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BUILDING TECHNOLOGIES PROGRAM

Strategy Guideline: High Performance Residential Lighting

J. Holton
IBACOS, Inc.

February 2012

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Strategy Guideline: High Performance Residential Lighting

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Prepared by:

J. Holton, Consultant

IBACOS, Inc.

2214 Liberty Avenue

Pittsburgh, Pennsylvania 15222

NREL Technical Monitor: Michael Gestwick

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Contents

List of Figures

**Unless otherwise noted, all figures and photos were created by IBACOS.*

List of Tables

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Definitions

CCT	Correlated color temperature
CFL	Compact fluorescent lamp
Color Rendering	Ability of a light source to show all colors in a scene
Color Temperature	An index for lamp light color in degrees Kelvin (K) that typically ranges from 1700K to 8000K
CRI	Color rendering index (20–100)
Decorative Fixture	An exposed fixture designed for visual appeal as well as lighting performance
DHW	Domestic hot water
DOE	U.S. Department of Energy
EISA	Energy Independence and Security Act of 2007
EPA	U.S. Environmental Protection Agency
FC	Footcandle, a commonly used measure of illumination (approximately $\frac{\text{lux}}{10}$)
FTC	U.S. Federal Trade Commission
Glare	Brightness that causes a reaction ranging from discomfort to inability to see the scene
HPL	High performance lighting
HVAC	Heating, ventilation, and air conditioning
IECC	International Energy Conservation Code
IES	Illuminating Engineering Society
LED	Light emitting diode
Light Color	Light that ranges from warm (e.g., candlelight) to cool (e.g., fluorescent grow light)
Luminaire	Light fixture, including the lamp (bulb)

Luminaire Efficacy	Total lumens emitted by the luminaire divided by the total watts drawn by the luminaire's power supply
MEL	Miscellaneous electric loads
SSL	Solid-state lighting

Executive Summary

As homes have become more energy efficient through improvements to the exterior envelope and the heating, ventilation, and air conditioning (HVAC) and domestic hot water (DHW) systems, lighting has emerged as a component of energy use where opportunities for improvement are still available. This guideline offers methods to greatly reduce lighting energy use through the application of high quality fluorescent and light emitting diode (LED) technologies. High performance lighting (HPL) strategies may be applied through the range of builder-installed lighting—from the simplest code compliance level to built-in lighting for each room of the house including exterior lighting. The strategies also may be applied in varying degrees of depth—from simply changing lamps (bulbs) in a standard layout, to changing the fixtures in the standard layout as well, or moving to the preferred level of a fresh HPL design for the whole house.

Fully executed, HPL is ambient lighting for the entire house. It provides light levels consistent with the recommendations of the Illuminating Engineering Society (IES), offers good light color and color rendering, controls glare, and is very energy efficient. High performance lighting also covers task lighting in those areas where builders normally install cabinets, appliances, and fixtures—the kitchen and bathrooms. By providing quite full illumination coverage, HPL greatly reduces the need for additional task lighting to perhaps a few reading or desk lamps. It does not cover accent lighting. Thus, HPL offers control of energy use for a large percentage of the total house lighting energy use component. Applying HPL in a whole-house design can result in as much as a 65% lighting energy reduction as compared to the same design executed with incandescent lamps.

For the preferred whole-house lighting design, this guideline offers strategies for three approaches: *direct* lighting, *recessed* lighting, or *indirect* lighting. These offer increasing levels of quality refinement with escalating levels of installed cost. High performance lighting strategies are presented for eight representative residential room types plus exterior lighting. These cover virtually all of the typically used rooms in a house plus its exterior. High performance lighting can provide an excellent quality of residential illumination.

The Need for a High Performance Lighting Guide

There are now more residential lighting options available to homeowners than ever before. In the interest of using energy wisely, fluorescent lighting technologies have been developed for residential application. To overcome some of the shortcomings of residential fluorescent lighting and for even greater energy efficiency, light emitting diode (LED) lighting technology is now entering the residential market. The pace of change in the lighting industry is rapid.

This guideline has been developed to create a structure for informed decision making and appropriate design and application by homeowners and builders. This guideline, along with the references provided in the Application Resources section, will assist users in successfully completing a high performance lighting (HPL) installation.

New homes are being built to increasingly stringent energy performance levels. Typically, this involves a significantly improved thermal enclosure with higher levels of insulation, energy-efficient windows, air sealing, and high efficiency heating, ventilation, and air conditioning (HVAC) and domestic hot water (DHW) systems. These measures can greatly reduce annual energy use. Because of the HVAC and DHW energy reductions, the balance of energy use for lighting, appliances, and miscellaneous electric loads (MEL) emerges as the end uses that present opportunities for improvement. Figure 1 illustrates the relationship of annual energy consumption for the lighting, appliance, and MEL group when comparing a house built to the 2009 International Energy Conservation Code (IECC) and one built with 30% whole-house energy reductions. As illustrated, lighting efficiency is not typically considered for residential energy use reduction. Most codes, with the exception of California’s Title 24, place little emphasis on residential lighting efficiency. Lighting and the selection of appliances are the end uses that builders and homeowners most practically control in new construction, and excellent new LED lamps and compact fluorescent lamps (CFLs) and fixtures are now commonly available. With existing homes, lighting tends to be a proportionally smaller component of energy use but one easily improved through retrofit. By fully applying HPL in a home, lighting energy use may be reduced by up to 65% compared to a standard incandescent-based design.

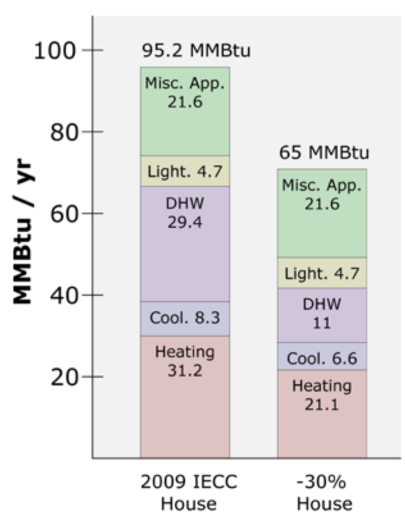

Figure 1. Comparison of annual energy use.

The Purpose of the High Performance Lighting Guide

High performance lighting is lighting of excellent quality that is also very energy efficient. It is based principally on the use of new and improved fluorescent and LED lighting technology. The HPL strategies featured in this guide are drawn from recent advances in commercial lighting for application to typical spaces found in residential buildings. It is important to note that these strategies not only save energy in the home, but also serve to satisfy the homeowner's expectations for high quality lighting.

For the greatest reduction in and control of lighting energy use, HPL should be applied to all rooms in the house and to outdoor lighting. This will satisfy the requirement for ambient lighting in all areas of the home and task lighting in key activity areas: the kitchen and baths. This complete coverage should reduce the need for additional lighting to a few small task lights such as those for reading or desk work. Accent lighting, if desired, is considered an optional additional energy use category and should employ high efficiency lamps and fixtures.

The Characteristics of High Performance Lighting

As suggested in *The Lighting Handbook.* 10th edition, published by the Illuminating Engineering Society (IES), a well-conceived lighting design prepared by an experienced lighting designer is the best way to develop the illumination plan for a home. The design would be keyed to the specifics of the homeowners' living patterns and would sensitively feature the aesthetic aspects of the home's architectural design and furnishings. It would accomplish this through a skillful balance of lighting science, technology, aesthetics (shadow, contrast, sparkle, color, glare control, etc.), and energy efficiency.

Most homeowners are not in a position to address home lighting in this manner. Indeed, new homes often come equipped with only the minimum lighting fixtures needed to meet the building code safety requirements. Then the balance of the lighting in the home is left to the homeowner to provide through personal choice or with the assistance of lighting showroom sales staff. Although this process can achieve satisfactory results, it typically includes little attention to energy-efficient lighting selections.

High performance lighting provides basic ambient lighting for all areas of the home—effective illumination to meet the IES guidelines in *The Lighting Handbook,* to provide excellent light quality (e.g., color, color rendering, and glare control [see the Definitions section of this guide]), and is very energy efficient. Lighting is typically considered as functioning in three layers: ambient, task, and accent. *Ambient lighting*, the principal component of HPL, is the light needed for basic circulation and occupancy of a room. *Task lighting* meets the visibility needs of specific functional tasks such as food preparation or grooming. *Accent lighting* provides visual relief, visual attraction, and emphasis. Because builders normally include kitchen cabinets and appliances and bathroom fixtures in new home construction and often in major retrofits, and because these components define task areas, the task lighting for kitchens and baths is also a component of HPL. Task lighting for other functions such as reading or desk work is considered additional owner-provided fixtures. Accent lighting generally is not a feature of HPL. It is recommended that the homeowner-provided task and ambient lighting be installed using high efficiency lamps and fixtures to complement an HPL design. Figure 2 shows an example of ambient lighting with accent lighting, and Figure 3 shows an example of ambient lighting with task lighting.

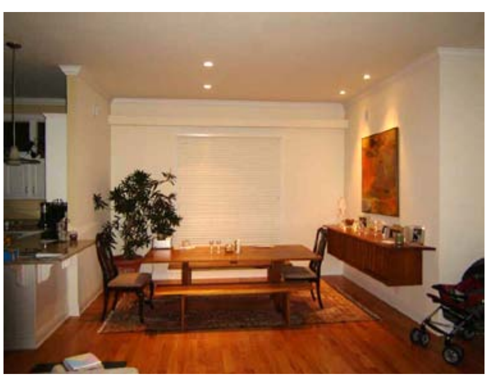

Figure 2. Ambient lighting with accent lighting.

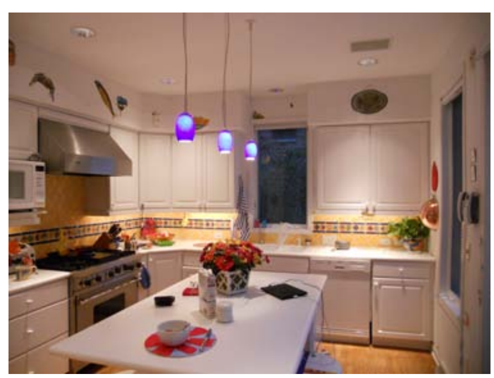

Figure 3. Ambient lighting with task lighting.

This guideline addresses a number of key aspects of lighting quality: color, accuracy of color rendering, control of glare, and presentation of a harmonious relationship with the architectural characteristics of the home (see Figure 4).

Figure 4. Architecturally integrated light cove.

One advantage of HPL is the longevity of the lamps. Screw-in CFL bulbs generally last up to ten times longer than standard incandescent "A" lamps. Pin-base CFL lamps last up to twelve times longer than incandescent lamps, linear fluorescents last up to thirty times longer, and LEDs last up to fifty times longer. With HPL, lamps do not have to be replaced as often, providing reduced cost and the distinct advantage of convenience when fixtures are hard to reach or are used frequently. Figure 5 compares lamp life for LED, fluorescent, CFL, and incandescent lamps.

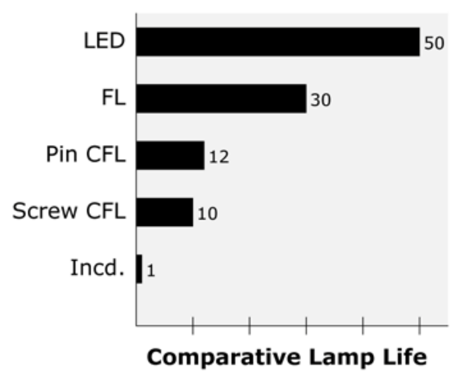

Figure 5. Lamp life, 1,000 hours.

The HPL described in this guide is builder-installed, hard-wired lighting. The builder and homeowner can control this lighting design at initial construction of the home, in either new construction or major remodeling.

The lighting designs in this guide are effective in rooms with relatively light-colored walls, ceilings, and floor surfaces, as shown in Figure 6. Dark-colored room surfaces, as shown in Figure 7, will reduce illumination levels—in some cases, drastically. To achieve the same illumination levels, more fixtures or higher wattage fixtures may be necessary in dark-colored rooms. The amount of increase that is necessary depends on the extent and intensity of the dark-colored surfaces in the room.

Figure 6. Ambient lighting in a light-colored room.

Figure 7. Ambient lighting in a dark-colored room.

Many forms of HPL employ fixtures that are "design neutral"; in other words, the fixtures are incorporated into the basic construction of the house and do not require the aesthetic choice of a fixture style. With such neutral lighting, it is easier to achieve wide coverage for basic ambient lighting before requiring the homeowner's fixture style decisions. Examples of such fixtures are downlights, wall washers, soffit lights, valance lights, and cove lights as shown in Figure 8 through Figure 12, respectively.

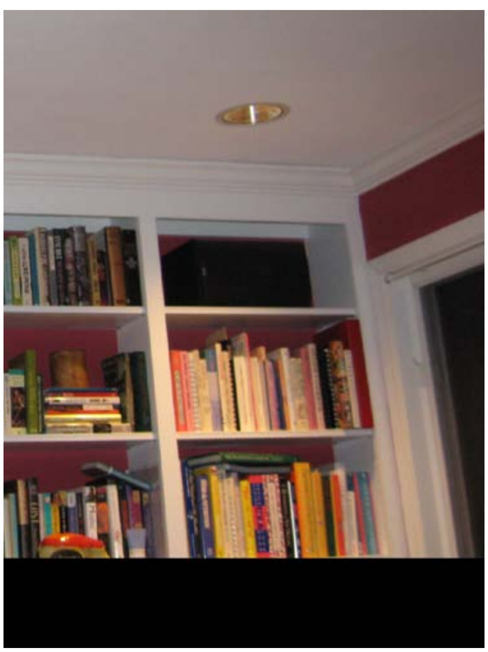

Figure 8. Recessed downlight.

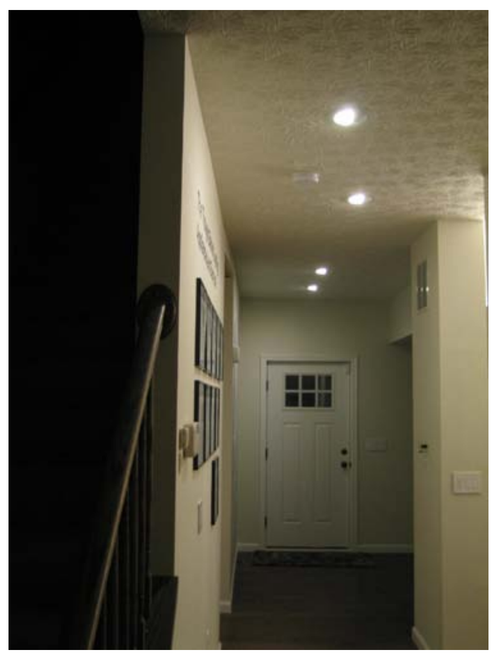

Figure 9. Wall washers.

Figure 10. Light soffit.

Figure 11. Valance lighting.

Figure 12. Light coves.

There is a great range in the extent of coverage of lighting systems built into a house at initial construction, represented by the following levels:

- *Code compliance (lowest level)*. At this level, only the lighting required to meet the building code is installed, which typically includes the fixtures that are installed along circulation paths such as outdoor entry lights, halls, and stairs and a single light in the kitchen and bathrooms. All other rooms may simply have a switched outlet that would control an owner-supplied portable lamp. At this level, a monetary lighting allowance typically is offered for homeowners to select a limited number of additional built-in, hard-wired fixtures. This level of built-in lighting typically does not provide the minimum illumination to meet the levels recommended by IES.
- *Key room lighting (mid-level)*. At this level, in addition to code compliance lighting, light fixtures are installed in rooms where the fixtures, cabinetry, and appliances generally determine the principal use patterns. This includes lighting in the kitchen and bathrooms, as well as an entry hall chandelier and a dining room chandelier. Much of a lighting allowance may be used by the homeowner in making these selections. Similar to the code compliance level, this approach may not offer sufficient coverage throughout the house to meet the guidelines of *The Lighting Handbook* by IES.

- *Whole-house lighting (highest level)*. Increasingly, builders are working with homebuyers, lighting suppliers, and designers to install basic, built-in lighting in each room of a home. To a considerable degree, this lighting consists of the use of recessed downlights of various types (e.g., open reflectors, wall washers, accent spots) but also includes many types of ceiling fixtures, pendants, and wall sconces. This level typically meets all the needs for ambient lighting and satisfies many of the needs for task and accent lighting as well. Upon completion of such lighting installation, there will be relatively little need for additional portable lighting. When combined with an HPL approach, whole-house lighting offers the most complete performance and efficiency.

This guide explains how to provide room ambient light levels consistent with *The Lighting Handbook* by IES, a recognized technical authority of quality practices in the lighting industry. The ambient light levels discussed here will cover all but highly specialized uses of a space.

The Resources Needed to Apply High Performance Lighting

The successful application of HPL in residential construction requires many players. Lighting is an aspect of house construction that involves the homeowner, the architect, the builder, the interior designer, the technical trades, realtors, assessors, and the financial industry. The following is a discussion of the major issues that each player must support in the application of HPL in residential construction.

Homeowners

Homeowners will benefit from an understanding and appreciation of a quality lighting environment. This would include issues such as the following: glare control, layers of light, light color and color rendering, the architectural integration of lighting, light-colored surfaces, the sparkle and contrast in lighting, and IES illumination levels. This understanding is best acquired through the experience of real lighting installations such as those found in model homes. When homeowners gain this understanding of lighting, they will value quality lighting and will ask for it. This is the basis of the HPL process.

Builders

Builders need to understand the characteristics of HPL and the value it can add to the home. They should understand the design issues in order to work with architects and interior designers in designing the lighting system. They also must understand the purchasing implications and the extent of trade management that may be involved, such as framing and coordination with the electrician, drywaller, and painter. A good HPL installation must be carefully scheduled rather than being only a last-minute rush to buy energy-efficient light bulbs. Finally, the builder’s sales staff must be comfortable in explaining the quality and value that HPL brings to the new home.

The builder’s Selections Coordinator should work with the homeowner and the interior designer and/or architect, if appropriate. The Selections Coordinator should gain a working understanding of HPL objectives and process in order to be an effective interface between the homeowner and the electrical supply house or lighting showroom where the HPL purchases will be made.

Architect and Interior Designer

The architect and interior designer may use this guide in developing a lighting design for the home to understand how light affects the perception of space; glare control; how surface brightness (walls and ceilings) affects the expansiveness of rooms; shadows; sparkle; ambient, task, and accent layers of light; correlated color temperature (CCT); color rendering index (CRI); architectural integration (e.g., coves, valances, soffits); IES light levels; and fixture efficacy. This guide will provide information to help architects and designers keep abreast of the rapid changes in lamps, fixtures, and controls, in order to translate the homeowner’s wishes into a real installation.

Trade Partners

Several trades typically are involved in a lighting installation. The key player is the electrician. Because some of the elements of an HPL design may be new to the electrician, it is valuable to bring the electrician into the discussion somewhat earlier than would normally occur. High performance lighting is not difficult for the electrician to install, but it often requires a bit of advance planning in both ordering and installation. Advanced control systems may require commissioning by the electrician as well as installation. Coordination with carpenters will be required in the case of cove, valance, or soffit lighting. Kitchen lighting often must be coordinated with cabinet installation. The drywall contractor will have to work around more built-in fixtures. The painting contractor may be required to address a few special painting areas for reflectivity. None of this is difficult, but it requires a bit more thought and coordination early in the process. Note that after several homes are built using HPL, much of this construction practice will become routine.

Realtors, Appraisers, and Mortgage Lenders

The realty and mortgage industries play an important role in the success of HPL application. High performance lighting is quality, energy-efficient lighting, and these team members must value it as such. Realtors need to appreciate and promote the quality and value that HPL adds to the home. Appraisers must include this value in their assessments, and mortgage lenders must be equally supportive. If homeowners want HPL as part of their home, realtors, appraisers, and mortgage lenders will respond.

Electrical Suppliers

Electrical suppliers play a key role in implementing HPL. They are the local source of the lamps, fixtures, controls, equipment, and supplies required for HPL installation. As HPL is applied in homes, electrical suppliers must develop the inventory to meet builders' requirements on schedule. This is not always easy because some of the leading-edge technology employed in HPL, notably LED and CFL fixtures, is just now entering the market. As the HPL design is being developed, it would be helpful to include the electrician and supplier in an assessment of supply needs well before the schedule calls for delivery. This gives the supplier adequate time to order and receive the needed materials, thereby reducing the potential for future delays in construction. Also, electrical suppliers need to be aware of the danger of product substitutions. High performance lighting products are often selected carefully, and their specific performance characteristics are important to the success of the project. Any proposed product substitution should be evaluated with equal care. Again, this is not a difficult process; it simply requires a bit of forethought.

Lighting Manufacturers

Lighting manufacturers are the ultimate source for most of what goes into an HPL installation. Much is available today from manufacturers' product lines that meets most, but not all, the needs of an HPL design. The leading edge of lighting technology is currently LED lighting and, to a lesser extent, CFL lighting. Understandably, the first luminaires are developed for commercial applications where cost tolerance levels are higher. But manufacturers must recognize the huge residential market potential and must introduce appropriate products that can fit into the economics of residential construction. For example, a limited offering of a few fixture types in LED technology that applied to recessed downlights, wall washers, undercabinet lights, and cove lighting would go a long way toward meeting the needs of a whole-house HPL design. Although significant advances are being made rapidly in LED lighting, most LED lamps and fixtures are lacking in performance, price level, or both.

Codes, Standards, and Guidelines

Several codes, standards, and guidelines are resources for the application of HPL. These include the following:

- IES Residential Illuminance Guidelines
- ENERGY STAR® Labeling
- U.S. Department of Energy (DOE) Lighting Facts Label
- U.S. Federal Trade Commission (FTC) Lighting Facts Label
- Energy Independence and Security Act (EISA) of 2007 Minimum Lamp Efficiencies
- California Title 24 Building Energy Efficiency Standard.

Illuminating Engineering Society (IES) Guidelines

The 10th edition of *The Lighting Handbook* (see Figure 13), in Chapter 33, presents Residential Illuminance Guidelines providing an extensive list of illumination values for different room types and activities. These cover both ambient and task lighting. Accent lighting is covered in Chapter 15. The guidelines are focused on light levels for good lighting and are not the same as the energy codes that are focused on energy consumption. Designing to IES light levels is a great help in meeting residential energy code requirements.

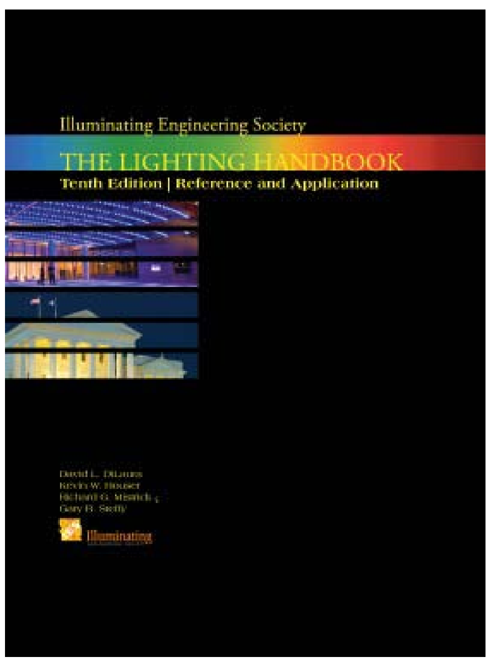

Figure 13. *The Lighting Handbook,* 10th edition, by IES.

The IES guidelines are expressed in footcandles (FC) of illumination, a common measurement in the lighting industry. The examples below show common lighting experiences expressed in footcandles (see Figure 14):

- Bright moonlit night: 1/100 FC
- Enough light to see in a dim room: 1 FC
- Ample light to move about in a room: 3 FC
- Kitchen counter with under-cabinet lights: 20 to 90 FC.

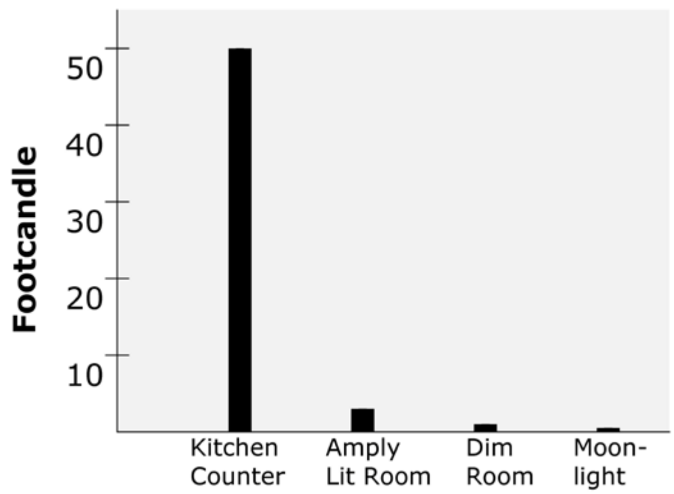

Figure 14. Example illumination levels.

Figure 15 shows illuminance measuring heights for the kitchen, bathroom, and floor.

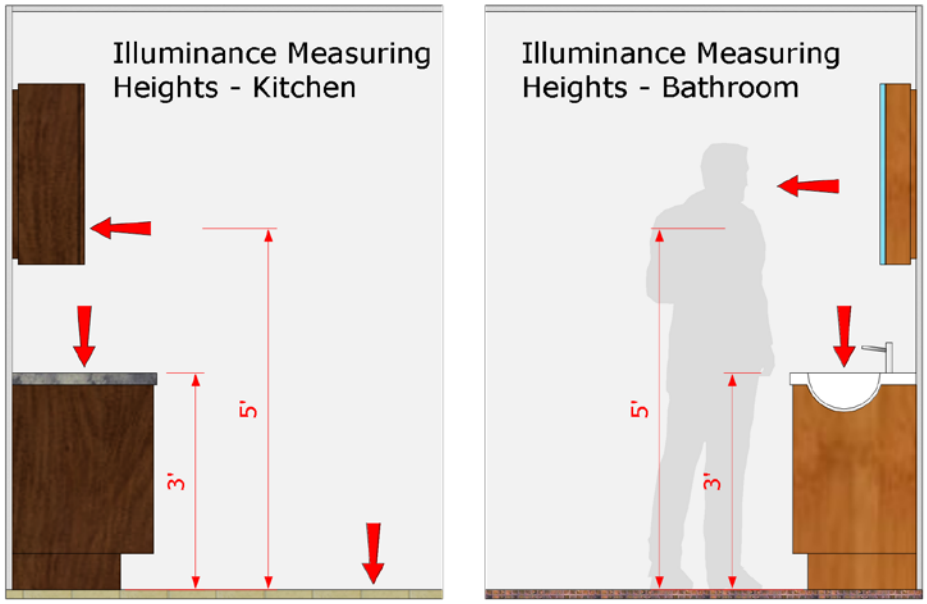

Figure 15. Illuminance measuring heights for (left) kitchen, (right) bathroom, and floor illumination.

(Arrows indicate surfaces to be illuminated).

IES has defined outdoor lighting zones, as shown in Table 1, based on the generally perceived light level of the area. They range from LZ0, no ambient light, to LZ4, high ambient light levels (shopping mall). Typical residential areas are approximately LZ3, moderately high ambient level. (See Table 26.4 in *The Lighting Handbook* by IES.)

Table 1 shows illuminance levels that apply to the ambient and task headings appropriate to HPL. The table lists both horizontal and vertical illuminance values.

In most cases the horizontal illuminance is the value of interest. The principal areas of interest for vertical illuminance are kitchen cabinets, vanity (grooming), and outdoor entry. The recommended horizontal illuminance levels for most rooms may be measured at the floor. Where working areas are installed, such as kitchen counters or bath vanities and fixtures, horizontal illuminance may be measured at the work surface, typically about 3 feet. For measuring vertical illuminance, a height of 5 feet is satisfactory for vanity, entry locations, and kitchen cabinets. Furthermore, the values listed are applicable to the occupant age group 25 to 65 years old. The tabulated values are taken from Table 33.2 in *The Lighting Handbook* by IES. The handbook may be referenced if greater detail or different age ranges is desired.

Table 1. Residential Illuminance Recommendations.

Room	Area/Task	Horizontal Illuminance (FC)	Vertical Illuminance (FC)
Bath			
	Shower/tub	5	2
	Toilet	10	3
	Vanity (grooming)	30	40
Bedroom	General (dressing)	5	3
Hallway		3	0.6
Closet			
	Non-walk-in	10	4
	Walk-in	30	10
Dining			
	Formal	5	2
	Informal	10	4
	Study use	20	5
Family Room		10	4
Foyer	(night)	3	1
Garage	(general)	5	5
Kitchen			
	Breakfast area	20	5
	Cabinets	0	5
	Cooktop	30	5
	General	5	2
	Prep. Counter	50	7.5
	Sink	30	5

Room	Area/Task	Horizontal Illuminance (FC)	Vertical Illuminance (FC)
Laundry	(general)	20	5
Living Room		3	3
Home Office		20	3
Stairs	(general)	5	0
Exterior	(based on Light Zone 3)		
	Entry – Primary	0.8	1.5
	Entry – Secondary	0.4	0.1
	Walk light	0.2	0.1
	Steps	0.2	0
	Decks/Patios	0.6	0.2

ENERGY STAR Labeling

The ENERGY STAR labeling program, run by the U.S. Environmental Protection Agency (EPA), provides assurance of good levels of performance and quality construction for a wide selection of both lamps (bulbs) and lighting fixtures. For HPL installations, ENERGY STAR-labeled lamps and fixtures should be employed to the greatest extent possible. Figure 16 shows the ENERGY STAR label.

Figure 16. The ENERGY STAR label.

U.S. Department of Energy Lighting Facts® Label

This label, first developed by the DOE, lists many of the key performance facts for a lamp (see Figure 17). Of particular interest in the application of HPL are lumen output, lumens per watt (efficiency), CCT, and CRI. These factors, developed from independent testing, provide a good means of judging lamp performance. The DOE Lighting Facts labeling program is a voluntary program but is being adopted by most major lamp manufacturers. Initial application has been for LED replacement lamps and luminaires and has been extremely helpful in assessing incandescent equivalence in both light output (lumens) and quality (CCT, CRI).

Note that the DOE Lighting Facts label is applicable to both lamps (bulbs) and luminaires (fixtures). Because of this, the term "efficacy" is used to express the efficiency of a lamp alone or a full light producing luminaire. This is essential for rating LED luminaires as the heat dissipating characteristics and optical properties have a significant impact on luminaire light output.

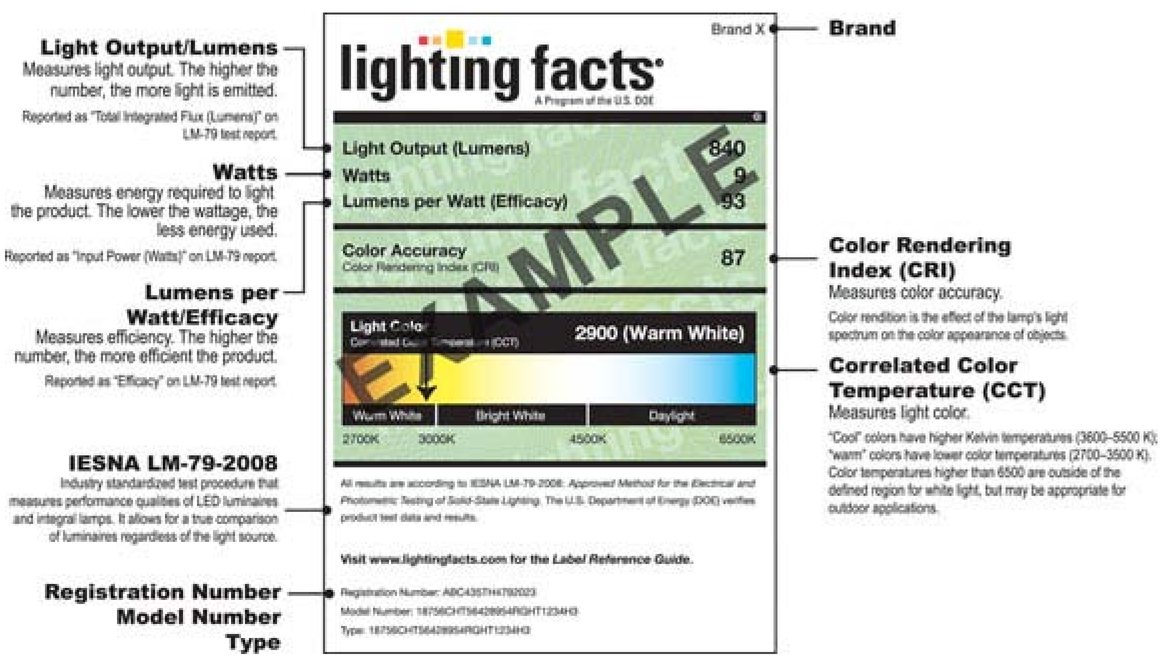

Figure 17. The DOE Lighting Facts label.

U.S. Federal Trade Commission (FTC) Lighting Facts Label

The FTC has adopted the Lighting Facts label (see Figure 18) in a somewhat similar form. It does not include a CRI or efficiency but does include information on lamp life. At the point of common use, the label can serve as a first-pass efficiency comparison for all medium screw-base lamp options. Its application will be mandatory for medium screw-base lamps of all technologies: incandescent, CFL, or LED.

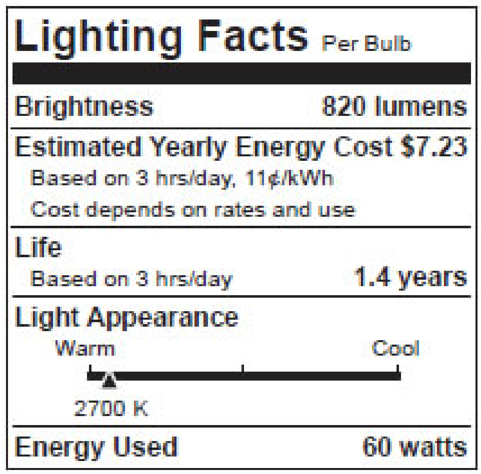

Figure 18. The FTC Lighting Facts label.

Energy Independence and Security Act of 2007, Minimum Lamp Efficiencies

EISA 2007 established minimum levels of efficiency for "general service" lamps. These are estimated to produce a reduction of 25% in operating energy from 2007 technology. The requirements are scheduled to be phased in starting in January 2012 for several lamp sizes, all less than 100W. The improvements are so slight that redesigned incandescent lamps will be acceptable. The efficiencies do not exceed 36 lumens/watt and cannot be considered suitable for HPL. Table 2 shows the current phase-in schedule.

Table 2. General Service Incandescent Lamps.

Rated Lumens	Maximum Rated Watts	Minimum Rated Lifetime (hr)	Effective Date	Lumens/Watt
1490–2600	72	1000	1/1/2012	36
1050–1489	53	1000	1/1/2013	28
750–1049	43	1000	1/1/2014	24
310–749	29	1000	1/1/2014	26

U.S. Department of Energy CALiPER Program

The DOE Solid-State Lighting (SSL) "Commercially Available LED Product Evaluation and Reporting" CALiPER program (see Figure 19) independently tests and provides unbiased information on the performance of commercially available SSL products. Results are presented at several levels of detail, as follows:

- Summary reports
- Detailed reports
- Benchmark reports.

The entire SSL luminaire is tested, not only the lamp, for the following two reasons:

1. There is no industry standard test procedure for rating the luminous flux of LED devices or arrays, and
2. LED performance is temperature sensitive, and luminaire design has a material impact on the performance of LEDs used in the luminaire.

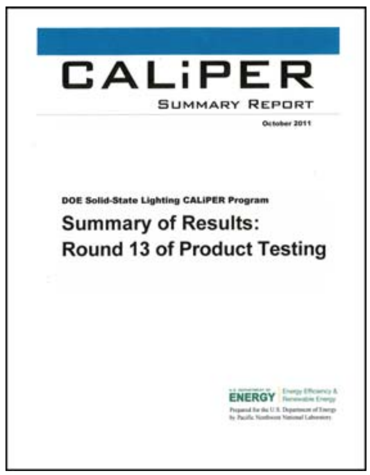

Figure 19. A DOE CALiPER summary report.

California Title 24 Requirements

In California, the 2008 Title 24 Building Energy Efficiency Standard set requirements for fixture efficacy and control for many rooms of the house. It requires the use of high efficacy fixtures or low efficacy fixtures with lighting controls in different combinations in all rooms. What it does not do is key installed lighting to illumination requirements. Thus, while allowing great design flexibility for a lighting installation, Title 24 does not guide the reduction of installed lighting to levels that meet the guidelines of *The Lighting Handbook* by IES.

The *Title 24 Residential Lighting Design Guide* (see Figure 20) provides representative designs for many rooms of the house and includes fixture specification and control options consistent with the Title 24 requirements. This *Strategy Guideline: High Performance Residential Lighting* may be used in conjunction with the Title 24 guide to develop a wide range of lighting solutions.

This includes the range in extent of coverage (code compliant, key rooms, and whole-house design) and a range in lighting quality (direct lighting, recessed lighting, or indirect lighting).

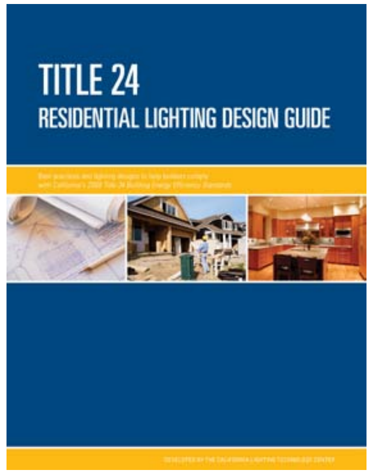

Figure 20. California Title 24 Lighting Guide.

The Interaction of High Performance Lighting with Other Construction Components

Perhaps the strongest HPL interaction is with the HVAC system. Because the wattage of the lamps (bulbs) is much lower than that of typical incandescent lighting, cooling loads are reduced and heating loads are increased. Residential lighting is not typically included, either positively or negatively, in *Manual J Residential Load Calculation* (Rutkowski 2006). Therefore, actual reductions in cooling load will not show up in sizing of the air conditioning unit nor will the actual increases in heating loads affect the sizing of the heating equipment. However, because more efficient lighting runs cooler than standard incandescent lighting, during air conditioning periods the cooling load in the home will be lower, and the air conditioning energy and electricity costs will be reduced as well. During heating seasons, the more efficient HPL will not provide as much internal heat as standard incandescent bulbs, and this will be made up by the heating system. However, the home heating system is generally a more cost-effective way of heating than are electric lights, so there will be overall energy and cost savings, even during winter months.

Particularly when light coves, valances, or soffits are used in an HPL design, coordination with *carpentry trades* will be critical. Carpenters will need to understand the light performance needs and the fixture details and dimensions to properly construct these lighting "built-ins."

Several aspects of the *interior designer's* work on the home will interact directly with an HPL installation. The choice of light-colored surfaces for ceilings, walls, floors, cabinetry, countertops, and furnishings greatly improves the effectiveness of the lighting installation. When light coves, valances, or soffits are employed, they may beneficially be considered as components of an interior trim and finish schedule process. When decorative fixtures are selected, such as chandeliers, pendants, wall sconces, or bathroom fixtures, while chosen for aesthetic properties, they should also be fixtures of high efficiency and good performance characteristics (e.g., CCT and CRI). ENERGY STAR fixtures are a good way to ensure this performance quality. Figure 21 and Figure 22 show examples of decorative fixtures.

Figure 21. Example of a decorative bath fixture.

Figure 22. Example of a decorative ceiling fixture.

Measuring High Performance Lighting Accomplishment

Because HPL strategies can be applied at several levels of coverage, there are different measures of accomplishment that are appropriate.

- For the code compliance or key room lighting levels of completeness as previously described, one may choose to replace lamps in conventional (incandescent) fixtures or to change-out fixtures to HPL types. In either case, a practical measure is to assess the total installed wattage of the HPL installation employing different combinations of tubular fluorescent, CFL, or LED sources. The lowest total wattage is the most energy efficient. Note that the installed cost will affect the choices as well, and this is discussed in a later section of this guide.
- With a whole-house HPL design, it is practical to assess total installed wattage and wattage per square foot of floor area for alternative designs. It is also practical to assess savings in installed wattage as compared to the incandescent equivalent.

It is tempting to consider annual lighting energy cost savings as a measure of an HPL installation. Part of such an assessment calculation is known: the difference in installed wattage between the base system (incandescent) and the HPL system. What is not known is the pattern of use of the system by the building occupants and thus the annual hours of use of each fixture in the system. Further, this pattern of use is highly variable based on the homeowners' living patterns and even the climate region. For these reasons, installed watts and watts per square foot are the appropriate measures of merit for an HPL installation.

The Availability and Cost of High Performance Lighting

Traditional residential, incandescent lighting varies widely in both availability and cost. It ranges from inexpensive fixtures available at big-box retailers to costly and elaborate custom fixtures available only on order or through lighting showrooms. There is a similar wide range of availability and cost for HPL, although the total number of fixture choices of both CFLs and LEDs is much smaller than that of incandescent offerings. High performance lighting also focuses primarily on background or "design neutral" built-in lighting fixtures that do not bear an aesthetic premium. Availability and cost are a bit different for the several categories of HPL: tubular fluorescents, built-in CFLs, decorative CFLs, built-in LEDs, and decorative LEDs. Key characteristics of each of these categories follow.

Tubular fluorescent strip lights (see Figure 23 through Figure 25)—the simplest of fluorescent fixtures used in coves, valances, and soffits—are generally available in both big-box and lighting supply stores and range in cost from $20 to $30, depending on length and lamp diameter. Ceiling surface and under-cabinet tubular fluorescent fixtures are similarly available but are somewhat more expensive because of their decorative features or lenses necessary to create appropriate lighting quality.

Figure 23. Strip light.

(Courtesy of Progress Lighting)

Figure 24. Ceiling surface fixture.

(Courtesy of Progress Lighting)

Figure 25. Under-cabinet fixture.

(Courtesy of Progress Lighting)

Compact fluorescent lighting fixtures for built-in applications, recessed downlights, and wall washers are somewhat limited in availability. Figure 26 shows an example of a recessed downlight. Big-box retailers stock only the simplest versions of these; for a wider range of wattage, reflector type, and trim, fixtures usually must be ordered from electrical supply houses or lighting showrooms. For basic models of recessed downlights, CFL versions cost approximately twice what the incandescent versions cost and thus fall in the $30 to $60 range. The costs for all other versions of built-in CFLs increase appreciably.

Figure 26. Recessed downlight.

(Courtesy of Progress Lighting)

Decorative CFLs, ceiling surface fixtures (see Figure 27), sconces (see Figure 28), and pendants (see Figure 29) are available in a wide range of styles from major residential lighting fixture manufacturers. They are available on order principally through electrical supply houses and lighting showrooms. Big-box retailers offer a very limited range of these fixtures. As with downlights, decorative CFL fixtures are more costly than their incandescent counterparts (i.e., they have more components, notably ballasts).

Figure 27. Ceiling surface, CFL fixture.

(Courtesy of Progress Lighting)

Figure 28. Wall sconce.

(Courtesy of Progress Lighting)

Figure 29. Pendant fixture.

(Courtesy of Progress Lighting)

Built-in LED fixtures, downlights, and strip lights are becoming generally available as of this writing (fall 2011). Big-box retailers offer LED recessed downlights, equivalent to the widely used 65W BR30 incandescent downlight in its most basic white reflector form (see Figure 30). It is interesting to note that some of these LED fixtures cost no more than their CFL equivalents. Clearly, LEDs are improving in performance and decreasing in cost at a rapid rate. LED strip lights are generally available, but their light output, similar to that of incandescent "rope lights," is suitable only for modest accent lighting. LEDs are much better suited than CFLs for installations that employ occupancy sensors giving instant on to full output. LED under-cabinet lights (see Figure 31) are also coming on the market, and some offer good light output. They are still much more expensive than their incandescent counterparts.

Manufacturers are just beginning to develop decorative LED fixtures. Some of the most interesting fixtures are in applications not well suited to CFL technology, such as the following:

- Chandeliers with sparkling points of LED light
- Track lights with the crispness of halogen MR16 lamps (see Figure 32)
- Dimmable fixtures of all types (LEDs may be dimmed with the proper driver and controls)
- Recessed step lights that benefit from the long life of LEDs (see Figure 33)
- Cove lights with the ability to run any length without gaps (see Figure 4)
- Accent lights and picture lights (see Figure 34)
- Outdoor fixtures (LEDs work well in cold weather) (see Figure 35)

These types of fixtures are available on order through electrical supply houses and lighting showrooms. Their costs are not yet competitive, but that is changing rapidly.

Figure 30. LED recessed downlight.

Figure 31. LED undercabinet light.

Figure 32. LED track light.

Figure 33. LED step lights.

Figure 34. LED accent light (picture light).

Figure 35. LED outdoor light.

High Performance Lighting Strategies

There are three levels of HPL strategies that may be applied in new construction or remodeling: changing the lamps (bulbs), changing the fixtures, or changing the design.

Changing the Lamps (Bulbs)

In this strategy, high efficiency replacement (medium screw-base) CFL or LED lamps are substituted for incandescent lamps in all of the fixtures in the house (see Figure 36 through Figure 38). The CFLs are quite good substitutes for general purpose A lamps (the standard light bulb) and are available in wattages to meet nearly all residential requirements. For reflector lamps, R, BR, MR, and PAR lamps, CFLs are only moderately effective replacements because they have relatively large light sources that do not work well with reflectors. (A filament point source is ideal.) Fortunately, LED technology that has compact light sources that work well with reflectors is becoming available. In combination, replacement CFL plus replacement LED lamps can be used to change out nearly all residential incandescent lamps.

This is the simplest strategy, and it will save energy with every incandescent lamp (bulb) that is changed out. Unlike changing the fixtures, there is always the possibility of “back sliding” (i.e., returning to the use of incandescent lamps). For this reason, most energy codes give no credit to the installation of screw-in replacement CFL or LED lamps. Also, LEDs offer higher efficacy for a lighting application (say, a recessed downlight) with a well-designed LED luminaire than with a screw-in conversion lamp.

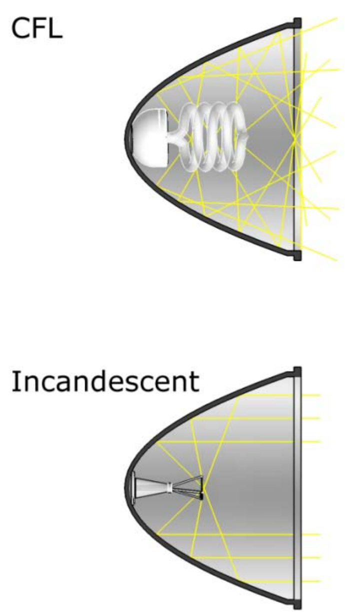

Figure 36. Comparison of CFL versus incandescent reflector lamps (bulbs).

Figure 37. CFL replacement lamp.

Figure 38. LED replacement lamp.

Note that it is not practical to change-out old tubular fluorescent lamps with new higher efficiency lamps because the ballasts are specific to a lamp wattage. This change-out can be accomplished at the change-the-fixtures level.

Changing the Fixtures

In this strategy, high efficiency light fixtures are installed in place of standard fixtures wherever they are located in the house. This strategy is applied to the typical lighting layout used by the builder and does not require any new lighting design. High efficiency fixtures are available for nearly all types of lighting applications used in residential construction. High efficiency fixture types include CFL, tubular fluorescent, and LED. They include “design neutral” fixtures such as recessed downlights and many types of decorative fixtures of both CFL and LED. Decorative fixtures include ceiling surface fixtures, wall sconces, bath fixtures, chandeliers, pendants, and exterior fixtures. All fixtures—CFL, tubular fluorescent, and LED—include the ballast/LED driver specific to the lamps installed. If dimming is desired, attention must be paid to the specific requirements and compatibility of ballast/LED driver and dimmer.

Changing the Design

The most effective way to employ HPL for a given room is to change the design in accordance with one of the three design packages: *direct lighting*, *recessed lighting*, and *indirect lighting*. This approach includes incorporating as much hard-wired fluorescent and LED lighting as possible to minimize the amount of portable lighting used in the house. The lighting design should provide the ambient lighting needed for each room and, in some rooms, should also incorporate fluorescent/LED solutions for task lighting or even accent lighting.

Direct Lighting

This package is the simplest and, in some respects, the most efficient because it floods the entire room with light from a surface-mounted ceiling or wall fixture or white reflector recessed downlights. The main concern with this unshielded light source is glare, which can be unpleasant or even debilitating, with bright sources. The most appropriate application of this design is in service areas such as the laundry room, closets, garage, and basement. Figure 39 shows an example of direct lighting in a laundry room.

Figure 39. Direct lighting.

Recessed Lighting

This package involves the use of ceiling recessed downlights with clear reflectors (see Figure 40). The clear reflector functions much like a PAR30 or PAR38 lamp in controlling the spread of light from the fixture and directing it downward. Light for the room comes from the objects illuminated by this downlight, typically the room furnishings and the floor. Light-colored furnishings and floor surfaces help to produce good illumination in the room. Dark-colored furnishings and surfaces, however, reduce illumination. Recessed downlights with clear reflectors provide an elegant appearance to the room, and, as concealed sources, they greatly reduce glare. With this type of lighting, the ceiling may be somewhat darker (depending largely on the brightness and reflectivity of the room furnishings and floor surface) and may appear lower. Wall surfaces may or may not be illuminated, depending on fixture position in the ceiling. When turned off, these fixtures present a noticeable circle in the ceiling.

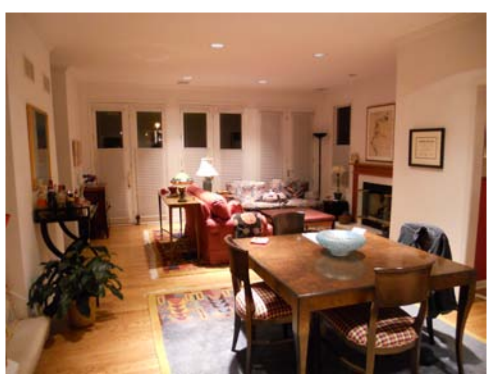

Figure 40. Recessed lighting.

Indirect Lighting

In this package, room surfaces—ceiling, walls, and floors—are illuminated by concealed source, indirect lighting from source types such as coves, valances, soffits, and ceiling recessed wall washers. For example, above kitchen cabinets there is often a natural cove created where linear fluorescents may easily provide an excellent wash of light across the ceiling for room ambient lighting. Coves may also be found as a clean extension of framing for a coffered or "tray" ceiling area. A cove or valance may fit readily to either side of a fireplace and can offer a logical emphasis to this key feature of a room. A typical and effective application of soffit lighting is above the vanity mirror in a bathroom, where its lighting quality can be excellent. Although useful in many locations, recessed wall wash downlights should not be aimed toward windows or doors because they can cause a blinding glare when viewed directly. Figure 41 shows various types of indirect lighting.

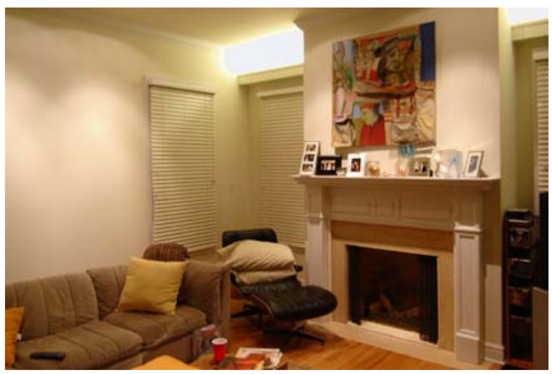

Figure 41. Indirect lighting.

The great advantages of lighting room surfaces are the inherent "naturalness" of the concealed source indirect light, its control of glare, and the ability to relate to and reinforce the visual forms of a room. The construction of coves, valances, and soffits requires some effort, but the reward is great in terms of the quality of the illuminated room.

Coves, valances, or soffits can be applied in a single location in a room or in several locations. Valances flanking a fireplace, for example, will provide ambient light that tapers to the far side of the room and can be quite effective as long as the lowest levels still meet the guidelines of *The Lighting Handbook* by IES. A cove in a raised ceiling area will generally continue all around the room and may offer quite even lighting conditions. Recessed wall washers are excellent for giving emphasis to one or more surfaces of a room. Pairing a cove along one side of a room with wall washers along adjacent walls is an effective combination that gives a rich visual play of ceiling and wall emphasis—all inherent, logical components of the room.

High Performance Lighting Strategies, Room by Room

The following designs are representative of the three lighting approaches—direct, recessed, and indirect—applied to the conditions of the specific type of room. Actual installations may require more or fewer fixtures, depending on the room size, configuration, and/or finish color (light or dark surfaces). Guidance for an actual installation will require both the design approach from this guide and the more detailed information on the selection of lamps, fixtures, and controls as found in the Application Resources section of this guide.

It is recommended that fluorescent and LED lamps be specified for 3000K CCT and 80+ CRI to the greatest extent possible. Such lamps will give an excellent fresh white light with good indoor color rendering, similar to the light of a halogen lamp.

The CRI is a measure of how accurately all colors are shown. The CRI of daylight is 100; thus, a CRI of 80 gives very good indoor color rendering (see Figure 42). Color temperature is a measure of how "warm" or "cool" the light is with standard incandescent bulbs at 2700K and cool white fluorescent at 4100K. A numeric representation for the desirable properties, the number 830 (80 CRI, 3000K), often appears printed on the bulb or on the packaging.

Figure 43 shows the color differences among fluorescent lights with CCTs ranging from 2700 to 6500.

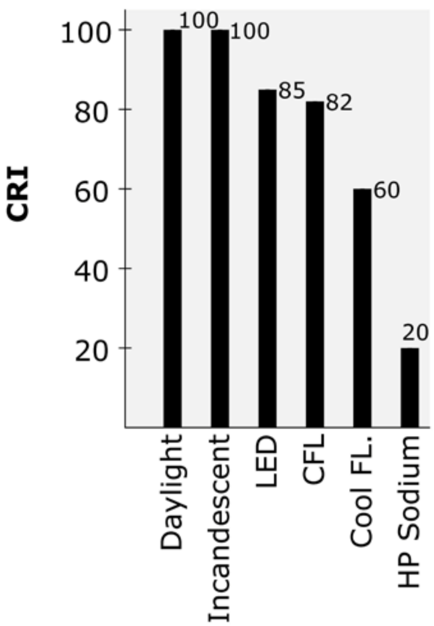

Figure 42. Examples of CRI values.

(From bottom to top) 2700, 3000, 3500, 4100, 5000, and 6500.

Figure 43. Fluorescent lights of different CCTs.

The following room designs consider the principles of direct lighting, recessed lighting, and indirect lighting. Figure 44 provides a legend that applies to the diagrams for each room design.

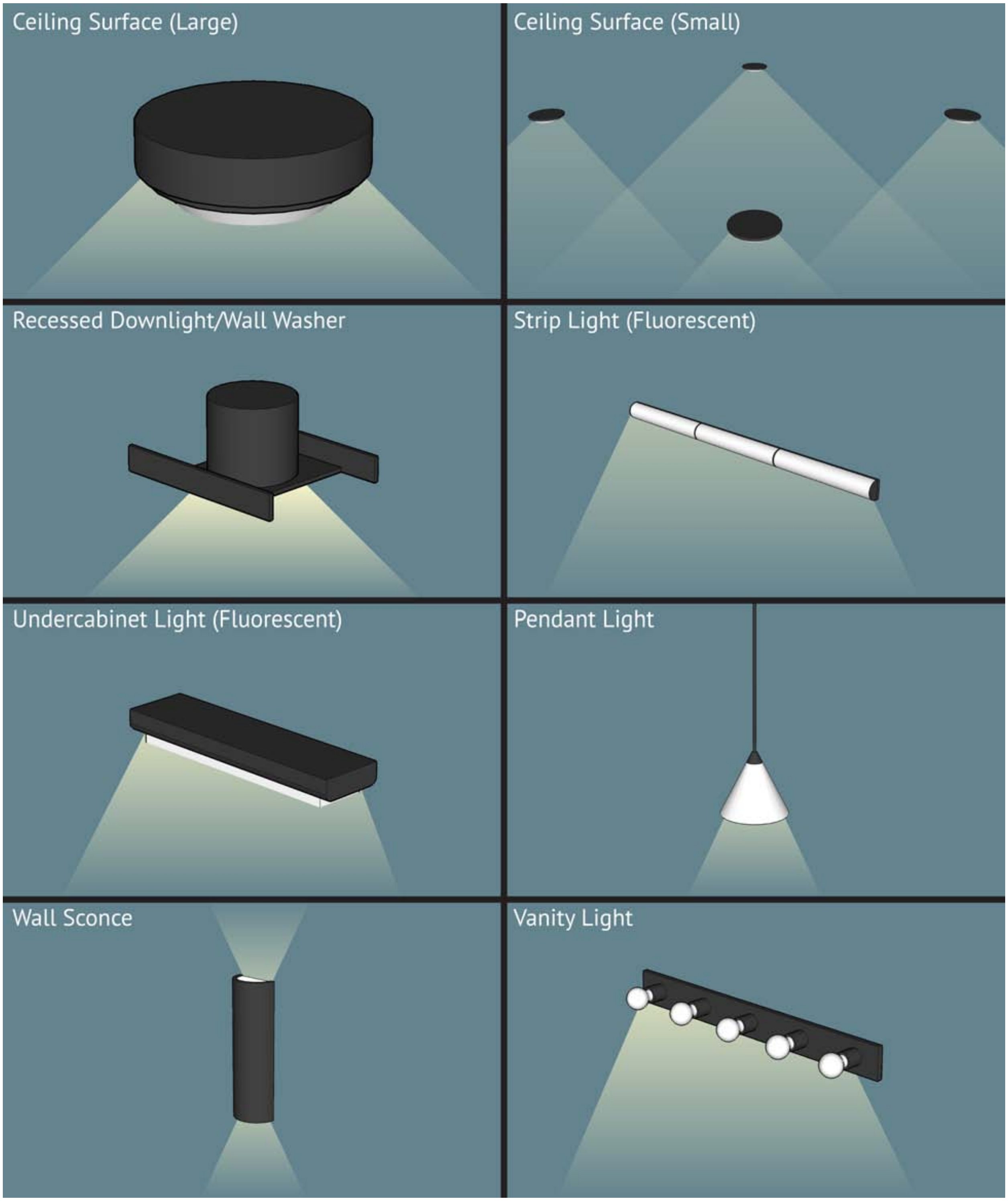

Figure 44. Legend for room designs.

Family Room and Living Room

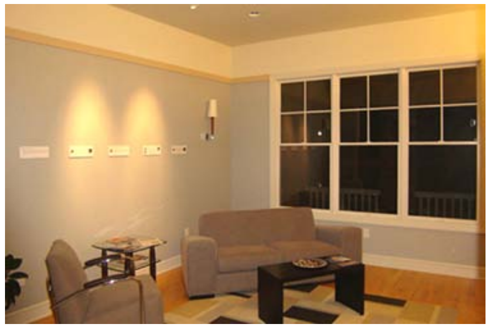

Figure 45. Family room.

Principles

The family room (see Figure 45) and living room areas are similar in purpose, so the lighting designs serve the same strategy. These lighting designs are intended to provide ambient illumination, meeting the guidelines of *The Lighting Handbook* by IES, for general room use and circulation.

These light levels may also be satisfactory for some room tasks such as watching TV, operating audio equipment, or playing board games. Other tasks in these rooms, such as reading or writing, may warrant the provision of specific task lights. These would normally be portable lamps selected as part of an interior design activity.

The *direct lighting* designs provide simple, efficient direct illumination.

The *recessed lighting* design, using recessed downlights (with clear reflectors), provides a subdued and elegant pattern of general lighting with excellent glare control. A light-colored floor contributes greatly to the effectiveness of this design. A row of fixtures may be located relatively close to a wall to provide wall surface illumination. However, this will present scallops of light on the wall.

The *indirect lighting* design uses wall washers or coves to provide the most well-integrated lighting with excellent glare control. Wall wash lighting might feature a display of a painting or a fireplace. Wall wash lighting will tend to visually expand the size of the room. Cove lighting, by brightening the ceiling, will give a sense of greater ceiling height.

Designs

Figure 46 through Figure 50 show some representative designs for family rooms and living rooms.

Figure 46. Direct - ceiling surface fixtures.

Large or small fixtures.

Figure 47. Direct - downlights.

Recessed downlights with white reflectors.

Figure 48. Recessed downlights.

Recessed downlights with clear reflectors.

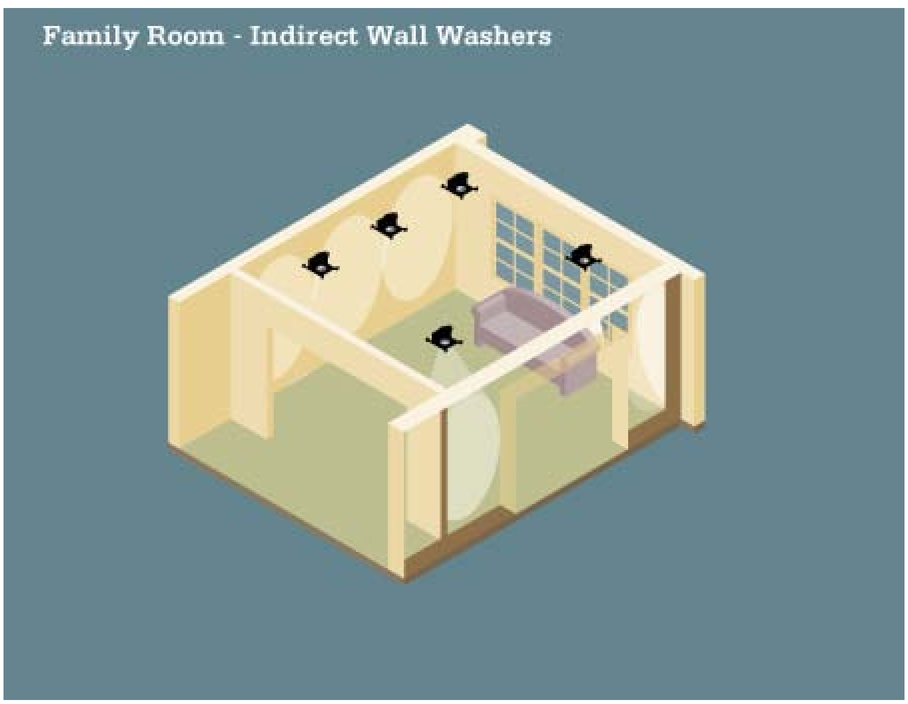

Figure 49. Indirect - wall washers.

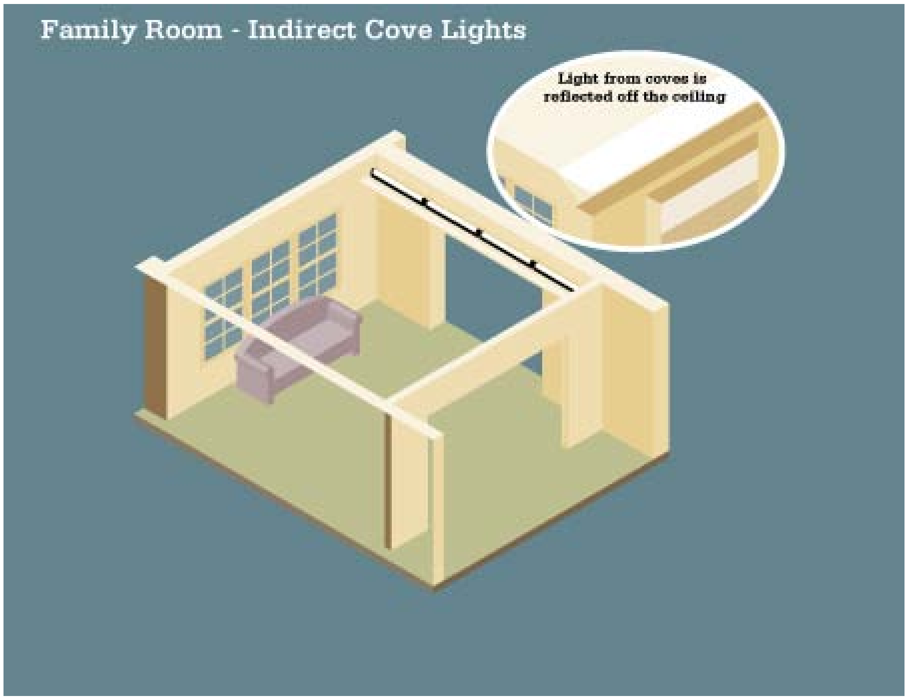

Figure 50. Indirect - cove lights.

Light cove with strip lights, continuous.

Kitchen

Figure 51. Kitchen.

Principles

These lighting designs for kitchens (see Figure 51) are intended to meet or exceed the guidelines of *The Lighting Handbook* by IES. These guidelines provide an acceptable level for general room illumination. However, in kitchen lighting, levels tend to be significantly higher because ambient lighting often plays a second role as task lighting. The principal task areas in kitchens are the counter areas, including sinks and appliances. An important secondary task area is the interior of cabinets.

Kitchen designs are somewhat more extensive than those of other rooms because builders typically install the lighting for kitchen task areas, such as counters, cabinets, and appliances. Thus, it is practical to develop designs that include light fixtures for both task and ambient lighting. Most of the fixtures in the designs are “background fixtures” that have little or no aesthetic impact on the interior design, with the exception of pendants, which are included in the designs because they can play an important role in task lighting in areas without overhead cabinetry. A number of hard-wired CFL pendant fixtures are available from manufacturers that use pin-base CFL lamps, not screw-base CFL bulbs. LED pendants are also increasingly coming onto the market. Aesthetic considerations are critical in this selection, and, in many cases, this choice is left to the homeowner.

The *direct lighting* designs provide simple, efficient direct illumination. The high level flood of light throughout the room provides task lighting for countertops, peninsulas, or additional tables. Undercabinet lights prevent shadows from a person working at the counter.

The *recessed lighting* design, using recessed downlights (with clear reflectors), provides a subdued and elegant pattern of lighting with excellent glare control. Position the recessed downlights directly above the front edge of the countertop to provide good counter illumination and to put light into the interior of cabinets. Additional recessed downlights should be added to provide general room illumination. Undercabinet lights may be installed to ensure good, shadow-free, counter task illumination. Pendants may be substituted for recessed downlights over peninsula counters, freestanding counters, or additional tables.

The *indirect lighting* design primarily involves cove and undercabinet lighting. When wall cabinets are mounted with 10 to 12 or more inches of space to the ceiling, this cove with simple strip fluorescent fixtures provides excellent ambient light that unobtrusively integrates into the design of the kitchen. This design requires the use of undercabinet lights to provide good counter task light levels. At locations without wall cabinets, such as at the sink or at peninsulas, recessed downlights (with clear reflectors) provide good task and ambient light. Pendants may be substituted for these downlights with a similar lighting effect.

Designs

Figure 52 through Figure 55 show some representative designs for kitchens.

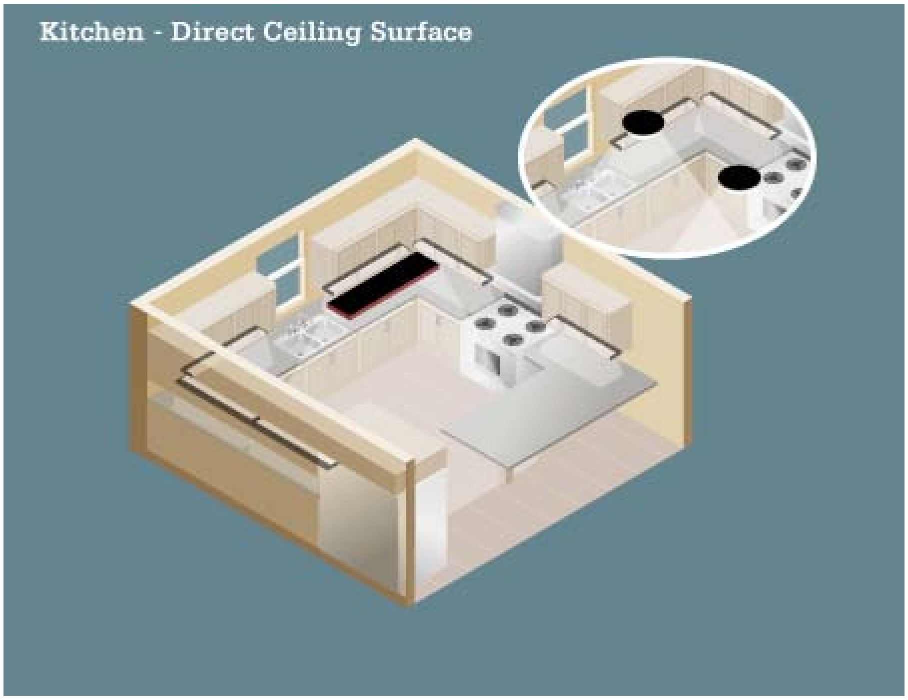

Figure 52. Direct - ceiling surface fixture.

Ceiling surface, 1X4, plus undercabinet lights. Or ceiling surface, circular fixtures, plus undercabinet lights. Alternative, ceiling surface, 2X4, no undercabinet lights.

Figure 53. Direct - downlights.

Recessed downlights with white reflectors, plus undercabinet lights.

Figure 54. Recessed downlights.

Recessed downlights with clear reflectors at the counter edge and peninsula centerline, optional undercounter lights. Or substitute pendants over a peninsula or table.

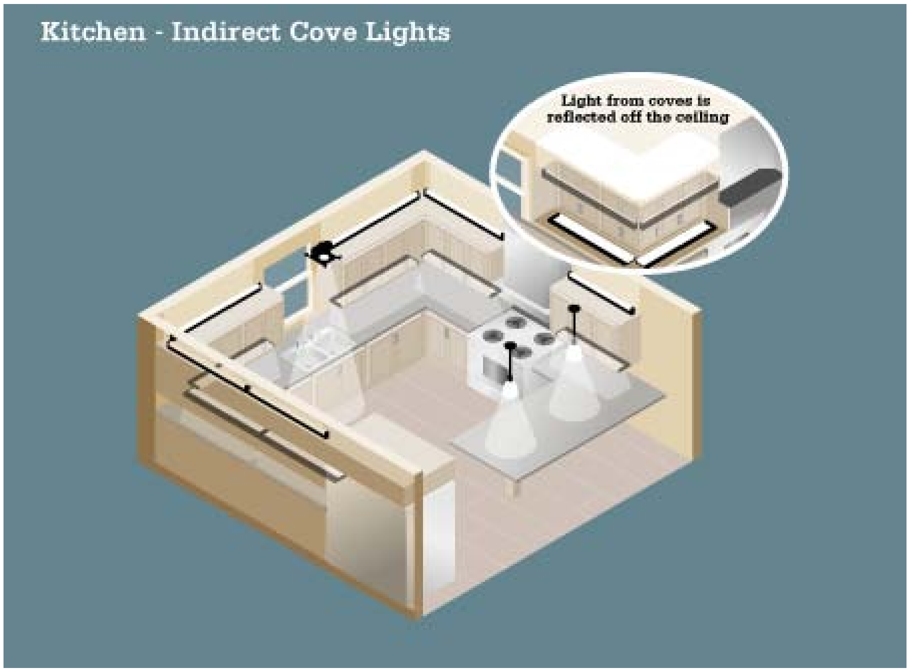

Figure 55. Indirect - cove lights.

Above cabinet cove with T-5 or T-8 strip lights, recessed downlights with clear reflectors above the sink and a peninsula or table, and undercabinet lights. Or substitute pendants over a peninsula or table.

Bedrooms

Figure 56. Bedroom.

Principles

Bedrooms (see Figure 56) require general ambient illumination for basic room use and circulation. These lighting designs are intended to provide ambient illumination meeting the guidelines of *The Lighting Handbook* by IES. These light levels may also be satisfactory for some room tasks such as watching TV or dressing. Other tasks, such as reading, may warrant the provision of specific task lights. These would normally be portable lamps selected as part of an interior design activity.

The *direct lighting* designs provide simple, efficient direct illumination.

The *recessed lighting* design, using recessed downlights (with clear reflectors), provides a subdued and elegant pattern of lighting with excellent glare control. Downlights can be positioned to give reading light if the location of the bed is known. A light-colored floor contributes greatly to the effectiveness of this design.

The *indirect lighting* designs use wall washers or coves to provide the most well-integrated lighting with excellent glare control. Wall wash lighting will tend to visually expand the size of the room. Cove lighting, by brightening the ceiling, will give a sense of greater ceiling height. Wall wash or cove lighting can give a directional emphasis to a bedroom that is reflective of the bed placement.

Designs

Figure 57 through Figure 61 show some representative designs for bedrooms.

Figure 57. Direct - ceiling surface fixtures.

Figure 58. Direct - downlights.

Recessed downlights with white reflectors.

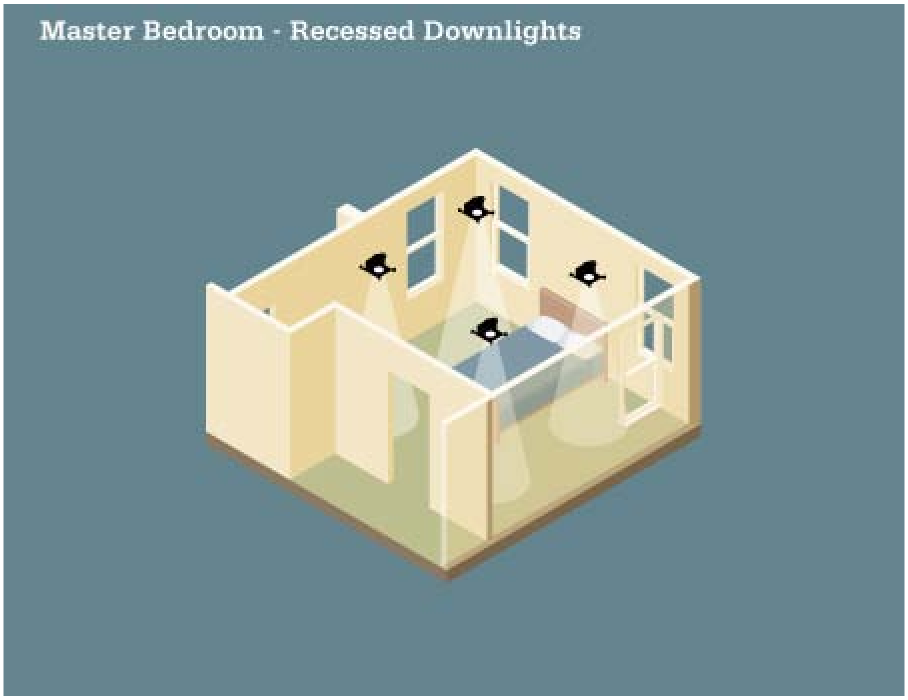

Figure 59. Recessed downlights.

Recessed downlights with clear reflectors.

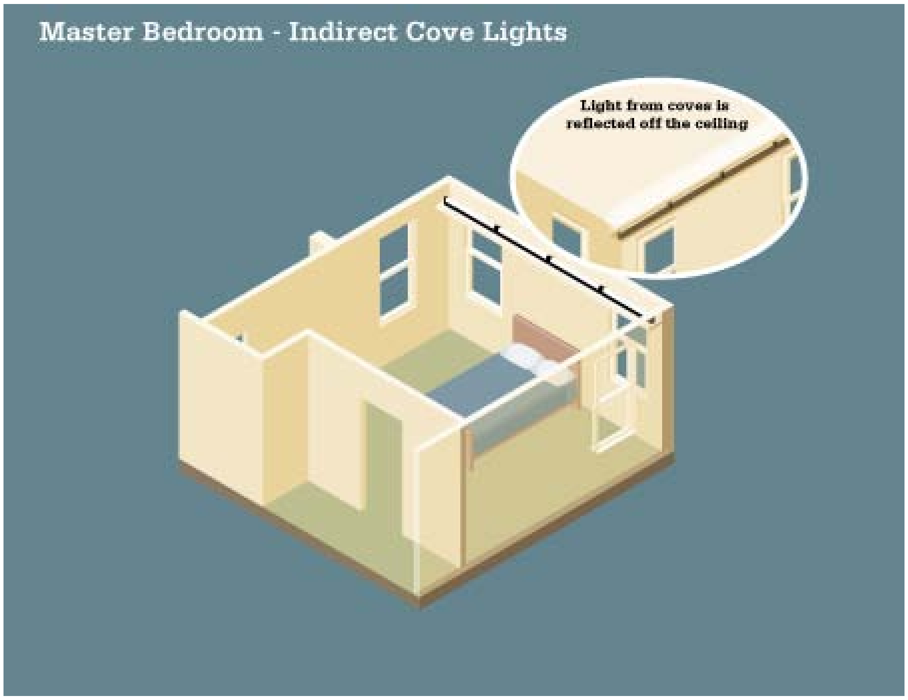

Figure 60. Indirect - cove lights.

Light cove, T-5 or T-8 strip lights, continuous.

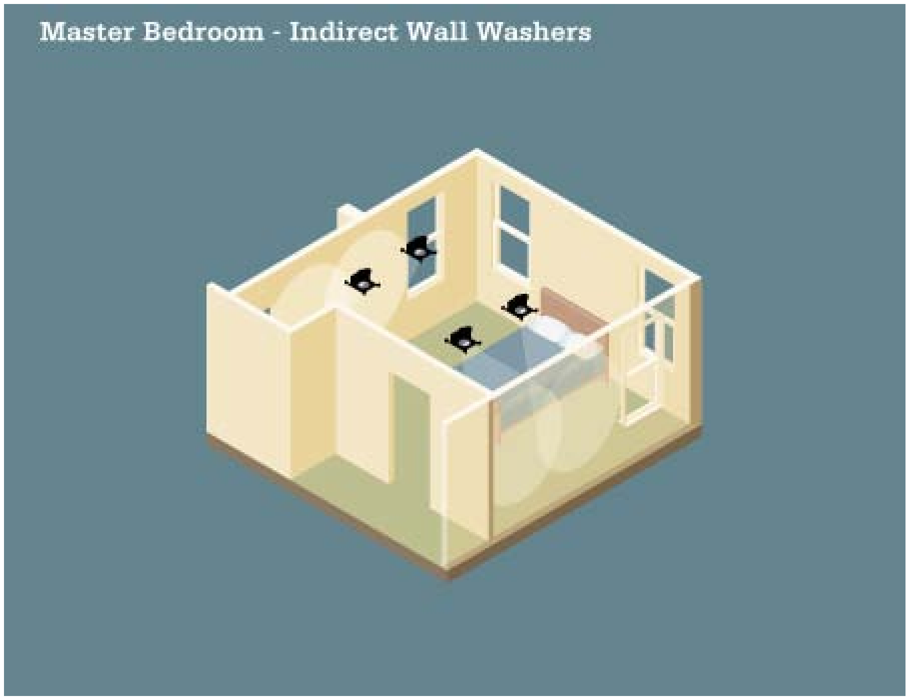

Figure 61. Indirect - wall washers.

Home Office

Figure 62. Home office.

Principles

The key lighting requirement in the home office (see Figure 62) is to control glare conditions on a computer screen. For this reason, no *direct lighting* designs are presented because, although they provide efficient illumination, they do so with considerable glare. These lighting designs are intended to provide ambient illumination meeting the guidelines of *The Lighting Handbook* by IES.

The *recessed lighting* design, using recessed downlights (with clear reflectors), provides a subdued pattern of lighting with very little computer screen glare. A light-colored floor contributes greatly to the effectiveness of this design.

The *indirect lighting* designs use wall washers, coves, or valances to provide the most well-integrated lighting with excellent glare control. Wall wash and cove lighting can provide illumination without visual hot spots. Valance lighting can visually expand the room both horizontally and vertically.

Designs

Figure 63 through Figure 65 show some representative designs for home offices.

Figure 63. Recessed downlights.

Recessed downlights with clear reflectors.

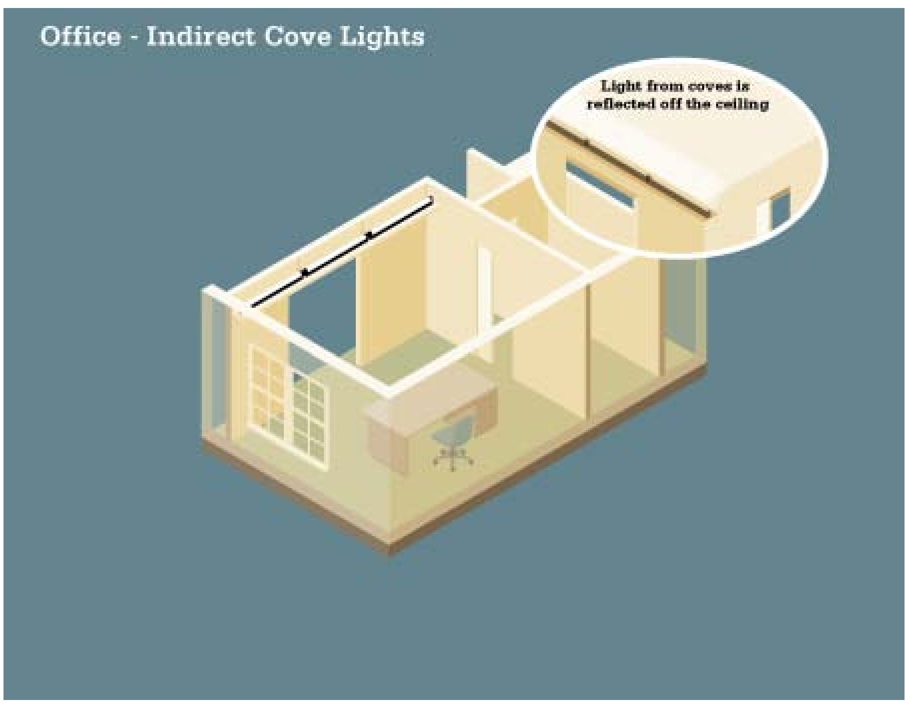

Figure 64. Indirect - cove lights.

Light cove or valance, T-5 or T-8 strip lights, continuous.

Figure 65. Indirect - Wall washers.

Dining Room

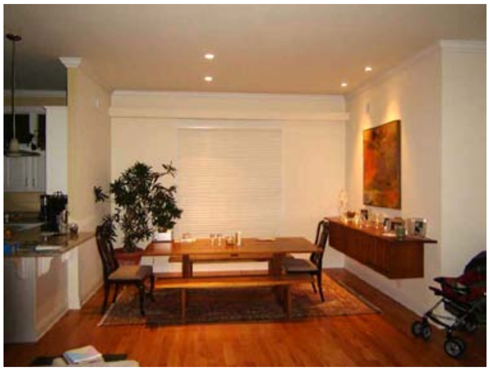

Figure 66. Dining room.

Principles

Dining room lighting typically features specific lighting at the dining table and sometimes at a sideboard. Functionally, the dining room (see Figure 66) may play several roles, including a formal dining area or a workspace. The HPL recommendations of this guide are intended to provide the IES-recommended ambient illumination level in a glare-free manner. This type of lighting will be compatible with the later addition of specific task lighting, such as a chandelier or pendant lamps over the dining table or as accent lighting at the sideboard. Dimming is often a desirable control in dining rooms.

Because of the desirability of glare-free illumination for ambient light in the dining room, no *direct lighting* designs are offered because they generally provide efficient light but with considerable glare.

The *recessed lighting* design, using recessed downlights (with clear reflectors), provides a subdued and elegant pattern of general lighting with excellent glare control. A light-colored floor contributes greatly to the effectiveness of this design.

The *indirect lighting* designs use wall washers or coves to provide well-integrated lighting with directionality and excellent glare control. Wall wash lighting will tend to visually expand the size of the room. Cove lighting is also often used with a “tray” ceiling, providing continuous illumination around the room and giving a sense of greater ceiling height.

Designs

Figure 67 through Figure 69 show some representative designs for dining rooms.

Figure 67. Recessed downlights.

Recessed downlights with clear reflectors.

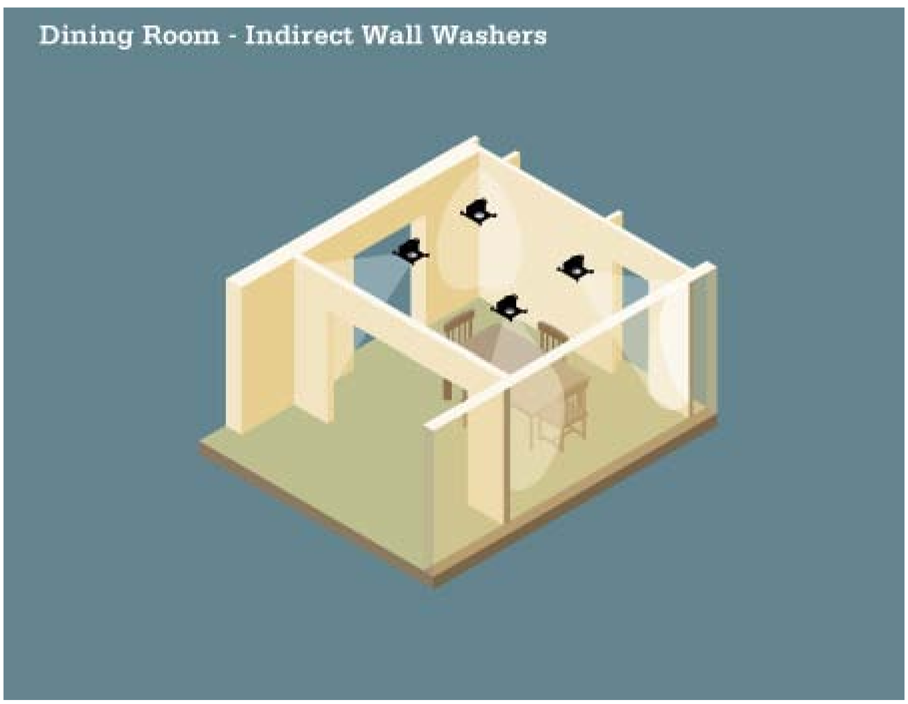

Figure 68. Indirect - wall washers.

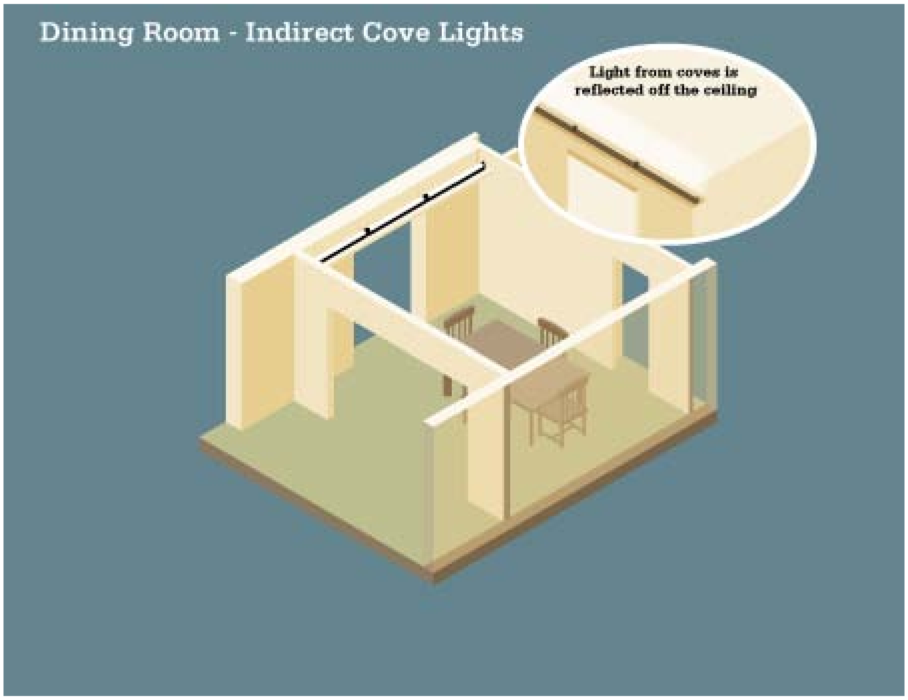

Figure 69. Indirect - cove lights.

Light cove, T-5 or T-8 strip lights.

Bathroom

Figure 70. Bathroom.

Principles

Bathroom lighting, similar to kitchen lighting, puts great emphasis on specific task areas. Because bathrooms (see Figure 70) are completed with fixtures and cabinetry during initial construction, it is practical to install lighting that is appropriate for the task areas. The most demanding area for lighting is at the vanity mirror. Here the ideal light illuminates the face from the sides as well as from above, reducing shadowing effects. The tub, shower, and commode areas all need adequate light as well. This may be provided by overall ambient lighting in open plan bathrooms or may require individual fixtures where these areas are partitioned off.

Small, open plan bathrooms and powder rooms can often be effectively illuminated from a single good-quality fixture at the vanity. Larger bathrooms generally require fixtures in addition to those at the vanity. Most of the designs include vanity lighting above or beside the mirror. This choice is often guided by fixture aesthetic considerations.

The *direct lighting* designs provide simple, efficient direct illumination. These fixtures flood the room with light in all directions. Direct lighting for the entire bathroom is sometimes provided by a light bar above the vanity mirror.

The *recessed lighting* design, using recessed downlights (with clear reflectors), provides a subdued and elegant pattern of lighting with excellent glare control. A light-colored floor contributes greatly to the effectiveness of this design. It generally requires the addition of vanity lights or sconces at the mirror.

The *indirect lighting* designs use valances, wall washers, or coves to provide the most well-integrated lighting with excellent glare control. Wall wash lighting will tend to visually expand the size of the room. A single light valance at the vanity is often sufficient for the entire room.

Designs

Figure 71 through Figure 76 show some representative designs for bathrooms.

Figure 71. Direct - ceiling surface.

Ceiling surface mount, vanity light above mirror, or sconces beside mirror. Shower and toilet have recessed downlights, wet location.

Figure 72. Direct - downlights.

Recessed downlights with white reflectors. Vanity light above mirror, or sconces beside mirror. Shower and toilet have recessed downlights, wet location.

Figure 73. Recessed downlights.

Recessed downlights with clear reflectors. Vanity light above mirror, or sconces beside mirror. Shower and toilet have recessed downlights, wet location.

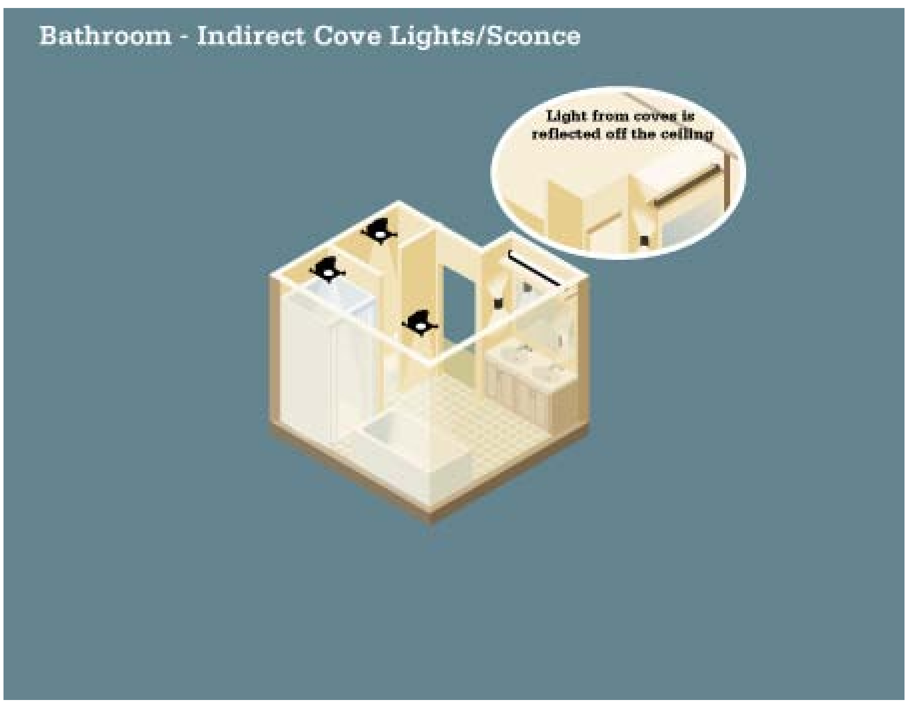

Figure 74. Indirect - cove lights.

Cove, T-5 or T-8 strip lights. Sconces beside mirror. Shower, tub, and toilet have recessed downlights, wet location.

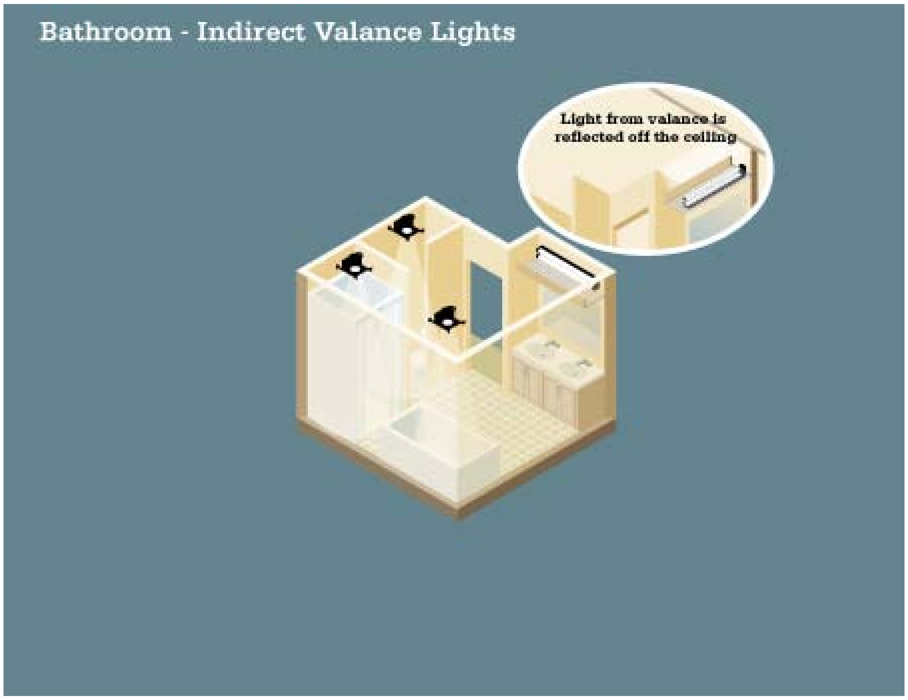

Figure 75. Indirect - soffit light.

Soffit above vanity, T-5 or T-8 strip lights. Shower, tub, and toilet have recessed downlights, wet location.

Figure 76. Indirect - wall washers.

Wall washers. Vanity light above mirror, or sconces beside mirror. Shower and toilet have recessed downlights, wet location.

Service Areas

Figure 77. Closet.

Principles

Service areas include closets (see Figure 77), laundry rooms, utility rooms, workrooms, unfinished basements, and garages. Because of their utilitarian nature, service areas benefit from the simplest level of *direct lighting* with surface mounted fixtures. Although the frequency and length of use of these rooms may not be high, it is common for occupants to leave these lights on and often unattended for long periods; therefore, the efficiency of HPL can provide significant value in reducing lighting energy costs. Use limiting controls are particularly effective in these areas.

The lighting in these rooms often serves as both task lighting and ambient lighting. Thus, it provides somewhat higher levels of illumination than ambient lighting criteria alone would require. It is recommended that 830 (80 CRI, 3000K) lamps be used, even in these utilitarian spaces, for consistency with HPL in other rooms. It is particularly important to use these lamps for closet lighting so that clothing colors appear accurately. Selecting *recessed lighting* for closets will provide a crisp, dramatic illumination of clothes.

In laundries and other workrooms where cabinetry is mounted above counter surfaces, the use of under-cabinet lighting is recommended for good task illumination. The high quality of light provided by *indirect lighting* is typically considered unnecessary for service areas.

Designs

Figure 78 through Figure 84 show some representative designs for various types of service areas.

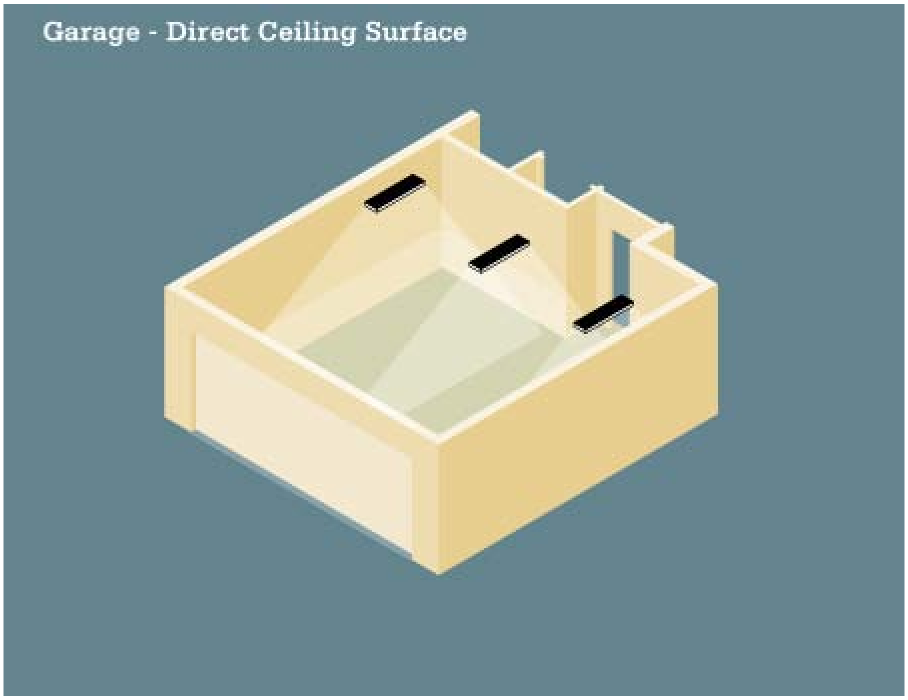

Figure 78. Direct - ceiling surface fixtures.

Ceiling mount or pendant mount, garage.

Figure 79. Direct – wall surface light.

One under-cabinet light, small closet.

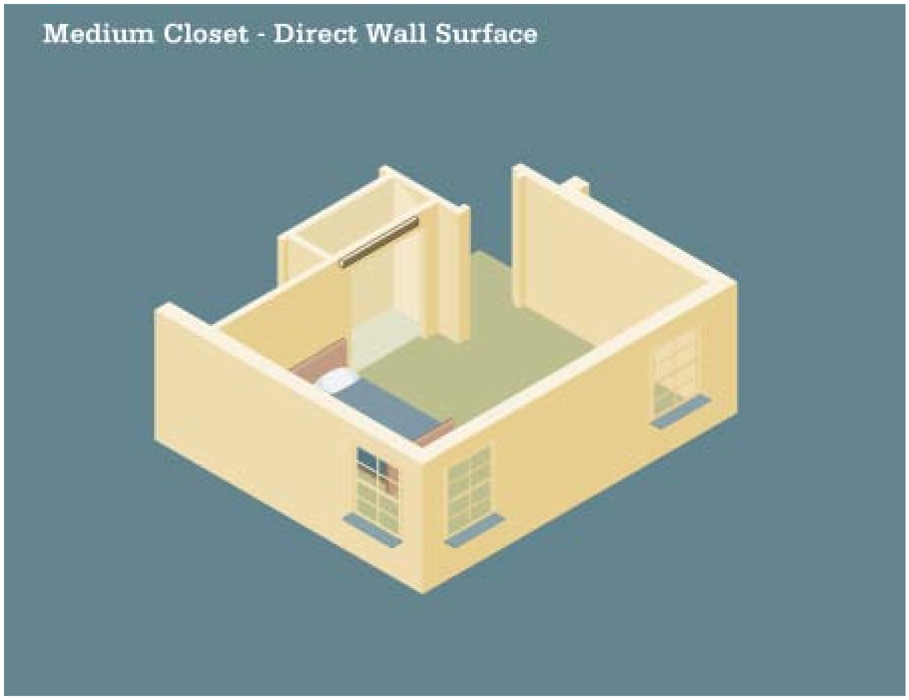

Figure 80. Direct – wall surface light.
One under-cabinet light, medium closet.

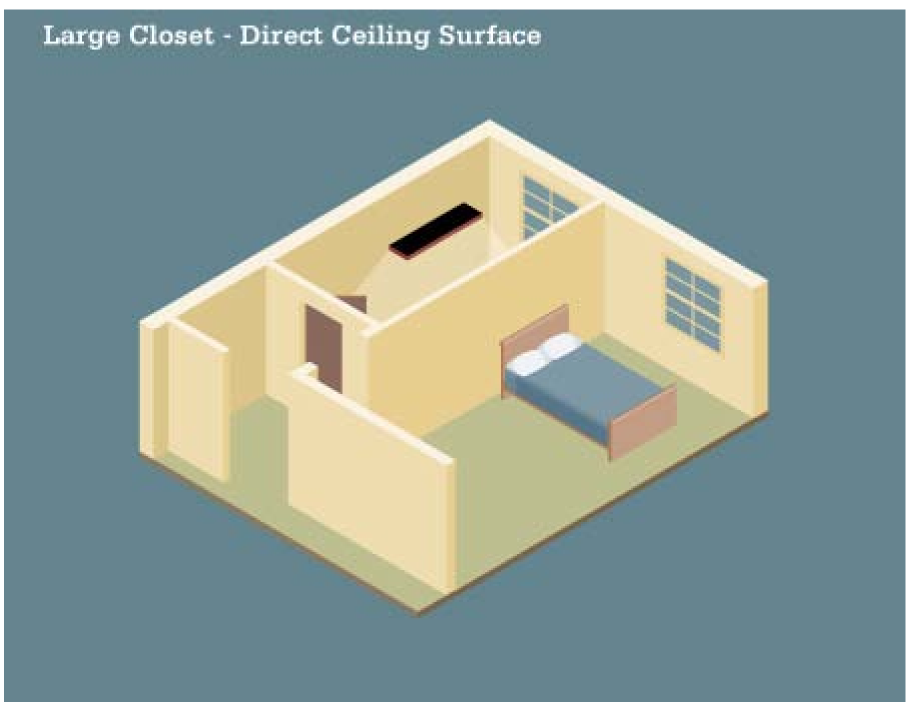

Figure 81. Direct - ceiling surface fixture.
Ceiling mount, large closet.

Figure 82. Direct - downlights.

Recessed downlights with white reflectors, large closet.

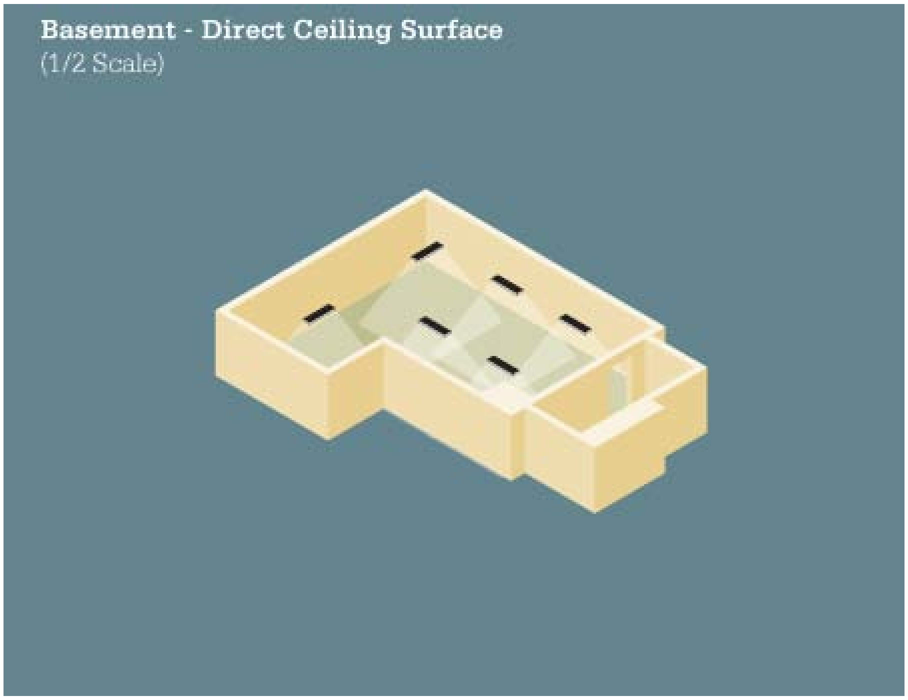

Figure 83. Direct - ceiling surface fixtures.

Ceiling mount, 1X4, basement.

Figure 84. Recessed downlights.

Recessed downlights with clear reflectors, large closet.

Hallway

Figure 85. Hallway.

Principles

To meet the guidelines of *The Lighting Handbook* by IES, hallway designs (see Figure 85) should provide ambient illumination for hallways up to 6 feet wide. For halls wider than 6 feet, lighting should be increased proportionally. The designs shown are applicable to hallways with up to 10-foot ceiling height. Greater heights will require higher wattage fixtures.

The *direct lighting* designs will provide simple, efficient direct illumination.

The *recessed lighting* designs, using recessed downlights (with clear reflectors), provide a subdued and elegant pattern of illumination with excellent glare control.

The *indirect lighting* design employs wall washers for illumination. These give brightness patterns on the walls that may be continuous or intermittent, depending on spacing. The light areas of the walls may also serve as illumination for artwork. Recessed wall washers are a good option to control glare.

Designs

Figure 86 through Figure 90 show some representative designs for hallways.

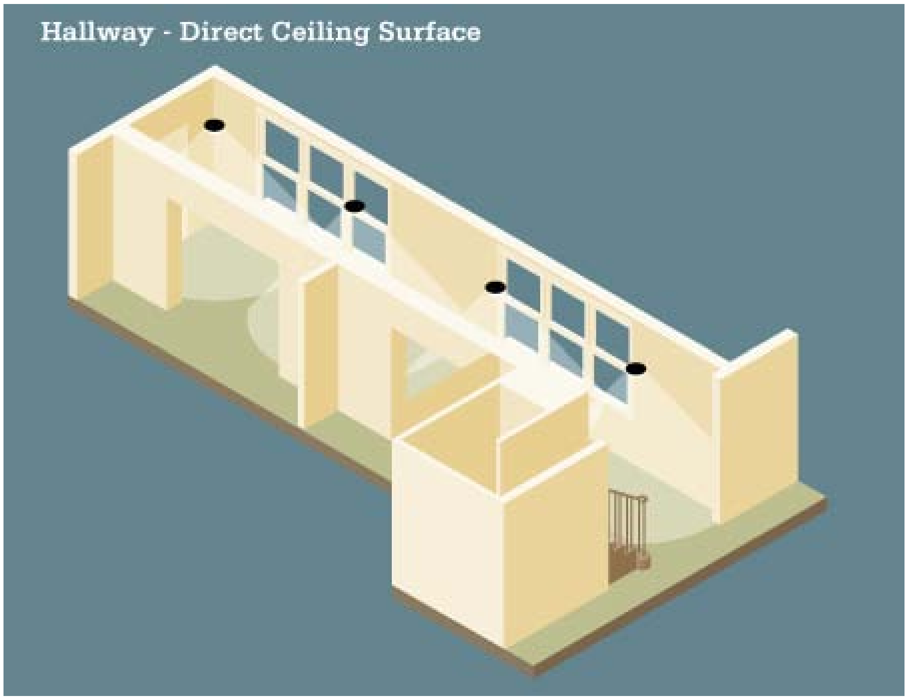

Figure 86. Direct - ceiling surface fixtures.

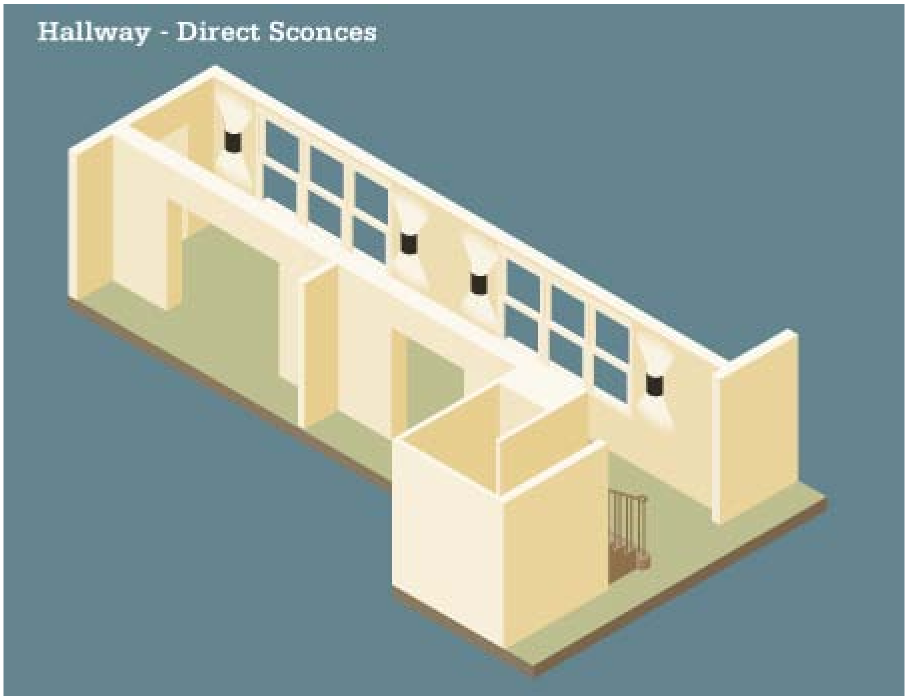

Figure 87. Direct - wall sconces.

Figure 88. Direct - downlights.

Recessed downlights with white reflectors.

Figure 89. Recessed downlights.

Recessed downlights with clear reflectors.

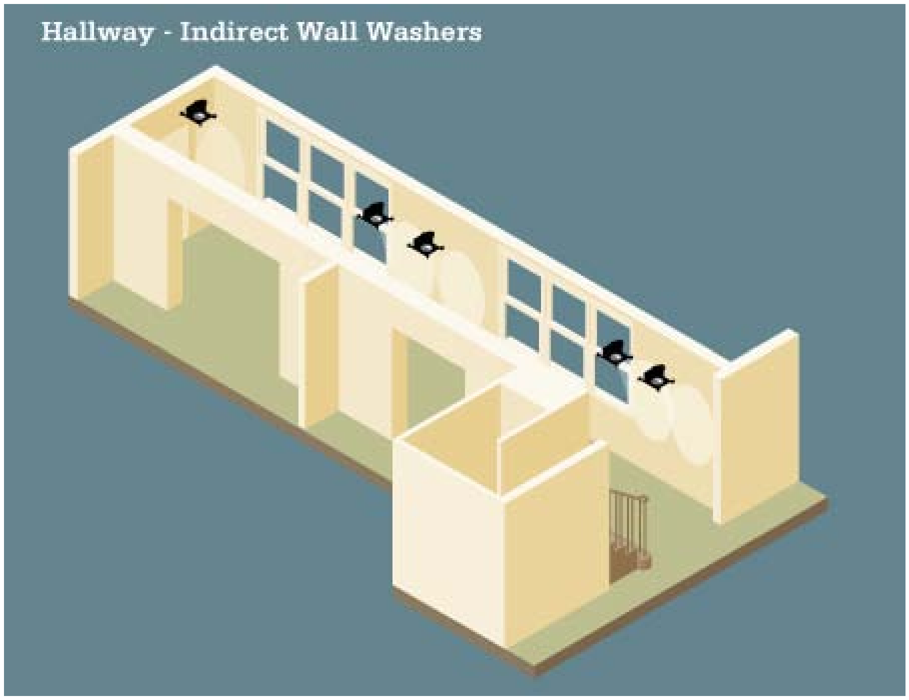

Figure 90. Indirect - wall washers.

Exterior Lighting

Figure 91. LED exterior lighting.

Principles

Only recently have high efficiency fixtures, both CFL and LED, become available to apply in residential exterior lighting (see Figure 91). Because of this, it is now practical to extend HPL principles to the outside of the house as well as the interior. In an HPL exterior lighting design, illuminated exterior areas would generally be limited to areas of practical functional purposes rather than decoration. Thus, high-efficiency fixtures would be applied in three functional areas:

- Circulation paths and points of entry: doors, walks, driveways
- Activity areas: patios, decks, service yards
- Security lighting: building surfaces, service areas.

Note that when decorative lighting is desired, such as for seasonal (Christmas) lighting or landscape lighting, high efficiency fixtures should be employed. For example, very efficient LED Christmas lights are now available.

Designs

Figure 92 shows a representative design for exterior lighting.

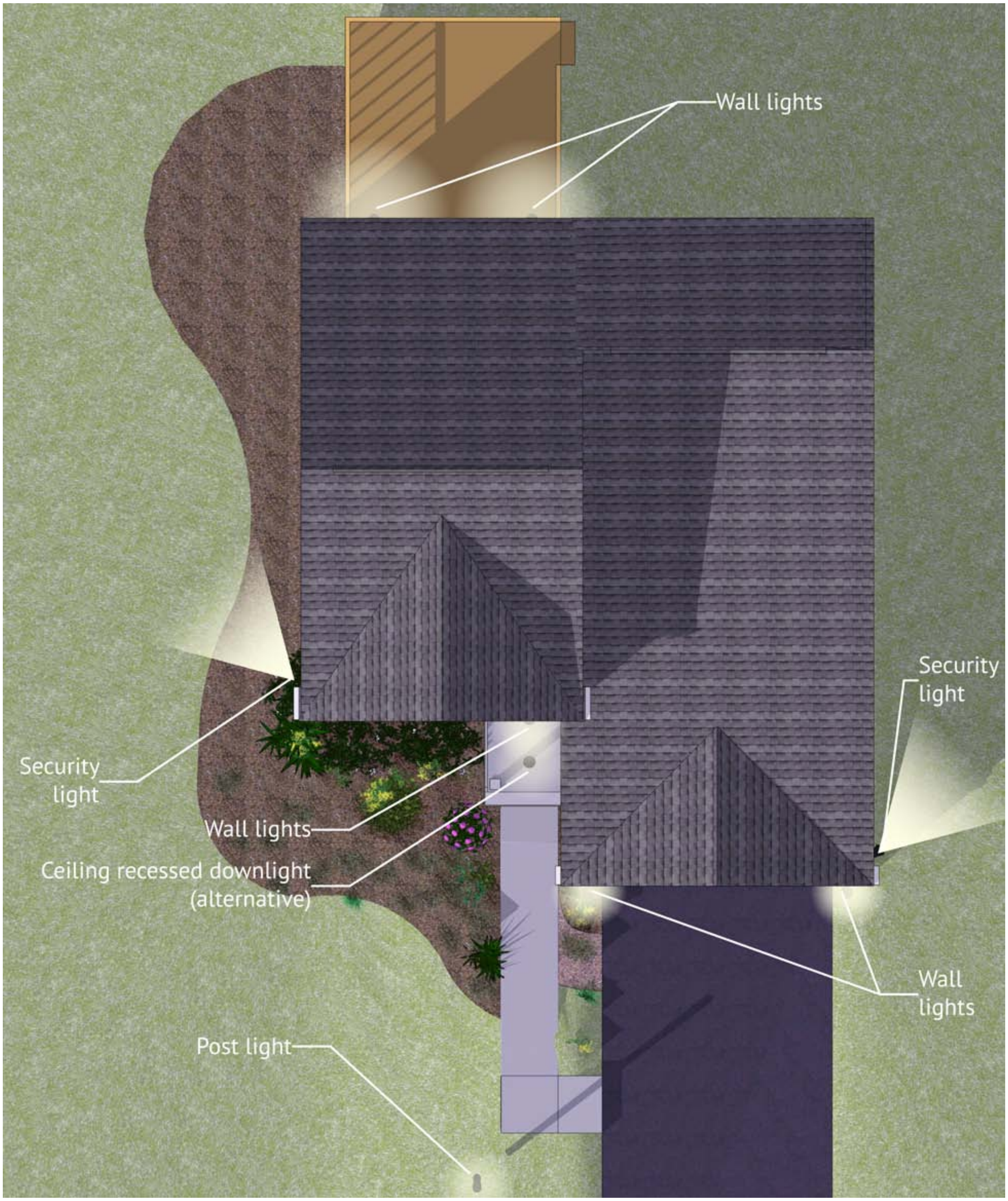

Figure 92. Exterior lighting design.

Controls

An integral part of HPL design is the selection of appropriate controls for the lighting of each room. The controls used for HPL fall into three categories:

- Use limiting: standard switches, occupancy sensors, timers, solar controls (see Figure 93 and Figure 94)
- Intensity limiting: dimmers (see Figure 95)
- Programmed patterns of use: lighting management systems (see Figure 96).

Use limiting controls are the most widely applicable. Every light will have at least an on/off control. Some lights will benefit from occupancy sensor control, the most useful being the manual on/automatic off that prevents lights from staying on after people leave the room. Because unintended shutoff may occur when room occupants are very still, say, when reading or watching TV, the use of motion control automatic off switches may best be limited to rooms where lights are often inadvertently left on. Setting the shut-off interval to a longer time period, such as 20 or 30 minutes, may also help to reduce unintended shutoff. Motion controlled automatic on/automatic off is activated when a person enters or leaves the room. Such controls also are used often on exterior lights where they may be triggered by roaming animals. Sensitivity adjustments may help to limit such annoying performance. Timers and solar controls are particularly applicable to controlling exterior lighting where they respond to daylight conditions.

Intensity limiting controls are very desirable in rooms where the function, and thus the light levels, varies for different activities. A good example is the dining room table, which may be used for both formal dining as well as school homework preparation. Dimmers must be properly teamed with the fluorescent, CFL, or LED fixtures they control. Fixture manufacturers provide specific recommendations for appropriate dimmers, usually from several manufacturers.

Programmable controls and light management systems may be installed to control some or all of the lights in a home. In addition to dimming and on/off control, they can include occupancy sensors, timers, and daylight sensors. Different lighting combinations can be programmed for a variety of activities, such as day, night, vacation (security), party, etc. The system can be controlled from wall mounted terminals or remotely. Some systems include temperature control and window shade control options.

The inclusion of use limiting, intensity limiting, or programmable lighting controls in a lighting installation should result in energy savings over and above that of the more efficient lamps and luminaires. The amount of additional energy and cost savings that will be realized is highly variable and depends on the homeowners' pattern of use. Clearly, for lights that may be left on unattended for long periods of time (e.g., lights in closets, laundries, basements, exterior), the inclusion of use limiting controls, which is a modest cost item, can result in considerable potential savings. Dimming controls are somewhat more costly and offer savings, but such savings are modest. The greatest benefit of dimming controls is the ability to adjust light to desired levels. The most costly control systems are the programmable whole-house lighting management systems, which may offer energy use savings but principally give a high level of multiscene lighting pattern control.

Examples

The following are examples of controls applications:

- Manual on/automatic off
  - Basement
  - Children's bedrooms
- Automatic on/automatic off
  - Interior rooms with no daylight, closets, bathrooms
  - Exterior security lighting
- Timers
  - Garage
- Dimmers
  - Dining room
  - Kitchen, breakfast area
  - Family room
  - Entry hall
- Timers/solar control
  - Exterior lighting.

Figure 93. Manual on/automatic off control.

Figure 94. Occupancy sensor.

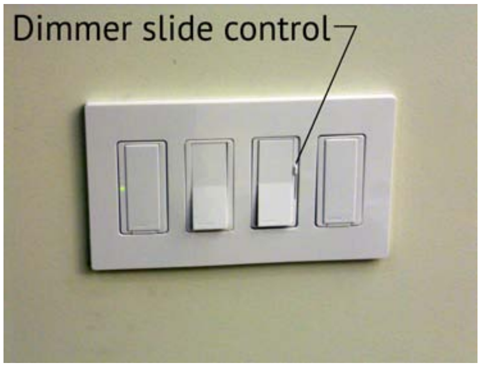

Figure 95. Dimmer control.

Figure 96. Programmable control.

Conclusions

This guideline presents a range of lighting design strategies that may be applied to the rooms of a house. The strategies may be applied from the simplest of actions such as changing the lamps (bulbs), to changing fixtures, to a comprehensive whole-house lighting design. For the individual room designs, light quality options are offered that cover direct lighting, recessed lighting, or indirect lighting.

This document is written to provide a high-level review of high performance residential lighting design strategies. It does not, however, provide application-specific details for implementation of these strategies. In the future, such companion documents may be developed and published under the DOE Building America program; however, the author is not aware of any plans to do so at this time.

An Application Resources section has been provided that lists many sources of application information from manufacturers and independent authorities. Information such as light output and mounting and spacing recommendations from such sources will assist in implementing the HPL strategies.

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Application Resources

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New Buildings Institute, "Advanced Lighting Guidelines." Vancouver, WA: New Buildings Institute; available at http://newbuildings.org.

Zelinsky, M. (2006). "Complete Lighting Design: A Practical Design Guide for Perfect Lighting." Minneapolis, MN: Quarry Books.

Examples of manufacturer's information are as follows:

- Progress Lighting: "Progress Lighting's LED Recessed Brochure"
  "Progress Lighting Green Brochure"

  Available at progresslighting.com
  (resources, print materials)

- Lithonia Lighting; DOM 6 LED, downlight specification sheet
  Reality-6" LED module, specification sheet

  Available at lithonialighting.com
  (LED lighting, LED lighting products)

- Juno Lighting: VuLite LED Module, specification sheet

  Available at junolightinggroup.com
  (VuLite retrofit LED module, V6RL3K-WH, specification sheet)

- Halo Lighting: LED downlight specification sheets
- Available at cooperindustries.com/content/public/en/brands/halo
  (LED, 494 open reflector trims, H7 LED trims, specification sheet)

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