High-Efficacy Lighting

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Scope

Choose high-efficiency lighting for energy savings in new homes.

- Determine the lighting criteria for local applicable codes and any efficiency program targets.
- Design a lighting plan to meet or exceed these minimum targets.
- Consider including lighting controls such as motion sensors, timers, and dimmers for increased savings.

See the Compliance Tab for related codes and standards requirements, and criteria to meet national programs such as DOE’s Zero Energy Ready Home program, ENERGY STAR Certified Homes, and Indoor airPLUS.
Lighting represents about 20% of a home’s electricity bill. Installing or switching from less efficient bulbs such as traditional incandescent bulbs to high efficiency lighting such as light emitting diodes (LEDs) and compact fluorescent lamps (CFLs) is one of the easiest steps to take to save on one’s energy bills. CFLs and LEDs use approximately 75% less energy than traditional incandescents to produce the same amount of light. They also last longer and produce less heat. Other ways to reduce lighting costs including adding lighting controls, such as dimmers, motion sensors, and photo sensors, and designing rooms to incorporate daylighting with traditional windows, clerestory windows, skylights, and solar tubes.

With passage of the Energy Independence and Security Act of 2007, new requirements were phased in requiring manufacturers to cut energy use for common light bulb types about 27% by January 2014. (For example after the standard went into effect, “100-Watt” bulbs were required to use ? 72 W; 75 W were required to use ? 53 W; 60 W were required to use ? 43 W; and 40 W were required to use ? 29 W). By 2020, most standard light bulbs will need to be 60% to 70% more efficient than standard bulbs in 2007. Most LED and CFL lights were meeting that higher standard by 2011, cutting energy use 75% compared to standard incandescents, according to the EPA.

One concern about high-efficiency lighting choices has been color rendition, as early compact fluorescents often appeared whiter or bluer than the familiar "warm" incandescents. Light color is measured on a temperature scale using Kelvin (K) units. Energy-efficient lighting products are available today in a variety of color renditions ranging from lower Kelvin (<3000K) "warm" yellowish lights to higher Kelvin (>5000K) cool white lights. For comparison, daylight is typically identified as 4500K or higher.

- For a warmer light, look for bulbs marked 2700-3000K.
- For a whiter light, look for bulbs marked 3500-4100K.
- For cooler white light, look for bulbs marked 5000-6500K.

Desired light output may also be hard to gauge for consumers used to thinking in terms of watts. Light output is measured in lumens. For comparison, a standard 100-Watt incandescent bulb puts out about 1600 lumens and a standard incandescent 60-W bulb puts out about 800 lumens. Lumens and color temperature should be listed on the bulb packaging. Look for ENERGY STAR labeled lighting, which is required to meet criteria for light output, color, longevity, and efficiency. See these DOE websites for more on the history of lighting technology and basic principles of artificial lighting.

Compact Fluorescents (CFLs)

CFLs produce light much more efficiently than incandescent bulbs, using about 75% less energy than incandescents. Standard incandescent bulbs produce light when an electric current passes through a filament and causes it to glow; they give off 90% of their energy as heat not light. In contrast, fluorescent bulbs give off only about 30% of their energy in the form of heat. They produce light when an electric arc passes between cathodes to excite mercury and other gases, producing radiant energy, which is then converted to visible light by a phosphor coating.
Due to the fact that CFLs use a ballast to help "kick start" and then regulate the current once the electricity starts flowing, they can take longer than other types of lighting to reach full brightness. However, CFLs have come a long way since their first inception and many of today's CFLs start faster, are more efficient, produce light in a variety of color renditions, cost less, and are available in a variety of sizes and shapes. They can last 10 times longer (7,000-24,000 hours) than standard incandescents. In addition to the now common screw-based CFLs, there are also pin-based CFLs and tubular fluorescent lamps, which are made to fit specific lighting fixtures where the ballast is part of the fixture.

Some types of CFL bulbs may not match their traditional incandescent counterparts in terms of bulb size, light output, or color rendition. Check the packaging for color temperature and light output comparisons. Not all CFLs are dimmable. Make sure dimmable CFLs are specified where desired. When installing dimmable CFL lighting, make sure to install a dimmer switch that is compatible. Most photocells, motion sensors, and electric timers are not designed to work with CFLs, which limits their use with lighting controls and smart lighting technology. Check with the manufacturer of the control for compatibility.

One other concern with CFLs is that they contain a small amount of mercury. Because mercury is harmful to humans and to the environment, CFLs must be disposed of properly, typically through municipal or hardware store recycling programs.

Solid State Light Emitting Diodes (LEDs)

LEDs, or light–emitting diodes, are a type of solid state lighting (SSL) that produce visible light very efficiently. As LEDs come down in price, they are spurring a dramatic change in residential lighting due to their vast energy savings potential, low environmental impact, long lifetime, maintenance savings, size versatility, and compatibility with lighting controls. ENERGY STAR certified LED products use at least 75% less energy and last up to 25 times longer than traditional incandescent lighting. By 2027, widespread use of LEDs could save about 348 terawatt hours of electricity. This is equivalent to the annual electrical output of 44 large power plants (1000 megawatts each) and equals a savings of more than $30 billion at today's electricity prices.

LEDs produce light when voltage is applied to negatively charged semiconductors, causing electrons to flow from one material in the structure to another, which causes a series of complex interactions to create a unit of light (photon) in a very efficient, predictable, and orderly manner. This method of producing light is fundamentally different than that of any other light source. Key differences include the following:

- **Light Source**: The actual diode is the size of a fleck of pepper and comes in red, green, blue, or amber. These colors are typically combined to make white light.

- **Direction**: Unlike incandescent and fluorescent lamps, which emit light in all directions, LEDs emit light in a specific direction, which reduces the need for reflectors and diffusers and makes LEDs more efficient for uses such as recessed downlights and task lighting. With many other types of lighting such as incandescent and fluorescent lighting, the light is emitted in all directions and must be reflected toward the desired direction; with these types of lighting, more than half of the light may never leave the fixture.
Heat: LEDs emit very little radiated heat. Heat is produced from the power going into the LED and this heat is absorbed and dissipated by a heat sink designed into the base of the LED.

Durability: Because the actual light source in the LED is a tiny solid state chip rather than a fragile filament or glass tube, LEDs are more durable. Also LEDs don't "burn out." Instead, LEDs experience lumen depreciation, meaning that over the life of the bulb, the amount of light produced decreases and the color appearance of the light can shift. Therefore, an LED product’s “lifetime” is determined by when its light output is predicted to decrease by 30%. Although many LED products today are designed to mirror the shape of traditional incandescent fixtures, the tiny size of the actual light source lends itself to great versatility in product size and shape.

Figure 3. Quality LED light bulbs save energy, last longer, are more durable, and offer comparable or better light quality than other types of lighting (Source: U.S. DOE).

When installing dimmable LED lighting, make sure to install a dimmer switch that is compatible with the light source. The High Efficacy Lighting New Construction Guide by Pacific Northwest National Laboratory provides insight on how to ensure success with energy-efficient lighting selections.

ENERGY STAR Certified Lighting

Lighting that earns the ENERGY STAR certification has met strict criteria ensuring energy efficiency, light output, color, and longevity. ENERGY STAR certified light bulbs:

- Use about 70%-90% less energy than traditional incandescent bulbs.
- Last at least 15 times longer and save about $80 in electricity costs over their lifetime.
- Meet strict quality and efficiency standards, are tested by accredited labs, and certified by a third party
- Produce about 70%-90% less heat, so they are safer to operate and can cut energy costs associated with home cooling.

The ENERGY STAR and DOE websites provide a wealth of information to consumers about selecting energy-efficient lighting:

- The DOE article Buying the Perfect Energy-Efficient Light Bulb in Five Easy Steps provides a concise checklist for light bulb shopping, including a helpful table that identifies the replacement light bulb options for specific light fixtures.
- The ENERGY STAR Choose a Light Guide is an online tool that can help the homeowner identify the light bulb shape, color, and brightness appropriate to the household application. The Choose a Light Guide provides the homeowner with the right specifications to use in the purchase of new light bulbs.
- The homeowner can also use the ENERGY STAR LED Bulb Checklist as a resource in determining the light bulb replacement that’s appropriate for the application.
- For homeowners who want a detailed assessment of energy savings, the ENERGY STAR Savings Calculator for Certified Lighting provides custom energy savings based on bulb type, usage, incremental cost, and lifetime.
- Homeowners interested in understanding more about lighting can review the following ENERGY STAR web pages:
  - Learn About Color and Mood
  - Learn About Brightness
  - Glossary of Terms

- When purchasing lighting at brick-and-mortar stores, homeowners should pay attention to the Lighting Facts Label, which is a mandatory product packaging label that provides the specifications detailing the lamp’s brightness, color, annual energy cost, lifetime, and power draw.
• **Lighting controls** such as timers and photocells save electricity by turning lights off when not in use. Dimmers save electricity when used to lower light levels. The homeowner should make sure to select lighting control products that are compatible with the energy-efficient bulbs.

• The homeowner can use the **ENERGY STAR Product Finder** to find ENERGY STAR certified light bulbs and fixtures that meet the household’s needs.

• The homeowner or contractor will want to check the **Database of State Incentives for Renewables & Efficiency**® or the **ENERGY STAR Rebate Finder** to determine whether a light bulb or fixture model is eligible for a rebate or incentive in the area.

![Figure 4. LEDs cut energy costs by using less watts to produce the same amount of light as other light sources. (Source: ENERGY STAR Lighting).](image)
Figure 5. The Lighting Facts label can help consumers select the appropriate light bulb based on brightness, yearly energy cost, lifetime, appearance, and power. (Source: Federal Trade Commission)

Installing High-Efficacy Lighting

1. In new construction, specify high-efficiency lighting in a lighting plan that is part of the overall design package (Figure 6).

Figure 6. Design high-efficiency lighting into home plans.
2. Select high-efficiency lighting that is rated for its installed location (e.g., interior or exterior) and that provides the desired light level, color rendering, and functionality (Figure 7). Select the right dimmer for the specific lighting being installed (Figure 8); some dimmers are specifically rated for CFLs or LEDs.

![Figure 7](image1.png)

**Figure 7.** Some LEDs lamps are designed for recessed lighting fixtures.

![Figure 8](image2.png)

**Figure 8.** Select dimmer switches that are compatible with installed lighting.

3. Inspect to verify that correct lighting products were installed.
Ensuring Success

Hire a lighting designer knowledgeable in energy-efficient lighting, if necessary, to assist in developing a lighting plan. Choose the right lighting type for the application: install high-efficiency lighting that is rated for its installed location (i.e., inside, outside), and provides proper light level (lumens), color rendering, and functionality for its location and purpose. Select the right dimmer for the technology; some dimmers are specifically rated for CFLs or LEDs. Inspect to verify correct lighting products were installed.
Climate

Because high-efficiency LEDs and CFLs produce less heat than traditional incandescent light sources, they may help to reduce cooling loads in warm and hot climates while seasonally reducing cooling loads in mixed or cool climates.

In cold climates, when specifying exterior lighting, consider light source options and applications. CFLs that are slow to come to full brightness at cold temperatures may not be a good choice for entrance lighting and motion-sensor activated security lighting.
Training

Right and Wrong Images
None Available
None Available
Compliance

The Compliance tab contains both program and code information. Code language is excerpted and summarized below. For exact code language, refer to the applicable code, which may require purchase from the publisher. While we continually update our database, links may have changed since posting. Please contact our webmaster if you find broken links.

ENERGY STAR Certified Homes, Version 3/3.1 (Rev. 09)

National Program Requirements

Exhibit 1: ENERGY STAR Reference Design Home.
The ENERGY STAR Reference Design Home is the set of efficiency features modeled to determine the ENERGY STAR ERI Target for each home pursuing certification. Therefore, while the features below are not mandatory, if they are not used then other measures will be needed to achieve the ENERGY STAR ERI Target.

ENERGY STAR light bulbs modeled in 90% of ANSI / RESNET / ICC Standard 301-defined Qualifying Light Fixture Locations.

Please see the ENERGY STAR Certified Homes Implementation Timeline for the program version and revision currently applicable in your state.

DOE Zero Energy Ready Home (Revision 07)

Exhibit 1 Mandatory Requirements.

Exhibit 1, Item 1) Certified under the ENERGY STAR Qualified Homes Program or the ENERGY STAR Multifamily New Construction Program.

Exhibit 1, Item 5) 80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 80% of sockets.

2009 IECC and 2009 IRC

The 2009 IECC R404.1 (2009 IRC N1104.1) requires that at least 50% of the lamps in permanently installed lighting fixtures be high-efficacy lamps.

2012 and 2015 IECC / 2012 and 2015 IRC

The 2012 IECC and 2015 IECC R404.1 (2012 IRC and 2015 IRC N1104.1) require that at least 75% of the lamps in permanently installed lighting fixtures be high-efficacy lamps.

2018 IECC and 2018 IRC

The 2018 IECC R404.1 (2018 IRC N1104.1) requires that at least 90% of the lamps in permanently installed lighting fixtures be high-efficacy lamps.


Section R101.4.3 (Section R501.1.1 in 2015 and 2018 IECC). Additions, alterations, renovations, or repairs shall conform to the provisions of this code, without requiring the unaltered portions of the existing building to comply with this code. (See code for additional requirements and exceptions.)


Section N1101.3 (Section N1107.1.1 in 2015 and 2018 IRC). Additions, alterations, renovations, or repairs shall conform to the provisions of this code, without requiring the unaltered portions of the existing building to comply with this code. (See code for additional requirements and exceptions.)

Appendix J regulates the repair, renovation, alteration, and reconstruction of existing buildings and is intended to encourage their continued safe use.
Case Studies
None Available

References and Resources*

1. **2009 IECC - International Energy Conservation Code**
   - **Author(s):** International Code Council
   - **Organization(s):** ICC
   - **Publication Date:** January, 2009
     
     Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems and service water heating systems in homes and commercial businesses.

2. **2009 IRC - International Residential Code for One and Two Family Dwellings**
   - **Author(s):** International Code Council
   - **Organization(s):** ICC
   - **Publication Date:** January, 2009
     
     Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.

   - **Author(s):** International Code Council
   - **Organization(s):** ICC
   - **Publication Date:** January, 2012
     
     Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems and service water heating systems in homes and commercial businesses.

4. **2012 IRC - International Residential Code for One and Two Family Dwellings**
   - **Author(s):** International Code Council
   - **Organization(s):** ICC
   - **Publication Date:** January, 2012
     
     Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.

5. **2015 IECC - International Energy Conservation Code**
   - **Author(s):** International Code Council
   - **Organization(s):** ICC
   - **Publication Date:** May, 2014
     
     Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems and service water heating systems in homes and commercial businesses.

6. **2015 IRC - International Residential Code for One and Two Family Dwellings**
   - **Author(s):** International Code Council
   - **Organization(s):** ICC
   - **Publication Date:** May, 2014
     
     Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.

   - **Author(s):** International Code Council
   - **Organization(s):** ICC
   - **Publication Date:** October, 2017
     
     Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems and service water heating systems in homes and commercial businesses.
8. **2018 IRC - International Residential Code for One and Two Family Dwellings**  
   **Author(s):** International Code Council  
   **Organization(s):** ICC  
   **Publication Date:** August, 2017  
   Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.

9. **DOE Zero Energy Ready Home National Program Requirements (Rev. 07)**  
   **Author(s):** U.S. Department of Energy  
   **Organization(s):** DOE  
   **Publication Date:** May, 2019  
   Standard requirements for DOE’s Zero Energy Ready Home national program certification.

10. **EIA 2015 Residential Energy Consumption Survey (RECS)**  
    **Author(s):** EIA  
    **Organization(s):** EIA  
    **Publication Date:** June, 2016  
    Federal statistics about national energy consumption in residential homes.

11. **ENERGY STAR Light Bulb Key Product Criteria**  
    **Author(s):** U.S. Environmental Protection Agency  
    **Organization(s):** EPA  
    **Publication Date:** December, 2017  
    ENERGY STAR lightbulb criteria.

12. **LED Lighting**  
    **Author(s):** Department of Energy  
    **Organization(s):** DOE  
    **Publication Date:** December, 2017  
    The light-emitting diode (LED) is one of today’s most energy-efficient and rapidly-developing lighting technologies.

13. **LED Lighting Basics**  
    **Author(s):** Department of Energy  
    **Organization(s):** DOE  
    **Publication Date:** December, 2013  
    Information about LED lighting technology.

14. **Lighting Choices to Save You Money**  
    **Author(s):** EnergySaver  
    **Organization(s):** DOE  
    **Publication Date:** October, 2017  
    Webpage describing high-efficiency lighting choices for homeowners including LEDs, CFLs, and halogen bulbs.

15. **Recycle Compact Fluorescent Light Bulbs (CFLs)**  
    **Author(s):** ENERGY STAR  
    **Organization(s):** ENERGY STAR  
    **Publication Date:** December, 2017  
    Information about recycling CFL lightbulbs.

    **Author(s):** Holton  
    **Organization(s):** IBACOS, National Renewable Energy Laboratory  
    **Publication Date:** February, 2012  
    Document offering methods to greatly reduce lighting energy use through the application of high quality fluorescent and light emitting diode (LED) technologies.
**Types of Lighting**

Author(s): Department of Energy  
Organization(s): DOE  
Publication Date: October, 2013  
Website with consumer information about various types of lighting.

18. **Yes, You Can! Dimming LEDs and CFLs Made Easy**  
Author(s): Lutron  
Organization(s): Lutron  
Publication Date: October, 2014  
Website discusses differences between CFL and LED bulbs.

*Publication dates are shown for formal documents. Dates are not shown for non-dated media. Access dates for referenced, non-dated media, such as web sites, are shown in the measure guide text.

**Contributors to this Guide**

The following authors and organizations contributed to the content in this Guide.

- Florida Solar Energy Center, lead for the Building America Partnership for Improved Residential Construction (BA-PIRC), a **DOE Building America Research Team**
- Pacific Northwest National Laboratory