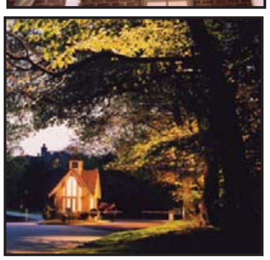
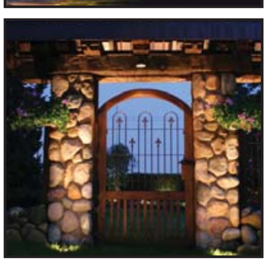
ENERGY EFFICIENT LANDSCAPE LIGHTING





OPTIONS FOR COMMERCIAL & RESIDENTIAL SITES

June 2008.

CASEY GATES

ENERGY EFFICIENT LANDSCAPE LIGHTING

OPTIONS FOR COMMERCIAL & RESIDENTIAL SITES

June 2008.

A Senior Project
Presented to the Faculty of the
Landscape Architecture Department
University of California, Davis
in Partial Fulfillment of the Requirement for the
Degree of Bachelors of Science of
Landscape Architecture

Accepted and Approved by:

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Faculty Committee Member, Byron McCulley

____
Committee Member, Bart van der Zeeuw

____
Committee Member, Jocelyn Brodeur

____
Faculty Senior Project Advisor, Rob Thayer

CASEY GATES

THANK YOU

Committee Members: Byron McCulley, Jocelyn Brodeur, Bart Van der zeeuw, Rob Thayer

Thank you for guiding me through this process. You were so helpful in making sense of my ideas and putting it all together. You are great mentors.

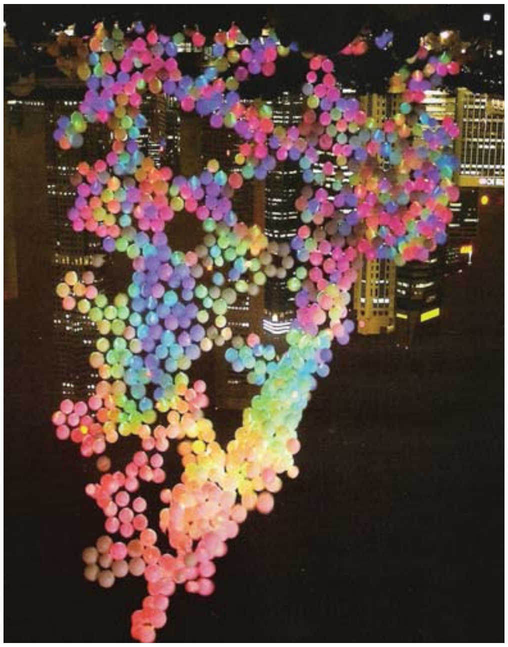
Family: Mom, Dad, Kelley, Rusty

You inspire me every day.

One of my LDA projects 2007

One of my LDA projects 2007, Walker Hall

The family



Balloons illuminated by LED lights

ENERGY EFFICIENT LANDSCAPE LIGHTING IN COMMERCIAL AND LARGE SCALE RESIDENTIAL SITES

Summary

Landscape lighting in commercial and large scale residential sites is an important component to the landscape architecture industry. It is a concept that is not commonly covered in university courses but has a significant impact on the success of a site. This project examines the concepts of landscape lighting and suggests ideas to improve design standards while maintaining energy efficiency.

This project will discuss methods and ideas of landscape lighting to improve energy efficiency. Designers should know lighting techniques and their energy efficient alternatives. This project demonstrates how design does not have to be compromised for the sake of energy efficiency. This subject matter is relevant to design regulations and environmental codes that are becoming more restrictive. These codes should not damper the design but provide and opportunity for it to be better. This project examines lighting catalogs and explains their terms and graphs to help make them more accessible to landscape architects. It provides a glossary of terms and images to demonstrate lighting techniques.

Energy efficient landscape lighting is gaining more momentum in the landscape architecture industry and should soon become familiar to anyone who plans to design a successful commercial or large scale residential site.

Grandly illuminated residence

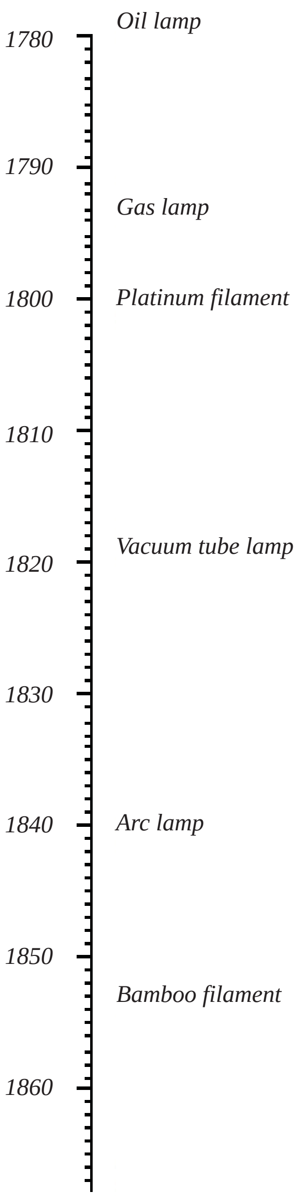
Softly illuminated garden

THE PROJECT

The Louvre landscape lighting

Lighting the landscape of commercial and large scale residential sites with energy efficient lighting sources has the ability to save energy, reduce electricity costs and provide new elements of design. Commercial and residential buildings make up 1/3 of all United States energy demands (CLTC). The research conducted in this project will introduce appropriate systems and styles to create a successful lighting scheme. It will also suggest potential energy efficient lighting techniques. This project can help to create an opportunity for lighting in the landscape to be more cost effective, environmentally conscious and aesthetically pleasing

Timeline of Lighting History



Energy Efficient

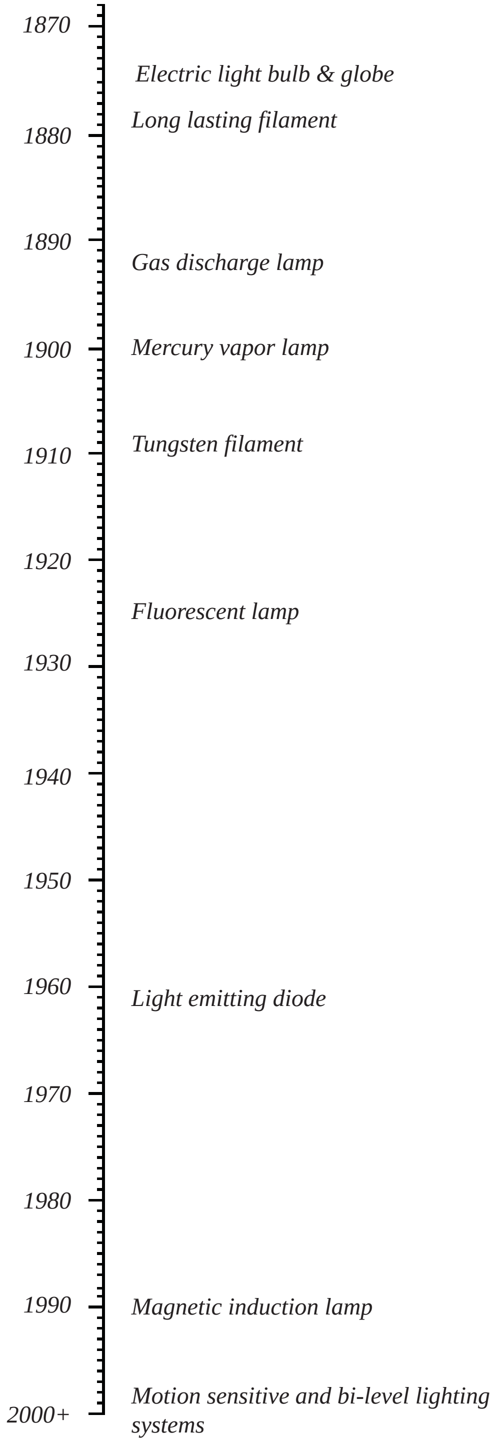
"Energy efficient" can be an ambiguous term. In this project energy efficient is considered to mean requiring less energy to function and cost effective.

Lighting the Landscape

Design has to expand beyond daylight hours to fully encompass the needs of a site. Today's society does not wake and sleep with the sunlight hours. Many activities are conducted when the stars and moon are in the sky. Not all sites need lighting, however, commercial and residential sites that area in use after sunset should embrace energy efficient landscape lighting. A flood light can reveal a building in a way the sun never does. In a night time lighting scheme trees become mysterious and water becomes calm. Landscape lighting shouldn't be used to mimic the daylight, but instead to create a nighttime mood (Alpern, Andrew). Landscape lighting can provide safety, security, and aesthetic value.

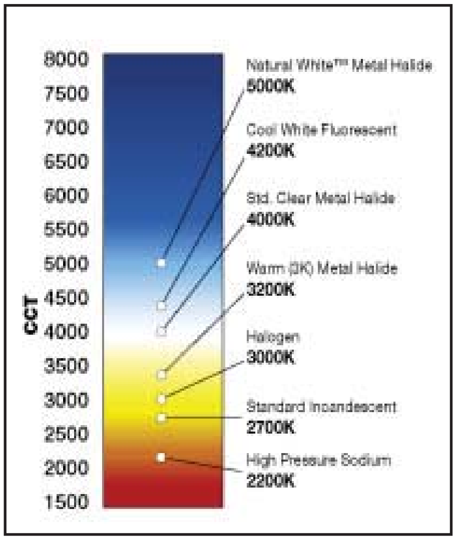
History Timeline

- Since the world began, people used the sun as their main source of light.
- 70,000 BC A hollow rock or shell or other natural found objects was filled with moss or a similar material that was soaked in animal fat and then ignited
- 4500 BC oil lamps
- 3000 BC candles are invented.
- 1780 Aimé Argand invents central draught fixed oil lamp
- 1784 Aimé Argand adds glass chimney to central draught lamp
- 1792 William Murdoch begins experimenting with gas lighting and probably produced the first gas light in this year.
- 1802 William Murdoch illuminated the exterior of the Soho Foundry with gas.
- 1805 Phillips and Lee's Cotton Mill, Manchester was the first industrial factory to be fully lit by gas.



- 1813 National Heat and Light Company formed by Fredrich Winzer (Winsor).
- 1815 Humphry Davy invents the miner's safety lamp.
- 1835 James Bowman Lindsay demonstrates a light bulb based electric lighting system to the citizens of Dundee.
- 1840 first kerosene lamps (oil lamps that burn fuel from petroleum)
- 1853 Ignacy Lukasiewicz invents petrol lamp
- 1854 Heinrich Göbel invents the first incandescent lamp by passing an electric current through a carbonized bamboo filament that was placed inside of a glass bulb
- 1856 glassblower Heinrich Geissler confines the electric arc in a tube.
- 1867 A. E. Becquerel demonstrates the first fluorescent lamp
- 1875 Henry Woodward patents the electric light bulb.
- 1879 Thomas Edison and Joseph Wilson Swan patent the carbon-thread incandescent lamp.
- 1880 Edison produced a 16 watt lightbulb that lasts 1500 hours.
- 1893 Nikola Tesla uses cordless low pressure gas discharge lamps, powered by a high frequency electric field, to light his laboratory. He displays fluorescent lamps and neon lamps at the World Columbian Exposition.
- 1894 D. McFarlane Moore creates the Moore tube, precursor of electric gas-discharge lamps.
- 1901 Peter Cooper Hewitt demonstrates the mercury-vapor lamp.
- 1911 Georges Claude develops the neon lamp.
- 1925 The first internal frosted lightbulbs were produced.
- 1926 Edmund Germer patents the fluorescent lamp.
- 1962 Nick Holonyak Jr. develops the first practical visible-spectrum light-emitting diode
- 1986 The "White" SON Sodium vapor lamp is introduced.
- 1991 Philips invents a fluorescent lightbulb that lasts 60,000 hours. The bulb uses magnetic induction.
- 1994 First commercial sulfur lamp.
- 2008 Konstantinos Papamichael researches daylight harvesting (CLTC).

TECHNICAL LIGHTING INFORMATION AND REGULATIONS



Color temperature with associated light sources

Most industries in these days are becoming more conservation conscious. Regulations are being adopted by cities and companies to set standards for energy efficiency and light pollution. Landscape designers should have some familiarity with the terms and concepts of lighting and lighting catalogs so that they can make educated decisions about lighting options while still adhering to design goals.

Some of the terms used to define light sources and their characteristics can be confusing. The following concepts are a brief description of terms to help clarify concepts of this project. In the appendix there is a more in depth glossary and a "How To" section on decoding lighting catalogs. These sections should be referred to for further information.

Illuminance: the amount of light received by a surface, independent of what the surface may be

Illuminance and Luminance

Illuminance is often used to describe the amount of light emitted by an individual light source. It is a measure of the intensity of light. Illuminance is measured in lux or lumens per square meter. A foot-candle is a unit of illuminance. The foot-candle is the amount of illumination on the surface of an imaginary one square foot surface. One foot-candle equals one lumen per square foot (Brown, Steve). The illuminance of a light source is independent of the texture or shape of the surface. *Luminance* is affected by the surface. Luminance is the measurement of the human eyes perceived amount of light. This concept is often demonstrated in lighting catalogs as a photometric graph. Photometric describes the measurements of luminance. These graphs can show how much light will be perceived by the human eye at different distances from the light source (Narboni, Roger).

Luminance: measurement of the human eye's perceived value of light, it is measured in lumens and is dependent on the color, texture and material of the surface

Color Rendering Index

A *color rendering index* is a scale that measures the color rendition of a light source. Color rendition describes how well a light reveals the true color of an object. A whiter light typically has higher color rendition and therefore, a higher rating on the color rendering index. The color rendering index ranges from 1-100. A color rendition score of 85-95 means excellent and lower than 65 means poor (Tremblay, Leanne and Peter).

Color rendering index: a scale that ranges from 0-100. Between 85 and 95 is considered good color rendition and below 65 is poor

Luminous Tonality

Different types of lights burn at different temperatures. These temperatures are equivalent to the color of light that they emit. Color temperature is expressed in Kelvin and helps describe the warm or cool tonality of a light source's illumination. Color temperatures greater than 3,000 K are considered "warm" and color temperatures lower that 3,000 K are considered "cool" (Moyer, Janet).

Luminous tonality: the color temperature (T) expressed in Kelvin (K). This helps to determine the "warm" or "cool" appearance of light. It is measured with a colorimeter. Color temperatures greater than or equal to 3,000K are "warm" and color temperatures lower than 3,000K are cool

Efficieny and Efficacy

Efficacy is the ratio of light output compared to the power it consumes. It is measured in lumens per watt. *Luminous efficiency* is the ratio of the efficacy to the maximum possible value. *Luminous efficacy* is the ratio of visible light emitted to the total input of the lamp. This is also measured in lumens per watt. The highest possible ratio for luminous efficacy is in white light is 240 lm/w (Narboni, Roger).

Regulations

Some landscape lighting designs waste a lot of energy with overspill and undirected light. The sky is harder to see with brightly lit sites and energy is wasted with over illumination. The International Dark Sky Association provides tips on how to avoid over lighting and ways to make a site more efficient. The IDA recommends efficiently directed lighting angles and glare control designers can light the object they want illuminated and not everything else. Many cities have recognized the goals of the dark sky association and installed regulations of their own. Eventually, all lights will be held to more efficient standards.

LEED Standards reference landscape lighting. These LEED standards have three main components to its lighting section. The first one insists on limiting light levels to meet or be lower than the recommended energy efficient standard provided by the Illuminating Engineering Society of North America (IESNA). The second part aims to enhance natural skyglow by prohibiting the use of *luminaires* with lumen output greater than 3500. Lastly, LEED standards regarding landscape lighting forbid light trespassing. It more specifically states that luminaires within two and a half times their mounting height from the property line cannot produce light across that property line. There are some lights that meet these standards but are banned because they are not energy efficient. One significantly stated "bad" lighting option is the 175 watt metal halide fixture. It is commonly suggested because of its cut-off abilities but is not an energy efficient choice (IESNA). The International Dark Sky Association has created a seal that is displayed on all approved lighting fixtures. These seals can make light selection a simpler process (IDA).

LEED Logo

Efficacy: the ratio of light output from a lamp to the electric power it consumes, it is meaured in lumens per watt (LPW)

Luminous efficiency: the ratio of luminous efficacy to the maximum possible value

Luminous efficacy: the ratio of visible light energy emitted to the total power input of a lamp. It is measured in lumens/watt. The highest possible ratio for white light is 240 lm/w. Relationship between the power consumed by a lamp and the luminous flux emitted by it

Luminaire: a piece of lighting equipment that serves to emit, distribute, and control the light generated by one or more lamps

FIXTURE SEAL OF APPROVAL

International Dark sky Association; Seal of Approval

LIGHT SOURCES

There are many lighting options in today's landscape lighting design. This chapter will examine some of the options with their advantages and disadvantages as well as evaluated energy efficiency.

Incandescent light bulb

Incandescent lights: light source is which light produced by an electric current passing through a filament that heats to produce light, the glass exterior prevents oxygen from reaching the filament and therefore preventing immediate oxidation

Incandescent

Incandescent bulbs are the most common light source found in the average home. They are familiar, available and inexpensive to buy. The incandescent bulb is available in a wide range of watts, from 1-1,500 (Manski, W.). The classic bulb is known as the standard A form. It has a glass bulb that protects a small filament which is heated by the current of electricity. The burning filament produces heat and light. About 90% of an incandescent bulb's power is emitted as heat, instead of visible light. This type of bulb has a very low efficiency and an efficacy of 12.6 lumen/watt on average. It produces a warm white light with a color temperature of 2700 K (EERE). The bright visible light an incandescent bulb produces allows for great color rendition. These factors have allowed the incandescent bulb to be successful and accessible. However, the incandescent bulb has the shortest life span of all possible electric light sources. The life hours can be as low as 750 hours (Narboni, Roger).

Fluorescent bulb

Compact fluorescent lights (CFL): a light source that produces visible light when an electric current is conducted through mercury and other inert gases causes the vapor to excite and emit ultraviolet light. They run on ballasts

Fluorescent

Fluorescent bulbs come in a variety of shapes and sizes. In some instances they can be interchanged with incandescent bulbs. They are run by an electric current that is passed through the gases within the glass bulb encasing. Mercury and other inert gases are used as the conductors of electricity in this kind of light source. The electricity that passes through the gas excites the vapor and emits ultra violet light. This ultra violet light then excites the phosphor coating in the interior of the glass and produces visible light. More coats of phosphor create a whiter bright light and therefore raise the color rendering index to about 80. The light that they produce ranges from cool to warm white and has a color temperature between 2700 K and 6500 K. The bulbs come in wattages from 4 to 220 and range in efficacy from 50 to 80 lumens/ watt (EERE). Fluorescent lights have a significantly longer lifespan than incandescent lights. They last between 10,000 and 24,000 hours, more than tripling the hours of an incandescent bulb (Manski, W.). Two main factors cause fewer people to swap out the incandescent for the fluorescent and those are the initial cost of a fluorescent and the amount of time it takes for the bulb to reach its full glowing capacity. The in store sale price can be intimidating but over time the fluorescent bulb will save money in the number of bulb replacement and electricity costs. As the technology becomes more familiar and perfected, the prices are

Reflector/ refractor: lens or mirror used to direct light

decreasing. The other issue with the fluorescent bulb is the lag time between when the light is turned on and when it begins to emit its full capability of visible light. This down time can cause undesirable results in lighting design if areas are under lit for a short period of time. Fluorescent light sources come in bulbs, which are also known as compact fluorescent and tubular form (Narboni, Roger).

HIGH INTENSITY DISCHARGE (HID)

A few different kinds of lights fall under the high intensity discharge category. The most common ones consist of mercury vapor, metal halide, high pressure sodium and low pressure sodium. All of these light sources use an electric arc between two electrodes to produce intense light. Mercury, sodium and metal halide gases are used as conductors. These lights require a ballast to monitor the flow of electricity. They also require a *reflector* or *refractor* to control the distribution and direction of the light they produce. Each of these HID lamp types call for a warm up period before they are illuminating at their full capacity (Narboni, Roger).

Mercury Vapor Lamp

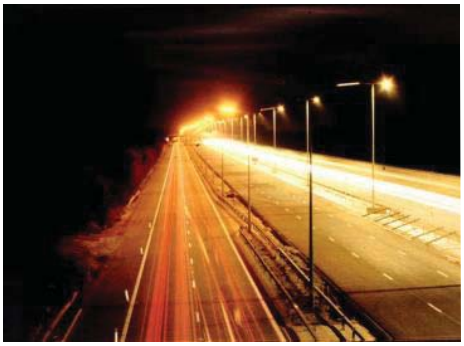
Mercury Vapor

Visible light is produced in a mercury vapor lamp when electricity moves through the contained mercury vapor. These lamps typically produce about 50 lumens/ watt but have a tendency to lose up to 2/3's of their light output over time. Mercury vapor lamps are available in 40 to 1,000 watts. Their color temperature is between 3200 K and 7000 K, putting them at the cooler end of the spectrum. The light they produce is a cool blue/green white light that has poor color rendition. Some mercury vapor bulbs can be coated with red phosphor, to balance out the blue tint and to create a white glow and higher color rendition (Narboni, Roger). A mercury vapor lamp lasts about 8,000 hours and has an efficacy between 25 and 60 (EERE).

Metal Halide Lamp

Metal Halide

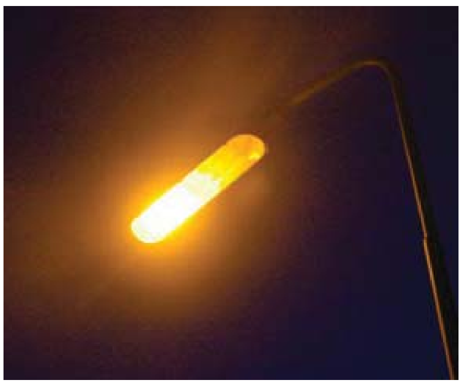
Metal halide lamps have the same structure as mercury vapor lamps with the addition of metal halide as a gas conductor. This alteration allows for higher light output and softer, slightly warmer white light. This warmer light also creates better color rendition. Metal halide lamps are commonly used in sports arenas and commercial landscape sites because they have the highest color rendition of all the HID lamp sources. However, they also have the shortest lifespan of all the HID lamps with only about 5,000 to 10,000 hours (Narboni, Roger). Their color temperature is about 3700 K and their efficacy is between 70 and 115 lumens/ watt (EERE).



High Pressure Sodium lamps

High Pressure Sodium

High pressure sodium lamps are run with high pressure sodium as the gas conductor. These lights are often used on freeways or parking lots because there is not a need for high color rendition in these areas. A high pressure sodium lamp emits a soft yellow/white light and burns at a color temperature of 2100 K (Narboni, Roger). Their efficacy ranges from 50 to 140 and their watt availability spans from 35 to 1,000. High pressure sodium lamps have the longest lifespan of all the HID lamps at an average of 20,000 hours (EERE).



Low Pressure Sodium lamp

Low Pressure Sodium

Low pressure sodium lamps are not technically HID lamps, although they are often included within the category. Low pressure sodium lamps are a monochromatic light source that produces only yellow light, but they are operated in a very similar fashion to other HID lamps. Their watt availability ranges from 18 to 180, an efficacy of 60 to 150 and a lifespan of 12,000 to 18,000 hours (Narboni, Roger). From a design stand point; these lights are not a good option. They render all objects and design elements in a dull shade of grey. Their color rendition runs at a -44, meaning worse that the worst (EERE).

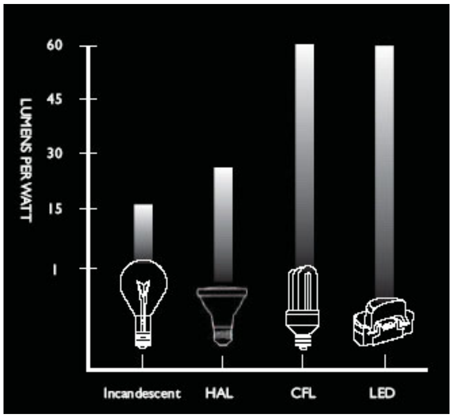
Light Emitting Diode

LIGHT EMITTING DIODE (LED)

LEDs have been in the electronics industry for a long time, serving as the illumination in alarm clocks or remote controls, but they have just recently joined the landscape lighting field. They are illuminated by the movement of electrons through a semiconductor material. In LEDs the conductor material is typically aluminum- gallium-arsenide. This material absorbs very little of the light energy and allows more photons to be released outward. The cost of LEDs used to be extreme because of this semiconductor material but in recent years this is no longer an issue because the cost has significantly lowered (Harris, Tom). The initial cost of LED lamps is higher than other lighting options but the lifespan is much longer, lasting around 200,000 hours. They have a good color rendition and a color temperature around 3200K to 5500k. LED's are available in white lights and color. They have an efficacy of 25-100 lumens/ watt (Redmond, Gary).

Multiple light emitting diodes creating and LED lamp

LIGHT SOURCE COST COMPARISON



Typical light output of an incandescent, halogen, compact fluorescent and LED light source

This chapter will examine the costs and efficiencies of various lighting options to demonstrate the overall gain of energy efficient lighting.

Incandescent vs. Fluorescent

The fluorescent bulb has been the upcoming rival of the incandescent bulb for the past decade. The fluorescent bulb can fit into the same outlet at the incandescent bulb and give similar light quality for less energy and cost over time. The following calculations show the cost comparison between a fluorescent and incandescent bulb in the same lighting conditions. The chart below graphically displays the variable of the situation. A 60 watt incandescent bulb has a 1,000 hour life span and an initial cost of $0.50. The equivalent of this in lumen output of fluorescent bulbs in a 15 watt bulb with 10,000 hour life span and an initial cost of $3.50. The average cost of electricity in this scenario is set at $0.98 *kilowatt* hours. The use of the fluorescent light bulb over its 10,000 hour life span will save ten light bulb changes, $40.50 in electricity costs, $1.50 in light bulb replacement, and a total of $42.00.

Incandescent Bulb	Fluorescent Bulb
60 watt	15 watt
1,000 hour bulb life	10,000 hour bulb life
Initial Cost: $0.50	Initial Cost: $3.50

*Wattage determined by similar visible lumen output

Average Cost of Electricity: $0.98

Results:

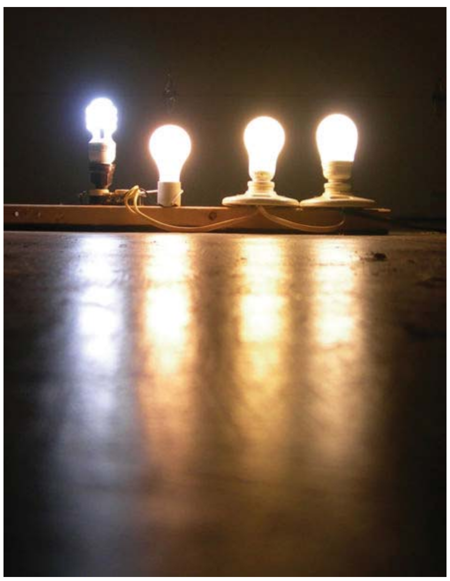
The use of the fluorescent bulb over its 10,000 hour life span will save

•10 light bulb changes

•$40.50 in electricity costs

•$1.50 in bulb replacement costs

•With a total savings of $42.00



A photograph of various lamps illustrates illumination differences (left to right): (1) Compact Fluorescent: General Electric, 13 watt, 6500 K (2) Incandescent: Sylvania 60-Watt Extra Soft White (3) Compact Fluorescent: Bright Effects, 15 watts, 2644 K (4) Compact Fluorescent: Sylvania, 14 watts, 3000 K (Manski, W.)

Comparison Charts

The initial cost of lighting fixtures can be intimidating, but the overall savings should encourage the use of energy efficient options. The following chart compares incandescent, fluorescent, HID and LED light sources. They have been calculated in consistent circumstances with the closest approximation in visual lumen output (O'Niell, Robert). However, some of the lights are not easily comparable and adjustments have been made to demonstrate the savings more accurately.

Kilowatt hour: electricity is charged by the kilowatt hour. 1kilowatt hour would be running a 1 kilowatt appliance for 1 hour. A 100 watt bulb uses 0.1 kilowatts because 1,000 watts =1 kilowatt

15 HID lights were used in this hypothetical situation as opposed to 30 because HID bubls are not available at such low light outputs to be comparable to an incandescent. To maintain realistic comparisons in this hypothetical situation, their numbers were reduced to half that of the other bulbs.

Energy Savings for Replacing Light Bulbs

	Incandescent Light Bulbs	CFL (Compact Fluorescent Light Bulbs)	HID (High Intensity Discharge)	LED (Light-Emitting Diode Light Bulbs)
Life Span (in hours)	1,500	10,000	7,500	60,000
Watts	60	14	70	6
Cost	$1.345	$2.98	$14.50	$54.95
KWh of electricty used over 60,000 hours	3,600	840	4,200	360
Electricity Cost (@ $0.98/ KWh)	$3,528.00	$823.20	$4,116.00	$352.80
Bulbs needed for 60,000 hours of usage	40	6	8	1
Equivalent 60,000 hour bulb expense	$53.80	$17.88	$116.00	$54.95
Total 60,000 Hour Lighting Spend	$3,583.15	$841.08	$4,232.00	$407.75
Calculate Energy Savings				
# of light bulbs	30	30	15	30
Your estimated daily usage (hours)	5	5	5	5
Days in month	30	30	30	30
Savings over 60,000 hours (energy + replacement)				
Cost	$107,494.35	$25,232.40	$63,480.00	$12,232.50
Savings by switching from Incandescent	$0.00	$82,261.95	$44,014.35	$95,261.85
Monthly energy savings				
KWh used per month	270	63	158	27
Electricity Cost (@ $0.98/ KWh)	$264.60	$61.74	$154.35	$26.46
Savings by switching from Incandescent	$0.00	$202.86	$110.25	$238.14
Yearly energy savings				
KWh used per year	3,285	767	1,916	329
Electricity Cost (@ $0.98/ KWh)	$3,219.30	$751.17	$1,877.93	$321.93
Savings by switching from Incandescent	$0.00	$2,468.13	$1,341.38	$2,897.37

This chart shows that LED's are the leading source in energy efficiency. They require the least amount of energy and render the most savings.

LED wall mount by KimLighting, can be used to provide security lighting

LED bell wall mount by KimLighting, can be used to illuminate walls and planting areas for security lighting

LED floodlight by The LED Light.com

LANDSCAPE LIGHTING DESIGN TECHNIQUES AND ENERGY EFFICIENT ALTERNATIVES

There are many elements that must be considered in landscape lighting design. Security, safety, usability and aesthetic value are to most important components to successfully lay out a landscape lighting design. This chapter will discuss the techniques to achieve these goals and the energy efficient alternative lighting sources that can be used in place of today's common practice.

Security

The design of lighting for public spaces must always consider the comfort of the visitors. A landscape lighting designer wants the visitors of the site to have a positive experience. Security relates to the comfort level of a visitor. A well lit area deters intruders and inappropriate behavior. If key areas are lit with lower levels of light that still provide sufficient light to see, then the lighted areas will be only slightly brighter than the shadowed areas and leave no space for dark spots. If lighting is at a level setting the human eye will have an easier time adjusting to darker areas and therefore not leaving a visitor vulnerable (Parrot, Steve).

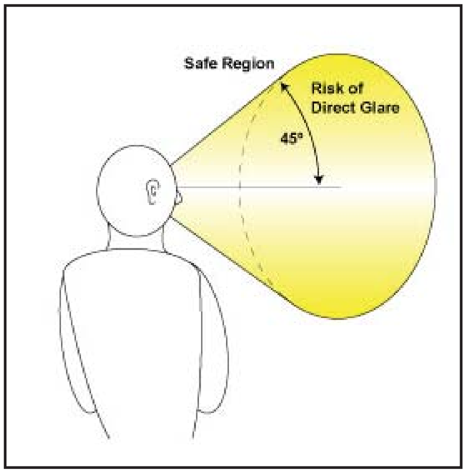
Security: Energy Efficient Options

Large areas can be lit without the extreme of floodlights, which tend to wash out and create dark spots. LED luminaires are available in various sizes. They can be mounted on walls and their light will graze the surface to illuminate space and emphasize texture. A lighter and softer light can be used in the LED luminaires to maintain a steady light and avoid dark spots.

Safety

Even lighting in this area allows no dark spots and a good sense of security

The concern for safety dictates a significant part of design. Safety controls where lights must be located to promote visibility in places of higher risk. Steps, pathways and areas near water features always need to be sufficiently illuminated so visitors are visually aware of potential risks. A hazardous area in a commercial site is unacceptable and can be avoided with the proper lighting. In the process of illuminating a designer must consider all the angles of the light and how it may affect the viewer. The angle of glare can be dangerous if it is within a certain range. A bit of direct glare from a light source could render a visitor temporarily blinded and leave that person at risk for an accident (Parrot, Steve).



Direct glare risk zone

Safety: Energy Efficient Options

Standard pathways and stair lights are available in LED form. There are also some potential design options that are unique to LED lamps. An LED paver is a new option in which pavers directly in the pathway or driveway are illuminated. These pavers can indicate a direction or show edges. LED illuminated cables are another new technique that can be placed under the riser of a step to light up the landing beneath it.

LED bell light, ideal for pathway lighting, KimLighting

LED pavers

LED pathway lights

LED rope lighting

LED rope lighting interior example

Usability

Lighting levels may vary between differing activities. The ambience of eating is different from a field of recreation. The activities of an area should be determined before design so lighting can be adjusted accordingly. Eating areas have moderate lighting, seating and waiting areas are slightly lower levels and recreation and sports require the most illumination.

LED wall sconce by DG Lighting

Usability: Energy Efficient Options

A successful way to create energy efficient ambiance can be LED wall sconces. They give an artful elegance while providing subtle light. LED uplights and well lights can also be used to light surrounding objects and therefore create understated lighting on the designated areas.

Artistic illumination of pots

Photograph of an evening on Rodeo Drive, lit for casual strolls and window shopping

A creative use of LED in the dining

Blue colored LED lighting a fountain to create a mystical appearance

Aesthetics

Depth created with the moonlighting effect

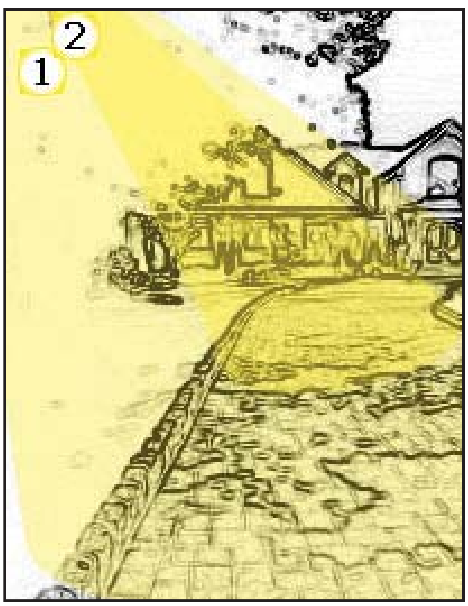
The overall goal of landscape lighting design is to create a desrable space. A space that is pleasing to the human eye. Lighting design in regards to aesthetics can seem general, but some concepts make it much more tangible. These factors to consider when designing landscape lighting for aesthetic value are depth, perspective, focal points and cohesion.

Aesthetics: Depth

To create depth, a designer has to manipulate the near and far to create an illusion of space. Light should be used throughout the site in different phases with transitional areas. Some places should be more brightly lit than others and in the end, there will be a sense of distance and depth. One token technique to create depth is called moonlighting (Parrot, Steve). This technique mimics the light of the moon to create soft evening shadows with a dappled effect. A brighter white light is mounted high up on a tree or a building and angled down to shine from above. Ideally, more than one light is mounted up high in this fashion and they are scattered all over the site. The end result is cool shadows that look like moonlight even on a cloudy evening.

Aesthetics: Depth Energy Efficient Options

Creating a moonlight effect is completely attainable with energy efficient light sources. LED uplights can be mounted on buildings and trees and aimed in downward directions. LED pavers and well lights can be used to elongate pathways or illuminate planting areas to enhance a sense of distance. Rope LEDs at the base of a structure create a glow that emphasizes a destination and in the process, reinforces depth.



Moonlighting effect: 1 is light source one and 2 is light source two and each demonstrate how they are orientaed to create the moonlight effect

The Four Seasons Hotel, Maui, demonstrating a successful lighting scheme with strong sense of depth

Aesthetics: Perspective

Point of view from a less likely stand point

A site can be viewed from all angles and this needs to be kept in mind while composing a landscape lighting design. All points of view should be recognized to enhance beauty. Many light sources come in neutral colors, to blend into the landscape and others can be exposed as part of the display. A designer needs to be conscience of what is being seen and what is better hidden and place items accordingly (Parrot, Steve).

Aesthetics: Perspective Energy Efficient Options

The view from the doorway of a building is as vital to design as the view from the parking lot. In order to create well rounded and developed landscape lighting systems, energy efficient light sources should be used discretely and purposefully. An LED uplight or well light can illuminate a façade without the imposition of an unattractive fixture. LED rope lights can also achieve subtle lighting without exposing hardwiring. HID lights are often used in parking lot areas for overhead lighting and are not terrible in the sense of efficiency, but as far as design, they have very poor color rendition. LED lights can be used in street lamps to replace the sodium lights and provide better color rendition (Proefrock, Philip).

LED Street lamps by optics.org

Perspective was taken into account when lighting the arches of this entry as well as the sculpture itself

KimLighting LED well light

Aesthetics: Focal Points

A walk through a place can be an experience. In landscape lighting a designer has the opportunity to control a visitor's path and visual experience by selecting focal points. The designer can choose the course that the eyes follow through a lit landscape. Focal points should be a point of interest or a destination. A focal point could be a fountain or sculpture as well as a tree, bench or building entrance. The focal points of a site can determine what is important to be seen. These lit areas will guide a viewers experience of a lighted landscape and ultimately determine their experience of the site altogether (Parrot, Steve).

Aesthetics: Focal Points Energy Efficient Options

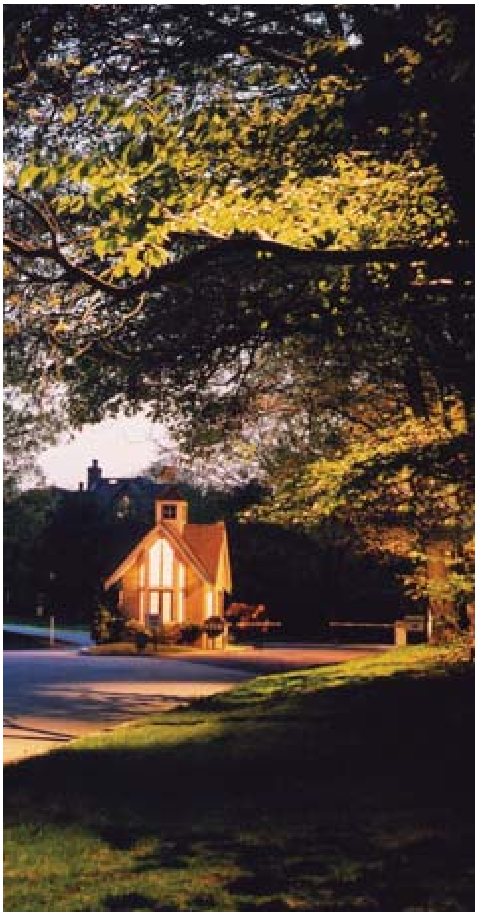
Focal points can be illuminated strongly and subtly or a mix of the two. There can be a hierarchy of brightness in regards to importance or level of interest. Focal points can be lit with consistent lighting and create an experience in their union. LED lights can illuminate in these different styles. Uplights can be adjusted to ideal angles while remaining inconspicuous.

Example of focal points illuminated throughout a site

KimLighting LED "scarab" uplight

Aesthetics: Cohesion

The cohesion element of landscape lighting design is what brings all the pieces together and determines the relationships between all the elements of an area. The focal points, depth and perspective views are all brought to one culmination. One cohesion technique is lighting interior pathways or the periphery of a site. This linear lighting method creates a unity between all the illuminations in the site. A simple practice of cohesion can be light and bright foreground, lower amounts of illumination in the mid area, and even lower light levels and less uniformity in the background. This technique gives depth and distance while still allowing for focal point (Alpern, Andrew). Focal points can create



Example of cohesion with an overall lighting

cohesion if they are closely spaced without complete darkness between any of them. In this scenario the focal points make cohesion by creating the illusion of a linear path of illumination through the site. Cohesion can also be achieved with a site wide lighting plan such as moonlighting (Parrot, Steve).

Asthetics: Cohesion, Energy Efficient Options

Cohesion is the combination of depth, perspective and focal points. It can be created with the same tools, including, LED well lights, uplights, bell lights, ropes and street lamps.

Example of cohesion created with a linear path of illuminated planting beds

LED uplighting of a columnar tree

LIGHTING TECHNIQUES FOR VEGETATION

Trees

Trees of varying shapes and forms have different features that should be emphasized with lighting. A columnar tree is best represented with an uplight. This creates a long illumination and gives the tree an inner glow. Trees with a spreading form such as a cedar or oak are flattered with a soft uplight that is placed at a right angle to the side of the tree. With this effect, the upper part of the tree is brighter than the base, giving a grand demeanor to the tree. Trees with a voluminous, conical or pyramidal shape, such as chestnut, pine, fir and acacia, can benefit from lighting at many angles. These trees can be illuminated from the ground to look more grand and full or from above to create shadow patterns on the ground. Thinner trees or trees with good architectural branching present themselves well when they are lit from the inside near the trunk. This method embellishes the angles and positions of the branches.

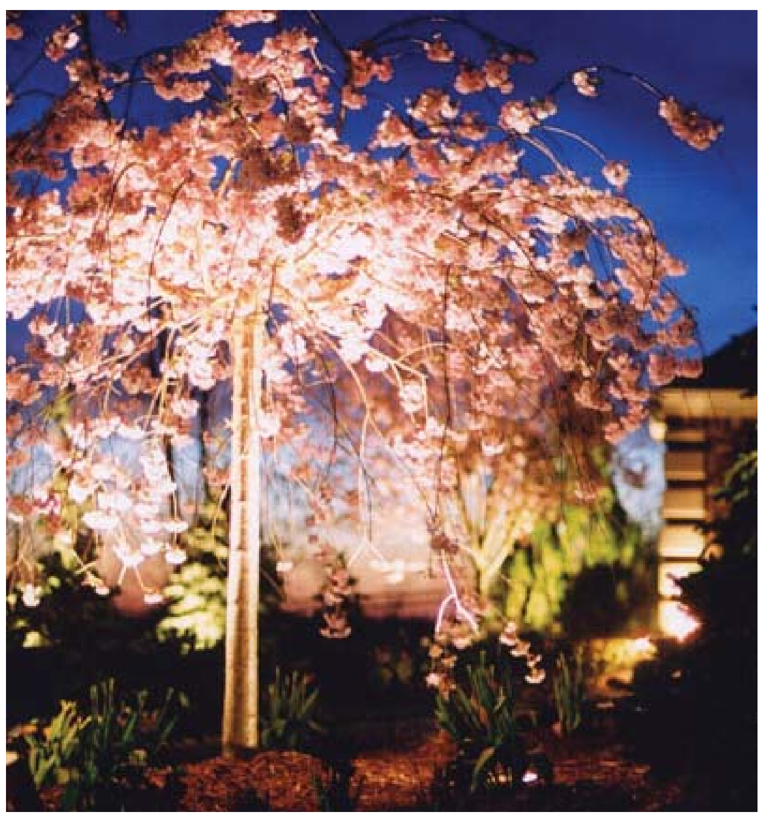
Vegetation Illumination

Vegetation comes in a wide array of shapes and colors. Good lighting design should take advantage of these characteristics. A cool colored plant, such as blue green, blue or silver is best illuminated with a light with cool luminous tones, meaning a color temperature greater than 3,000 K. Warm colored vegetation such as green, light green, yellow, orange or purple are best rendered by warm tones. Warm light tones include lamp sources with a color temperature lower than 3,000 K.

Cool foliage is best illuminated with cool color temperature lights

Warm foliage is best illuminated with warm color temperature lights

Up, side and back lighting allows for the creation of shadows while still lighting the plant itself



Above: LED uplight illuminating the spreading form
Right: Shrub illuminated from inside to enhance the branches and massing form

LIGHTING TECHNIQUES FOR PATHWAYS, STAIRS AND ARCHITECTURE

Pathways

Pathways should be lit for good visibility and safety. Typically, lights are close to the ground to provide optimum light. The lights are best alternating sides to follow the steps of visitors. LED lights are available in bell form and well lights that are ideal for path lighting. LED pavers can also be used to light the way of a path (Narboni, Roger).

LED pavers

Example of pathway lighting

Stairs

Steps can be illuminated for safety as well as aesthetic value. Lighting each step individually is necessary for precaution but also creates a union within the stairs and provides an ethereal glow. Stairs can be lit with individual LED mounted lights or LED rope under each riser. LED pavers can also be used in stone stairs.

Example of an LED stair lighting technique

Example of stair lighting

Architecture

Architectural lighting can create cohesion through out a site. A valuable lighting technique for architecture is bounce lighting. This is lighting upward, to a ledge or gutter, and using the reflection of the light to illuminate the side of a building and nearby planting beds. One light source can illuminate a building and nearby planting areas. Highly textured surfaces in architecture should be grazed as opposed to directly illuminated. The graze will enhance the grooves of a texture and emphasize its shape (Redmond, Garay).

Bounce lighting

NEW & UPCOMING IDEAS IN LANDSCAPE LIGHTING

The lighting industry never stops. Always trying to make something newer that's less expensive and more effective. The following are some of the potential items of the future for landscape lighting.

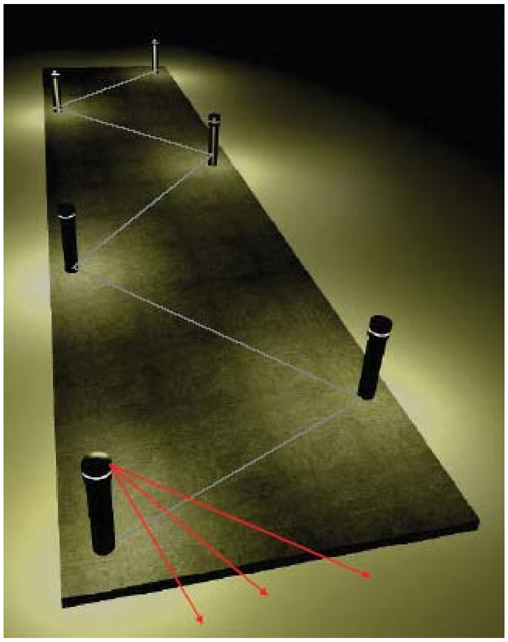


Diagram of Smart Bollards and sensor area

Smart LED Bollard

The California Lighting and Technology Center is in the works of creating an LED bollard that responds to motion. These bollards will provide adequate lighting for pathways and entries at all times but will switch to higher levels of illumination when motion is detected. A demonstration of this potential new product is planned for Cal Poly, San Luis Obispo in the summer of 2008 (CLTC).

HID Bi-level Smart Fixtures

In the Mondavi Center Administrative Parking Lot and the O & M Utilities Trailer Parking Lot at UC Davis there are test sites for HID bi-level smart fixtures. These light fixtures have the ability to run at high and low levels. They have been set to run at low levels during unoccupied hours of the night and high levels at occupied hours of the night. Soon a new test site will be added to the lower level of the North Parking structure on the UC Davis campus. These dimmable lights have not yet provided results but may have the potential to significantly reduce energy cost and use (CLTC).

Still Being Investigated

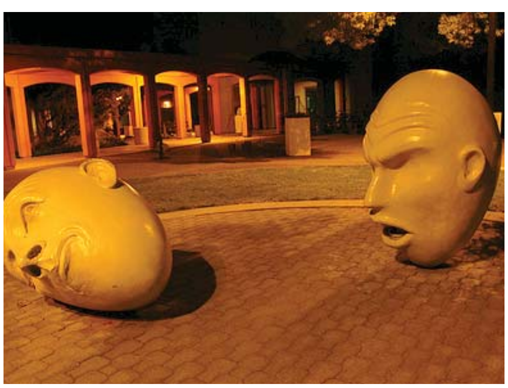
Greenhouses run on sensors that relay to a computer when the sun is too hot and the shades should be pulled or when there is low moisture in the soil and the plants should be watered. This same technology could soon make it to the lighting industry. Digital sensors, remote controls, and calibration digital wiring could control light levels all through computers. Sensors may read when the sun level is high, when there are high amounts of activity or many other things and adjust light levels accordingly.

ENERGY EFFICIENT LANDSCAPE LIGHTING

Front illuminated bronze statue

Energy efficient landscape lighting is an accessible option if designers can begin to embrace the new technology of LEDs and other things to come. When designers develop familiarity with these ideas, new regulations and environmental awareness codes will not affect the quality of their design. A people and designers we all need to be willing to learn new technologies as they arise and adjust our practices to improve the world with live in. With energy efficient landscape lighting design we can cut energy use and costs while still maintain aesthetic quality.

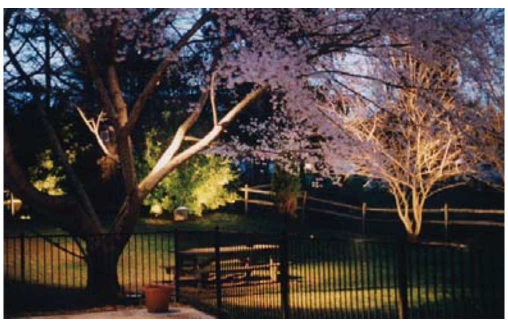
LED lights glowing under the snow



UC Davis egg heads lit at night

GLOSSARY

Example of backlighting



Example of downlighting

Example of modified front lighting, grazing

back lighting: illumination from the rear. Creates an ethereal, defining and mysterious mood

ballast: device required by some light sources to regulate the flow of power through the lamp

candela: measurement of luminous intensity

compact fluorescent lights (CFL): a light source that produces visible light when an electric current is conducted through mercury and other inert gases causes the vapor to excite and emit ultraviolet light. They run on ballasts

color rendering index: ranges from 1-100. 85-95 means excellent color rendition. Lower than 65 is not good color rendition.

daylight harvesting: consists of two sensors that read the light levels of the sun and another that adjusts the interior lighting

daylighting: designing for the use of natural light

diffusion: phenomenon in which the spatial distribution of a luminous beam is altered when it is deflected by a surface

downlighting: lighting mounted from above that shines downward to create a natural, subdued, romantic and mellow environment

efficacy: ratio of light output from a lamp to the electric power it consumes, it is meaured in lumens per watt (LPW)

footcandle: measurement of illuminations. A footcandle of illumination is a lumen of light distibuted over 1 square foot area

front lighting: lighting from the front of an object to create a revealing, dramatic and flattening appearance

illuminance: the amount of light received by a surface, independent of what that surface may be.

illumination: distribution of light on a horizontal surface, it is measured in footcandles

Incandescent light bulb

incandescent lights: light produced by an electric current passing through a filament that heats to produce light, the glass exterior prevents oxygen from reaching the filament and therefore preventing immediate oxidation

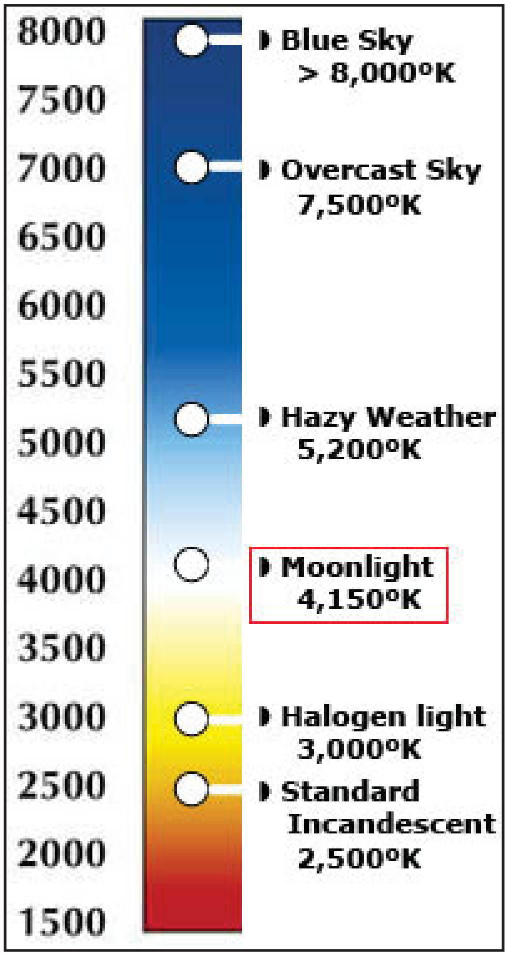
Ingress Protection Ratings: rating used to specify environmental protection and electrical enclosure of electric equipment. It is usually represented by the IP initials and two or three numbers. The first number represents how well the item is protected from solid objects or materials. The second number indicates protection from liquids and the third number shows the item's protection against mechanical impacts. The third number is not typically included in the evaluation. The numerical ratings for protection against solids range from zero to six. The rating for liquid protection ranges from zero to eight. All ratings are broken down as follows:

Rating	Description of Numerical Rating Against Solids
0	No special protection
1	Protected against solid objects up to 50mm, e.g. accidental touch by hands
2	Protected against solid objects up to 12mm, e.g. fingers
3	Protected against solid objects over 2.5mm (tools and wires).
4	Protected against solid objects over 1mm (tools, wire, and small wires).
5	Protected against dust limited ingress (no harmful deposit).
6	Totally protected against dust.

Rating	Description of Numerical Rating Liquids
0	No special protection
1	Protection against vertically falling drops of water e.g. condensation
2	Protection against direct sprays of water up to 15^{o} from the vertical
3	Protected against direct sprays of water up to 60^{o} from the vertical
4	Protection against water sprayed from all directions ^{o} limited ingress permitted
5	Protected against low pressure jets of water from all directions ^{o} limited ingress
6	Protected against low pressure jets of water, e.g. for use on ship decks - limited ingress permitted
7	Protected against the effect of immersion between 15cm and 1m
8	Protects against long periods of immersion under pressure

(Ingress Protection Ratings).

kilowatt hour: electricity is charged by the kilowatt hour. 1kilowatt hour would be running a 1 kilowatt appliance for 1 hour. A 100 watt bulb uses 0.1 kilowatts because 1,000 watts =1 kilowatt



Luminous tonality, color temperature scale

UL Standards seal of approval

light emitting diode (LED): an electronic component which emits lumious radiation when supplied with electric current

luminaire: a piece of lighting equipment that serves to emit, distribute, and control the light generated by one or more lamps

luminence/ luminous flux: the measurement of the human eye's perceived value of light, it is measured in lumens and dependent on color, texture and material

luminescence: phenomenon that occurs when a valence electron changes state, most commonly seen in gases when energy is passed through and electrons are excited

luminous efficacy: the ratio of visible light energy emitted to the total power input of a lamp. It is measured in lumens/ watt. The highest possible ratio for white light is 240 lm/w. Relationship between the power consumed by a lamp and the luminous flux emitted by it

luminous efficiency: the ratio of luminous efficacy to the maximum possible value

luminous tonality: the color temperature (T) expressed in Kelvin (K). This helps to determine the "warm" or "cool" appearance of light. It is measured with a colorimeter. Color temperatures greater than or equal to 3,000K are "warm" and color temperatures lower than 3,000K are cool

nominal luminous flux: the quantity of light energy radiated per second by the source

power density: measurement of light in watts per square foot

reflector/ refractor: lens or mirror used to direct light

side lighting: lighting from a side angle that creates a textural, defining, and dramatic scene

UL Standards, Underwriters Laboratory Safety Standards: Each category of electronic equipment has been scoped for safety standards. Many lighting companies show the section of the standards that applies to their product

Example of uplighting

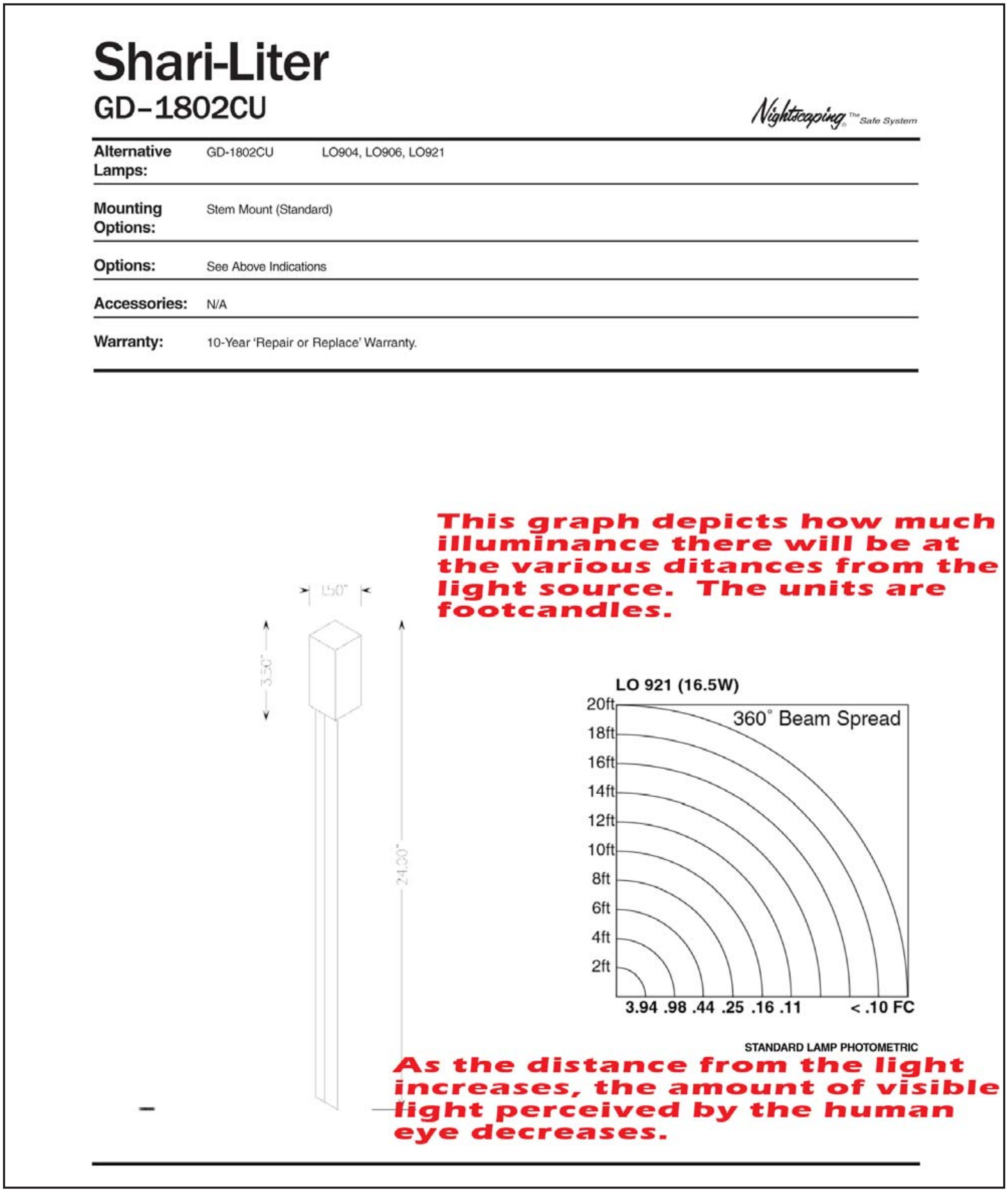
uplighting: lighting from low angles or ground level to create a dramatic, uplifting, grand and spooky atmosphere

white light: the apparent visible color of lamps with a color temperature between 2,500K and 7,000K

HOW TO READ A LIGHTING CATALOG

This section will provide real cut sheets from lighting catalogs. Each page will have red markings explaining what each item means. The glossary should also be used as a reference for further information.

Shari-Liter catalog sheet



Shari-Liter
GD–1802CU

Nightscaping® The Safe System

Alternative Lamps:	GD-1802CU	LO904, LO906, LO921
Mounting Options:	Stem Mount (Standard)	
Options:	See Above Indications	
Accessories:	N/A	
Warranty:	10-Year 'Repair or Replace' Warranty.	

Eclipse Lighting Catalog Sheet

Model Number.

2007 2007 2007 2007 new lamping technology

MR16 High Power LED

Much more user friendly!

SPECIFICATIONS

- LAMP— 1, 3 or 5 Watt High Luminance Super-Bright White LED — 20,000 HOUR LIFE
- LUMENS— 1W = 50Lm, 3W = 90Lm, 5W = 120Lm **Light output.**
- DIMENSIONS— 1.97" dia. x 1.6" length
- LIGHT DISTRIBUTION— 10°, 30° or 60° Beam Angle **Adjustment options.**
- POWER FACTOR— Electronic Driver
- COLOR RANGE— Warm (WW) to Cool White (CW) **Color temperature**
- OPERATING TEMP— -20°C to 60°C (-4°F to 140°F)
- POWER SOURCE— AC/DC 12 Volt
- PATENT— PENDING
- UL/ULC— PENDING **Safety standard.**
- FIXTURES— For Use in Open Fixtures Only

Features/Benefits

- High Luminance
- Low Power Consumption
- up to 20,000 Hours Long Life
- Easy Install

Applications

- Ideal for Medical, Landscape, Architectural, Entertainment, Ambient Lighting and More!

ECLIPSE™ LIGHTING

9245 W. Ivanhoe St.
Schiller Park, IL 60176
p: (847) 260-0333 f: (847) 260-0344
www.eclipselightinginc.com
quotes@eclipselightinginc.com

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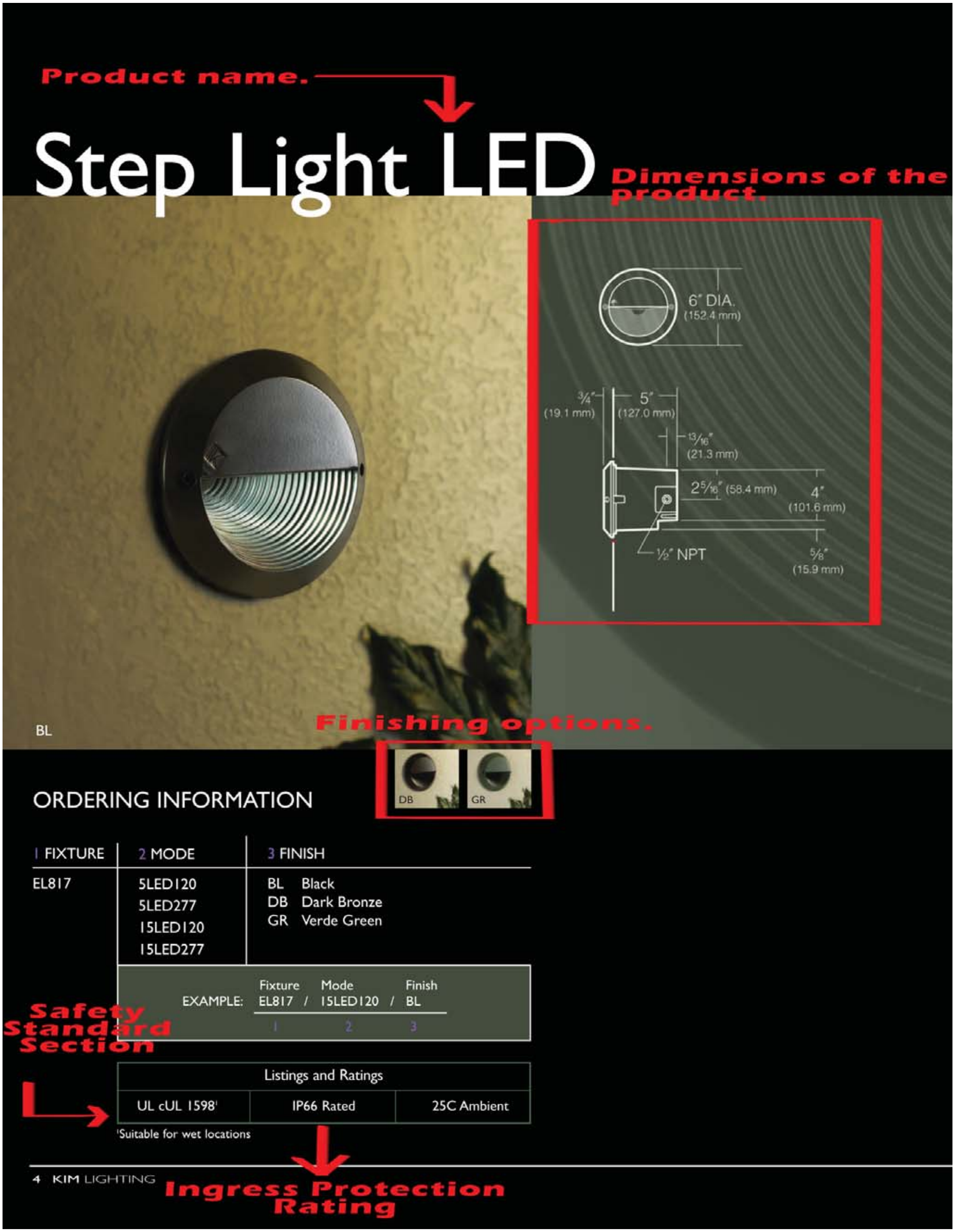
Rev. 08/09/07 | 1

KimLighting LED Light



Available voltages

EL817

120V/277V

5W or 15W | Die-Cast Aluminum | Wall, Step, Path Lighting

Safety, reliability, and now energy efficiency are hallmarks of Kim Lighting's new LED series of step lights. Offered in round and rectangular faceplate designs, these rugged pre-lamped fixtures are ready to install right out of the box and are ADA compliant for high traffic areas requiring continuous, abundant, and effective egress illumination.

Type of fixutre, cast, lens and

Explains the LED arrangement in the fixture and how it runs.

SPECIFICATIONS

HOUSING: Die-cast low copper alloy (<0.6% Cu) aluminum with clear anodized finish. Two ½" NPT in sides. Housing mounts into concrete, brick, or masonry (non-combustible materials). Internal splice area provided behind lamp plate.

LENS FRAME: Die-cast aluminum, with silicone gasket, attaches to housing with two captive 10-32 stainless steel, hex socket cap screws.

LENS: Tempered prismatic glass with silicone gasket, concealed above lens frame opening.

FINISH: On lens frame only, Super TGIC thermoset polyester powder coat paint, 2.5 mil nominal thickness, applied over a titanated zirconium conversion coating; 2500 hour salt spray test endurance rating. Standard colors are Black (BL), Dark Bronze (DB), and Verde Green (GR).

OPTICAL SYSTEM: A total of 3 or 9 LED emitters are configured together as a module. Available in "Halogen White" (approx. 3500K).

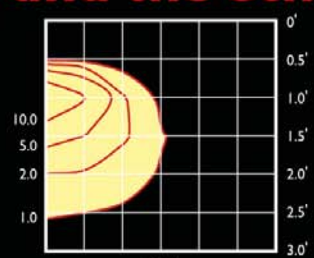
DRIVER: Constant current electronic driver. Available in 120V or 277V input. 0°F. starting temperature. All drivers are Underwriters Laboratories recognized.

NOTE: The 120V driver can be dimmed with an off-the-shelf phase control line dimmer (SCR/TRIAC style).

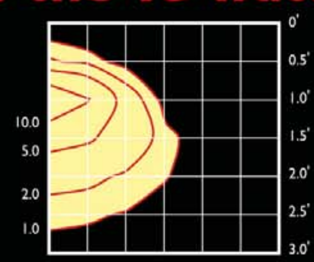
PHOTOMETRIC DATA

HORIZONTAL FOOTCANDLE CHART • TYPICAL HALF • MOUNTING HEIGHT 12"

Shows the distance of illuminance provided by the light source with an assumed mounting height of 12". One graph shows the 5 watt option and the other the 15 watt option.



5W



15W

Safety approved symbol.

c UL us LISTED

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