This chapter discusses the overall goals of building lighting operation and maintenance (O&M). It provides a number of practices and tips that can reduce lighting energy consumption while maintaining users’ visual comfort, productivity, and safety. Reducing lighting energy use can help reduce operating costs and the overall effects of electricity generation on the environment. Environmental benefits range from the local (lower pollution emissions from power plants), to the national (less dependence on fossil fuels and reduced impacts from their extraction and transportation), to the global (reduced emissions of carbon dioxide and other greenhouse gases).

Nationally, energy for lighting accounts for up to 22% of all U.S. electricity use. The lighting of offices, hallways, reception areas, and other spaces constitutes the largest use of energy in most office and commercial buildings—about 35%. This proportion increases even more when the energy needed to cool the heat generated by all the lighting systems and when electricity used for lighting outdoor parking and public areas are...
factored in. Yet, good lighting is essential to provide worker productivity and occupant comfort indoors, as well as to ensure visibility and safety outdoors.

The design, commissioning, operation, and maintenance of a building’s lighting need to be considered as an integrated, functional system to achieve maximum utilization and to control factors that affect system efficiency. Operation and maintenance practices for indoor and outdoor lighting systems must also be considered an important and integral part of the building energy efficiency equation. Newly available lighting and control technologies also require building lighting maintenance personnel to stay informed to get the most out of existing systems, as well as identify new technologies that can help improve O&M practices.

Building maintenance engineers and maintenance staff face a difficult task in trying to keep costs low while balancing occupant lighting needs with equipment efficiency. A building’s lighting quality has a direct impact on occupant satisfaction and may outweigh the cost of lighting, especially in public spaces. Similarly, a reduction in some public and outdoor area lighting may result in safety concerns, and can cast a negative light on all efficiency measures.

This chapter has guidelines to help you develop a combination of building O&M practices and schedules that works for your particular needs. Applying a combination of specific measures will best serve the building occupants’ lighting needs, maximize energy efficiency, and maintain the proper lighting levels and light quality where needed.

**LIGHTING AUDITS**

Lighting operation and maintenance practices vary widely. It is almost impossible to come up with a set of specific O&M practices that exactly fit all operations or buildings. However, before embarking on any modifications or upgrade, the PHA should conduct a lighting audit.

Audits are essential because a systems approach is preferable to a piecemeal approach and can yield better results. A systematic approach helps to identify and take advantage of easy efficiency measures offering very short payback periods, depending on the age and type of lighting equipment in service. Energy service companies, architecture and engineering firms, or utilities can conduct audits. They can also be done by qualified internal staff or maintenance engineers. The PHA should:
• Conduct a preliminary energy audit of lighting usage in all the buildings, as well as the outdoor spaces (at a minimum, focus on the public spaces). The audit should note the number and type of fixtures in use, their light sources (and lamp type/model/wattage), the light levels in various areas, how long the fixtures are on per day (and variations during weekends), and what controls are in use. A good lighting auditor can also note the placement and light distribution of fixtures and suggest changes if needed.

• Use the audit as a baseline, if one is not available, to monitor building energy use. An audit also helps to identify the types and quantity of devices not connected to any control systems, and whether or not they should be.

• Use the results from the audit to assess the savings potential of various efficiency measures so that they can be properly considered before implementation.

**INDOOR AREA LIGHTING OPERATIONS AND MAINTENANCE**

**Balancing Needs and Efficiency**

The building maintenance team must strike a balance between system efficiency and occupants’ visual and safety needs, which at times seem incompatible. This balance can be achieved by considering a range of factors, summarized below from broader to narrower focus:

• **LIGHTING NEEDS DIFFER ACCORDING TO TASKS OR AREAS:** Generally, the focus of lighting O&M should be to provide and maintain good, high-quality lighting for areas and tasks. Areas such as hallways require lower light levels than lobbies. Similarly, laundry areas require different light levels than corridors or stairs. Finding ways to provide occupants with comfortable light levels, instead of providing the same light level throughout the building, is the key to improving energy efficiency and maintaining comfort and safety. This practice not only can help to reduce a building’s lighting loads, but also reduce

**ACTION ITEMS**

1. Provide good, high-quality lighting suitable to occupant needs, and maintain adequate levels for public spaces without over-lighting.

2. Keep up with “regular” system maintenance, such as inspections, light level checking, fixture cleaning, and bulb replacement.

3. Use the most efficient light sources and fixtures feasible, switch off or reduce the amount of light in lower use areas where appropriate, and incorporate daylight.

4. Consider external factors that affect lighting levels and comfort, such as direct sunlight and the layout and paint color of spaces.

5. Review building energy performance and integrate user feedback on a regular basis to identify issues and ensure timely responses to them.
its cooling load substantially by reducing lighting heat build-up. It increases occupant comfort and reduces overall complaints regarding lighting levels.

- **“REGULAR” SYSTEM UPKEEP MANAGES ENERGY USE:** Maintaining “normal,” routine maintenance practices, as required by the buildings’ particular lighting systems and operation schedule, helps to manage energy use. Upkeep includes routine practices such as fixture cleaning, lamp replacement, and other measures such as testing and fine-tuning sensors. Generally, this is the best, simplest, and most conventional approach to maximizing energy efficiency in any building. Often, a poorly designed building with good O&M practices will outperform a well-designed building with poor O&M practices.

- **USING THE MOST EFFICIENT LIGHT SOURCES AND FIXTURES PROVIDES SAVINGS:** In addition to O&M practices discussed above, a number of relatively low-cost or no-cost, quick-return measures can help existing systems maximize their operating efficiency, increase efficiency, or reduce energy consumption. These measures range from using the most efficient light sources and fixtures available and affordable to you, to changes in operating procedures, to automating system settings. For example, installing occupancy sensors for low-use areas, automatic switching, activating day-light dimming, or de-lamping may yield additional savings.

- **EXTERNAL FACTORS AFFECT OCCUPANTS’ VISUAL NEEDS:** Often, occupants’ lighting levels and visual comfort needs are affected by other factors. For example:
  - Dark or dirty walls and floors reduce the amount of light available in any space.
  - Glare from south-facing windows affect occupants differently than occupants with north-facing windows during the latter part of the day.

These external factors will require different lighting strategies for public spaces such as lobbies and hallways. Blinds, window shades, film, timers or manual switches, and other measures may help to control the lighting loads in these different situations more effectively. Another consideration is that older occupants may require more light and need more individual or localized lighting solutions, such as reading lights.

Periodic or ongoing tracking and reviews of lighting (and building) energy performance complement routine O&M: Ongoing tracking and periodic reviews (monthly or quarterly) of lighting and building energy performance can complement routine O&M practices by providing both a feedback loop and an early-warning system, especially in mixed or residential areas, where systematic controls may not be possible or as easily accomplished. The tracking complements routine O&M practices by creating a baseline for building energy use to indicate
whether new or changes in routine affect energy use and user comfort. Tracking also identifies unusual changes in energy use pattern for further investigation.

**Lighting Level Recommendations**

As noted above different tasks and areas require differing light levels. It is better to provide high-quality light where needed, rather than high levels of light in all areas needlessly. The Illuminating Engineering Society of North America (IESNA) has determined a range of suitable light levels measured in foot-candles for certain indoor tasks. Nine categories cover typical office, institutional, and educational settings.

Five of the IESNA-recommended light levels for residential and mixed-use buildings are listed in Table 1. Many states have also incorporated American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Standard 90.1 into their energy codes. ASHRAE 90.1 requires new and renovated spaces to meet strict power densities and lighting control measures. Similarly, California’s Titles 20 (commercial buildings) and 24 (residential buildings) have very specific requirements for power densities and controls addressing various building areas.

Note that the IESNA recommended light levels do not distinguish the ambient light levels that are required for general illumination from the light level needed at the work surface. The opportunity for energy savings in some areas is that the ambient, or general, level of lighting can be lowered as long as there are sufficient light levels to meet the appropriate IESNA level.

**TABLE 1. COMMON TASK CATEGORIES AND RECOMMENDED LIGHT LEVELS**

<table>
<thead>
<tr>
<th>Application or Task</th>
<th>Recommended Illumination Levels (range in foot-candles)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Spaces</td>
<td>2–5</td>
<td>General or ambient lighting</td>
</tr>
<tr>
<td>Short, temporary visits or short visual tasks (for example, bathrooms, closets)</td>
<td>5–10</td>
<td>General lighting</td>
</tr>
<tr>
<td>Occasional visual tasks (for example, lobby)</td>
<td>10–20</td>
<td>General lighting</td>
</tr>
<tr>
<td>Visual tasks of high contrast or large size (for example, reception areas)</td>
<td>20–50</td>
<td>Required at work surface. Can be met with a combination of ambient/general lighting and task lighting</td>
</tr>
<tr>
<td>Visual tasks of medium contrast or small size (most office work fall into this and the above category)</td>
<td>50–100</td>
<td></td>
</tr>
</tbody>
</table>

Source: IESNA

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1 Chapter 10 of the IESNA Lighting Handbook contains a “Lighting Design Guide” that provides recommended levels for general application categories. The guide also provides a methodology for combining these recommended levels with other criteria to apply to light different tasks and locations.
Many fluorescent lighting systems put in place a decade or more ago provide too much light or provide low quality or inappropriate lighting for current use. For example, glare is a common complaint. These 10- to 15-year-old systems also tend to use more energy and produce excess heat. In addition, dark color walls and floorings, and dirt/dust in older or less well maintained buildings, “absorb” light levels, causing them to appear dark.

Strategies to bring these spaces into conformation with IESNA recommendations include:

- Bringing overlit areas to more comfortable levels through de-lamping
- Improving existing fixtures (through add-ons) to distribute and improve light quality
- Improving areas with poor quality lighting through re-lamping with appropriate lamp types
- Retrofitting or replacing existing systems with the most efficient luminaires
- Cleaning or painting interior walls with lighter colors to maximize the illumination level.

**De-Lamping**

Of the above measures, de-lamping is the simplest and yields improved energy savings along with visual comfort. This practice involves the removal of a lamp or lamps from multiple-lamp fixtures (for example, converting a 4-lamp 2 x 4 fixture to a 2 lamp 2 x 4 fixture). Areas that are typically overlit include public spaces, corridors with outside windows (in daytime), hallways, kitchens, storage areas, and meeting spaces. Even laundry areas can be overlit.

Following the IESNA recommendations also allows the ambient light levels in public areas to be reduced or turned off if sufficient daylighting levels are available. Where possible, lighting levels in areas such as interior hallways (where no natural light is available) can also be reduced, yielding additional savings. If you choose to practice de-lamping, remove lamps in a uniform fashion to eliminate “dark spots” and ensure that the remaining light levels are sufficient for the tasks or occupants. In addition, de-lamping is most effective when the remaining lamps and ballasts are still matched. Depending on the existing wiring, some ballast can consume as much energy with a partial load as with a full load. Additionally, de-lamping can be effectively combined with a campaign to clean or paint interior walls with a lighter color in order to maximize the illumination level and occupant comfort.

Applying measures other than re-lamping ideally requires the services of qualified lighting experts who can address both light distribution and quality
In addition, depending on the scale, replacement of existing systems can also require compliance with energy codes governing energy use and lighting installations for new and retrofit facilities. Finally, user interaction and feedback provides some indication of light levels and quality. Complaints such as glare or flickering can indicate too much light or poor quality light. Working with users can help increase understanding and acceptance of implemented measures.

A NOTE ABOUT LEED: The U.S. Green Building Council’s Leadership in Energy and Environmental Design (LEED) program has certification programs for both new developments and existing buildings, including LEED O&M. If your building(s) have been LEED-certified, they need to be operated based on the operational procedures under which they were certified. Conversely, your existing building can earn LEED certification for its O&M practices. LEED O&M certification includes requirements for strict energy management practices and lighting controls, including manual and automatic switching requirements.

LIGHTING CONTROLS

Lighting Schedules

The implementation of regular building-specific or even area-specific lighting schedules saves energy in buildings where occupants keep fairly regular hours. The following strategies can also be incorporated in a building’s lighting schedule to further increase lighting energy savings:

- **MANUAL SWITCHING:** The easiest way to save energy is to switch off energy-consuming equipment when not needed. Lights that can be shut off during unoccupied hours should be shut off promptly. Where zone control is available, lighting in unoccupied zones can be shut off with no loss to occupant comfort or safety. “Zoned” systems can provide better control of building lighting during both day and evening hours.

- **TIME SCHEDULING:** Large, open areas (for example, lobbies or public areas) tend to work well with simple time scheduling—regular, automatic switching of lights at fixed hours of the day (for example, off or dimmed during the day if daylight is available). Generally, maintenance crews can carry out time-scheduling if more sophisticated computer controls are not avail-

<table>
<thead>
<tr>
<th>ACTION ITEMS</th>
</tr>
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<tbody>
<tr>
<td>1. Use time scheduling to match lighting to usage hours.</td>
</tr>
<tr>
<td>2. Use natural daylight and dim or switch off interior lights as appropriate.</td>
</tr>
<tr>
<td>3. Set infrequent and less intensive use areas to lower lighting levels.</td>
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</tbody>
</table>

2 Such services may be available from the local utility.
able. Time-scheduling controls should be set so that the switching times and intervals serve the needs of the occupants and usage pattern of the area. In addition, occupants need to be informed about the system and how to override the schedule when needed. Adjusting the on-off schedule to account for seasonal changes and available natural light can also yield incremental savings.

- **EMS:** Energy Management Systems (EMS) are often used to control HVAC systems but can also control lights. If lighting is not already integrated into your existing EMS, check whether or not it could be used in low-use or work areas (for example, loading docks). If you are in the process of purchasing a new EMS, consider the addition of lighting control options.

- **DAYLIGHTING:** Natural daylight can be used to great benefit and allows interior lights to be dimmed or switched off when appropriate. Natural daylight consumes no electricity and produces less heat than any electric light source, so the careful use of daylight can reduce air conditioning costs as well as lighting costs. Simple O&M practices can include such manual measures as adjustable blinds and individual light switches to maximize the use of daylight. Available automatic dimming systems can be used to maintain the proper light levels automatically. In addition, reflective film may be used to control intensity and glare, especially on east- and west-facing windows.

### ACTION ITEMS

1. Use sensors to switch lights off or to lower light levels when and where possible.
2. Set sensors to avoid “false-offs,” watch for non-human sources of motion that can trigger sensors, and inspect regularly for user overrides to the sensor settings.
3. Keep clear and accurate diagrams with marked areas of sensed zones, distinguishing high- and low-sensitivity areas.
4. Be aware of equipment that uses radio frequencies or emits infrared signals, which may affect sensor settings.
5. Set sensors to fail on the “on” position in dark areas.

### Occupancy Sensors

Simple occupancy sensors are the most common lighting control measures in buildings today, and some state building codes (for example, Title 24 in California) require them. Sensors located throughout a building can help maximize the energy savings potential of infrequently used areas. Some sensors allow for both temperature and occupancy detection, and can be the basis of an automated setback system for both lights and HVAC in public spaces.

There are two main occupancy sensor technologies for lighting:
• **INFRARED (IR):** IR (also known as passive infrared, or PIR) sensors detect temperature changes in a room. PIR sensors are very resistant to false triggering, but tend to be reliable only within a short range.

• **ULTRASONIC (US):** Ultrasonic sensors use high frequency sound to detect motion, even around corners. US sensors can cover larger areas than PIR sensors and are more sensitive, but they are also more prone to false triggering.

There are also dual-technology sensors that combine both technologies or use acoustic sensors, increasing accuracy and flexibility, but they are more expensive.

Sensors work best in areas with low occupant densities, such as meeting rooms, hallway, laundry rooms, warehouses, loading areas, and storage spaces. Sensors pay for themselves through energy savings. Even though lamp life may be somewhat shortened by increased on-off switching, the overall life of lamps is usually extended by the reduced daily burn hours.

When setting up and using sensors, building staff should:

• Be aware of false sources of sensor triggers, such as air diffusers or curtained windows.

• Be aware, too, that radio frequencies such as remote controls or other emitters may affect sensor settings.

• Set sensors to fail to the “on” position in dark areas to avoid creating dangerous conditions.

• Inspect sensors on a routine basis to account for user overrides.

• Keep clear and accurate diagrams with marked areas of sensed zones, distinguishing high- and low-sensitivity areas.

As with any automated controls, maintenance practices must ensure that the sensor controls are operating properly. The proper installation and maintenance of daylight and occupancy sensors is an essential O&M task. Placement of sensors should take into account furniture placement and the geometry of the space as much as possible, as occupancy sensors need to sense all occupants to avoid turning off lights while the space is occupied. At the same time, “false-on” incidents can be triggered by an automatic on/off sensor that senses passersby in an adjoining hallway if the settings are too sensitive. Sensors with too low a sensitivity or too short a delay time can annoy occupants.

Lights in bathrooms or other infrequently used areas are frequently left on for extended periods, either due to forgetfulness or deliberately to serve as night-lights (especially by seniors and in living centers, nursing homes, etc., as well as residences with younger children). They can be a significant source of lighting.
energy use. The nightlight function is generally useful in all residential housing, but especially critical for seniors, for whom tripping and falling is a serious concern. Managers have been reluctant to use occupancy sensors in these areas because the controls can switch off lights if occupants remain motionless for long periods.

For these cases, an option is a combination “nightlight” and occupancy sensor. Recently introduced from a concept developed by the California Lighting Technology Center, these systems combine LED-based nightlights with occupancy sensors. The LED-based lights provide sufficient illumination to assist occupants in the transition from light to dark, and then switch on the appropriate light when occupants enter the space or resume movement. These systems address concerns about lights turning off in areas where occupants tend to remain inactive for long periods, and can reduce lighting energy use in these areas by 50 to 75%.

LAMP REPLACEMENTS AND BULK PURCHASING OF LAMPS AND LUMINAIRES

This section covers both routine replacement of lamps in service and replacement of existing lamps with more energy-efficient options. In addition to color rendering and color temperature (both of which can affect lamp/lighting system performance and user satisfaction), the two most important environmental characteristics of linear fluorescent lamps are:

- **LAMP LONGEVITY**: Most linear fluorescent lamps last for a long time. However, a number of factors affect system performance and reduce lamp life. The selection of a durable system not only ensures that less solid waste will be introduced into the environment, but also it means that the components have been tested for use as a system, thus ensuring user satisfaction and reducing failure incidents. Systems with rated lamp life of 20,000 hours or more should be considered.

**ACTION ITEMS**

1. Set a regular inspection schedule and a replacement schedule for lamp replacement in common areas (at a minimum).
2. Select replacement linear lamps with a minimum of 20,000 hours rated life.
3. Use fluorescent lamps with low mercury content (3.8 mg per 4-ft lamp or less).
4. Use CFLs (compact fluorescent lamps) instead of incandescent bulbs.
5. Replace existing lamps with more efficient equivalents.
6. Use specifications for bulk purchasing to obtain the appropriate lamps.
• **LAMP MERCURY CONTENT:** All fluorescent lamps contain a small amount of mercury, which is necessary for their operation. We recommend that you select lamps with the lowest mercury content for your particular application. Maximum lamp mercury level should not exceed the State of California’s requirements, which is 3.8 milligrams per 4-ft lamp. Manufacturers are required to state whether or not they meet this requirement, or indicate the amount of mercury contained in the lamps in both catalogs and consumer packaging information.

## Routine Replacement of Existing Lamps

If your O&M practice involves individual replacement of fluorescent lamps (especially linear tubes) as they burn out, consider switching to replacement of all lamps or all lamps of the same type at once on a set schedule, based on the lamp types in use and their rated hours. However, if group replacement is not an option in your maintenance schedule, consider adopting or incorporating other maintenance tasks into the replacement routine, such as fixture cleaning and ballast inspection, to maintain light output and keep fixtures at peak performance.

In general, it is best to develop specifications for replacement lamps to avoid having many different replacement lamp types in stock and/or different lamp types or color/performance in use at the same facility (or in the same fixture). Even if you replace lamps individually, it is better to purchase them in bulk with predetermined lamp specifications to obtain the best performing lamps for your needs, rather than depend on a distributor or dealer’s stock at any moment.

Reasons to consider switching to group lamp replacement include the following:

• **COST:** Group relamping costs less on a per-lamp basis. To replace one individual fluorescent tube (or CFL) takes a maintenance worker as much as 30 minutes or longer from start to finish. Having materials on hand and systematically moving from one fixture to another reduces the per-lamp replacement time to about 3 to 5 minutes. The replacement process can be done at a suitable time for occupants to minimize disruptions.

### ACTION ITEMS

1. Inspect building for lamp failures on a periodic basis (monthly or longer, depending on the types of lamps in use).
2. Do not wait for complaints from users.
3. Set up a maintenance request system for occupants to report lamp failure.
4. Inspect ballasts and perform other maintenance (such as cleaning) on a regular basis.
• **SCHEDULING:** Group replacement is an easy task to schedule, and can even be handled by an outside contractor. This can reduce costs and the need for dedicated staff time for lamp replacement.

• **EFFICIENCY:** Other maintenance activities can be incorporated into the replacement process, such as ballast inspection, as well as reflector and diffuser inspection and cleaning. It also provides an opportunity to upgrade reflectors, install lenses, or other servicing tasks.

• **CONTROL:** Group replacement provides better control over replacement lamps, since the same types and color lamps will be used. It helps to reduce instances of incompatible lamps, or mixtures of lamps of different color temperatures and color rendering indices, which affect user comfort.

• **IMPROVED LIGHTING:** Group relamping can provide users with brighter and uniform light levels, because it reduces the chances of lamps reaching their end-of-life characteristics or lumen depreciation curve. It also reduces user complaints (flickering lamps) and on-the-spot maintenance calls.

• **BETTER SELECTION:** Group relamping allows for purchasing in bulk to obtain the best lamps for your needs, rather than purchasing individual replacement lamps and settling for what is available because they are needed immediately.

Note that you can typically calculate group relamping intervals, but the exact burn hours and lamp life usually are not known with enough accuracy. Thus, some organizations use a simple method of determining when to re-lamp: When group re-lamping, they buy 10% more lamps than are needed to re-lamp the area. The use of this 10% overstock is limited to spot relamping only. When they have depleted the 10%, this indicates that it is time to group re-lamp again. This method typically results in group relamping at about 70% rated lamp life.

### Selecting Lamps for Efficiency

One of the most cost-effective lamp replacement strategies is to replace existing lamps or lamp systems with a more energy efficient (and longer lasting) equivalent or to take higher energy-consuming lamps or systems out of service. As a rule, replacing both indoor and outdoor sources with the most efficient light sources possible without compromising user comfort and safety, while limiting the lighting operating hours, yields the most energy savings.

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3 Many utilities offer financial incentives for the replacement of lamps with more efficient equivalent, or for efficient upgrades of lamp-ballast combinations. Details can typically be found on the utility’s website or other information venues.
For office and other commercial/institutional spaces, this strategy often involves replacing linear fluorescent lamps and lamp systems with more efficient alternatives (such as converting from T12 to T8 or T5 lamps and/or magnetic to electronic ballasts), and replacing incandescent lamps with CFLs, both of which are briefly covered below. Note that the most inefficient incandescent lamps are being gradually phased out of the market starting with the 100W incandescent lamp in 2011 in California and in 2012 for the rest of the country.

The efficiency measure of a light source is termed “efficacy” or “luminous efficacy” and is the ratio of luminous flux or light output (measured in lumens) to input power (measured in watts). Figure 2 compares the efficacy of various light sources available on the market today in terms of lumens per watt. Note that care must be taken to apply the most efficient sources to the right application. High pressure sodium, for example, is an extremely efficacious source, but provides very low light quality, especially for visually demanding tasks.

**CFLs**

The cost of CFLs has dramatically dropped, as have lamp sizes, making CFLs the most cost-effective incandescent alternative today. CFLs are now available in a variety of shapes and sizes to fit most incandescent fixtures. Using the “1/3 or 1/5 to 1” rule for CFL replacement wattage (use CFLs that are 1/3 to 1/5 the wattage of the equivalent incandescent lamp, depending on lamp types) should provide the space previously served by incandescent lamps with the same, if not more, light. Replacement of incandescent lamps with CFLs will dramatically reduce the energy consumption of any space.

At a minimum, look for CFLs that carry the USEPA/DOE’s ENERGY STAR label, which have met certain performance requirements such as efficacy, lamp life, and UL/safety testing. If you are able to specify CFLs through a PHA procurement contract, choose CFLs with:

- electronic ballast
- 10,000 hours rated life or more
- illumination within 1 second
- minimum color rendering index (CRI) of 80
- mercury content of 3 mg or less.

The chart below provides the most common incandescent equivalencies and minimum CFL efficacy (lumens per watt is defined as the amount of light output for the amount of power input) for bare lamps.

Another alternative is to take incandescent lamps out of service completely. If you have spaces where the ambient light levels are provided by incandescent downlights (also known as “cans” or “high hats”), such as hallways, meeting rooms, and bathrooms, consider taking these fixtures out of service and installing fluorescent fixtures in their place. While downlight fixtures can accept the newer generation of CFLs, the design of these fixtures tends to shorten the service life of CFLs due to heat build-up. CFLs used in these fixtures also suffer performance and optic problems such as glare, and can result in user discomfort. However, if you choose CFL reflector type bulbs, use the above criteria suggested for life, mercury content, and color quality. The chart at left will help with your selection.

One more consideration regarding CFLs is their use in enclosed fixtures. Ensure that the lamps intended for enclosed fixtures (with little or no ventilation options) are suitable for this application, by verifying with the distributors or manufacturers. CFLs not intended for use in enclosed fixtures can suffer significant light loss or shorter useful service life when used in these situations, leading to user complaints and frequent replacements.

**Halogen Lamps**

For applications that CFLs cannot fulfill, such as on a dimming circuit or spot lighting, replacing incandescent lamps with halogen equivalents yields modest savings in some applications. Where available, coated, infrared (IR) halogen lamps are typically the most efficient type available, and can be up to 20% or more efficient than incandescent lamps of the same type. However, rooms lit
with halogen lamps usually require more fixtures and use more energy than rooms lit with fluorescent lamps and can generate a lot of heat. Because halogen lamps are intended to be used as spotlights rather than for ambient lighting, they should not be the only illumination in a room, as they tend to have less even light distribution in addition to high energy usage.

**Light-Emitting Diodes**

Recently, light-emitting diode (LED)-based lighting products have appeared on the market, with a number of models specifically targeting incandescent or halogen reflectors. LED lighting technology produces light in a whole new way, and the market is rapidly evolving. LED is rapidly approaching the quality and efficiency of existing lighting technologies, such as fluorescent and incandescent—but not all LED lighting is created equal.

While these products may offer sizeable wattage reduction and possible energy savings, it is important to keep in mind that as of October 2010, testing by the U.S. Department of Energy’s CALiPER program showed that many models on the market cannot deliver the light output, quality, and concentration (known as “center beam candle power”) needed to adequately replace a halogen or incandescent reflector lamps (known as PAR or BR lamps) nor can they maintain their claimed output and lifetime. The testing also showed that very few models on the market now can deliver the light output, quality, and distribution to adequately replace any halogen reflector lamps, nor can they match halogen reflector lamps’ claimed output and even lifetime.

The same selection rule for CFLs should be applied in selecting LED-replacement lamps: that is, at a minimum, the product must meet the requirements of the ENERGY STAR program for solid-state lighting (SSL) products. In addition, the high costs of the qualified replacement lamps currently available tend to make them more economic for new installations, not for retrofit or replacement.

**Linear Fluorescents**

**LINEAR LAMPS.** Fluorescent tubes have also seen steady technological improvement. Advances have added to the recent efficiency improvements made possible by electronic ballasts and better phosphor/lamp technologies. Lamp lifetimes have also improved. The more modern electronic ballast, matched with an efficient fluorescent tube, can reduce energy costs as much as 50% compared to older magnetic ballasted systems. The amount of mercury needed in each lamp has also been reduced significantly.

One of the most common ways to save significant lighting energy in most (older) buildings is upgrading existing T12 lamps with magnetic ballasts to T8
or “super T8” lamps with electronic ballasts. The most common lengths for T8 lamps are 4 and 8 feet, although T8 lamps are available in 2, 3, 5, and 6 feet lengths as well. T8s lamps are also available as u-tubes. U-tube lamps are available in both 6-inch and 3-5/8-inch leg spacing and have an overall length of 22 inches. Where possible, lamps and ballasts should be selected as a matched set.

A new generation of fluorescent tube technology—the T5 lamp—has recently been introduced for general lighting use, but due to their unique size, length, and luminance, T5 lamps are better for new than retrofit installations. T5 lamps come in metric lengths, and the lamp holders are generally smaller and incompatible with T8 and T12 holders. T5 lamps are slightly more efficient than T8 lamps, but have substantially higher luminance, which can cause glare problems in existing installations. T5 lamps are often used for indirect lighting or in shielding or lensing applications, and are also ideal in high-ceiling applications, such as high-bay fixtures for maintenance shops, gymnasiums, and warehouses.

BALLASTS. Magnetic ballasts, found in a T12 fixture, are less efficient, noisier, and heavier than the electronic ballasts in T8 fixtures. The costs of electronic ballasts, like the cost of CFLs, have decreased dramatically, making them much more affordable. In selecting replacement ballasts, consider:

- **BALLAST FACTOR:** In applications, fluorescent lamps generate less light when operated on a commercial ballast than they do on the laboratory reference ballast used to establish the lamp lumen ratings listed in lamp manufacturers’ catalogs. The ballast factor is the ratio of a lamp’s light output for a given ballast and fixture combination, compared to the lamp’s rated light output with a reference ballast. A lower ballast factor means less lumen output. Electronic ballast factors range from about 0.7 to 1.2, with a ballast factor around 0.9 being the most common. The ballast factor can be multiplied by a lamp’s rated lumen output to determine actual light output. Note that a low ballast factor does not necessarily mean that the efficiency of a fluorescent fixture is worse, because the input power to a fixture will also decrease with a lower ballast factor. In retrofit applications, choosing the appropriate ballast factor can help achieve the desired lighting level without resorting to the replacement of the entire fixture.

- **STARTING METHOD:** Another important parameter of fluorescent systems is the starting method. T8s are typically equipped with rapid-start or instant-start ballasts. Rapid-start ballasts heat the electrodes quickly and then apply a starting voltage to create the arc and begin the illumination process. There is a slight delay of 1 second or less with rapid start ballasts before the lamp begins to illuminate. Rapid-start

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4 Linear fluorescent lamps are specified by diameter size in 1/8ths of an inch. A T8 lamp is a 1-inch diameter lamp and a T12 lamp is a 1.5-inch diameter lamp.
ballasts continue to heat the electrode even after the lamp has started, which typically results in a power loss of 1.5–2 Watts per lamp.

Instant-start ballasts allow the lamp to start without delay by applying a high initial voltage and instantly creating an arc across the electrodes. Instant-start ballasts have the lowest power losses but can decrease the life of the lamp because of degradation of the emissive coating on the electrodes from the high starting voltage. Typically, lamps operating with instant-start ballasts will withstand 10,000–15,000 switch cycles compared to 15,000–20,000 switch cycles for rapid-start ballast.

Generally, the selection of new lamps, especially replacement lamp-ballast systems, should be done in consultation with experienced assistance in order to maximize savings and performance potentials. Your facility’s lighting use will determine the lighting levels required, and therefore the equipment you need. Below are some general guidelines to assist in the selection process. To ensure the efficient lighting energy performance, the fluorescent tube must match the ballast.

**General Lamp/Ballast General Replacement Recommendations**

- Choose T8 lamps and electronic ballasts where both lamp and ballast replacement is feasible. (Choose “super T8” for applications requiring higher lumen output for higher ceilings or dusty areas, for example).
- Choose replacement lamps with the lowest mercury content available for your application (3.8 mg of mercury or less per 4 foot lamp).
- Select replacement linear fluorescent lamps with 20,000 hours rated life or more.

**Ambient Lighting General Replacement Recommendations**

In addition to the general lamp/ballast recommendations, also consider:

- A 2-lamp in a 2-by-4 foot troffer (grid-like reflector) luminaire is suitable for most applications. Most 4-lamp fixtures can be de-lamped to this configuration.
- For areas where visual tasks are regularly performed (offices, reception areas), parabolic troffers are generally better than lensed troffers for better glare control, and should be kept in use where task lighting is not available.

**Replacing linear fluorescent with LEDs**

**SELECTING LEDS REPLACEMENT LAMPS.** As in the case of LED-based reflector lamps discussed earlier, LED-based linear fluorescent replacement lamps are
also available. And as in the case of LED-based reflector lamps, it is important to note that as of October 2010, testing by the US Department of Energy’s CALiPER program has shown that very few models on the market can deliver the light output, quality and distribution needed to adequately replace any linear fluorescent lamp, or can maintain their claimed output and lifetime.

Note that some “replacement” lamps require disconnecting or bypassing the existing ballast, potentially adding to the installation costs and maintenance confusion. The same selection rule for CFLs and LEDs should be applied here—at a minimum, these product must meet the requirements of the ENERGY STAR program for SSL products, and demonstrate their lighting and lifetime performance qualities with test results rather than marketing claims.

**Exit Signs and Emergency Lighting**

**EXIT SIGNS.** While individual exit signs do not consume much electricity relative to other lighting fixtures, a building has many exit signs, and they are on 24 hours a day. As a category, they may account for a significant portion of building electricity use depending on how they are lit, and therefore deserve some consideration during a lighting survey or maintenance routine. Commercially available exit signs use incandescent bulbs, CFLs, or LED arrays as light sources.

Due to their low consumption, LED exit signs can be purchased with built-in back-up power supplies (i.e., batteries). With an estimated service life of 10 years or more, LEDs require significantly fewer lamp replacements than exit signs equipped with either incandescents or CFLs. Non-electrically powered photo-luminescent (PL) exit signs utilize a glow-in-the-dark material to provide illumination. While PL exit signs do not require a direct connection to a source of electrical power to operate, they must be charged by another light source in order to function properly. Therefore, PL exit signs are not suitable for all applications.

The use of exit signs with incandescent light bulbs should be discontinued immediately. The Energy Policy Act of 2005 required a new minimum federal efficiency standard for electrically powered, single-faced exit signs with integral lights. All exit signs manufactured on or after January 1, 2006, must have an input power demand of 5 watts or less per face.

**EMERGENCY LIGHTING.** Safety product maintenance can be a time-consuming and expensive part of operation and maintenance, with codes requiring system testing every 30, 60, or 90 days. Energy-efficient and sources such as CFLs and LEDs can now provide long-lasting, energy-efficient emergency lighting that offers reliability and requires less maintenance and less battery draw from back-up sources. These new systems may also offer self-diagnostic features to monitor battery voltage, lamp continuity, incoming utility power, and unit performance on a regular basis.
**FIXTURE AND LAMP CLEANING**

O&M managers should consider developing and implementing a maintenance action plan that include both regular cleaning and relamping to achieve the full range of benefits generated by well-maintained lighting. Develop a lighting system maintenance policy and review it with your maintenance team to ensure they use the correct lamps and ballasts and that they clean and maintain lighting system and sensor components properly.

### Benefits of Regular Cleaning

The routine cleaning of lamps and fixtures is one of the most important (and sometimes, most neglected) tasks in lighting O&M. All light sources used for interior lighting lose their ability to produce light as they age. Light levels from fluorescent systems can decline gradually over a period of months, due to dust accumulation and system decline. This condition is more noticeable with fluorescent systems due to their longevity. The term "lamp lumen depreciation" (LLD) describes this phenomenon. The values of LLD, also called lumen maintenance, vary between lamp types and manufacturers.

Generally, the LLD characteristics of T8 fluorescent lamps are better than those of T12 lamps, as the newer lamp types with rare-earth phosphor tend to lose less light output over time. The T8 lumen depreciation curve tends to level off as it reaches its low point at about 90%, instead of continuing to depreciate as the T12 does. In addition, new T8 HO (high output) lamps have especially good lumen maintenance. Figure 3 compares light output over time for different linear fluorescent lamp types.

Because of the light from both LLD and poor maintenance practices, lighting designers typically plan for more fixtures and...
bulbs than needed to ensure sufficient light levels. Therefore, a good maintenance plan that includes routine cleaning alone can justify the de-lamping of some spaces. Typically, the money saved in energy and lamp costs from de-lamping can more than pay for the regular fixture cleaning and relamping practices, depending on the size of the facility. Lamp cleaning practices are simpler today, as buildings tend to be less dusty, especially in facilities in which smoking is limited to designated areas.

A number of sources of dirt and dust remain even in non-smoking buildings, especially in kitchens and laundry areas. These areas are often overlooked, but they greatly contribute to the amount of dust and dirt generation. Clothes dryers release fine dust that can coat fixture surfaces. The most effective solution is to move these types of equipment to an area with a separate exhaust.

Replacing incandescent lamps with CFLs can significantly extend maintenance periods, but can allow more dust and dirt to accumulate on fixtures between replacements. Therefore, the routine cleaning of lamps and fixtures that have been retrofitted with CFLs should be part of the overall maintenance routine. At a minimum, fixtures, covers/reflectors, and lenses should be cleaned when lamps are replaced. Depending on where the CFLs are used, more frequent cleaning may be required for high use/high dust areas such as laundry areas, bathrooms, and kitchens.

### Cleaning Methods

It is recommended that the lamp-replacement crew clean the interior reflecting surfaces of fixtures when lamps are changed. In some environments (such as offices), fixtures may need to be cleaned before the lamps are replaced, but in most interiors, cleaning at lamp change intervals (for group relamping) may prove to be adequate.

Generally, cleaning fixtures and lamps does not require harsh chemicals or volatile cleaning solutions. Fixtures usually require a simple dusting of the interiors, as well as the dusting of lamps, depending on your cleaning and re-lamping schedule. Below are recommended environmentally safe fixtures and lamp cleaning practices:

- Clean fixtures and lenses at every relamping, and replace lenses whenever ballasts are replaced.

<table>
<thead>
<tr>
<th>ACTION ITEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Turn off all lamps before cleaning. Turn off power to the whole circuit where possible.</td>
</tr>
<tr>
<td>2. Clean lamps and fixtures with a soft, moist (to prevent static) cotton cloth.</td>
</tr>
<tr>
<td>3. Keep turning the cloth to present a clean surface as the cloth becomes dirty.</td>
</tr>
<tr>
<td>4. Avoid using disposable cleaning materials such as paper towels. Other acceptable re-useable cleaning devices include soft-bristled brushes with anti-static material or a low-powered hand vacuum.</td>
</tr>
<tr>
<td>5. Clean both sides of acrylic lenses with a mild solution of dishwashing detergent and allow to air-dry.</td>
</tr>
<tr>
<td>6. Use an environmentally safe laundry fabric-softener in the rinse water to reduce static electricity where needed.</td>
</tr>
</tbody>
</table>
• Unusually dirty fixtures or multi-celled, metal parabolic louvers may need to be professionally cleaned with an ultrasonic machine.

• Lamp and fixture cleaning can typically be done with soft, moist cotton cloth, which needs to be continually turned to present a clean surface as the cloth becomes dirty. Care should be used to keep the cloth moist, thereby avoiding the building up of static electricity, which will re-attract dust. Other re-useable cleaning devices (such as a soft-bristled brushes with anti-static material or low-powered hand vacuum) can and should be used instead of disposable materials.

• Most fixtures’ acrylic lenses can come clean with a mild solution of dishwashing detergent, while glass covers can be clean with diluted vinegar or other mild glass cleaners. Both sides of the lens should be rinsed and allowed to air-dry. (A dirty lens can reduce a fixture’s light output up to 50%).

• Static electricity can be a problem in attracting airborne dirt for some fixtures. The use of an anti-static material, such as an environmentally safe laundry fabric-softener in the rinse water, is a possible solution where static electricity is a problem.

There can be some resistance to cleaning practices when electricians or maintenance crews are asked to clean lamps and fixtures instead of custodial workers. Usually, electricians can be put towards more productive tasks than changing lamps or cleaning fixtures. In addition, custodians who are tasked with relamping may be more likely to clean fixtures properly.

**DEVICES BROUGHT IN BY OCCUPANTS**

High on the list of “external factors” that affect lighting and energy use are devices brought in by building occupants to help them deal with variable lighting conditions at their locations. These devices range from desk lamps to incandescent and halogen torchieres (up-lights) and other lighting fixtures for lighting larger areas. At best, these devices help provide occupants with the additional light needed for their tasks, and at worst, become

**ACTION ITEMS**

1. Pay attention to the presence of extra lighting brought by occupants, which indicates additional lighting needs.

2. Watch for fire hazards (and energy wasters) in the form of halogen torchieres (up-lights) and other high-wattage lamps.

3. Negotiate an agreement with all occupants where they can choose from a variety of energy-efficient desk, task, or general lighting options to meet their needs.

4. Set guidelines for supplemental fixtures (maximum wattages, safety ratings, lumen output, etc.).

5. Consider providing CFLs for most of occupants’ devices.
a nuisance, if not a fire hazard, as in the case with halogen torchieres.\textsuperscript{5} In general, most people require more light as they age.

However, if the goal of O&M practices is to minimize building energy use, these additional fixtures have the potential to wreak havoc with system settings and other reduction measures, resulting in an increase in the building’s energy consumption, instead of reducing it.

To maximize savings, one approach is to negotiate an agreement with building occupants, where they can choose from a variety of energy-efficient desk, task, or table lighting to meet their needs. In exchange, the building’s lighting levels can be set to take these devices into account. A pilot program can identify the devices that work well for occupants and the lighting levels that they need. Guidelines can also be set for supplemental fixtures (maximum wattages, safety ratings, lumen output, etc.) during these pilots. If needed, the pilot program can also familiarize occupants with CFLs before wholesale replacement.

Overall, there are opportunities in reducing energy consumption if these devices are taken into account, rather than ignored. In addition, the involvement of the building occupants in the pilot and decision-making process often makes the process work better, resulting in maximum energy savings.

**OUTDOOR, EXTERIOR, GARAGE, AND PARKING LOT LIGHTING MAINTENANCE**

**ACTION ITEMS**

1. Use daylight controls or photo sensors to turn off lights whenever adequate daylight is available. Inspect and test sensors regularly. Turn off all unnecessary lights.

2. Use energy management systems and time clocks to limit operating hours.

3. Check system setting and adjust time clocks with time of year to minimize operating hours and maximize savings.

4. Adjust timer switches and sensor to turn on non-essential or non-security lights for only short duration (loading docks, for example).

5. Clearly label all switching devices to save time and help employees identify which lights should be shut off at specific times.

6. Check and adjust fixtures so that lights are aimed where needed

7. Use incandescent sources only if they are integrated with a control mechanism that significantly limits the time that they operate.

Effective outdoor and exterior lighting design incorporates careful consideration of many variables, such as overall visibility, safety and security, and energy efficiency. Other outdoor lighting concerns may also need to be evaluated depending on the location and type of application. Most often, there will be concerns with a combination of issues, listed in Table 2, which arise from a combination of poor design and overuse of outdoor and exterior lighting.

\textsuperscript{5} Note that the Energy Independence and Security Act (EISA), as well as other federal and state regulations, banned halogen/incandescent greater than 190W.
### TABLE 2. OUTDOOR AND EXTERIOR OVER-LIGHTING ISSUES

<table>
<thead>
<tr>
<th>Issue</th>
<th>Description and Cause</th>
<th>Ways to Minimize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glare</td>
<td>Glare occurs when a bright source causes the eye to continually be drawn toward the bright image, or the brightness of the source prevents the viewer from adequately viewing the intended target. Glare may create a loss of contrast or an afterimage on the retina of the eye reducing overall visibility.</td>
<td>Equip luminaires with louvers and/or exterior visors to prevent viewing a bright source at lower angles. Luminaire shielding, or “cut off” luminaires (luminaires with specific light output patterns), can prevent the direct image of a bright source and lower the intensity of the light at high angles and direct more light downward. The use of quality prismatic or opaque lens materials can reduce the brightness of the source.</td>
</tr>
<tr>
<td>Light trespass</td>
<td>Light trespass occurs when neighbors of an illuminated space are affected by the lighting system’s inability to contain its light within the area intended. The inappropriate selection, tilting, or aiming of outdoor luminaires for the particular lighting task causes light trespass.</td>
<td>Minimize light trespass through careful selection of lamp wattage, luminaire type, and placement. Appropriate reflector selection, aiming, and shielding of the luminaires can keep the projection of the light within property boundaries.</td>
</tr>
<tr>
<td>Sky glow</td>
<td>Sky glow is the haze or ‘glow’ of light that surrounds highly populated areas and reduces the ability to view the nighttime sky. It results from: • Light emitted from a luminaire in a direction above the plane of the horizon. • Light emitted from a luminaire in a direction below the plane of the horizon but reflected from the surrounding surface towards the sky.</td>
<td>Turn off non-critical lighting late at night. Limit the use of non-cutoff luminaires. Ensure that luminaires emit little to no light above the plane of the horizon. Utilize internal or external shielding that minimizes the component of light above horizontal. Note: Non-cutoff luminaires, such as post lamps, have no shielding or are open at the top, allowing light to shine upward as well as downward.</td>
</tr>
</tbody>
</table>

Many states and municipalities have developed outdoor lighting codes to reduce sky glow, minimize light trespass onto adjacent properties, and limit glare and energy consumption. These legislative efforts may include requirements such as use of specific light source types or wattages, pole height limitations, or requirements for full-cutoff luminaires. (More information is available in the chapter on Parking Garage and Surface Lot Maintenance and on the website of the International Dark-Sky Association at http://www.darksky.org.)

Parking lots and garages are another area where careful O&M can save energy and minimize the above effects. Parking lots and garages are challenging environments to light. The lighting must accommodate both vehicular and pedestrian traffic, endure harsh operating environments, and take into account public safety considerations and light trespass issues (especially for parking lots, but also for garages). At the same time, these objectives must be met in the most economical way possible. Specific issues that O&M for parking lot and garage lighting must address include the following:
• Vibration from vehicle traffic can create a harsh operating environment for light sources.

• Most parking garage lights operate 24 hours a day.

• Public safety concerns may favor whiter light and a high color rendering index (CRI) despite higher cost (as compared to sodium lamps).

• Failed lamps can create safety hazards and generate complaints if not promptly replaced.

• Lamps not protected with shatter (or bullet) resistant lenses can be frequently damaged and increase routine maintenance needs.

As in the case for indoor lighting, the Illuminating Engineer Society of North America has arrived at the levels of illumination for outdoor applications (see Table 3).

**TABLE 3. IESNA RECOMMENDED OUTDOOR LIGHTING LEVELS**

<table>
<thead>
<tr>
<th>Location (a) Streets, local commercial Residential</th>
<th>Light level in foot-candle (fc)</th>
<th>Uniformity ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Streets, local commercial Residential</td>
<td>0.9 Avg.</td>
<td>6:1</td>
</tr>
<tr>
<td>(b) Parking, multi-family residential:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Low vehicular/pedestrian activity</td>
<td>0.2 Min.</td>
<td>4:1</td>
</tr>
<tr>
<td>• Medium vehicular/pedestrian activity</td>
<td>0.6 Min.</td>
<td>4:1</td>
</tr>
<tr>
<td>(c) Parking, industrial/commercial/institutional/municipal:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• High activity, e.g., regional shopping centers/fast food facilities, major athletic/civic/cultural events.</td>
<td>0.9 Min.</td>
<td>4:1</td>
</tr>
<tr>
<td>• Medium activity, e.g. community shopping centers, office parks, hospitals, commuter lots, cultural/civic/recreational events</td>
<td>0.6 Min.</td>
<td>4:1</td>
</tr>
<tr>
<td>• Low activity, e.g., neighborhood shopping, industrial employee parking, schools</td>
<td>0.2 Min.</td>
<td>4:1</td>
</tr>
<tr>
<td>(d) Sidewalks</td>
<td>0.5 Avg.</td>
<td>5:1</td>
</tr>
<tr>
<td>(e) Building entrances, commercial, industrial, institutional</td>
<td>5.0 Avg.</td>
<td>—</td>
</tr>
</tbody>
</table>

Notes:
1. Illumination levels are maintained horizontal footcandles on the task, e.g., pavement or area surface. Light levels need to be measured with a calibrated light meter capable of reading low light levels for outdoor use.
2. Uniformity ratios dictate that average illuminance values shall not exceed minimum values by more than the product of the minimum value and the specified ratio. E.g., for commercial parking high activity, the average footcandles shall not be in excess of 3.6 (0.9 x 4).

The following measures can maintain outdoor and exterior illumination levels necessary for the safety of the public, employees, and property, while reducing total electrical usage:

• Evaluate existing exterior lighting systems and identify non-critical lighting (which can be done as part of an overall lighting audit, as described earlier).
• Clearly label all switching devices to save time and help employees identify which lights should be shut off at specific times.

• Replace inefficient light sources (mercury vapor, incandescent, halogen) with energy-efficient lamp technologies wherever possible (metal halide, high-pressure sodium, and linear and compact fluorescent sources, as well as LEDs where it is cost-effective). Avoid fluorescent sources that are not suited for low-temperature operation. Eliminate incandescent sources or significantly limit the time that they operate.

• Use IESNA-recommended light level ranges. Use the lower recommended values to lower energy usage. Abnormally bright lights can create glare and deep shadows, which hampers sight. Illumination ratios between areas should be minimal (e.g., less than 10:1).

• Locate outdoor lighting where it is needed, and with minimum interference to the light path.

• In parking lots, use efficient cutoff lighting fixtures that emit no light above the horizontal or into the sky, and use fixtures that emit no more than 2.5% of the lamp lumens upward.

• Use cutoff lighting fixtures for all lamps greater than 2800 lumens to minimize wasted light going up into the atmosphere.

![Figure 4. Examples of Common Lighting Fixtures and Their Distribution](image-url)

Source: BC Hydro (2005)
Outdoor and Exterior Lighting Controls

As with indoor lighting, excellent automatic lighting controls are available to turn off exterior lights when not needed:

- Daylight controls or photo sensors turn off lights whenever adequate daylight is available.
- Energy management systems (EMS) and time clocks limit operating hours.
- Timer switches turn on lights for only short duration.

Evaluate and set specific outdoor lighting, as appropriate, to automatically lower or turn off after the close of business and/or after all employees have left the premises, or in non-critical, specific areas with no residential functions. After business hours, lower light levels to minimal levels, just enough to detect movement and provide sufficient security. Use timers, motion sensors, or an EMS to turn off or reduce lighting.

Security lighting activated with motion sensors, so that lights come on only when someone is in the immediate area (consult with local law enforcement or local codes), is an effective way to reduce operating time. Energy-efficient lamp sources ideal for these applications include fluorescent and induction lamps.

When using "on-off" motion sensors for security lighting, avoid the use of sources that require a period of time to achieve full brightness (HID sources such as Metal Halide [MH] or High Pressure Sodium [HPS]). Incandescent sources can also be an effective source for this type of application since they are not sensitive to temperature effects, especially if they only operate for short periods.

Parking Lot and Garage Lighting Options

Many outdoor areas, garages, and parking lots use area luminaires for general illumination (generally, lighting specifiers and designers refer to a complete lighting fixture—lamp, ballasts, lens, housing, etc, as a "luminare"). These luminaires tend to be HPS, MH, or linear fluorescent lamps. HPS lamps are used because of their low cost, high efficacy, and long life. MH or fluorescent sources typically have shorter lives but produce a whiter light.

A number of solid-state lighting-based (SSL-based) luminaires (products using a LED light source) are currently being introduced into the market as replacements for HID-based luminaires. Generally, the adoption of LEDs will require the replacement of the whole fixture, not just the light source, and can represent a significant investment beyond routine O&M measures. However, well-designed SSL-based fixtures have the potential to provide greater control of light distribu-
tion, better lighting color quality, longer life, and energy savings when compared to some traditional light sources.

Parking lot and garage lighting can be excellent applications for LED lighting for several reasons:

- LEDs can provide longer life, better color rendition, and lower energy use than HPS.
- LEDs can be directed to achieve better light distribution.
- LEDs can be easily adapted for controls such as motion sensors and photoelectric cells.
- LEDs can function well in cold temperature environments.
- LEDs can also withstand significantly more abuse.

Unlike conventional light sources, LEDs typically do not “burn out” and fail suddenly, but rather produce diminished light output over time. Some LED luminaires on the market claim to have a life expectancy of 50,000 hours or more, meaning they will still be producing 70% of their initial light output at 50,000 hours of use. High operating temperatures can reduce LED light output and shorten the operating life; conversely, cooler operating conditions may extend the life of the diodes. The same selection rule for other lighting products should be applied here: At a minimum, these product must meet the requirements of the ENERGY STAR program for SSL products, and demonstrate their lighting and lifetime performance qualities with test results rather than marketing claims.

From an economic perspective, the initial purchase price may limit acceptance of LED replacement fixtures. Despite the significant reduction in annual energy consumption and maintenance costs that they can offer, LED products’ high upfront cost can be a significant barrier to their adoption for retrofit projects. However, one additional advantage that LEDs may have is that they can withstand a fair amount of abuse (when properly constructed) because they use multiple point sources of light rather than a large bulb that can easily be damaged.

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6 Note, however, that the long-term performance of LED luminaires is still largely untested. For example, a claimed product life of 50,000 hours translates to nearly six years of continuous operation. IESNA has only recently published an official test method for lumen depreciation testing (LM-80, released in September 2008). Consequently, no independent data is available to corroborate manufacturers’ lifetime estimates.
LAmp dIspos AL

overview of regulations

Fluorescent and other high-intensity-discharge (HID) light sources generally require care in their handling and disposal. Fluorescent light sources, HID, and mercury vapor lamps all require various amounts of mercury to operate (ranging from 3 mg to over 100 mg, or about the tip of a ballpoint pen to a small bearing). Care is needed during the unpacking, installing, or replacing process for these light sources, as they can break if dropped or mishandled.

Mercury, especially in larger quantities, is considered a hazardous material, and the EPA and states regulate its disposal and handling. In general, state waste disposal regulations take precedence over federal regulations. Additionally, some county disposal regulations are even more stringent than a state’s regulations.

On July 6, 1999, EPA added hazardous waste lamps to the federal list of “universal wastes.” Hazardous waste lamps are any lamps that are characteristically hazardous, as determined by the TCLP (Toxicity Characteristic Leaching Procedure). This includes fluorescent, high intensity discharge, neon, mercury vapor, high-pressure sodium, and metal halide lamps, if they are characteristically hazardous (that is, as confirmed by the TCLP test results).

The new rule became effective on January 6, 2000. Options for managing lamps include managing them as hazardous waste, managing them under the universal waste rule, or using a type of lamp that is not hazardous. “Universal wastes” are also hazardous wastes; however, they have less stringent requirements for storage, transport, and collection. Universal wastes are regulated under 40 CFR 273 and other state codes.

Federal regulations currently allow a conditionally exempt, small-quantity generator (someone generating less than 220 pounds of hazardous waste/month) to dispose of its waste in a municipal waste landfill. Newer lamps on the market have lower levels of mercury and thus are not considered hazardous waste. If the lamps pass the TCLP, they are not hazardous waste and may be disposed in a municipal waste landfill. Manufacturers are required to disclose whether or not their lamps pass the TCLP tests, and indicate the amount of mercury present in a lamp in product catalogues and consumer packaging.

ACTION ITEMS

1. Handle spent lamps with care.
2. Avoid crushing or breaking lamps during transport.
3. Set aside a location to collect spent lamp.
4. Educate everyone on the need for careful handling and disposal options.
5. Follow recommended guidelines on how to handle broken lamps.
6. Do not discard broken lamps—they should also be put aside for recycling.
7. Arrange for regular recycling pickup.

Overview of Regulations

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If a collection and recycling system already exists in the building for linear fluorescent lamps, it can be easily expanded to include CFLs. If, however, a collection and recycling program does not exist for either linear or compact lamps, then it should be considered and included as part of a comprehensive user and occupant outreach and education on energy efficiency (especially to help address user-supplied devices and programs to provide CFLs to occupants). A list of fluorescent lamp recyclers is generally available from the state departments of environmental protection, or from the resources listed below. Generally, a collection area or areas will be needed and designated for spent (and broken) lamps, and a location will be needed to set aside for collection and storage in between recycling pick-ups. (See also the chapters on Recycling and Special Waste Programs and Resident Education.) Information from the EPA on CFL cleanup can be found at: http://www.epa.gov/cfl/cflcleanup.html.

**User Education, Lamp Collection, and Recycling**

If CFLs are being provided to occupants and workers and installed in housing units as a part of the building’s comprehensive energy efficiency measure, the measure should also include:

- Educating users on the care, handling, and application of CFLs
- Providing users with clear information on recycling and disposal of spent and broken lamps
- Providing users with options for recycling and disposal of spent and broken lamps on site.

The EPA, through the ENERGY STAR program, has created comprehensive user guides and guidelines that can help in communicating with occupants about CFLs and mercury. They can be found at: www.energystar.gov. Some relevant points on handling CFLs are summarized below.

**CFL USE IN LIVING AREAS:** CFLs are mostly made of glass, and can break if dropped or roughly handled. Everyone needs to use care when removing from packaging, installing, or replacing CFLs. Screw and unscrew these lamps by their base, and never forcefully twist them into or out of light sockets.

**HANDLING OF BURNED-OUT CFLS:** EPA recommends that CFLs be recycled where possible. Recycling options or drop-off points need to be provided to users and residents. Users should not send fluorescent light bulbs or any other mercury-containing product to an incinerator.
**BROKEN CFLS CLEAN-UP STEPS:** EPA recommends the following clean-up and disposal steps for broken lamps:

1. Air out the room before clean up: Open a window and leave the room for 15 minutes or more.

2. Hard surfaces: Scoop up glass fragments and powder using stiff paper or cardboard and place in a sealable container or bag, then use sticky tape to pick up any remaining small glass pieces and powder. Wipe the area clean with damp paper towels or disposable wet wipes. Place towels in a container or plastic bag and seal shut.

3. Carpeting or rugs: Pick up glass fragments and place them in a sealable container or plastic bag, then use sticky tape to pick up any remaining small glass fragments and powder. Vacuum the area if needed. Put the vacuum bag or vacuumed debris in a container or bag and seal shut.

4. Clothing, bedding, etc.: Wrap up and throw away clothing or bedding with embedded broken lamp fragments to avoid spreading broken fragments. Do not wash such clothing or bedding.

5. Disposal of clean-up materials: Place all clean-up materials outdoors in a trash container or protected area for the next normal trash pickup, and wash your hands after disposal and clean up.

**Resources**

Four of the best and most accurate resources on lamp recycling and consumer mercury information can be found on the Internet, listed below.

- The U.S. Environmental Protection Agency (EPA) maintains a website that lists contact information for state agencies charged with hazardous waste regulations: http://www.epa.gov/epaoswer/hazwaste/state/links.htm

- The ENERGY STAR program (DOE and EPA) website provides information about CFLs and mercury, along with links to recycling and other information sources and factsheets: http://www.energystar.gov


- Earth’s 911, a nonprofit educational organization, provides recycling resources by zip code at its website: http://www.1800cleanup.org
REFURBISHING AND UPGRADING OF RESIDENTIAL UNITS

For residential and office units, one of the main opportunities to reduce future energy consumption is the unoccupied period between occupants, when extensive and thorough upgrading work can be carried out without interruption, and in integration with other energy-efficient measures. As discussed earlier, an energy audit should be conducted for the area to be refurbished to identify the major efficiency opportunities, including HVAC, windows, and lighting.

This section focuses on a few main points to improve lighting energy efficiency during the refurbishment process. Consider these suggestions in addition to the points regarding light levels, fixtures and lamps selection, bulk purchasing, proper applications, and sensor selection covered elsewhere in this chapter. (Other environmentally beneficial practices to accomplish between occupancies are discussed in the Unit Turnaround chapter.)

REPLACEMENT OF LAMPS AND FIXTURES: During the refurbishment process, it is essential that existing indoor linear fluorescent systems be replaced, delamped, or upgraded with the most energy-efficient lamp-ballast combination possible. Check that the upgraded areas meet IESNA recommended levels and state building codes. Similarly, evaluate and upgrade as needed the outdoor and public area fixtures and systems.

Next, incandescent and other fixtures (both indoor and outdoor) should be upgraded or replaced with CFL-based fixtures. For residential units, we recommend that CFLs in all high-use sockets such as kitchens, living rooms, and bathrooms. Where possible, we also recommend replacing incandescent fixtures with dedicated CFL fixtures. If you install dedicated CFL fixtures, stock replacement lamps and make them available to occupants, or include these fixtures on a regular inspection schedule. Finally, because of the decreasing costs of CFLs, you may want to conduct a cost-benefit analysis of the tradeoff between dedicated CFL fixtures (as they tend to cost more) compared to making CFLs available to occupants on an as-needed basis.

The selection of linear systems and CFLs should follow the guidelines provided in the sections on CFL and linear lamp replacement earlier in this chapter. It may be important to consider using the most efficient fixtures, lamps, and ballast

ACTION ITEMS

1. Upgrade fixtures and lamps to the most energy-efficient options.
2. Upgrade bath and other infrequently used areas with sensors or sensor-nightlight combinations, and integrate with control systems.
3. Choose light colors for upgraded walls and floor areas.
4. Thoroughly clean walls and floors not upgraded of dust and dirt.
5. Thoroughly clean fixtures and lenses not upgraded.
6. Educate everyone on the need for careful handling and disposal options.
7. Follow recommended guidelines on handling broken lamps.
systems throughout the building, as this can reduce inventory size and the need to stock specialized replacement parts.

**CODE COMPLIANCE:** Depending on how extensive the refurbishment process, you will need to check with local authorities on compliance with building and energy codes. Many states have adopted ASHRAE 90.1 for energy management requirements, controls, and power density. Similarly, California’s Title 20 (commercial buildings) and Title 24 (residential buildings) also have very specific requirements for power densities, controls, and specific fixture (luminaire) types used in various building areas.

**SENSORS AND OTHER CONTROL SYSTEMS:** During the refurbishment process, consider including or upgrading sensors and other control systems to further reduce energy use. These systems include occupancy sensors in bathrooms, storage, hallways, meeting rooms, and other low-use areas, as well as integration of public areas, parking, etc. into an existing or new EMS if available. Consider the LED-nightlight systems, discussed in the earlier section on occupancy sensors, for sensors for bathrooms and other low-use areas. Again, the selection process should follow the discussions and recommendations above to ensure proper installation and use. Consider the same sensor systems throughout the building, as this can reduce sensor inventory size and the need to stock specialized replacement parts.

**HANDLING AND DISPOSAL OF MERCURY-CONTAINING LAMPS:** Set aside used and replaced fluorescent and HID lamps from the refurbishment process for collection and recycling. If a collection system already exists in the building for linear fluorescent lamps, then it should be utilized. If, however, a collection and recycling program does not exist for either linear or compact lamps, consider starting one as part of a comprehensive refurbishment process. A list of fluorescent lamp recyclers is available at the websites listed in the previous section. If lamps are broken during the refurbishment process, follow the guidelines above for handling of broken lamps to maintain safety and to avoid contamination of other materials discarded from the refurbishment process.

**WALLS AND WINDOWS:** If new paint, wall covers, and/or flooring are called for, consider light, cheery colors and semi-gloss paints for the walls, as well as flooring (to the extent possible). These colors reduce the light loss from darker wall colors and flat, dull surfaces. In addition, during the refurbishment process, take note of large window areas; south-facing windows, if not replaced, should be covered with reflective film to manage glare and solar heat gain. Other window coverings should also be considered for both daylight harvesting and thermal control.
CLEAN FIXTURES, WALLS, AND FLOORS:
Finally, during the refurbishment process, thoroughly clean areas not slated for new paint or fixtures. At the conclusion of the refurbishment process, make sure that the cleaning crew responsible for the final cleanup not only cleans vertical and horizontal surfaces, but also cleans fixtures and lenses that are upgraded, as well as those that are not. These actions are especially needed in dusty, dirty areas such as kitchens, laundry rooms, and printer rooms in offices. This will help to maintain the light level for the new occupants, and reduce the accumulation of dirt and dust to an acceptable level.

ACRONYMS IN THIS CHAPTER

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ASHRAE</td>
<td>American Society of Heating, Refrigeration, and Air Conditioning Engineers</td>
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<tr>
<td>CFL</td>
<td>Compact fluorescent lamp</td>
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<td>CRI</td>
<td>Color rendering index</td>
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<td>EMS</td>
<td>Energy management systems</td>
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<td>HID</td>
<td>High intensity discharge</td>
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<td>HPS</td>
<td>High-pressure sodium</td>
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<tr>
<td>HVAC</td>
<td>Heating, air conditioning, and ventilation</td>
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<td>IESNA</td>
<td>Illuminating Engineering Society of North America</td>
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<td>IR</td>
<td>Infrared</td>
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<td>LED</td>
<td>Light emitting diode</td>
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<tr>
<td>LEED</td>
<td>Leadership in Energy and Environmental Design (U.S. Green Building Council)</td>
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<tr>
<td>LLD</td>
<td>Lamp lumen depreciation</td>
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<tr>
<td>lpw</td>
<td>Lumens per watt</td>
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<td>Operations and maintenance</td>
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<td>Toxicity characteristic leaching procedure</td>
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