ASSIST *recommends...*

How to Select Residential LED Directional Lighting

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Introduction

LED lamps and fixtures are one of several light source choices for directional lighting, such as downlights and track lights. Commercial LED systems are available as replacement lamps for existing fixtures or as complete fixtures with the light source built in. However, from one lamp or fixture to the next, there may be differences in light output, light color, lighting distribution or uniformity, life, and wattage, to name a few. So what can you expect from LED directional lighting and how can you pick the best LED lighting for your needs?

This guide discusses issues to consider when selecting LED directional lighting lamps and fixtures for your home. For more about directional lighting in general, see *ASSIST recommends…A Guide to Residential Directional Lighting*.

A variety of LED directional lighting lamps and fixtures.

Important Questions to Ask

- What type of fixture is this?
- How will the type of installation affect lighting quality and life?
- What is the cost?
- What is the quality and quantity of the light? Is it sufficient for the application?
- How long will it last? Will replacements be available several years after purchase? If not, what happens?
- Is there a warranty, and what does it cover?

Fixture Type

What type of fixture is this?

There are two basic types of fixture available for directional lighting: a dedicated fixture and a non-dedicated fixture.

A dedicated fixture can hold only one specific type of lamp or lamp module. Usually, the ballast or driver (i.e., the power supply for the fixture) is mounted within or near the fixture housing. When the lamp dies, a new lamp or lamp module of the same type must be installed, or the entire fixture must be replaced.

A non-dedicated fixture can hold several types of lamps, as long as the lamp base and fixture socket match. For example, a directional fixture originally intended for a halogen reflector lamp may hold an LED replacement reflector lamp, given that both lamps have the same type of screw-in base and the same size bulb. The ballast or driver, if necessary, must be built into the lamp itself (i.e., self-ballasted).

Dedicated LED fixture
with replaceable LED module

Non-dedicated fixture
with LED replacement lamp

The type of fixture, along with its installation, will influence the performance of the lamp and the quality of lighting. For more information, see the “Installation” section below.

Installation

How will the type of installation affect lighting quality and life?

Under perfect conditions, LEDs may operate 50,000 to 100,000 hours. But in reality, LEDs can have drastically shortened lives and substandard lighting quality as a result of poor fixture design or installation. The most common threat to LED lighting quality and life is heat. Heat buildup inside the fixture can affect the useful life of the LED lamps and cause their color to change. The amount of heat surrounding an LED is often a result of the type of installation. This is because LEDs conduct their heat away in all directions through the fixture, rather than radiating heat directly from the source, like an incandescent lamp. Since

LED fixtures have to transfer the heat to the surrounding area, the mounting area around the fixture must be properly ventilated.

There are three types of installations for directional lighting:

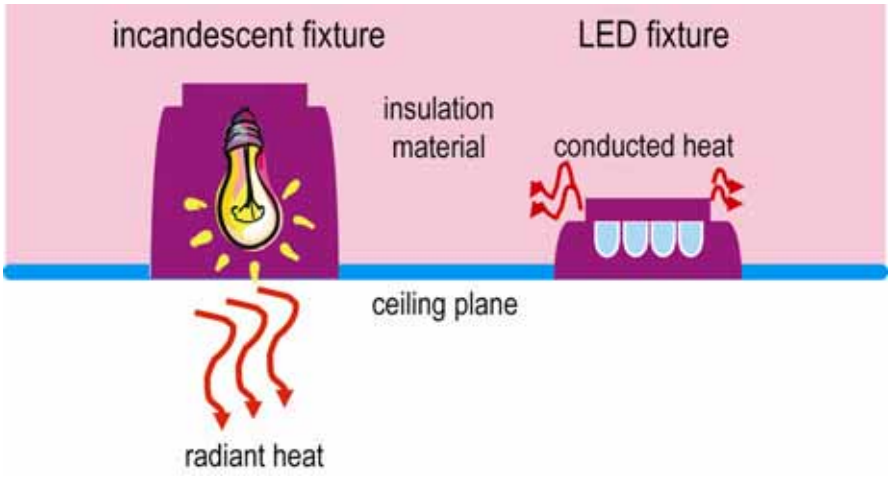
- **Open air:** Here the light source and the driver have plenty of ventilation around them for convection heat transfer to keep them at appropriate temperatures. An example is track lighting.

- **Semi-ventilated:** Here the light source and the driver have limited ventilation around them for convection heat transfer. In certain applications, a "non-IC" rated fixture would be considered for a semi-ventilated environment.

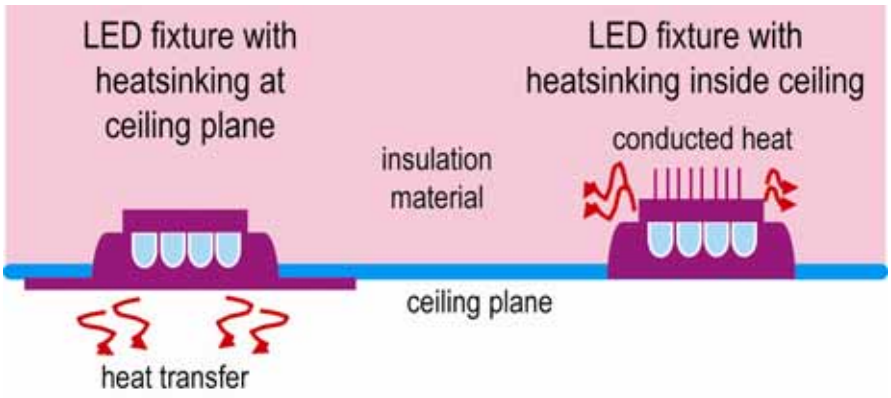
- **Enclosed:** Here the light source and the driver have almost no ventilation around them for convection heat transfer. An "IC" rated fixture would be used in this type of environment.

A well-built LED fixture uses proper thermal management techniques, including components called heat sinks, to extract the heat. Fixtures with smaller, 5 millimeter (mm) LEDs tend to have better heat sinking and thermal management, but the LEDs themselves do not have internal heat sinks (as larger, high-power LEDs do). Therefore, 5 mm LED fixtures may not last a long as fixtures with high-power LEDs.

Heat sinks are especially important for installations where heat may build to high levels, such as in an enclosed IC installation. The location of the heat sink is also important. A heat sink above the ceiling plane will not transfer heat away as well when placed in an insulated ceiling. Therefore, it is important to consider the type of installation where the LED fixture will be used. Ask the manufacturer if the fixture you are considering is rated for your type of installation.



Heat transfer for an incandescent fixture and an LED fixture.



Heat transfer for two LED fixtures with different heat sinking options.

Cost

What is the lifecycle cost of an LED fixture compared with other lighting technologies?

While the easiest way to compare lighting fixtures is by the initial purchase price, that measure does not provide the complete story on how much it will cost to own the fixture. The lifecycle cost considers the overall price of a lighting fixture or system, including initial purchase cost, installation cost, and operating cost over the life of the system.

At the present time, most LED lighting fixtures have a higher initial purchase cost than incandescent or fluorescent fixtures, approximately 6 to 10+ times higher. The higher cost is due to its newness in the market, technology costs, and its novelty factor. However, as with most technologies, LED fixture prices are expected to drop as the technology matures.

The operating cost over life takes into account the overall power usage of the system, the average life of the fixture, the need for lamp replacement, and other maintenance. A well-made LED fixture may last more than 10 years, making its expected life much longer than that of incandescent or fluorescent fixtures. Its power use is generally lower than that of incandescent fixtures (and lower than fluorescent in some cases), bringing down its cost to operate.

However, it is also important to consider how much it will cost to light the space. An LED fixture producing less light than a comparable fixture with a traditional light source may not be as cost-effective. With less light output per fixture, more LED fixtures will be required to provide an appropriate amount of light, increasing the purchase cost and total lighting operating cost for the space.

For more information about the lifecycle costs of directional lighting fixtures, see *ASSIST recommends…A Guide to Residential Directional Lighting*.

Quality

Does the LED fixture provide the lighting quality desired?

Your satisfaction with a particular directional lighting fixture will depend heavily on its lighting quality. Lighting quality refers to the:

- **Light level** – How much light is the fixture producing and how much is reaching the intended task area?
- **Lighting uniformity and distribution** – How even is the lighting and how much coverage is there over a work space?
- **Lighting color** – Is the light a yellowish-white, bluish-white, or neutral white? How do the colors of objects underneath the light appear? Can the color change for the purpose of mood lighting?

Light level

The amount of light exiting the fixture and falling on a surface will differ with the type of lamp and the design of the fixture. Lamps or fixtures made of 5 mm LEDs typically require more LEDs than those made of high-power LEDs. Those with 5 mm LEDs, which require 1/10 of a watt (W) each, use many low light-output LEDs clustered together. Those with high-power LEDs, which require 1/2 W to 1 W each, will have fewer LEDs with higher light output.

5 mm and high-power LED replacement lamps.

How Much Light?

The Illuminating Engineering Society of North America recommends a light level of 30 to 50 *lux* (a unit of light measurement) on the floor for circulation, entertainment, relaxation, dining and general passage. A suitable light level for ambient illumination in a kitchen would be 110 lux at counter height.

It is important to understand that some LED lamps and fixtures currently marketed as replacements for incandescent often do not provide the same amount of light as the original lamp. Using these lamps or fixtures can lead to light levels that are too low to be useful for many tasks, like reading, or too dangerous for some critical tasks, such as chopping and dicing. Side-by-side comparisons are usually needed to make this determination. The packaging may also list the number of "lumens" for the product, which would give an indication of the amount of light (see *Determining the number of fixtures needed* below for more information about light level and lumens).

The Illuminating Engineering Society of North America recommends light levels for a whole range of areas in interior and exterior applications. These recommendations are based on characteristics of visual tasks such as size, contrast, speed to finish the task, and safety.

The following table summarizes the recommended light levels for typical areas in residential applications. The table also lists additional criteria to consider in each space. Lighting qualities such as uniformity, sparkle, color of light and color rendering play an important role in the perception of the visual environment. Features such as dimming add value to the lighting in a space because they allow for fine-tuning of the lighting for different situations. The values listed in the table apply to most homes and would be acceptable to most people. These guidelines should be considered a starting point, as each application may call for different considerations. The following sections and *ASSIST recommends…A Guide to Residential Directional Lighting* explain the criteria in more detail.

Table Definitions

Horizontal illuminance. A measure of the amount light on a horizontal work surface, such as a table or kitchen counter. Illuminance measurements are typically used by lighting professionals.

Vertical illuminance. A measure of the amount of light on a vertical surface, such as a wall or kitchen cabinet. Illuminance measurements are typically used by lighting professionals.

Color rendering index (CRI). The recommended color rendering for a given task or space. CRI may be printed on product packaging.

Typical preferred correlated color temperature. The recommended color temperature, measured in kelvin, for a given task or space. The color temperature may be printed on product packaging.

Dimming. The importance of dimming for a given task or space: Dimming has many benefits. It allows you to create the mood in a space, reduce energy use, and, in some cases, extend the life of the light source.

Modeling of faces or objects. The importance of lighting to define faces and objects for easy recognition: Lighting should not create sharp shadows and should illuminate faces in a pleasing way that allows facial expressions to be easily read.

Sparkle/desirable reflected highlights. The importance of sparkle for a given task or space: Small points of high brightness can enhance visual interest (e.g., a candle flame or decorative tree lights).

Uniformity. The importance of a uniform light distribution for a given task or space: Patterns of light on a work surface can be distracting, confusing, or beneficial. Patterns of light and shadow can affect task visibility, comfort, and perception. Illuminances on the floor or work surface should not vary widely, or else it will be hard to see details in the darker areas.

Illuminating Engineering Society of North America
Recommended Lighting Qualities for a Given Task and Space

Task Area	Horizontal illuminance (lx)	Vertical illuminance (lx)	Color rendering index (CRI)	Typical preferred correlated color temperature (K)	Dimming	Modeling of faces or objects	Sparkle/desirable reflected highlights	Uniformity
Kitchen								
Counter - general tasks	323	54	>80	2800-3500	y	y	n	n
Counter, sink, range - critical tasks	538	108	>80	2800-3500	n	y	n	y
Pantry	323	32	>70	2800-3500	n	n	n	y
Living Room								
Reading	323	54	>80	2800-3500	y	n	n	y*
Music	538	32	>80	2800-3500	n	n	n	n
General	32	32	>80	2800-3500	y	y	n	n
Dining Room								
Table	54	NA	>80	2800-3500	y	y	y	n
Bedroom								
Reading	323	54	>70	2800-3500	y	n	n	y*
Closet	54	32	>80	2800-3500	n	y	n	y
Dressing	323	54	>80	2800-3500	n	y	y	y
General	108	NA	>80	2800-3500	y	y	n	n
Bathroom								
Toilet	108	32	>70	2800-3500	n	n	n	n
Vanity	323	54	>80	2800-3500	y	y	n	y
General	323	54	>80	2800-3500	y	y	n	n
Hallway								
Passage/Circulation	32	32	>80	2800-3500	n	y	n	y

n – not applicable or not a common feature of most applications
y – important or desirable feature
y* – refers to the uniformity of the reading task

Determining the number of fixtures needed

The number of fixtures needed will depend on the amount of light required in a space and the amount of light provided by the lamp or fixture. Lamp packages typically list the number of lumens.

For a given space, determine the square meters of your space (approximately 11 sq. ft. = 1 sq. m) and the average light level you are trying to achieve (see the table above). Manufacturers' specification sheets will provide a recommended spacing criterion for each fixture. Based on recommended spacing of 8 ft. on

Calculating Lumens

Calculate the area: 16 ft. x 16 ft. = 256 sq. ft. or approx. 24 sq. m.

Determine the number of lumens needed: Multiply square meters by desired illuminance. 24 sq. m area × 160 lx = 3840 lumens.

With an 8 ft. ceiling, fixture spacing will be up to 8 ft. on center (1 to 1 ratio of ceiling height to spacing), resulting in a 2 x 2 or a 2 x 3 array of fixtures. Therefore, either 4 fixtures at 960 lumens each or 6 fixtures at 640 lumens each will give 3840 lumens.

center, for example, each fixture would cover an area of approximately 64 sq. ft. Since fixtures will vary in distribution and light output will depreciate over time due to many factors, 600 to 1000 lumens per fixture will be required to achieve 100 to 150 lx. For better uniformity, you could select more fixtures of a lower lumen output, thereby increasing your cost.

Lighting uniformity and distribution

The ideal lighting from recessed fixtures depends on the application, whether it is general downlighting, accent lighting, or wall-washing. For general downlighting, a smooth, even illumination that covers the area is desirable, using wide or flood distributions. For accent lighting, whether in the form of adjustable recessed fixtures or track lighting, the beam spreads can range from very narrow to wide. For wall-washing or to illuminate an expanse of wall uniformly, wide beam spreads are recommended. The uniformity and distribution often depend on the combination of fixture design, lamp choice, and placement.

LED downlight fixtures are appearing with a variety of reflector choices similar to their incandescent and fluorescent counterparts. The reflector color and finish, position of lamp within the reflector, and lens options affect light output and color. A frosted lens covering the LED lamps, for example, can provide better uniformity and a more diffuse light, but will also reduce intensity.

Left: High-brightness lamp with white reflector.
Right: High-brightness MR-16 lamp deeply recessed in white step baffle.

What Color Light?

For warm tones in a home, such as paints, flooring, carpeting and fabrics, look for warm CCTs in the 2700–3500 kelvin (K) range. Skin tones usually look better under warmer CCTs due to the red in the spectrum; that's why incandescent lamps have been so popular in bathroom vanity areas.

For cool tones, such as grays, greens and blues, look for cool CCTs in the 3500–5000 K range.

Some manufacturers label the CCT of their products. If they are not labeled, look for in-store displays where you can see the color of the lighting first-hand.

Lighting color

The color appearance of a white lamp can be yellowish to neutral white to bluish. One measure of color appearance is correlated color temperature (CCT). The choice of CCT is a matter of personal preference, but it also depends on the décor and finishes used in the space to be lighted.

White LEDs tend to cast a bluish light, though warm white LEDs are becoming more common. One caveat, however, is that the term "warm white" is not standardized.

One benefit of LEDs is that the lighting color can be more than just white. LED fixtures containing a mix of red, green, and blue (RGB) LEDs can create any color of light desired (including white), giving them a decorative advantage over traditional white lighting fixtures. Color-changing LED fixtures may be desirable for parties and other mood-setting needs, as an accent in a glass-front kitchen cabinet or to create special effects – on a wall in a teenager's room, for example.

The best way to evaluate the lighting quality of a fixture is to see it first-hand. Look for lighting showrooms and in-store displays where you can compare the

lighting quality of different fixtures. For more about lighting quality and getting the best lighting, see *ASSIST recommends…A Guide to Residential Directional Lighting*.

Reliability

What are the rated life and the manufacturer's guarantee for the LED fixture?

Rated life and replacement timeframe

How Long Will It Last?

You can calculate life using the manufacturer's life rating. For example, if your downlights will be on for 3 hours a day, an LED fixture rated to operate 30,000 hours before reaching 70% of its initial light level theoretically will last about 27 years.

In reality, though, other components within the fixture may burn out earlier, giving the fixture a shorter life than calculated.

Because LEDs fade over time rather than burning out, at some point the amount of light coming from the fixture will be too low to be useful. This point is considered as the LED's end of "useful life." While there presently is no standard for an LED's end of life, the general consensus is that the LED fixture should be replaced when it has reached 70% of its initial light level. When selecting an LED fixture, look for products that list the average life in hours based on the 70% timeframe. This life rating should be based on the type of installation (i.e., open air, non-IC, IC) for which the lamp or fixture was designed. Some LED fixtures are designed to automatically shut off after their light level depreciates too much.

Warranty

Warranty may be an important factor for LEDs because of the problems that may occur when too much heat is present. Find out about the warranty for the fixture you are considering to purchase. For example, if the manufacturer rates the life of the fixture at 50,000 hours, will the warranty cover that entire period (e.g., 6 years under the worst-case scenario of 24 hours per day of use)? Will this warranty include materials plus labor for replacing the product? If a similar replacement fixture is not available, will the warranty cover replacement of all the fixtures?

Replacement and Availability

Will the LED fixture be easy to replace if one fixture burns out? Will the manufacturer have replacement products available at the end of the fixture's rated life?

Ease of replacement – Dedicated vs. non-dedicated

Unlike incandescent and fluorescent fixtures, not all dedicated LED fixtures have lamps that can be replaced. When the light from an LED fixture diminishes too much to be useful, the entire fixture may need to be replaced. Some manufacturers are integrating a system that allows functioning LEDs to compensate for that one or two in an array that are malfunctioning. In general, long-life LEDs extend the time between fixture replacements to more than 10 years. Nevertheless, it should be easy to replace the fixture if necessary, especially in the case of a faulty product.

In non-dedicated fixtures, lamp replacement should be easy as long as the lamp design does not become outdated over the life of the fixture.

Availability of products in the long-term

Directional lighting fixture designs using mature light source technologies (e.g., incandescent and compact fluorescent) generally have replacement lamps and other parts available over an extended period of time because these fixtures are commonplace in the market. Burned-out lamps are easily replaced using a standard lamp from one of many manufacturers. If one fixture fails completely or is damaged after several years of use, a replacement fixture can be purchased from the same manufacturer, or a similar fixture can be purchased from a different manufacturer.

Directional lighting fixtures featuring alternative light source technologies, such as LEDs, often boast long life and the advantages of reduced maintenance and potentially lower lifecycle costs compared with established lighting technologies. The disadvantage of less mature light sources, however, is the possibility that replacement products will not be available in the long-term. Technological advances may render older designs obsolete, prompting manufacturers to discontinue products in favor of newer and better designs with more advanced lamps. If a homeowner installs several LED-based directional lighting fixtures and one fails after several years, the homeowner may be in the position of replacing all the fixtures because a matching product can no longer be found. Even if a replacement product is found, the variability found among LEDs in terms of lighting color and light output may make the new fixture stand out as different from the rest.

To reduce the cost and potential hassle of replacing all fixtures, ask whether the manufacturer guarantees the availability of the same or relatively similar products over at least a five-year period.

Resources

ASSIST. 2007. *ASSIST recommends…A Guide to Residential Directional Lighting*. Vol. 3, Issue 1. Troy, N.Y.: Lighting Research Center, Rensselaer Polytechnic Institute.

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About ASSIST

ASSIST was established in 2002 by the Lighting Research Center at Rensselaer Polytechnic Institute to advance the effective use of energy-efficient solid-state lighting and speed its market acceptance. ASSIST's goal is to identify and reduce major technical hurdles and help LED technology gain widespread use in lighting applications that can benefit from this rapidly advancing light source.