach. However, on projects where the existing illumination or lighting equipment no longer suits the space or application, redesign is the better choice. A thorough assessment is necessary to determine if one (or both) of these methods is advantageous over the other.

When upgrading lighting in any space, it is important to know the recommended practice and illumination levels for the occupant programming. The IES publishes many standards on lighting applications, and a competent lighting practitioner/designer may be able to help with specifying accepted illumination levels in the building. There may be a nominal cost, but it is a sound investment to get the lighting upgrade project right the first time. When working on a lighting upgrade project, one must always be aware of the delicate balance between *quality lighting* and *energy savings*. When too much focus is placed on energy savings, quality may suffer.

1.1 Audience

This document is intended for commercial and institutional building owners, lighting practitioners, managers, facility engineers, energy service companies, retrofitters, and utility representatives considering a lighting upgrade.

This document is written in general terms; every lighting project is a little different because of the wide variety of architectural and luminaire styles.

According to the U.S. Department of Energy Buildings Energy Databook, 2010, lighting systems often consume about 26% of the electrical energy used by the building, depending on the type of building, location, age, and other factors.¹ A lighting upgrade generally offers one of the most cost-effective and easy means to reduce operating costs with a return on investment that is acceptable to the financial managers of the facility. However, appropriate illumination levels and light quality must also be achieved along with the energy savings. **Figure 1** illustrates why it is imperative to not lose employee productivity in the name of energy savings. If completed properly, a lighting upgrade may actually increase occupant productivity!

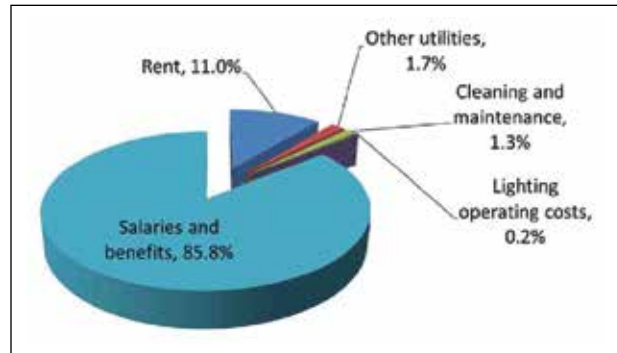


Figure 1. Average office costs show the importance of maintaining employee productivity. (Graphic courtesy of Elizabeth Gillmor)

1.2 Lighting Upgrade: Retrofit or Redesign?

The two basic ways to improve energy efficiency for an existing lighting system are retrofit and redesign. A retrofit, due to financial considerations, is the usual type of upgrade. Sometimes, however, it may make more sense to do a redesign. It is important to assess as soon as possible which process will be the most effective; it may be that both strategies are required in different parts of the same project.

- *Retrofit* is a method to modify a lighting system to lower the operating costs and/or improve the performance of that system based on efficiency and the task performed.
- *Redesign* is a method to modify a lighting system which will intentionally modify the goals of the existing lighting design. This may include an entirely new lighting distribution pattern, relocating and installing new luminaires and new circuits and controls to meet the new objectives.

While this document concentrates primarily on the retrofit process, concepts will be presented that may also be useful in redesign projects.

A lighting upgrade may result in energy savings when one or more of the following situations exist:

- Older technologies such as T12 fluorescent lamps and magnetic ballasts or older HID (high intensity discharge) systems such as mercury vapor or probe start metal halide are in place
- Illumination levels are too high
- Glare is a problem
- Inefficient optical components such as lenses, louvers or reflectors are used in the luminaire

- Inefficient luminaires exist that may be modified to increase efficiency
- Lighting is operated for more hours or at a higher light level than is actually needed
- New lighting controls are added to existing, or new luminaires
- Potential lowering of ambient light levels and the addition of low level task lighting

Note that a lighting upgrade is also an opportunity to increase light levels that are too low for the current tasks performed in the space. Sometimes upgrades can also create energy savings when light levels are too low, depending on the magnitude of the accompanying improvement in energy efficiency.

Refer to the current version of the *IES Lighting Handbook, 10th Edition* and the most recent editions of the various IES Recommended Practices, to determine the appropriate recommended light levels.

Even if a space has been previously upgraded with newer technologies such as T8 or T5 fluorescents, the space can often be made even more efficient by adjusting the light levels to suit the recommended practice for the task area beneath the light

When considering a retrofit for a space, without the guidance of a lighting designer, the old technology may be replaced lamp for lamp and ballast for ballast. T8 and T5 fluorescent lamps are much more efficient (lumens/watt) than many older T12 fluorescent technology and luminaires. If this approach is used, consideration may include attention to ballast factor (see **Annex C**) selection because there may be too much light from a simple one-for-one replacement concept. Switching or dimming (tuning) the luminaires to the appropriate light levels could also be considered (also refer to **Section 2.1** on Lighting Assessment for more information).

In general, existing lighting layouts may illuminate a space adequately with a lighting upgrade. However with technology changing quickly, a simple retrofit may not be the best solution, and a redesign may be needed, if:

- Existing illuminance levels are too low or too high, or the uniformity ratios are too low
- Existing lighting produces glare
- Existing lighting does not illuminate perimeter surfaces (in offices) or shelving (in retail and storage)

- Existing luminaire layout may produce uneven illumination
- Existing luminaire spacing is too wide, or partial-height partitions obstruct light
- Luminaire spacing or locations are inappropriate for current or proposed use, or for proposed furniture locations
- Existing room surfaces or furnishings are dark in color and illuminance levels are already on the low side
- Retrofit options will narrow the distribution of light or lessen the illuminance levels on vertical surfaces
- Existing luminaires (or luminaire layout) are no longer appropriate because the tasks or physical layout has changed
- Existing luminaires are in poor condition

1.3 The Upgrade Process

If a project appears to be an acceptable candidate for an upgrade (i.e., initial analysis indicates that there is a good payback or Return on Investment “ROI”) then, complete the following steps as part of the process (for additional information, refer to the *IES Lighting Handbook, 10th Edition*).

Assessment: Perform a relatively quick assessment of the building’s existing lighting system. Many buildings are good candidates for retrofit or redesign even if T8 or T5 fluorescent systems are already installed. For instance, the space may be too bright for a computer based task. Recommended illumination levels (footcandle/lux illumination values), in many cases, have decreased based on improved quality of lighting products and refined understanding of what light levels are actually needed to perform tasks (see *IES Lighting Handbook, 10th Edition*).

Initial Determination: Determine the potential for lighting improvements and financial opportunities based on the assessment in the step above. Perform a general analysis of the majority of the luminaires (perhaps following the so-called 80/20 rule, also known as the “Pareto Principle”) to establish the approximate financial performance of an upgrade, taking into account installation costs, utility cost savings, maintenance cost savings, rebates, and other incentives. Determine if there are any additional financial parameters which need to be met such as owner guidelines.



Funding: Often, the client will look to the lighting practitioner for information used in obtaining tax incentives, grants, rebates or loans to partially fund the project. Knowing where to obtain these sources of funding will help move a project forward. Good sources for this information include:

- Government Entities at All Levels
- Utility Companies
- Lighting Manufacturers
- Lighting Distributors.

Lighting Assessment: If the financial opportunity is acceptable, and the lighting can be improved, conduct a detailed lighting assessment. This will document exactly what lighting equipment, including lighting controls, is being used, where it is located, and whether the quantity and quality of light it provides is appropriate for the present and future tasks in each space. Determine the energy utilized per square foot or meter and compare this against the appropriate lighting power densities (LPDs) allowances in the *ANSI/ASHRAE/IES 90.1-2010* standard (or the most current version of this standard). This will give you an excellent guide to determine if your lighting is inefficient.

System Design: Using the lighting assessment, recommended practices and design guides, identify the appropriate lighting upgrades for each space.

Analysis: Prepare a cost analysis, identifying in detail the existing lighting, proposed upgrades, and economic justifications for the project (see *IES Lighting Handbook 10th Edition, Chapter 18*). If completed thoroughly, the analysis is an investment grade assessment (IGA), and can be utilized by the facility management's financial officer to determine if the project may be approved and funded.

Specifications: Prepare an exact description of the proposed equipment and details of the intended performance of components or assemblies.

Mock-up: Occasionally a mock up may be helpful to demonstrate that the proposed design will meet the needs of the facility manager or to obtain input from the users of the space. This is important if, for example, you are implementing a design with higher correlated color temperature (higher degree Kelvin) lamps (see *IES DG-10-11 Guide to General Light Sources*, and *IES TM-24-13 An Optional Method for Adjusting the Recommended Illuminance for Visually Demanding Tasks Within IES Illuminance Categories P through Y Based on Light Source Spectrum*) or changing the distribution pattern of the luminaires. If a mock-up is constructed, it is good to involve and get feedback from all interested parties.

In lieu of a mock-up, if there is a building with a similar lighting design nearby, it may be easier to take the client to this building. They would then be able to observe the lighting, ask the occupants how they like the lighting and if it achieved their visual and economic goals.

Acceptance: If the financial analysis is approved and specifications are acceptable, the project is ready to proceed.

Pre-installation Walkthrough: Installation specialists determine specific installation details such as storage, work hours, disposal, furniture protection and any other pertinent details.

Installation: Conduct the actual installation based on the contract documents.

Commissioning: Where appropriate, aim, adjust or calibrate lighting fixtures or controls and verify and document the final settings.

Post Installation Walkthrough: The owner, engineer or utility personnel conduct an inspection to ensure the project was installed correctly and completely.

Operation and Maintenance Manual: The contractor provides the owner with copies of manufacturers' catalogue information, trouble-shooting guides, reordering information, operation and maintenance manuals and installation and calibration guides (for controls). Include any calibration or time settings established during commissioning. If more than one type of lamp, ballast or component is used on the project, a chart documenting the various catalogue numbers and where products are located in the building is of great value to the maintenance personnel. Any training appropriate for maintenance personnel can be scheduled.

Energy Verification: Some owners and utility companies require long-term measurement and verification (M&V) to ensure the energy efficiency of the system is realized and maintained; commonly, a one time before and after measurement may be performed on the dedicated lighting circuits or local controls.

Occupant Satisfaction: Discuss with the owner or facility manager if an occupant survey could be conducted to determine if the occupants are satisfied with the new lighting. If the answer is yes, determine how and when the survey will be conducted and feedback handled.

1.4 Common Practice

The majority of commercial and institutional lighting consists of traditional lighting equipment, such as

fluorescent troffers and incandescent or HID down lights. For this reason, certain upgrades and products have become extremely common and essentially “standards of the industry.”

Cost-effective upgrading generally seeks out projects that will benefit from the use of commonplace equipment like T8 fluorescent lamps and electronic ballasts. Using commonplace equipment will simplify new systems as much as possible and avoid lighting components with unusual lamps, ballasts or drivers. Cost savings is typically the primary driver for proceeding with an upgrade project. A cost-effective and successful project focuses on standard lighting equipment used throughout most of the building.

With the use of electronic ballasts, one or two 4 foot, T8 lamp(s) can be used in the majority of spaces in a building. This will provide a maximum energy savings and also provide recommended illumination levels by using different ballast factors. Low, standard, medium and high ballast factor versions offer a range of about 50% variation in light output, while staying within lamp manufacturers’ guidelines for lamp operation that will achieve rated life and lumen depreciation.

Restrooms or custodian closets are not cost effective to upgrade due to limited operating hours. However, since these spaces are typically an insignificant percentage of the total project volume, they can be included in the project without significant impact on the economics; don’t forget simple controls that can automatically turn lighting off in these spaces when not occupied (lights are frequently left on in these spaces). Small areas are frequently in desperate need of an upgrade and it would be prudent to include them in the overall package.

1.5 Using This Document

The main body of *IES LEM-3-13* has been organized into three sections, each presenting more specific information than the last. The information has been assembled as a series of briefs, each typically being one to three pages, allowing the user to concentrate on the particular topic at hand.

1.5.1 Generic Issues for Upgrade Projects The upgrade briefs in **Section 2.0** describe the general issues involved with most upgrade projects. These are topics that the practitioner may consider, regardless of the technologies or applications involved. They include:

- Assessment
- Economic Issues

- Lighting Quality & Quantity
- Codes and Standards
- Commissioning
- Service and Maintenance Issues
- Lamp and Ballast Disposal

This section also includes a project checklist.

BUT - HOW FAST WILL THIS INFORMATION BECOME OBSOLETE?

Technology is a rapidly-moving target and any printed publication on technology will be outdated by the time it is distributed. This document will address only the general methods of performing a successful lighting upgrade. Consult the latest product information obtained directly from lighting manufacturers for the most current data.

1.5.2 Equipment Alternatives for Upgrade Projects

Key to a successful upgrade is a solid understanding of the equipment involved. The technology briefs of **Section 2.0** discuss the various types of equipment typically used in an upgrade, presenting those state-of-the-art alternatives currently available to the practitioner. Included here are:

- T8 Lamps and Electronic Ballasts
- T5 Lamps and Electronic Ballasts
- Electronically Ballasted Ceramic Metal Halide Lamps
- Compact Fluorescent Lamps and Electronic Ballasts
- LEDs
- Halogen and Halogen IR lamps
- Lenses and Louvers
- Reflectors
- Troffers
- Strips
- Industrial Luminaires
- Wraparounds
- Recessed Downlights
- High Bay and Low Bay Luminaires
- Task Lighting
- Controls
- Exit Signs
- Daylight Harvesting
- Peak Load Reduction
- New Technology and Current Research
- Demand Reduction

1.5.3 Energy-Saving Upgrades There is a wide range of applications where upgrading may offer substantial energy savings. Presented in **Section 3.0** are four applications that represent typical upgrade situations and the particular issues found in those situations. These include:



- Offices
- Retail Establishments
- Schools
- Health Care Facilities

1.5.4 Lighting Terminology This document closes with a glossary of terms typically used in the upgrade process and lighting in general (see **Annexes A and C**).

2.0 UPGRADE BRIEFS

The lighting assessment, lighting quality, economic issues, codes and standards, commissioning, service/maintenance and disposal are all critical to a successful lighting upgrade. Example checklists and surveys are provided here to help guide the upgrade effort and ensure that nothing important is overlooked.

2.1 Lighting Assessment

A detailed, complete lighting assessment is critical for a successful lighting upgrade project. We prefer to call it an assessment versus an audit due to negative connotations of the term audit. For a complete lighting assessment the following items may be useful:

- Building drawings
 - Obtain “as built” lighting plans (hopefully with furniture layout) in CAD (dwg) or pdf electronic format; either one is acceptable as long as you have a building layout and room names or numbers, as well as a luminaire schedule. Room numbers are generally preferred as they change less often than room names. Also, it is advisable to confirm whether or not these drawings have been kept updated as changes have been made to the site
- An Escort
 - Request that a person knowledgeable with the building and its use patterns be available as a guide around the facility. A guide will have knowledge of operating hours, explain the control systems and provide access into rooms. If you are doing an assessment without a guide, be sure to obtain keys
- Clip Board that opens or computer
 - If you are not using a computer, have a clip board that opens for storage of drawings, spreadsheet forms, and extra pencils.
 - Pencil vs. pen: spread sheets are much neater and easier to read if there is the need to erase something instead of striking it out

- Utilizing a tablet computer will make an assessment simple and reduce data input time
- Vest with pockets
 - A vest with large pockets is very handy for handheld equipment; a camera vest, a trap shooting vest or even a fishing vest works fine
- Camera
 - It is good to have pictures for the client, but it also aids in remembering rooms, controls and luminaires upon return to the office to work on the design. Take a picture of the room number when taking a picture of the luminaires and controls in that room
- Laser Measuring device
 - This will make the survey much simpler; invest in a good one that will measure at least 200 feet or 75 meters accurately
- Light Meter
 - See **Annex A & B** for a discussion of Field Measurements and Illuminance Meters.
- Mirror
 - This is helpful in preventing sore necks while inspecting lighting in coves, recessed spaces, and any hard to access spaces
- Mechanical Counter
 - A good quality mechanical counter is helpful to ensure a more accurate fixture count
- Flicker Detector
 - A passive or an electronic device used to measure hertz (Hz) can help identify fixtures with magnetic or electronic ballasts. This is increasingly useful in buildings where spot replacements of magnetic ballasts have occurred (a digital camera can also detect this).
- Voice recorder
 - Not critical, but some people find it useful for taking notes.
- Safety Equipment

A hard hat, safety glasses and steel toe shoes are often a must if the project is assessing an industrial type building

2.1.1 The Assessment Every assessment is a little different so bring only what is needed to each one. It is a good idea to have all the gear in a nearby vehicle; however, a backpack makes for great storage. When starting the assessment, have the client

ing drawing(s) ready on the clip board or stored digitally in a portable computer.

Be sure to write the rooms down by number on the spread sheet or data sheet. When completing a room or rooms, stop and highlight the areas just assessed. In this manner, each area will not be missed and any rooms that were not accessible can be identified. Be sure to enter NO ACCESS on the spread sheet for are those rooms. The client will appreciate clear documentation and typically allocate resources to complete the missed room(s). If it is not there you may be expected to upgrade the lighting in the missed rooms.

Take as many pictures of the different luminaires in the building as possible; extra images can always be deleted if not needed. Take a picture of anything unusual such as broken or discolored lenses and exposed wiring, even if it seems to be above and beyond the normal upgrade process. Note any controls that are not operational.

Be sure to note any quality issues you encounter. Pictures may also be helpful to document poor lighting quality.

Note any opportunities to take advantage of daylight entering spaces during operating hours. At the same time, note glare caused by the daylight that may need to be controlled.

It is recommended that you develop standard nomenclature for the different types of luminaires you may see. For example, a 2x4 grid troffer with four T12, 34 watt lamps and prismatic lens may be described as "2x4GT4-34PR". Developing a system and being consistent will make the process easier for all people involved with the assessment.

It is a good idea to start on either the top or bottom floor and work through the building level by level. A good place to start may be on a side or corner of the building and work through the building in a symmetrical pattern. Project Checklist and Lighting Assessment Forms are found in **Annex D**.

2.2 Economic Issues

This section explains the economic foundation for improving lighting performance and efficiency in an existing building.

2.2.1 Introduction This document does not duplicate information contained in the *IES Lighting Handbook, 10th Edition, Chapter 18, Lighting Economics* which discusses the format for light-

ing cost comparisons as well as the procedure for using Life-Cycle Cost Benefit Analysis. The following discussion emphasizes the income side of the cost-benefit equation because advance projections of lighting savings require special considerations. This section also describes a simple procedure that will lead to realistic savings projections. However, a full life cycle cost benefit analysis, conducted in accordance with published IES procedures, will provide a more accurate assessment of a project's financial feasibility.^{2,3}

In addition to improved lighting quality, the economic opportunity hidden in the lighting systems of existing buildings can have a significant impact on the bottom line profits of a business. Substantial energy reductions resulting from implementing lighting upgrades, as well as utilizing newer lighting technology, will benefit the owners and hopefully improve occupant comfort and performance.

Historically, electricians or maintenance personnel have maintained the lighting in a facility and have been responsible for many of the lighting decisions.

Although not formally trained, facility maintenance personnel may achieve about a 30% energy savings by simply changing from T12 to T8 fluorescent technology. Retaining a knowledgeable lighting practitioner experienced in upgrading existing buildings, may achieve as much as 50% or higher energy savings and provide the appropriate illumination levels for the task performed. Experienced lighting practitioners will be able to propose a variety of strategies beyond merely replacing light bulbs. The financial benefit of a well-designed lighting upgrade will far exceed a one-time, low cost, energy efficiency-only lighting upgrade.

For example, consider a retailer that changed 400W metal halide luminaires (operating at 465W) to 6-lamp F32T8 luminaire (each operating at 222W), on a fixture for fixture basis. No photometric calculations were completed and the store was illuminated to 90 fc (900 lux) when the current recommended practice is 50 fc (500 lux). The retailer could have installed a 4-lamp T8 luminaire (operating at 144W) which would have provided the recommended illuminance level. The retailer chose to go with the low cost installation to save \$9,000, but now will spend an extra \$6,864/ year in electrical costs (6-lamp vs. 4-lamp luminaire). This will go on over the next 15 years. The retailer saved \$9,000 up front and will spend an extra \$102,960, on higher electrical consumption over the useful life of the system!

	Luminaire	Total Wattage	Number of Luminaires	Operation Hours	kWh Cost	Energy Cost	Savings/ Year
Existing	400W MH	465W	100	8000	\$0.11	\$40,920	0
Installed	6- F32T8	222W	100	8000	\$0.11	\$19,536	\$21,384
Optimum Installation	4- F32T8 High Lumen	144W	100	8000	\$0.11	\$12,672	\$28,248

**Table 1: \$28,248 - \$21,384 = \$6,864 Extra Energy Costs/Year with the 6-lamp system.
\$6,864 x 15 years = \$102,960 Extra Energy Costs with the 6-lamp system.**

Just considering the energy savings, the simple pay-back for the 4-lamp (high lumen) system would have been 1.3 years. The decision maker of an energy efficient lighting upgrade project must have all the facts before an informed financial choice can be made; this includes an economic evaluation. The best evaluation will follow a systematic approach which includes measurement, assessment, comparison calculations, a planning estimate, project planning, program design, and contracting decisions.

Begin by performing a preliminary evaluation of the existing lighting system and developing planning estimates using the procedure outlined below to predict potential savings in energy and projected maintenance expenses. Once these parameters are evaluated, good decisions can be made about the practicality of the next steps, which range from undertaking major cost saving actions because the earnings potential is large to initiating a limited project to achieve the small savings available from an already efficient system.

Investing in a qualified energy efficiency lighting consultant (Lighting Certified “LC” – see www.ncqlp.org - accreditation, CEM, or CLEP certified – see **Section 2.2.3**) will increase the overall effectiveness of the lighting project while reducing the risk of costly mistakes. It is also important to seek competitive proposals and references. The actual amount used for such assistance will vary with the size and complexity of the project and the experience of the upgrade team. Employing a consultant in specifying and implementing an upgrade can produce credible economic benefits that will enhance long term return on investment (ROI).

Additionally, a good economic plan may include defined decision points with in-process evaluations of project investments and return on investment. A complete budget will include costs for system evaluation and design, material, installation, and projected maintenance costs.

2.2.2 Assessment and Initial Determination To determine the potential economic return, perform the following simple measurements and calculations on the facility. This is also referred to as determining the *rough order of magnitude*.

Step 1. Obtain a copy of the electric bill for the facility. In addition to identifying rates, evaluate it for information that may identify opportunities for energy saving.

Step 2. Take a small area or room that is typical for each of the space categories in the building and do a physical survey of the connected lighting power (watts) in each of these spaces and the area of each model space. Divide the connected lighting power by the measured area for the each model space. These quotients are the lighting power densities (LPD) for each space, measured in watts per square foot or watts per square meter.

Step 3. From building plans, physical surveys, or best estimates, record the total area of each space use category in the building and multiply each by the actual LPD for the model space for that space use category. Total the results for each category. This enables an estimate of existing lighting load (watts). A quick way to determine a best estimate is to determine the fixture spacing. Divide the gross square footage (or square meters) of the space end use category by the resultant square feet (or square meters) of this spacing (ex. 8'x10' = 80 sq.ft.).

Step 4. Repeat the same calculations replacing the actual LPD values with “achievable LPD” values as anticipated. This enables an estimate of lighting load (watts) after implementation of efficiency improvements.

Step 5.
Determine the wattage reduction.

Step 3 Watts – Step 4 Watts = Wattage Reduction

Divide the Wattage Reduction by 1,000 to convert to kilowatts (kW), then multiply by the annual



operating hours and electricity rate (\$/kWh) to determine the dollar savings.

$$\frac{\text{Wattage Reduction} \times \text{Annual Operating Hours} \times \$/\text{kWh}}{1,000} = \text{Annual \$ Electrical Cost Savings}$$

This method provides an initial estimate of annual savings from energy consumption reduction. Add to this any peak load (“demand charge”) reductions expected from this reduced lighting load; this provides initial insight into savings from power reductions.

Step 6. Determine the building’s total of “uncontrolled” lighting watts (lighting that is *not selectively switched by automatic controls*). Estimate the savings for new automatic lighting controls:

$$[0.2 \times (\text{annual operating hours}) \times (\text{building's total uncontrolled lighting watts}/1000) \times (\$/\text{kWh})]$$

(*Note: 20% is only an estimate*). This result is a planning estimate of dollars that may be saved from hours of use reductions from installation of new automatic controls.

Note: The 20% energy savings is an estimate of the saving from controls. (The paper titled “A Meta-Analysis of Energy savings from Lighting Controls in Commercial Buildings”, published in *IES LUEKOS Vol. 8, No 3, JANUARY 2012, PAGES 161-180*, reports savings of 24% based on their survey of various reports of findings for actual installations; some installations report up to 60% savings.)

This calculation is intended as a very rough estimate of savings potential from automatic lighting controls. It does not account for possible “double counting” that occurs when the wattage reductions from efficiency improvements are not factored into estimates of the benefits from controls. Subsequent evaluations upon which final investment decisions are made may be done with care to avoid any such “double counting” of savings. (Actual savings will vary from installation to installation based on the time delay before shut-off and occupant activity.)

When estimating the potential savings from controls, keep in mind automatic controls may not always make financial sense in some locations and in some space types, the use of automatic controls can introduce a safety issue.

Step 7. Combine the dollar savings in Steps 5 and 6. This result is the planning estimate of total annual dollar savings. It is a good rough estimate of the amount of money that can be saved through improving the lighting efficiency in the building. Use

this to decide whether or not this amount of money provides a sufficient annual return to justify initiating a lighting improvement project that will pay for itself. Of course, the costs for equipment and labor must be subtracted from these energy and power cost savings estimates to determine payback, life-cycle cost, and rate of return.

Note that the scope of the upgrade in many jurisdictions may require the installation of controls in order to meet the current energy code.

It is important to note this savings estimate projects only utility cost savings. *It does not include maintenance cost saving or potential gains in occupant performance and business profitability from improved lighting effectiveness*, information about frequency of replacement, or owner labor and material costs which can be used to help determine maintenance costs that will be avoided.

Occupant performance and business profitability gains may be difficult to quantify. One such study strongly suggests that productivity can be improved with better quality lighting. See *Lighting Quality and Office Work: A Field Simulation Study* at <http://archive.nrc-cnrc.gc.ca/eng/projects/irc/lighting-quality.html> for a full report. It is recommended that interviews of the occupants be conducted to gain insight about the existing lighting quality, any problems that might exist and take a few spot light level readings in typical spaces.

Although this document's scope covers replacement of inefficient lighting equipment without changing the visual aspects of the existing system, it is a mistake to overlook the opportunities that may exist in redesign. If the planning estimate indicates that there are significant potential savings, bring in a professional to take a look at the lighting effectiveness.

2.2.3 Gaining the Expertise to Realize Economic Gains

If the planning estimate predicts significant savings potential, it may make good economic sense to consult with a lighting professional. For many, getting professional help with lighting evaluations and design may be a new experience, but advisable to procure the best advice possible. Lighting practitioners who have “Lighting Certified” (LC) credentials are those that have met certification requirements of the National Council on Qualifications for the Lighting Professions (NCQLP). NCQLP is an independent body formed by a broad industry/government coalition to supply users with a reliable way to secure competent services in lighting design and application. Obtain the current LC registry for contact information about local Lighting Certified individuals from NCQLP at <http://www.ncqlp.org> or phone (703) 518-4370.



Documents

Document Sharing Hub

Additional resources are the IALD, International Association of Lighting Designers (www.iald.org) and the National Lighting Bureau (www.nlb.org). Other professional certifications such as The Certified Lighting Management Consultant (CLMC) through the National Association of Lighting Management Companies (<http://www.nalmco.org/>) and the Certified Lighting Efficiency Professional (CLEP) through the Association of Energy Engineers (<http://www.aeecenter.org/>) identify highly qualified individuals as well. As with any profession, in addition to seeking certified individuals, conduct interviews and check references to find the right person or firm to meet the needs of the project.

2.2.4 Economic Considerations That May Be Overlooked

- ✓ Consider the benefits that accrue from reduced maintenance expense. These amounts are not possible to estimate prior to specifying equipment for the project.
- ✓ In costing the project, incorporate the projected ongoing maintenance expense, including a plan to maintain the quality of the system over time. Don't overlook the possibilities for such approaches as group relamping, especially if new lamps have longer rated life than old ones, use of extended life universal start T8 lamps, and the longer life of compact fluorescent compared to incandescent lamps or the longer life of LED sources compared to many traditional light sources.
- ✓ Be certain that the project includes any lamp and ballast disposal costs in the up-front estimates and that this cost is not a "surprise extra" as the job progresses.
- ✓ Lighting upgrade projects can typically be financed through third-party lenders using a positive cash flow arrangement or under a shared savings performance contract.
- ✓ Utility or other incentive programs may be available to help off-set some of the up-front costs.
- ✓ The savings generated by reducing wattage during peak load times can dwarf off-peak savings, depending on the utility rate structure. (There may be local incentives available for projects providing load shed/demand response capability.)
- ✓ In some climate zones and for some building types, additional savings may be generated through a reduced need for air conditioning

due to lower cooling loads. Conversely, an energy 'penalty', or an increase in the energy consumption of the heating system may result from a reduction in lighting energy consumption.

- ✓ Prevailing Wage Laws (<http://www.dol.gov/compliance/guide/dbra.htm>) regulate wages paid to workers performing certain public work. They require that workers be paid the prevailing wage for work performed in a specific county or geographical area. The prevailing wage includes the hourly wage ordinarily paid for that work plus the value of the usual fringe benefits paid for that job. An employer must pay the combined total in either wages or cash wages plus benefit contributions.
- ✓ The Davis-Bacon Wage Determinations (<http://www.wdol.gov>) are wage determinations issued by the U.S. Department of Labor under the Davis-Bacon and related Acts. The Wage and Hour Division of the U.S. Department of Labor determines prevailing wage rates to be paid on federally funded or assisted construction projects.

Labor rates can vary substantially between job classifications. For example, a position classified as a "New Luminaire Installer" may cost significantly more than a position classified as a "Retrofitter."

2.3 Lighting Quality and Quantity

A successful upgrade requires that both the lighting quality and illumination levels be assessed. Lighting quality (glare and uniformity for example), color rendering index (CRI) and/or color temperature (CCT) should be reviewed for possible improvement and the illuminance levels should be adjusted to the task performed beneath the light to meet current IES recommended practice (refer to the *IES Lighting Handbook, 10th Edition* and *IES DG-18-08 Light + Design*). Please note: IES recommended practice continues to evolve as the science of lighting moves forward.

2.3.1 Redesign vs. Retrofit A successful upgrade provides energy savings and maintains or improves lighting quality. Assess a project from the outset to determine if the existing lighting system provides acceptable lighting quality. If so, determine if any proposed upgrade options would have a negative impact on this quality. It may be necessary to redesign the lighting in some or all of the spaces. A new lighting design may require relocating existing fixtures, new fixtures, controls and wiring. Unless there is a specific reason for the redesign, this undertaking may impact the financial incentive to move the project forward.



If an existing space is under lit, verify if there is enough power on the existing circuits to accommodate increased illumination levels and that any proposed redesign is within acceptable lighting power density limits as per the local code(s).

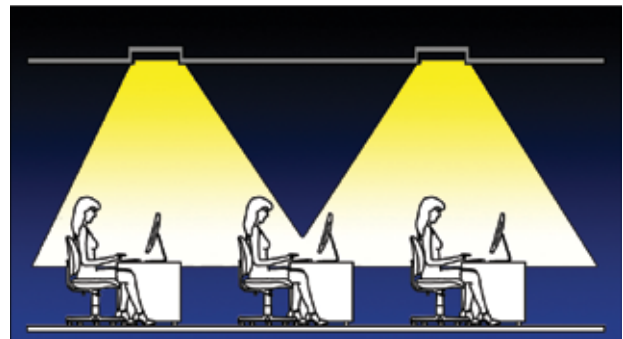
2.3.2 Uniformity With any lighting upgrade the uniformity should be checked for appropriateness to the installation by referring to the *IES Lighting Handbook, 10th Edition- Chapter 12 Components of Lighting Design*. This can be done by starting with the Spacing Criterion (SC) guidelines provided by the luminaire manufacturer in conjunction with accepted illumination levels, which is defined as the maximum spacing of a particular luminaire for a given mounting height. SC values are published on manufacturers' product sheets and may differ for spacing parallel vs. perpendicular to the lamps. Exceeding the recommended SC may result in uneven distribution of light on the work plane (e.g., desktops). Consider a closer spacing of luminaires if:

- Existing layouts exceed the manufacturer's spacing criteria.
 - There are partial height partitions (office furniture), especially with overhead shelving or bins, (see **Figure 2**).
 - The proposed upgrade will narrow the distribution of the light from the luminaire.

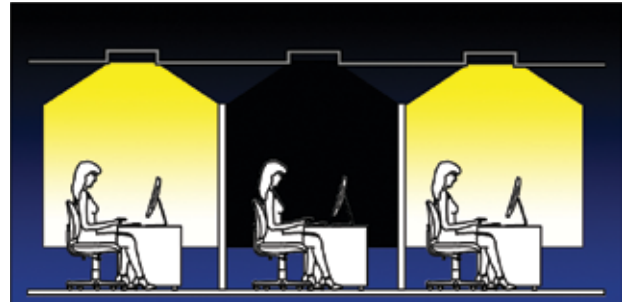
For example, if a recessed fixture in a 2.6 m (8.5 ft.) ceiling has a SC of 1.5, then the maximum on-center spacing of those luminaires is 3.9 m (2.6 x 1.5 SC) (or 12.75 ft. (8.5 ft. x 1.5 SC)). Keep in mind this calculation method assumes that there are no obstructions (as illustrated by **Figure 2**). Luminaire spacing may need to be modified to account for obstructions such as furniture partitions (as illustrated by **Figure 3**). The most accurate way to predict the uniformity is to do a point-by-point calculation, using industry accepted lighting software. If a model is installed, verify the uniformity using a good quality, well calibrated light meter.

In most workplaces, uniform lighting is generally more acceptable than spotty lighting. However, in retail and entertainment applications, greater contrast between high illuminance levels on the product and low ambient illuminance levels is often desirable, and the tolerance for glare and specular materials may be increased.

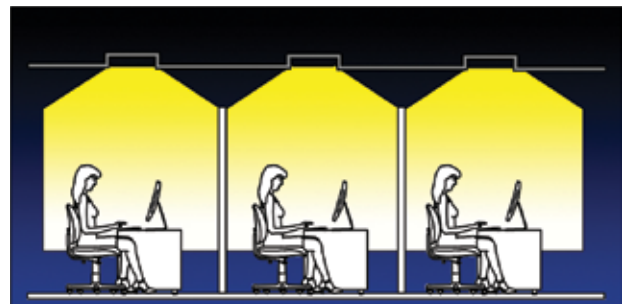
2.3.3 Lighting Walls and Ceilings Human perception of light in a space comes from the perception of luminance (more commonly referred to as "brightness", see **Annex C**) of the room surfaces, particularly the walls, ceilings, and furniture partitions in front of the observer. Even if it can be verified that



(a) Uniform light distribution is achieved following maximum spacing criterion.



(b) Spacing criterion does not, however, account for partitions



(c) Adjustments made to luminaire spacing to accommodate partitions.

Figure 2. Effects of partitions on spacing and mounting height.

the illuminance levels on the work plane meet IES lighting recommendations, the upgrade will not be successful unless the lighting on the walls and ceilings is sufficient. A starting point for evaluating the existing luminaire location would be to make sure the luminaires nearest the walls are centered not more than [distance = mounting height x 0.5(SC)] from the adjacent wall.

For general lighting in a low ceiling space, care should be exercised to avoid creating overhead glare with specular (shiny) reflectors and louvers. In addition to creating overhead glare, louvers with this finish can create a cave effect (dark upper walls), harsh patterns on walls, sharp shadows under shelves and overhead bins, or a continuing

of these conditions. In offices, use high reflectance, white painted reflectors in open-celled luminaires, or lensed luminaires designed to illuminate the walls as well as the work plane; specular reflectors should be avoided. For detailed guidance, see *ANSI/IES RP-1-13 Recommended Practice for Office Lighting*.

2.3.4 Glare Glare occurs when bright light sources interfere with the viewing of less bright objects. The contrast may be uncomfortable, or even disabling to one's ability to see ("Disability Glare" and "Veiling Reflections" - see **Annex C**). Luminaires located in front of a viewer's line of sight may cause direct glare. Reflected glare is caused by bright reflections in surfaces such as glossy paper or computer screens. Flat panel computer screens have reduced this issue. Overhead glare may also be caused by luminaires located directly overhead.

Glare Prevention Tips:

- Shield the lamp from view with baffles, louvers, lenses or diffusing overlays.
- Select only semi-specular or white painted louvers and reflectors. Avoid mirrored or specular reflectors or louvers visible from any angle in a low ceiling workplace.
- Reduce luminous intensity by using lamps of lower luminance; use more luminaires if necessary.
- In offices and other low ceiling applications, care should be taken when using high luminance sources such as T5, T5HO, high wattage compact fluorescent, metal halide and LED lamps. These lamps may be used in indirect applications or with lenses or overlays.
- If decreasing lamps and relocating lampholders within a luminaire, take care to maintain the lamp shielding. Modifying the quantity or location of lamps within a luminaire may adversely change the luminaire cutoff angle; this, in turn, may create glare and/or dark spots.
- Increase the overall luminous intensity or reflective color of the walls, ceilings, and desktops.
- Use light colored surfaces near luminaires and fenestration to reduce contrast.

2.3.5 Color Select color temperature (CCT see **Annex C**) and Color Rendering (CRI – see **Annex C**) based on the needs of the occupants, with consideration for the interior space finishes.

Correlated Color Temperature (CCT): The major lamp sources are available in many CCTs, ranging from 2700 K to 8000 K. These correspond roughly to the range of CCTs from the warmth of incandescents to cool bluish white. Most applications use CCTs in the range of 3,000 K to 4,000 K, however the science of color temperature and the physiological effects on humans is advancing rapidly (refer to *IES TM-24-13 An Optional Method for Adjusting the Recommended Illuminance for Visually Demanding Tasks Within IES Illuminance Categories P through Y Based on Light Source Spectrum*). It is recommended that the proposed CCT should not exceed the existing CCT without client approval of a mockup.

Color Rendering Index (CRI): Using lamps with a CRI of 80 or higher improves the appearance of people and objects in the space. Fluorescent lamps, for example, with a CRI below 80 are not recommended even though they might be a lower cost option.

2.3.6 Task Lighting Providing the light more precisely where it is needed is an excellent way to reduce energy consumption. Most office functions today involve lengthy viewing of a flat screen computer monitor. Ambient light levels should be appropriate to achieve comfortable viewing of the monitor. If ambient illumination levels are below 30 FC, task lighting should be utilized for occasional document reading. Typically this will be a halogen, fluorescent or LED source. The luminaire may come in the form of an articulated desk lamp or a strip mounted under a cabinet. Be sure to adjust the illumination values to the potential task performed beneath the light. Task lighting offers the occupant individual control of light level based on the task at hand.

2.4 Codes and Standards

Before embarking on a lighting upgrade, it is important to understand all applicable codes and standards. Some facility managers may also have their own internal lighting standards. There is an obligation on the part of everyone working on a lighting upgrade to follow all applicable codes and standards, as well as bring to the owner's attention any violations or unsafe conditions that may be discovered.

Codes and standards have been developed through a number of government and private organizations. In addition, a variety of organizations develop codes that may apply to lighting retrofits. For example:

U.S.

- American National Standards Institute Lighting Group (ANSI/ANSI/SLG)
- American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)

- Building Officials and Code Administrators International (BOCA)
- California Energy Commission (CEC)
- Department of Energy (DOE)
- Federal Aviation Administration (FAA)
- Illuminating Engineering Society (IES)
- International Code Council (ICC)
- National Electrical Code (NEC)
- National Fire Protection Association (NFPA-70)
- Occupational Safety and Health Administration (OSHA)
- Underwriters Laboratories (UL)
- Uniform Building Code (UBC)
- U.S. Green Building Council (USGBC)

Other sources to consult include the Department of Health and Human Services guidelines, local or state board of education requirements, Americans with Disabilities Act (ADA), local fire departments, and fire marshal offices as applicable to the occupancy.

Canada

- Canadian Occupational Safety and Health Board (COSHA)
- Canadian Standards Association (CSA)
- National Research Council Institute for Research in Construction (NRC/IRC)
- Natural Resources Canada (NRCan)

Mexico

- Comisión Nacional de Ahorro de Energía (CONAE)

International

- Commission internationale de l'Éclairage (CIE)
- International Electrotechnical Commission (IEC)

Some safety and/or performance related codes may affect replacement of luminaire components and some energy codes are setting requirements specifically for lamp and ballast only retrofits (*ANSI/ASHRAE/IES 90.1-2010, section 9.1.2* requires compliance even when just lamp and ballasts combinations are upgraded). If 10% or more of the connected lighting load in a space or area is affected, then you must comply with LPD requirements. The 2013 version of California Title 24 also has requirements for lamp/ballast upgrades. Also if systems or equipment are replaced, or additions are made to an existing system, then additional codes and standards may apply. This may pertain to interior and exterior lighting systems and equipment as well as controls.

Following are discussions of some of the issues related to codes and standards that may be triggered by a lighting upgrade.

2.4.1 Building Permits Building permits are required for some lighting upgrades. Check with the authority having jurisdiction (AHJ) to see if a permit is required before work is started on any project. Permits may be required to comply with fire and life safety regulations, structural integrity (including meeting earthquake requirements), or energy standards

2.4.2 Energy Standards and Codes There are numerous executive orders and energy standards on the national, state or province, and local levels that directly impact lighting upgrades. These standards may require that part or all of an existing lighting system, and/or lighting controls, be brought up to current energy standards under certain conditions. These conditions may arise when an alteration exceeds a specified percentage of the existing lighting system, when the connected electrical load is increased by any amount, or when particular federal or state government buildings undergo any lighting alteration. Requirements may include such items as maximum allowable lighting power densities or minimum efficacies and may mandate the use of lighting controls. In addition, components for lighting retrofits, such as lamps and ballasts, may be subject to equipment specific standards.

Codes are becoming more stringent on lighting upgrades and the reader should check with the authority having jurisdiction in the location where the work is being completed. Lack of compliance may lead to “red tagged” projects.

2.4.2.1 U.S Standards and Codes As of October 19, 2011, the Department of Energy set a new, minimum building efficiency standard, *ANSI/ASHRAE/IES 90.1-2010*. States must provide certification statements to the DOE by October 18, 2013. Legislation that provides compliance with this statute varies from state to state. Another energy code titled the *International Energy Conservation Code (IECC)* typically contains a reference to the *ANSI/ASHRAE/IES 90.1 Standard (IECC 2009 references ANSI/ASHRAE/IES 90.1-2007 and IECC 2012 references ANSI/ASHRAE/IES 90.1-2010)*. The IECC energy code is used by many states to meet the EPA's building energy code requirement. Both the IECC code and 90.1 Standard apply to new construction and major renovations. For information on the Department of Energy's Building Energy Codes Program (BECP), see <http://www.energycodes.gov>. For information on the status of state adoption of building codes, visit <http://www.energycodes.gov/#>.

The *ANSI/ASHRAE/IES 90.1* standard may be ordered from ASHRAE (<http://www.ashrae.org/>) or from IES (<http://www.ies.org/>). The IECC may

be ordered through the International Code Council (ICC) (<http://www.iccsafe.org/>). Another code to be familiar with is *ANSI/ASHRAE/IES 100-2006 "Energy Efficiency in Existing Buildings"*.

Lighting products for Federal buildings often must meet specific requirements or procurement guidelines. The DOE's Federal Energy Management Program (FEMP) has energy efficiency recommendations for federal government projects and covers several lighting products, including lamps, ballasts, exit signs, luminaires, and controls. Many of FEMP's recommendations for energy using products match the qualifications for the DOE/Environmental Protection Agency's ENERGY STAR® products, and must be selected when life-cycle costs warrant such selection. For more information, see <http://www.eere.energy.gov/femp/> and <http://www.energystar.gov>.

Many lighting products regulated by the U.S. Department of Energy (DOE) have labeling requirements (lumens or wattage for example) established by the U.S. Federal Trade Commission.

2.4.2.2 Canadian Standards and Codes The Canadian Standing Committee on Energy Efficiency in Buildings (SCEEB) develops National Energy Codes for commercial buildings and homes. The regulation of buildings in Canada is the responsibility of provincial and territorial governments. Provinces will have the option of adopting all or part of the National Energy Code for Buildings (NECB). Currently British Columbia, Ontario, and Nova Scotia have commercial energy code requirements that affect lighting and are based on either the *ANSI/ASHRAE/IES 90.1-2004* Standard or the Model National Energy Code for Buildings (MNECB) 1997. The city of Vancouver, B.C. has adopted 90.1-2007 and various provincial governments are considering adoption of a more recent version of *ANSI/ASHRAE/IES 90.1* or the newly developed NECB energy code.

Canadian lamp regulations have been in effect since November 1995. They are similar to the U.S. EPC standards for incandescent reflector, general service lamps and linear fluorescent lamps, although in 2003 the incandescent reflector lamp standards were adjusted and there are currently proposals to make additional changes to the incandescent reflector lamp standards. Change to the linear fluorescent lamps regulations are likely to follow. Canada's EnerGuide product efficiency labeling program does not cover any lighting products. However, regulated lighting products must carry a verification mark indicating that the energy performance of the product has been verified. The ENERGY STAR® program in Canada is administered by NRCAN. For more information, see Natural Resources Canada's Office of

Energy Efficiency's website, http://oee.nrcan.gc.ca/regulations/home_page.cfm.

In some cases, provincial regulations may differ from the federal requirements or may apply to other types of energy-using equipment. The federal Energy Efficiency Regulations do not take precedence over provincial regulations. The provinces of Ontario, British Columbia, Quebec, Nova Scotia, and New Brunswick have standards similar to the federal regulations for fluorescent lamp ballasts. Ontario and British Columbia have also implemented standards for incandescent reflector lamps and are considering adopting the standards for fluorescent lamps. In addition, Ontario and British Columbia have regulated compact fluorescent lamps and cobra-head HID luminaires based on recently published CSA standards for compact fluorescent lamps and roadway lighting. Adoption by local jurisdictions and provinces is ongoing and contact should be made with local building officials prior to assuming regulations are in effect.

2.4.2.3 Mexican Standards and Codes Mexico's energy efficiency standards are authorized by the Ley Federal Sobre Metrología y Normalización (federal standards and metrology law) of July 16, 1992, which defines two types of standards: voluntary Normas Mexicanas - NMX (Mexican Standards) and mandatory Normas Oficiales Mexicanas - NOM (Official Mexican Standards). Energy efficiency standards are the responsibility of the Energy Secretariat, through its agency Comisión Nacional para el Ahorro de Energía (CONAE). The Regulations apply to products that are marketed in Mexico. CONAE also implements a mandatory comparative labeling program. In 1995, México introduced the Sello FIDE, a voluntary energy efficiency endorsement seal given by the Fideicomiso para el Ahorro de Energía Eléctrica (FIDE).

Mexico has a voluntary standard for general service fluorescent lamps with different efficiency levels than the US/Canadian mandatory standards. It also has voluntary fluorescent ballast standards, as well as mandatory labeling for fluorescent lamps and fluorescent ballasts. Mexico also has a mandatory CFL standard with minimum efficacies, NOM-017-ENER/SCFI-2008 which is currently under revision. The FIDE seal applies to fluorescent lamps and compact fluorescent lamps (CFLs). For more information, see <http://www.conae.gob.mx>. Mexico has a standard for lighting in commercial buildings as well as for exterior lighting.

2.4.2.4 Additional Outdoor Lighting Standards and Ordinances Various states and local jurisdictions have, or are in the process of developing

ordinances that regulate outdoor lighting. These regulations may include limits on light trespass, sky glow, pole heights, or energy use, as well requiring automatic shutoff controls. Check with the authority having jurisdiction to understand all relevant outdoor lighting ordinances before proceeding with an outdoor lighting upgrade. For additional information, refer to the *IES/IDA MLO Model Lighting Ordinance* as well as to *IES TM-15-11 Luminaire Classification System for Outdoor Luminaires / Addendum A - Backlight, Uplight, and Glare (BUG) ratings*.

ANSI/ASHRAE/IES 90.1, IECC and several state specific building codes have recently specified more stringent outdoor lighting provisions.

2.4.3 Electrical Codes Most electrical codes set minimum requirements for electrical wiring connections and other functional and safety characteristics of a building's electrical system, but others may dictate specific requirements for lighting systems (e.g., lighting systems used in kitchens and storage closets).

Luminaire installation practices in the United States are dictated by the National Electrical Code (NEC), which is published by the National Fire Protection Association. The NEC requires that equipment be listed as meeting minimum safety standards by an organization that is acceptable to the municipal authority having jurisdiction over the installation. This authority is typically the local electrical inspector. The American National Standards Institute (ANSI) has accredited Underwriters Laboratories (UL) as the standards-making organization for luminaire safety in the United States. Virtually all local authorities require luminaires to be listed by UL or a similar safety testing organization such as CSA, ETL. They sometimes require other certifications as well.

Underwriters Laboratories Inc. (UL - <http://www.ul.com/>) is a global, independent, safety science company offering expertise in product safety, environment, life & health, verification services, and knowledge services. Millions of products and their components are tested to UL's rigorous safety standards with the result that consumers live in a safer environment than they would have otherwise. The UL Service Label is provided for most ballasts, lamp holders, and luminaires as well as for lighting controls, self-ballasted lamps (for the ballast portions), and LED drivers/power supplies (UL recognized). The Canadian Standards Association (CSA - <http://www.csa.ca/>) is a nonprofit association serving business, industry, government and consumers in Canada and the global marketplace. Among many other activities, CSA develops standards that enhance public safety. A Nationally Recognized Testing Laboratory,

CSA is very familiar with U.S. requirements. According to OSHA regulations, the CSA-US Mark qualifies as an alternative to the UL Mark.

The ETL Listed Mark (<http://www.intertek.com>) is an alternative to the CSA and UL marks. It is recognized by OSHA as a Nationally Recognized Testing Laboratory (NRTL), just as Underwriters Laboratories (UL), Canadian Standards Association (CSA) and several other independent organizations are recognized.

An NRTL (Nationally Recognized Testing Laboratories) listed laboratory that has been approved for the appropriate lighting products should be acceptable as a certifying laboratory (see <http://www.osha.gov/dts/otpc/nrtl/>).

Altering a luminaire may void its UL (or similar) listing, exposing the person performing the lighting upgrade to financial risk and liability in the event of a fire, electrocution resulting in injury or other damage. It is important to contact the certification agency and obtain certification for all custom luminaires or custom upgrades.

All applicable parts used in a lighting upgrade should be listed, recognized or certified as appropriate for the application by UL or similar agency. For example, lamp holders must be designed and rated for the lamp voltage being used, and all parts of a track lighting system should be listed for use together.

It should also be verified that all applicable elements of certification listing have been met for all lighting upgrade equipment. For example, an exit sign may be approved for cord connected wiring but may not meet the certification requirement for visibility of exit signs.

2.4.4 Electromagnetic and Radio Interference In the U.S., the Federal Communications Commission (FCC) regulates electromagnetic interference (EMI) emissions under FCC Title 47, CFR - part 18 for fluorescent and HID ballasts, or part 15 for LED drivers. There are two requirement levels, one for non-residential applications and one for residential applications. The residential requirement of part 18 (consumer) is more stringent than the non-residential requirement (FCC CFR 18 Non-Consumer). Similarly, the residential requirement of part 15 (Class B) is more stringent than the non-residential requirement (Class A).

Electromagnetic interference (EMI) occurs when unwanted EM emissions, which can travel through wiring or radiate through the air, interfere with desirable signals from other devices. In the United States,

the FCC regulates EM emissions in the communication frequencies of 150 kHz to over 1000 MHz; specific frequency ranges are defined in either part 18 or part 15. Canada also regulates EM emissions over these frequencies through Industry Canada. Mexico regulates EM emissions over these frequencies through NOM. Manufacturers must comply with FCC regulations to sell products in the United States, Industry Canada requirements in Canada and NOM requirements in Mexico. In general, these requirements are harmonized.

Radio frequency interference (RFI) or EMI is inherent in all electronic ballasts and control systems that rapidly switch a portion of input power. There are specific standards and limits to the radio noise permitted in the United States. The FCC publishes these standards and regulates the manufacture of devices that can emit radio noise. The Food and Drug Administration (FDA) publishes separate standards for radio noise for devices used in hospital environments. The FCC is concerned with all types of radiating devices, including various types of occupancy/motion sensors and wireless controls.

2.4.5 Health and Safety The mission of the U.S. Occupational Safety and Health Administration (OSHA) is to save lives, prevent injuries, and protect the health of America's workers (<http://www.osha.gov/>). Safety and health programs must address electrical incidents and the variety of ways electricity becomes a hazard. In general, OSHA requires that employees not work near any part of an electrical power circuit unless protected.

2.4.6 Hazardous Material Materials removed during a lighting upgrade may contain hazardous materials the disposal of which must be properly handled. These hazardous materials may be found in old ballasts containing polychlorinated biphenyls (PCBs), fluorescent and high intensity discharge (HID) lamps containing mercury, and asbestos insulated wiring.

Hazardous material disposal is covered in some depth in **Section 2.7 Lamp and Ballast Disposal**. Additional information may be found in *IES DG-22-12 Design Guide for Sustainable Lighting: An Introduction to the Environmental Impacts of Lighting*.

2.4.7 Emergency Lighting Codes specify minimum operating periods for emergency lighting as well as minimum illumination levels along paths of egress (a main aisle or pathway which leads to an exit). The Model National Energy Code for Buildings requires lighting outside the egress path. It is important that a lighting upgrade does not compromise an emergency lighting system. Be sure to closely examine luminaires near doors or exits for battery backup

units. Relevant codes published by BOCA (Building Officials and Code Administrators International, Inc.), the NFPA (National Fire Protection Association), and local codes should be consulted.

Some codes require an emergency light at the exit discharge from a building. This source provides the transition from the interior egress path to the exterior. In the U.S., any exterior door marked with an exit sign is required to have an exterior emergency light. The area covered by this light is determined by the applicable code and the authority having jurisdiction.

2.4.8 Exit Signs The National Fire Protection Association (NFPA) 101 *Life Safety Code*, states that exit signs that are externally illuminated shall have a minimum contrast of 0.50 and an illuminance of 50 lux (5 fc). Internally illuminated signs are required to comply with UL requirements and must have a brightness equivalent to that of the externally illuminated signs. U.S. Federal law (EPA 2005) limits each face of an exit sign to a maximum of 5 watts. Neither NFPA nor UL provide specifications for exit sign color, although many local jurisdictions do.

In Canada:

- CSA has no guidelines for externally lighted signs, but has mandatory contrast ratios for internally lighted exit signs.
- Only red exit signs are allowed.
- All signs must meet the CSA standard C860 specifying luminance, contrast ratios, letter size and font, and maximum wattage.

Exit sign retrofit kits should not compromise the electrical system. UL addresses standards for exit sign retrofit kits. One should make sure that the kit's listing is current and recognized by local regulatory bodies.

The following precautions should be followed:

- Verify the suitability of the retrofit kit for the exit sign and check the original manufacturer's recommendations.
- Some retrofits are UL listed for single face signs only.
- Some kits are UL listed for AC only. Not all kits can be used for battery backup signs.
- All supply wire connections must be made through lamp holders and not in the lamp compartment.
- Use the proper voltage lamp or lamp and ballast combination.

2.4.9 Vandalism Many interior and exterior locations require equipment that is safe from tampering and vandalism. Schools and certain outdoor lighting are examples of applications often requiring tamper-resistant equipment.

resistant equipment. Check to see if there are standards requiring vandal resistant lighting systems.

2.4.10 Manufacturer Warranties The mixing of various lighting components may nullify the manufacturer's warranty on one or more of those components, leaving the installer responsible for any resulting damage or failure. For example, installing a component that modifies the voltage or current may void the lamp and/or ballast warranties. Manufacturers list the operating conditions required for their equipment.

2.5 Commissioning

Commissioning of an upgrade project is much more than gathering punch list information. This process should involve verifying and adjusting the lighting system, including controls and sensors, so that it is actually working the way it was designed and adheres to the client's requirements.

Commissioning of upgraded lighting systems is a process for achieving, verifying and documenting that the performance of the lighting system meets design intent and the owner and occupant's operational needs. It may be advantageous to use a third party commissioning agent to ensure proper operation of the new lighting equipment. For detailed information, see *IES DG-29-11 Design Guide for The Commissioning Process Applied to Lighting and Control Systems*.

2.5.1 Luminaire Replacements and Upgrades

The commissioning process should include inspection and physical testing of luminaires, including functionality, ballast type and wiring, reflector installation, condition of lampholders, condition of lamps, illuminance measurements, lenses, fastening systems and overall cleanliness of luminaires. Special care should be given to louvered luminaires to ensure dust accumulation and oils from installers' fingerprints have been removed. This will aid in future recalibration procedures. Luminaire placement information should be gathered to ensure the accuracy of the as-built documentation that will be presented to the client upon acceptance of the project.

On certain applications it will also be necessary to aim and focus the upgraded luminaires to ensure the beam of light is directed properly, giving the desired illumination effect. It is also necessary to verify the performance of the emergency lighting system if affected.

2.5.2 Lighting Controls Lighting controls need adjustment after they are installed. Commissioning controls after installation is a necessary step to ensure the proper operation and functionality of

these units. The proper operation and functionality is typically defined by the controls intent documented in the project specification by the designer/engineer/architect. In addition, the manufacturer will provide installation and maintenance manuals that should be used for this purpose. Although commissioning does add cost to the installation, the benefit of prevention of occupant complaints and assuring stipulated savings will usually still meet the customer's payback requirements. People adapt well to controls that work; however, controls that are improperly adjusted and fail repeatedly will be circumvented, regardless of management mandates. Often occupants will bypass time controls to force lights on or they will place objects over the photocells. Other times they will alleviate these control issues by using table or floor lamps. This will result in reduced savings. Controls that are used in lighting upgrade projects are typically occupancy sensors. Daylighting Controls and Lighting Control Systems are occasionally installed when it makes financial sense, but they can increase the cost because of the additional wiring. Use of these systems is growing as wireless systems become more affordable and they are incorporated into building energy codes.

2.5.2.1 Occupancy Sensors The most prevalent control application during lighting upgrades is the installation of Occupancy/Vacancy Sensors. Location, orientation/field of view, time delay, and sensitivity are all important (for additional information, refer to **Annex C**, *IES LEM-7-13 Lighting Controls*, and *The IES Lighting Handbook, 10th Edition*). A minimum of a 15-minute time delay is recommended to balance energy savings and lamp life. To achieve a satisfactory commissioning of these sensors the installer should perform the following steps:

1. Check every device to ensure it performs its basic function. Most sensors have built-in test features to perform this task.
2. Check that the control meets minimum requirements.
3. Adjust the devices according to the manufacturer's specifications. Instructions and recommendations for settings are usually included with the devices. Most manufacturers have factory pre-sets for each feature of the device.
4. Gather occupants' feedback and make necessary adjustments. Be considerate of an occupant's concerns and make the necessary adjustment to devices to ensure a proper lighting environment for the individual.

In general, react quickly to erratic device behavior, failure or other problems.

2.5.2.2 Daylight Harvesting Daylight harvesting is an extremely efficient method of lighting a space. However with energy efficient lighting upgrades typically contingent on an ROI proposition, this may not fall into the ROI of the financially responsible organization.

Seldom is the original wiring in a space appropriate for daylight harvesting controls, consequently the space may have to be rewired. In addition, the added cost of dimming ballasts may not economically justify the project. Both of these examples will continue to change, as wireless technology becomes more common and the associated costs decrease. In either case, a thorough analysis, logistically and financially, will need to be completed and presented to the decision makers of the project.

Assuming you have overcome the financial constraints, maintaining the desired illuminance of a space whenever there is a contribution from daylight may involve anything from a simple photo control to a multi-scene, multi-zone dimming control installation.

2.5.2.3 Calibration of Daylight Harvesting Controls For continuous dimming systems this is a relatively simple task of calibrating the photocell to maintain the desired horizontal illumination on the task. This is most easily accomplished by following the manufacturer's installation instructions, which may vary based upon the type of photocell selected for the project. Take care to ensure there is a balance between horizontal and vertical illumination in the space, as most continuous dimming systems receive the majority of the daylight contribution from vertically oriented apertures.

For stepped dimming and on/off control of daylight harvesting systems, the calibration of stepping sequences should be done on site with management. Devices or systems with tunable set points facilitate this process as they can be adjusted over time incorporating user feedback. A single photocell can provide a single reading for the available daylight and the device or system can interpret that data and determine set points for various task zones. It is imperative to accurately map and index these zones to a base map so operators on site have a permanent document of the control zone wiring or network and various set points as well as target illuminance for various zones.

For more detailed information about daylight harvesting and control, see *IES RP-5-13 Recommended Practice for Daylighting Buildings*

and refer to **Section 3.1.1** for a detailed discussion of ballast types.

2.5.2.4 Zonal and Scene Controls The activities that take place in conference rooms and presentation rooms make them excellent applications for multi-scene dimming control systems as part of a lighting upgrade project. In a multi-scene, multi-zone dimming control installation, it is critical that the primary user of the space has input in determining the scenes and is available at the time of commissioning. A zone/scene dimming preset matrix should be developed and presented to the client as part of the as-built documentation. This should also include control operational schematics and programming instructions for on-site engineering staff for future modifications.

2.5.2.5 Lighting Control Systems Critical elements for a lighting control system include user-friendliness and adaptability. With the development of open software protocols, web access, graphical user interfaces and LAN/internet-based networking, actual long-term usefulness of the system is greatly enhanced and achievable.

An operator's manual for any control system installation should include zone mapping, operation schedules, photocell set-points, override authorizations, system password administration, affected circuits, and manufacturer's warranty and technical support information. The commissioning agent and process should be required to follow the steps in the operating manual to verify its accuracy and completeness.

2.5.3 Project Training and Documentation Communication and documentation, involving building occupants and maintenance staff, helps build consensus, reduces long-term maintenance costs, and ensures the energy savings are permanent. Use the operations and maintenance manual during training to verify its quality. This may help identify some points that need to be modified or additional information that would be helpful if added.

2.5.3.1 Project Training On-site instructional training about the lighting control devices and systems involves both building occupants and technicians:

Information for building occupants: Provide a simple explanatory letter delineating the multiple positive benefits resultant from the lighting upgrade. In documentation forwarded to administrative staff, include (as applicable) increased color rendering, reduction of flicker from ballast replacement, reduction of cooling load on the building and the positive environmental benefits. This communication builds consensus and ensures long-term permanence of savings.

On-site lighting technician training: At the beginning of the project closeout, provide a training meeting for the primary lighting technicians and/or maintenance staff that consists of a review of products installed, operating instruction for occupancy sensors, daylighting controls, lighting control systems, review of labeling schemes for ballast factor and voltage identification, and product warranties. Use the operation and maintenance manual as part of training as described above.

2.5.3.2 Equipment Warranties and Service Instructions Electronic ballast, lamp and control warranties are significant. If a follow-up service contract to handle lamp and ballast replacement is not in place after the lighting upgrade, inform the on-site technicians of warranty periods, hotline numbers, and replacement instructions. Documentation of purchase records should also be provided for all new equipment as it will assist with resolution of warranty replacements.

2.5.3.3 Project Documentation Consider the following user manuals and submittal packages to be components of the project documentation:

- Documents reflecting changes in scope from the original survey or what is known as an “As Built” report (or as-built documentation) - this generally entails making changes to a line-by-line, area-by-area, scope document. A spreadsheet is useful for formatting the final printed document. For more complex installations, floor plans of as-built conditions may be the most useful means of documentation.
- Site maps indexed to the scope of work - this is part of a professional grade lighting survey and scope of work. The site map should be modified with any changes during the actual construction and submitted as part of the project documentation. Existing plans, space plans or architectural background plans suffice for creating the original base map, which should have a unique identifying number for each area on the site.
- Summarized bill of materials and specification sheets - website links may not be adequate for the future, since websites change and products can be deleted. Instead, make a PDF electronic file incorporating scans or copies of individual cut sheets. Also, make a hard copy of all cut sheets to be kept in the project file.
- Manufacturers’ user manuals - these manuals are particularly important for lighting control systems from occupancy sensors to lighting EMS

(Energy Management Systems). Each piece of equipment that is user-adjustable should have its manual included in the project documentation.

- Manufacturers’ operation and maintenance manuals if different from the user manuals.
- Manufacturers’ warranty information.
- Hazardous material disposal documentation - some responsibility for hazardous material may remain with the owner; therefore, the owner should have documentation in hand if needed.

2.6 Service and Maintenance Issues

Whenever an upgrade is designed, service and maintenance issues, including life-cycle costing, should be a priority. Consider the issues and needs of the maintenance people who will have to order, stock and replace lamps and ballasts down the road.

2.6.1 Minimize Lamp Types Deployed Consider following these guidelines when upgrading a lighting system:

- Usually F20T12, F30T12, FB40T12 U-bend, F40T12, F48T12HO, F72T12, F72T12HO, F72T12VHO, F96T12, F96T12HO, and F96T12VHO, and some bi-axial lamps can be replaced with fewer lamp types using T8 or T5 systems.
- Halogen or compact fluorescent lamps can replace incandescent lamps; self-ballasted HID lamps may also be good options for some applications.
- Where LEDs are appropriate, compact fluorescent lamps (CFLs, halogen) or incandescent lamps can be replaced with LEDs. In some cases, LEDs may also be suitable replacements for linear fluorescent lamps.
- Avoid single source, uncommon, or hard to get lamps whenever possible.
- Do a comprehensive upgrade; remove any obsolete lamps from storage, thereby reducing the possibility of people replacing T12 or old T8 lamps in luminaires that have been upgraded and vice versa (“snapback”).
- Provide a small supply or attic stock of replacement lamps and/or a list of the lamps and ballasts used so the facilities/maintenance staff knows the correct items for a particular luminaire group; this helps avoid callbacks.