EFFICIENT LIGHTING STRATEGIES

Wise design choices can meet lighting needs and save energy

Buildings for the 21st Century

Buildings that are more energy efficient, comfortable, and affordable…that's the goal of DOE's Building Technologies Program. To accelerate the development and wide application of energy efficiency measures, the Building Technologies Program:

- Conducts R&D on technologies and concepts for energy efficiency, working closely with the building industry and with manufacturers of materials, equipment, and appliances
- Promotes energy/money saving opportunities to both builders and buyers of homes and commercial buildings
- Works with state and local regulatory groups to improve building codes, appliance standards, and guidelines for efficient energy use

INTRODUCTION

Convenient and effective artificial lighting is one of the important advances of the 20th century. Artificial lighting allows us to work and play inside and outside our homes independent of the time of day, and also often serves aesthetic purposes. Artificial lighting is generally employed for three types of uses:

Ambient lighting—Provides general illumination indoors for daily activities and outdoors for safety and security.

Task lighting—Facilitates particular tasks that require more light than is needed for general illumination, such as under-counter lights in kitchens, table lamps, or bathroom mirror lights.

Accent lighting—Draws attention to special features or enhances the aesthetic qualities of an indoor or outdoor environment.

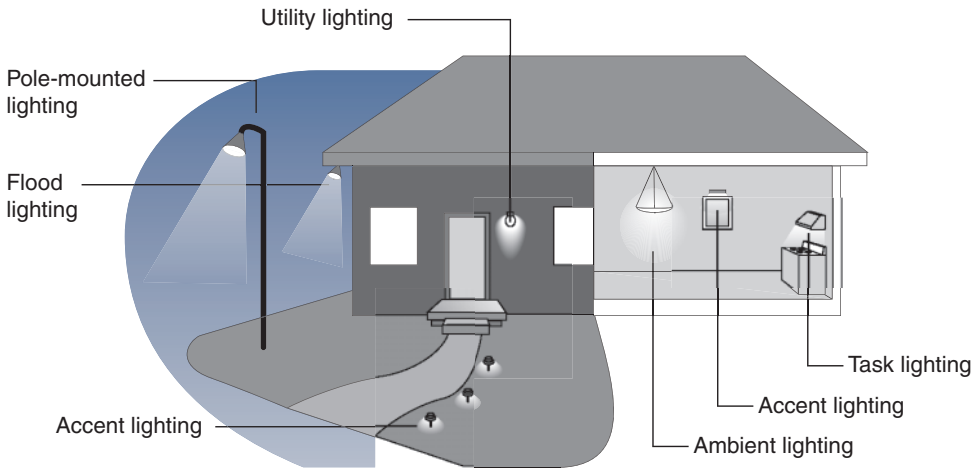
Recent technological improvements allow homeowners to substantially reduce the energy they use for lighting without loss of amenity.

BENEFITS OF ADVANCED LIGHTING

Artificial lighting consumes almost 15 percent of household electricity. The traditional incandescent bulb with screw base currently provides most household illumination. Use of new lighting technologies can reduce lighting energy use in homes by 50 to 75 percent. Advances in lighting controls offer further energy savings by reducing the amount of time lights are on but not serving a useful purpose. Advanced lighting controls also offer a new amenity—lights that come on automatically when they are needed.

INDOOR/OUTDOOR LIGHTING TYPES

There are varied lighting technologies for all lighting situations. Consideration should be given to energy-efficient lighting choices in fixtures that are on for more than 2 hours a day.



LIGHTING DESIGN CONCEPTS

Energy-efficient lighting design focuses on methods and materials that improve both quality and efficiency of lighting. Energy-efficient lighting design principles include the following:

- Keep in mind that more light is not necessarily better. Human visual performance depends on light quality as well as quantity.
- Match the amount and quality of light to the performed function.
- Install task lights where needed and reduce ambient light elsewhere.
- Use energy-efficient lighting components, controls, and systems.
- Maximize the use of daylighting.

INTERIOR LIGHTING OPTIONS

✓ Daylighting

Daylighting is the use of windows and skylights to bring daylight into the home. Today's highly efficient windows and advances in lighting design allow efficient use of windows to reduce the need for artificial lighting during daylight hours without causing heating or cooling problems. The sizes and locations of windows should be based on the cardinal directions rather than their effect on the street-side appearance of the house, for example. South-facing windows are most advantageous for daylighting and for moderating seasonal temperatures because they allow most winter sunlight into the home but little direct sun during the summer, especially when properly shaded. North-facing windows are also advantageous for daylighting because they admit relatively even, natural light, producing little glare and almost no unwanted summer heat gain. Although east- and west-facing windows provide good daylight penetration in the morning and evening, respectively, they should be limited because they may cause glare, admit a lot of heat during the summer when it is usually not wanted, and contribute little to solar heating during the winter.

✓ Indoor Lighting Technologies

Incandescent lighting has traditionally delivered about 85 percent of household illumination. Incandescents operate without a ballast, are dimmable and instantly controllable, and light up instantly. Most familiar are the standard pear-shaped, screw-in "A"-type incandescent light bulbs. They produce a warm light and provide excellent color rendition. They have a low efficacy compared to all other lighting options (10 to 17 lumens per watt) and a short average operating life (750 to 2500 hours).

Incandescent lamps can be made in other shapes and variations. Tungsten halogen lamps provide excellent color rendition. Reflector (R) and parabolic aluminized reflector (PAR) lamps direct light in a desired direction. All three are slightly more efficient than standard bulbs, have longer operating lives (2000 to 4000 hours), and are often used for accent lighting.

BULB COMPARISON CHART

	Efficacy (lumens/watt)	Lifetime (hours)	Color rendition index (CRI)	Color temperature (K)
Incandescent				
Standard "A" bulb	10-17	750-2500	98-100 (Excellent)	2700-2800 (Warm)
Tungsten halogen	12-22	2000-4000	98-100 (Excellent)	2900-3200 (Warm to neutral)
Reflector (R)	12-19	2000-3000	98-100 (Excellent)	2800 (Warm)
Parabolic aluminized reflector (PAR)	12-19	2000-3000	98-100 (Excellent)	2800 (Warm)
Fluorescent				
Straight tube	30-110	7000-24,000	50-90 (Fair to good)	2700-6500 (Warm to cold)
Compact fluorescent lamp (CFL)	50-70	10,000	65-88 (Good)	2700-6500 (Warm to cold)
Circuline	40-50	12,000		
Outdoor Lighting				
Mercury vapor	25-60	16,000-24,000	50 (Poor to fair)	3200-7000 (Warm to cold)
Metal halide	70-115	5000-20,000	70 (Fair)	3700 (Cold)
High-pressure sodium	50-140	16,000-24,000	25 (Poor)	2100 (Warm)
Low-pressure sodium	60-150	12,000-18,000	-44 (Very poor)	

Fluorescent lamps use 25 to 35 percent of the energy used by incandescent lamps to provide the same amount of illumination (efficacy of 30 to 110 lumens per watt) and last about 10 times longer (7,000 to 24,000 hours). Improvements in technology have resulted in fluorescent lamps with color temperature and color rendition that are comparable to incandescent lamps.

Fluorescent lamps require a ballast to regulate operating current and provide a high start-up voltage. Electronic ballasts outperform standard and improved electromagnetic ballasts by operating at a very high frequency that eliminates flicker and noise. They are also more energy-efficient. Special ballasts are needed to allow dimming of fluorescent lamps.

Two general types of fluorescent lamps are available. The traditional tube-type fluorescent is usually identified as T12 or T8 (12/8 or 8/8 of an inch tube diameter, respectively) and is installed in a dedicated fixture with a built-in ballast. The newer compact fluorescent lamps (CFLs) and circulines have smaller diameters and are usually bent or twisted into compact shapes. These are frequently sold with built-in or separate electronic ballasts and screw thread adapters for application in fixtures designed for incandescent bulbs. Dedicated fixtures that are equipped with electronic ballasts and that use plug-in (pin) CFLs are also available.

✓ Indoor Lighting Controls

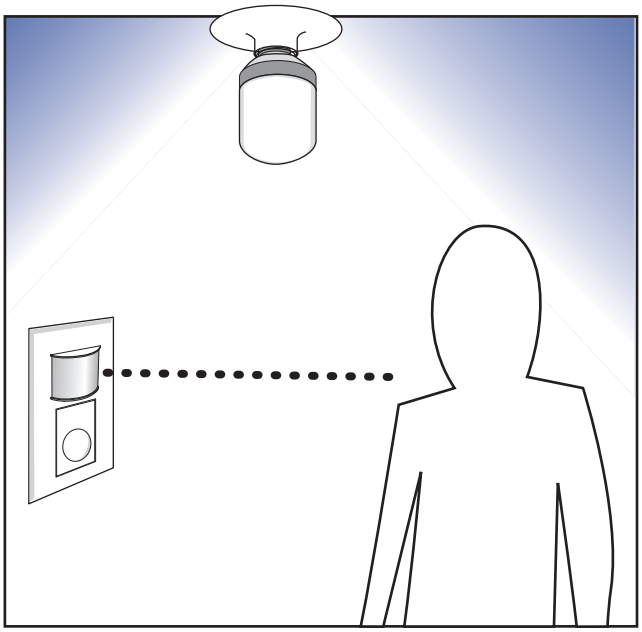
The traditional **on-off toggle** switch has long been the lighting control of choice in homes. For rooms with two entrances, three-way switches make it more convenient to turn off lights when leaving the room. However, experience shows that even with convenient light switch locations, lights are often left on when rooms are unoccupied.

Dimmer controls provide variable lighting for fixtures. Off-the-shelf switches for incandescent fixtures are inexpensive and provide some energy savings when lights are used at a reduced level. Fluorescent dimmers are dedicated fixtures and bulbs that provide even greater energy savings than a regular fluorescent bulb.

Photosensors have little utility in controlling lights inside the home because lighting needs vary with occupant activity rather than ambient lighting levels.

OCCUPANCY SENSORS

Home automation can be achieved on a small scale through smart switches. Occupancy sensors provide individual switching and timing for room lights and other fixtures.



Occupancy sensors detect activity within a certain area. They provide convenience by turning lights on automatically when someone enters a room. They reduce lighting energy use by turning lights off soon after the last occupant has left the room. Occupancy sensors must be located where they will detect occupants or occupant activity in all parts of the room. There are two types of occupancy sensors: ultrasonic and infrared. Ultrasonic sensors detect sound, while infrared sensors detect heat and motion. In addition to controlling ambient lighting in a room, they are useful for task lighting applications, such as over kitchen counters. In such applications, task lights are turned on by the motion of a person washing dishes, for instance, and automatically turn off a few minutes after the person stops.

Timers are sometimes used to give unoccupied houses a lived-in look. However, they are an ineffective control for an occupied home because they do not respond to changes in occupant behavior.

EXTERIOR LIGHTING OPTIONS

Exterior lighting for homes generally serves one or a combination of three principal purposes: **aesthetics**—illuminate the exterior of the house and landscape, **security**—placed on poles or high on the building to illuminate the grounds near the house or driveway, and **utility—**illuminate porch and driveway to help people navigate safely to and from the house.

✓ Outdoor Lighting Technologies

Incandescent lamps are the most commonly used outdoor lights around homes.

Fluorescent lamps are not always suitable for outdoor use because they may not operate well at temperatures below 40˚F. However, some CFLs are specially designed to operate at low temperatures down to –20˚F for outdoor use.

High-intensity discharge (HID) and low-pressure sodium lamps are suitable for some outdoor lighting purposes. The most common types of HID lamps are mercury vapor, metal halide, and high-pressure sodium—all of which are much more efficient than incandescent lamps. Metal halide lamps produce a bright, white light with fair color rendition, have a lifetime of about 6,000 hours, and are more efficient than mercury vapor lamps. Mercury vapor and high-pressure sodium lamps have poorer color rendition but longer lifetimes (16,000 to 24,000 hours). Mercury vapor lamps have an efficacy of about 50 lumens per watt, while high-pressure sodium lamps have an efficacy of 50 to 140 lumens per watt. Low-pressure sodium lights are the most efficient and have long lifetimes (12,000 to 18,000 hours), but they have very poor color rendition. HID and low-pressure sodium lights require up to ten minutes to start and have to cool before they can restart, so they are most suitable for applications where they stay on for hours at a time. They are not suitable for use with motion detectors.

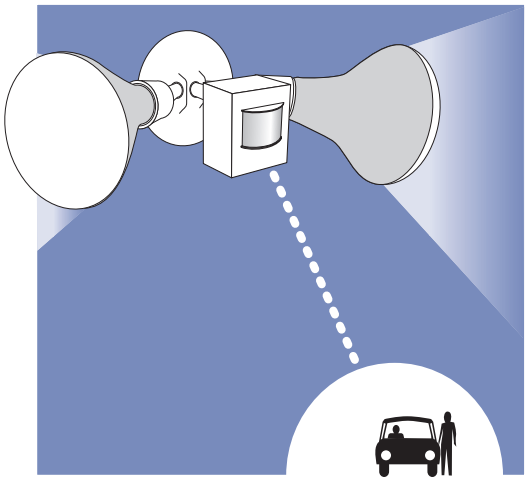
✓ Outdoor Lighting Controls

Outdoor lights are often controlled by toggle switches, but it is easy for occupants to forget to turn the lights off when they are not needed. Two controls that are especially useful with outdoor lighting are photosensors and motion sensors.

Photosensors sense ambient light conditions and are used to prevent outdoor lights from operating during daylight hours. They are useful with all forms of outdoor lighting.

MOTION SENSORS

Outdoor motion sensors have revolutionized outdoor lighting and security strategies. Economical models offer sophisticated features and energy-saving benefits.



Motion sensors automatically turn outdoor lights on when they are needed (when motion is detected) and turn them off a short while later. They are very useful for outdoor security and utility lighting provided by incandescent lamps.

Because utility lights and some applications of security lights are needed only when it is dark *and* people are present, the best controller may be a combination of motion sensor to turn on lights when people are present and photosensor to prevent lights from operating during daylight hours. Incandescent flood lights with photosensor and motion detector controls may actually use less energy than pole-mounted HID or low-pressure sodium security lights controlled by a photosensor. Even though HID and low-pressure sodium lights are more efficient than incandescents, they are turned on for a much longer period of time than incandescents using these dual controls.

Simple **timers** are not often used alone for outdoor lighting because the timer may have to be reset often with the seasonal variation in the length of night. However, they can be used effectively in combinations with other controls. For example, the best combination for aesthetic (decorative) lighting may be a photosensor that turns lights on in the evening and a timer that turns the lights off at a certain hour of the night (e.g., 11 P.M.).

INITIAL DESIGN RECOMMENDATIONS

Home designers and builders can reduce lighting energy use by selecting light fixtures and sources that use energy more efficiently, and by installing controls to reduce the amount of time lights are on.

✓ Indoors

- Maximize the use of daylighting.
- Install fluorescent light fixtures for all ceiling- and wall-mounted fixtures that will be on for more than 2 hours each day. These often include the fixtures in the kitchen and living room, and sometimes those in bathrooms, halls, bedrooms, and other higher-demand locations. Install dedicated compact fluorescent fixtures, rather than CFLs in incandescent fixtures, so that fluorescent bulbs continue to be used for the life of the house.
- Encourage occupants to use CFLs in portable lighting fixtures that are operated for more than 2 hours a day.
- If recessed lights are used in a ceiling with an unconditioned space above it, use only Underwriters Laboratory (UL) approved fixtures that are airtight, are IC (insulation contact) rated, and meet ASTM E283 requirements.
- Also consider
  - Light wall colors to minimize the need for artificial lighting.
  - Energy Star® lighting fixtures.
  - Occupancy detector controls.

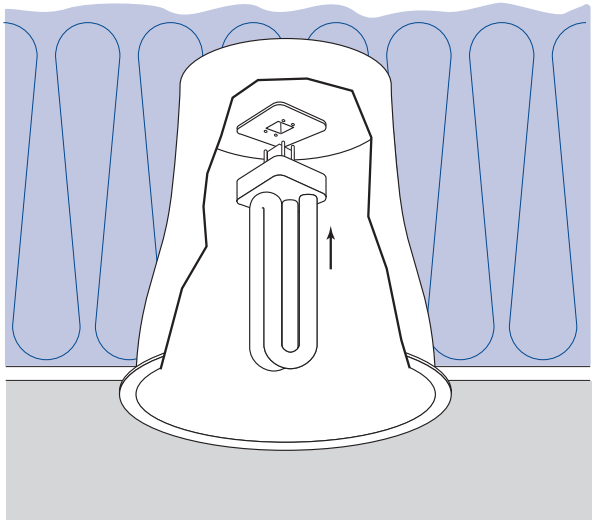
✓ Outdoors

- Security and utility lighting does not need to be bright to be effective.
- Use fluorescent, HID, or low-pressure sodium lights unless incandescent lights are automatically controlled to be on for just a few minutes each day.
- Consider incandescent flood lights with combined photosensors and motion sensors in the place of other security lighting options.
- Make sure outdoor light fixtures have reflectors, deflectors, or covers to make more efficient use of the light source and help reduce light pollution.
- In most applications, use
  - Photosensors to turn off lights during daylight hours.
  - Motion detectors to activate security or utility lighting when needed.
  - Timers and other controls to turn decorative lighting on and off.

DEDICATED COMPACT FLUORESCENT FIXTURES

Installing compact fluorescent fixtures that accept only CFLs ensures lifelong energy-saving benefits. Many new CFL fixtures offer a dimmable feature and perform much like incandescent fixtures.

- Insulation Contact (IC) rated recessed fixtures allow complete coverage of insulation in attic installations.



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LIGHTING PRINCIPLES AND TERMS

✓ Light Quantity

The quantity of light emitted by lamps is measured in *lumens*. By way of reference, a 100-watt incandescent lamp emits about 1750 lumens. While the quantity of light produced by a lamp is measured in lumens, the purpose of all lighting is to produce *illumination* (i.e., to provide light on a surface). The intensity of illumination is measured in *footcandles*. A footcandle is the illumination produced by one lumen distributed over a 1-square-foot area. For most home and office work, 30 to 50 footcandles of illumination is sufficient. For detailed work, 200 footcandles of illumination or more allows more accuracy and less eyestrain. For simply finding one's way around at night, 5 to 20 footcandles may be sufficient.

✓ Efficacy

One of the means to reduce lighting energy consumption is to use light sources that produce more light from little electricity. The ratio of light produced to energy consumed is called *efficacy*. Efficacy is measured as the number of lumens produced divided by the rate of electricity consumption (lumens per watt).

✓ Light Quality

Three concepts are important to understand lighting quality:

- **Color temperature** refers to the color of the light source. By convention, yellow-red colors (like the flames of a fire) are considered warm, and blue-green colors (like light from an overcast sky) are considered cool. Color temperature is measured in Kelvin (K) temperature. Confusingly, higher Kelvin temperatures (3600 to 5500 K) are what we consider cool and lower color temperatures (2700 to 3000 K) are considered warm. Cool light is preferred for visual tasks because it produces higher contrast than warm light. Warm light is preferred for living spaces because it is more flattering to skin tones and clothing. A color temperature of 2700 to 3600 K is generally recommended for most indoor general and task lighting applications.
- **Color rendition** refers to how colors appear when illuminated by a light source and is generally considered to be a more important lighting quality than color temperature. Most objects are not a single color, but a combination of many colors. Light sources that are deficient in certain colors may change the apparent color of an object. The *Color Rendition Index* (CRI) is a 1 to 100 scale that measures a light source's ability to render colors the same way sunlight does. The top value of the CRI scale (100) is based on illumination by a 100-watt incandescent light bulb. A light source with a CRI of 80 or higher is considered acceptable for most indoor residential applications.
- **Glare** refers to excessive brightness from a direct light source that makes it difficult to see what one wishes to see. A bright object in front of a dark background usually will cause glare. Bright lights reflecting off a television or computer screen or even a printed page produce glare. Intense light sources such as bright incandescent lamps are likely to produce more direct glare than large fluorescent lamps. However, glare is primarily the result of relative placement of light sources and the objects being viewed.

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