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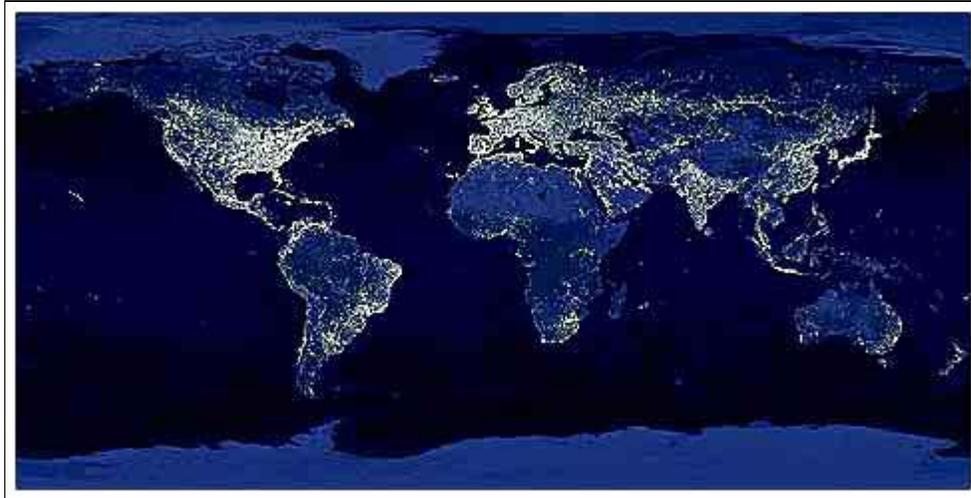
Abstract

Outdoor lighting has become a necessary integral part of society. Light pollution is a by-product of outdoor lighting. Light pollution can be reduced by lighting only what is actually needed, when it is needed, and to the appropriate level. This publication discusses the three elements of light pollution, which are sky glow, light trespass, and glare, and gives examples and recommendations for minimizing or eliminating the undesirable effects of each element when designing and using outdoor lighting.

Introduction

We light our outdoor nighttime environment to meet certain societal goals, such as increasing safety and security, enhancing economic development, as well as highlighting historic areas or landmarks of cities or towns. Our society has become a 24-hour society, and nighttime lighting has become a necessity to facilitate using our roadways and downtown areas. Figure 1 is a composite image that depicts the light emitted from the earth at night. The brighter areas in the figure are regions of higher population density and, thus, more outdoor lighting.

Figure 1. The earth at night



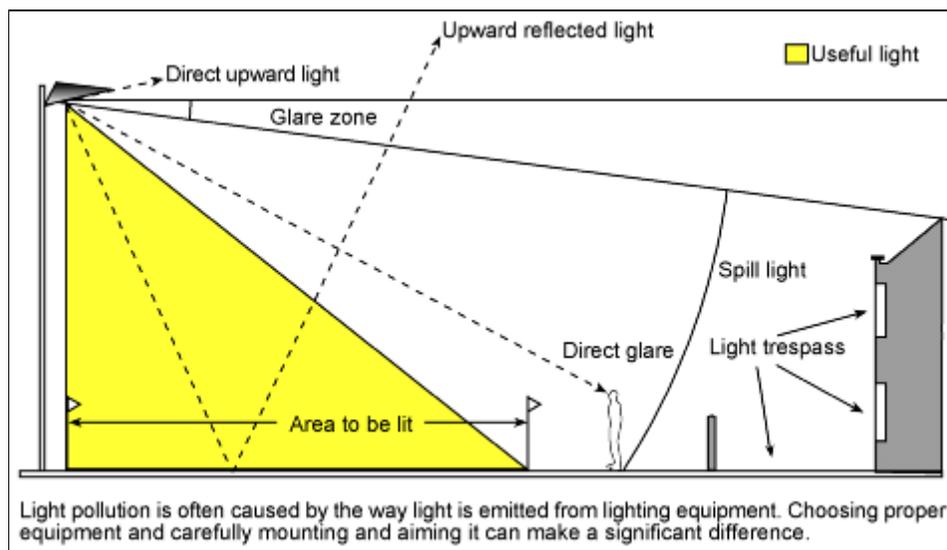
Source: Image and data processing by the National Oceanic and Atmospheric Administration (NOAA) National Geophysical Data Center. Data collected by the U.S. Air Force Weather Agency under the Defense Meteorological Satellite Program, 1994-1995

Light pollution is a by-product of lighting at night, especially when we use inefficient luminaires and lamps and when we light to excessive levels. We can minimize our impact on light pollution by lighting more efficiently. When we choose efficient luminaires and lamps, fewer lamps may be required to meet the lighting objectives, resulting in less wasted light emitted into areas where the light is not needed.

What is light pollution?

Light pollution is an unwanted consequence of outdoor lighting and includes such effects as **sky glow**, **light trespass**, and **glare**. An illustration of both useful light and the components of light pollution are illustrated in Figure 2. Sky glow is a brightening of the sky caused by both natural and human-made factors. The key factor of sky glow that contributes to light pollution is outdoor lighting.

Figure 2. Example of useful light and light pollution from a typical pole-mounted outdoor luminaire



Source: Adapted from Institution of Lighting Engineers

Light trespass is light being cast where it is not wanted or needed, such as light from a streetlight or a floodlight that illuminates a neighbor's bedroom at night making it difficult to sleep.

Glare can be thought of as objectionable brightness. It can be disabling or discomforting. There are several kinds of glare, the worst of which is **disability glare**, because it causes a loss of visibility from stray light being scattered within the eye. **Discomfort glare** is the sensation of annoyance or even pain induced by overly bright sources. Think of driving along a dark road when an oncoming car with bright headlights suddenly appears. The sudden bright light can be uncomfortable and make it difficult to see. Discomfort and even disability glare can also be caused by streetlights, parking lot lights, floodlights, signs, sports field lighting, and decorative and landscape lights.

What is sky glow?

Sky glow occurs from both natural and human-made sources. The natural component of sky glow has five sources: sunlight reflected off the moon and earth, faint air glow in the upper atmosphere (a permanent, low-grade aurora), sunlight reflected off interplanetary dust (zodiacal light), starlight scattered in the atmosphere, and background light from faint, unresolved stars and nebulae (celestial objects or diffuse masses of interstellar dust and gas that appear as hazy smudges of light). Natural sky glow is well quantified. In this publication, further discussion of sky glow considers only human-made sources.

Electric lighting also increases night sky brightness and is the human-made source of sky glow. Light that is either emitted directly upward by luminaires or reflected from the ground is scattered by dust and gas molecules in the atmosphere, producing a luminous background. It has the effect of reducing one's ability to view the stars, as seen in Figure 3. Sky glow is highly variable depending on immediate weather conditions, quantity of dust and gas in the atmosphere, amount of light directed skyward, and the direction from which it is viewed. In poor weather conditions, more particles are present in the atmosphere to scatter the upward-bound light, so sky glow becomes a very visible effect of wasted light and wasted energy.

Figure 3. Example of sky glow over a city



Source: Reprinted with permission from the Institution of Lighting Engineers and the Society of Light and Lighting

Sky glow is of most concern to astronomers because it reduces their ability to view celestial objects. Sky glow increases the brightness of the dark areas of the sky, which reduces the contrast of stars or other celestial objects against the dark sky background. Astronomers typically like very dry clear dark nights for observing. A typical suburban sky is 5 to 10 times brighter at the **zenith** than the natural sky (the zenith is the angle that points directly upward, or 180°, from the observation point). In city centers, the zenith may be 25 or 50 times brighter than the natural background.

Sky brightness is increasing, as recorded by professional and amateur astronomers. For example, at the Mars Hill Observatory in Flagstaff, Arizona, sky brightness is reported to have increased by 0.5 magnitude from 1976 to 1988 (Lockwood et al. 1990). An increase in brightness at this level means that certain stars may blend into the background, making them indistinguishable. Upgren (1991) performed naked eye observations of bright stars over the interval from 1977–1991. Upgren's data show an increase in light pollution and possibly air pollution in the area around Middletown, Connecticut.

How is sky glow measured or calculated?

With the growing awareness of light pollution, lighting professionals only recently began measuring **sky glow** in an attempt to quantify its relationship to electric lighting. This is a very challenging task, because many factors play a role in sky glow. One must not only consider the lighting, but also the angular distribution of the light emitted from the luminaire, the light reflected from the ground and its angular distribution, as well as atmospheric effects of humidity and the interaction of light with aerosols (particles in the atmosphere that may be caused by manufactured pollutants, fire, volcanic eruptions, etc.), all of which can change from moment to moment.

When observing the night sky, professional astronomers often measure the dark portion of the sky with their astronomical equipment to have a background value they can use to compare their star signal against. Professional astronomers use an instrument called a photoelectric photometer to make these measurements. Typically such measurements are made at the **zenith**. Other methods to measure sky brightness are discussed in the CIE technical report, Guidelines for Minimizing Sky Glow (CIE 1997).

Many amateur and professional astronomers have recorded sky brightness measurements to monitor the increase in sky brightness (Lockwood et al. 1990; Upgren 1991). From these data, a number of metrics or calculation methods have been developed to estimate sky glow (Garstang 1986, 1989, 1991; Walker 1977). One very simple approach used by casual observers, for example, is to estimate sky glow by looking for the Big Dipper constellation and then counting how many stars are visible to the naked eye. However, none of the metrics directly relate electric lighting emissions to sky glow. For example, both Garstang (1986) and Walker (1977) developed relationships using population multiplied by a given number of **lumens** per person to include lighting in their calculations. However, the distribution of the light sources, the number of light sources, wattage, and the amount of reflected light are all excluded from the calculation. Without the ability to model this lighting information, it is difficult to determine how to minimize sky glow while minimizing the impact on the use of light at night.

What is light trespass?

Light trespass occurs when **spill light** is cast where it is not wanted. Light trespass is somewhat subjective because it is difficult to define when, where, and how much light is unwanted. An example of light trespass is when spill light from a streetlight or floodlight enters a window and illuminates an indoor area. Figures 4 and 5 depict examples of light trespass. The light trespass shown in Figure 4 would be significantly reduced if a shield were placed on the luminaire. In Figure 5, the floodlight on the hotel casts light on the home across the street. Proper aiming of the floodlight and shielding would significantly reduce the light trespass shown in this example.

Figure 4. Example of light trespass



Source: David Fernández-Barba, Dep. d'Astronomia i Meteorologia, Universitat de Barcelona, SPAIN

Figure 5. Example of light trespass from a floodlight installed by a hotel that casts light onto a house across the street



How is light trespass measured or calculated?

The Institution of Lighting Engineers (ILE) specifies **light trespass** limits for light entering windows in terms of environmental zones (ILE 2000). (See "[What are lighting environmental zones?](#)") It is difficult to measure light trespass because the occurrences are so different. **Illuminance** on a vertical plane (for example vertical illuminance at the window, as depicted in [Figure 4](#)) may be appropriate in some cases. Horizontal illuminance might be appropriate in other cases (for example, horizontal illuminance on a bed). An illuminance level of 1 **lux** (0.1 **footcandle**) might be acceptable to some and completely objectionable to another. For reference, 0.3 lux (0.03 footcandle) is typical of the illuminance that results from moonlight.

In a recent study, Boyce et al. (2001) suggest that light trespass be measured in a relative manner, at property boundaries, to take into account both light coming into the property as well as light inside the property. When designing the lighting for a site, imagine a vertical plane at the boundary between the site property and an adjacent property. Measure the illuminance on the vertical plane at the property boundary, directed toward the lighting design site, 180° away from the adjacent property. Then rotate 180° away from the lighting design site, and measure the illuminance on the vertical plane, directed toward the adjacent property. Calculate the ratio of the illuminance on the plane pointing toward the lighting design site to the illuminance on the plane pointing

toward the adjacent property. If the ratio of the measured illuminances is less than unity (one), this implies that the design site receives more light from the adjacent property than the design site delivers to the adjacent property. If the ratio is greater than unity, then the design site delivers more light to the adjacent property than the adjacent property delivers to the site. The larger the ratio, the more likely light trespass complaints are to occur.

What is glare?

Glare is a visual sensation caused by excessive and uncontrolled brightness. It can be disabling or simply uncomfortable. It is subjective, and sensitivity to glare can vary widely. Older people are usually more sensitive to glare due to the aging characteristics of the eye. **Disability glare** is the reduction in visibility caused by intense light sources in the field of view, while **discomfort glare** is the sensation of annoyance or even pain induced by overly bright sources (Rea 2000). Compare the glare from the streetlight shown in Figure 6 to the glare from the luminaires shown in Figure 7. Reducing glare is an effective way to improve the lighting.

Figure 6. Example of lighting that can result in disability and discomfort glare

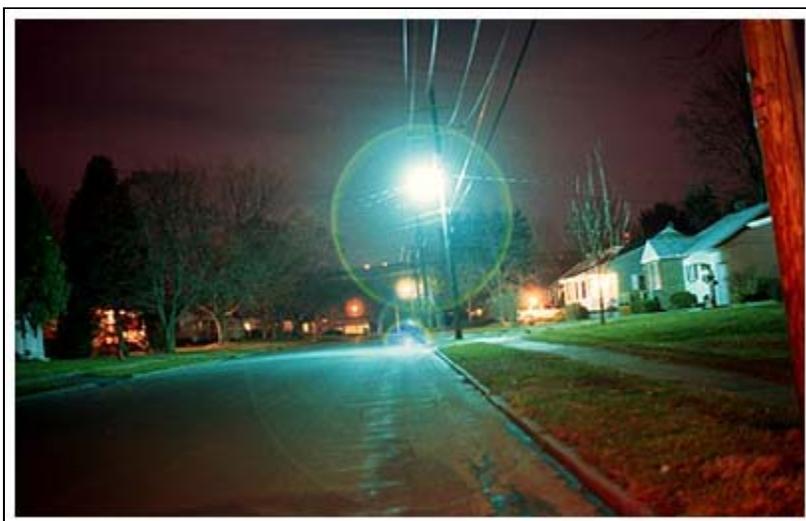
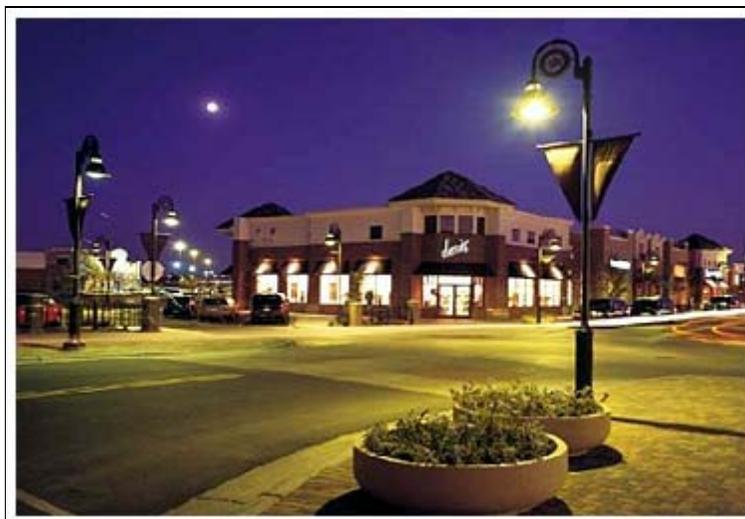


Figure 7. Example of how reduced glare improves the lighting



Source: Lumec

How is the issue of light pollution currently being addressed?

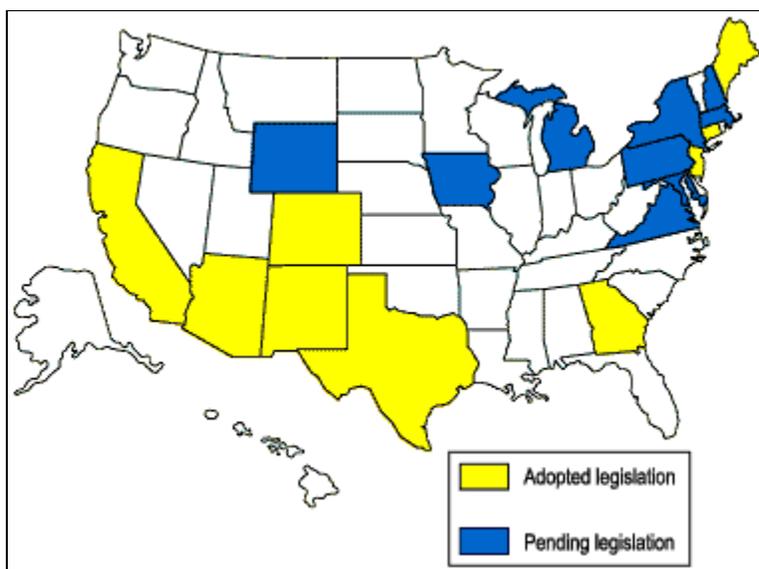
A number of educational, research, and developmental efforts addressing light pollution are underway, including work to design lighting equipment that produces less light pollution; but the main efforts currently involve education and legislation.

In response to the demand to reduce light pollution, research and development efforts have focused on advancements in technology to design luminaires to efficiently direct light where it is needed. Luminaire manufacturers have concentrated on providing highly efficient luminaires with given beam distributions while meeting the **cutoff classifications** set forth by the Illuminating Engineering Society of North America (IESNA) to reduce **glare** as well as wasted light. Advancements in lamp technologies have resulted in producing high efficiency light sources that reduce light pollution and have the added benefit of saving energy.

In an effort to increase public awareness on the topic of quality outdoor lighting, the number of state, local, and regional lighting ordinances is growing. Many states have adopted legislation controlling outdoor lighting, more states have pending outdoor lighting bills in front of their legislators. Numerous adopted and pending local ordinances pertain to the lighting of cities, towns, and counties. Figure 8 shows which states have adopted or pending statewide legislation.

Legislation typically includes requirements for **full cutoff** luminaires, minimum light levels, **lumen** or wattage limitations, light source type limitations, controlled operating periods, curfews, and the elimination of certain kinds of lighting. (Curfews for outdoor lighting are generally defined by local planning authorities based on anticipated use of the area and, thus, a need for lighting. During pre-curfew times, the need for lighting is warranted, so lighting levels are generally higher than during post-curfew times.) In addition to preserving dark skies, legislation is being justified on the basis of minimizing wasted energy and money, reducing unwanted light on adjoining properties (such as light in bedroom windows), reducing glare, and preserving animal breeding and migration habitats.

Figure 8. Adopted and pending legislation governing light pollution in the United States, as of January 2003



Luminaires are designed to have lighting distributions that are appropriate for specific applications. Virtually any luminaire can generate sky glow, light trespass, and glare if installed improperly or in the wrong application. These problems can be avoided by selecting luminaires that have the appropriate distribution for the application and installing them correctly to limit **spill light** and **uplight**.

What are lighting environmental zones?

Although the goal may be to eliminate light pollution, in some locations light pollution cannot be avoided altogether. The environmental consequences of the pollution, however, need not be equally detrimental across all locations. The Commission Internationale de l'Eclairage (CIE) has outlined four environmental zones to establish a basis for outdoor lighting regulations (CIE 1997). The environmental zone rating can be used to help ensure that the lighting goals of an environment are appropriately defined and met, but not exceeded. The Illuminating Engineering Society of North America (IESNA) has adopted the concept of environmental zones (described in Table 1) and recommends their use in developing new outdoor lighting (IESNA 1999). In some states legislation is being considered that would restrict outdoor lighting by environmental zone. For example, California has drafted environmental legislation that includes the designation of outdoor lighting zones (CEC 2002). Application of environmental zones is first envisioned for the protection of natural park preserves and astronomical observatories. Environmental zones promise to reduce overall light pollution by helping to limit, or in some cases eliminate, light wastage.

Table 1. Description of the lighting environmental zones, as adapted by IESNA

Zone rating	Description
E1	Areas with intrinsically dark landscapes National parks or residential areas with strict limits on light trespass Roads usually unlit
E2	Areas of low ambient brightness Outer urban or rural residential areas
E3	Areas of medium ambient brightness Urban residential areas
E4	Areas of high ambient brightness Urban areas, residential and commercial with high levels of night time activity

Source: IESNA 1999

The IESNA gives recommendations for pre-curfew and post-curfew light levels to limit light trespass (IESNA 1999). Pre-curfew is from dusk until 11:00 p.m. local time, when the area being illuminated is more likely to be in use. Post-curfew is from 11:00 p.m. to 7:00 a.m. local time. Recommended lighting levels are higher during pre-curfew time (IESNA 1999). The Institution of Lighting Engineers (ILE) provides guidelines on obtrusive light limits for **sky glow**, **light trespass**, and **glare** in exterior lighting installations (ILE 2000).

How can sky glow be reduced?

While it is difficult to accurately model **sky glow**, at this point it is presumed that the most important factors are light output and lamp spectral characteristics, light distribution from the luminaire, reflected light from the ground, and aerosol particle distribution in the atmosphere. If the quantity of light going into the sky is reduced, then sky glow is reduced. Thus, current practice is to reduce sky glow by 1) using **full cutoff** luminaires to minimize the amount of light emitted upward directly from the luminaire; 2) reducing light levels; 3) turning off unneeded lights; 4) limiting lighted hours of outdoor sales areas, parking areas, and signs around important observing sights; 5) limiting lighting installations; and 6) mandating low-pressure sodium light sources, which allows astronomers to filter the line spectra from telescopic images. For reducing sky glow, the Institution of Lighting Engineers (ILE) has suggested limits on the amount of luminaire-emitted light that goes directly into the sky. The ILE's limits are specified by environmental zone, as shown in Table 2.

Table 2. Limits on sky glow for different environmental zones

Environmental zone	Sky glow ULR* (max %)
E1	0.0
E2	2.5
E3	5.0
E4	15.0

* ULR is the Upward Light Ratio of the installation and is the maximum permitted percentage of luminaire flux for the total installation that goes directly into the sky.

How is light trespass controlled?

Light trespass may be controlled or minimized by following the general suggestions provided by the Illuminating Engineering Society of North America (IESNA 1999):

- Consider the surrounding area during the lighting design, and select luminaires, locations, and orientations that minimize **spill light** onto adjacent properties.
- Select luminaires that control the intensity (candela) distribution.
- Use well-shielded luminaires.
- Keep floodlight aiming angles low so that the entire beam falls within the intended lighted area.

The Institution of Lighting Engineers (ILE) has suggested limits on light trespass in terms of the amount of light that is cast on the surface of a window for different environmental zones (see Table 3).

Table 3. Limits on light trespass for different environmental zones

Environmental zone	Light into windows, vertical illuminance (lux)	
	Before curfew	After curfew
E1	2	1*
E2	5	1
E3	10	2
E4	25	5

Source: ILE 2000

* Acceptable from public road lighting installations only

How is glare controlled?

The **cutoff classifications** of the Illuminating Engineering Society of North America (IESNA) were developed to control **glare**. The IESNA **full cutoff**, **cutoff**, and **semicutoff** designations limit the intensity values in the glare zone. (See "[What are the IESNA cutoff classifications?](#)") The Institution of Lighting Engineers (ILE) has suggested limits for glare for the different environmental zones, as shown in Table 4. In the table, the source intensity applies to each source in the potentially obtrusive direction, outside of the area being lit.

Table 4. Limits on glare for different environmental zones

Environmental zone	Source intensity (kilocandela)	
	Before curfew	After curfew
E1	0	0.0
E2	20	0.5
E3	30	1.0
E4	30	2.5

Source: ILE 2000

Glare and **light trespass** are of special concern when installing floodlights. The Commission Internationale de l'Eclairage (CIE) provides design guidelines on the siting and aiming of floodlights (CIE in press). One objective when the lighting is installed is to ensure that, to the extent practicable, direct view of the bright parts of the floodlights is prevented from positions of importance at eye-height on neighboring properties. Where possible, shielding should be considered. To determine the mounting height of luminaires, the CIE suggests the following considerations:

- Higher mounting heights can often be more effective in controlling **spill light**, because floodlights with a more controlled light distribution (i.e., narrower beam) may be used, and the floodlights may be aimed in a more downward direction, making it easier to confine the light to the design area.
- Lower mounting heights increase the spill light beyond the property boundaries. To illuminate the space satisfactorily, it is often necessary to use floodlights with a broader beam and to aim the floodlights in directions closer to the horizontal than would occur when using higher mounting heights.
- Lower mounting heights make bright parts of the floodlights more visible from positions outside the property boundary, which can increase glare.

Figures 9 and 10 show how a higher mounting height compares to a lower mounting height for providing a given amount of light.

Figure 9. Floodlight at a higher mounting height with narrow beam angle, resulting in less spill light

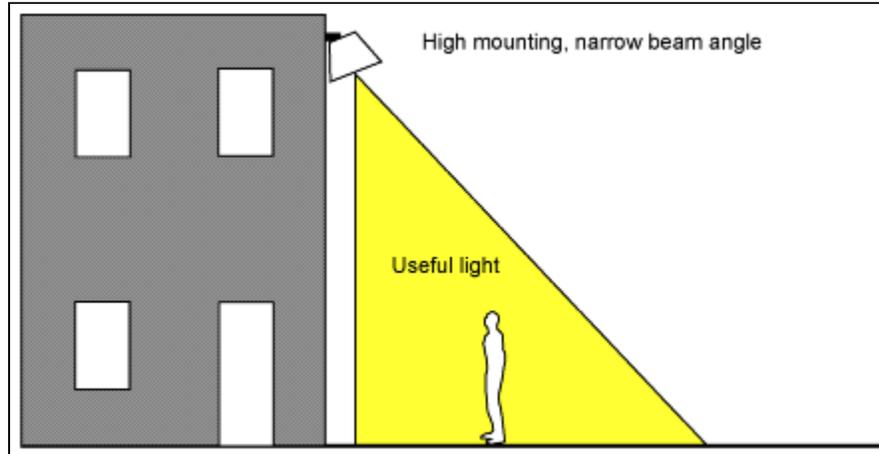
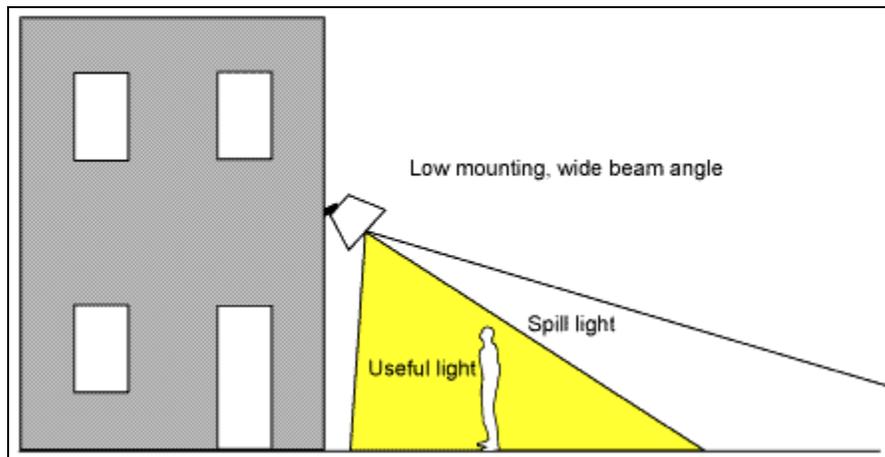


Figure 10. Floodlight at a lower mounting height with wider beam angle, resulting in more spill light



What are the IESNA cutoff classifications?

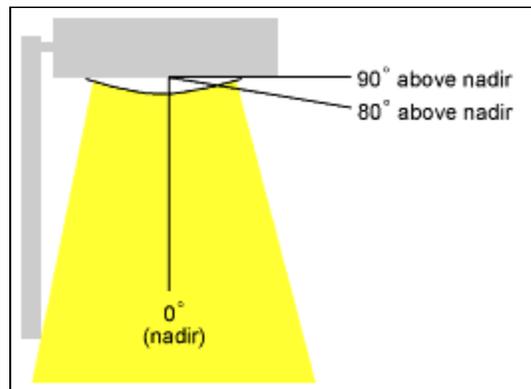
The Illuminating Engineering Society of North America (IESNA) defines several outdoor luminaire **cutoff classifications**, each with different photometric criteria. For these classifications, two relevant zones are defined with respect to the **nadir** of a luminaire (the nadir is defined as the angle that points directly downward, or 0° , from the luminaire). One zone applies to angles at or above 80° above nadir, and the second zone covers all angles at or above 90° above nadir, or above the horizontal plane of the luminaire (see Figure 11). Light emitted in the 80° to 90° zone is more likely to contribute to **glare**, and light emitted above the horizontal is more likely to contribute to **sky glow**. The four IESNA classifications are defined as follows (IESNA 2000):

- Full cutoff—The **luminous intensity** (in **candelas**) at or above an angle of 90° above nadir is zero, and the luminous intensity (in candelas) at or above a vertical angle of 80° above nadir does not numerically exceed 10% of the **luminous flux** (in **lumens**) of the lamp or lamps in the luminaire.
- Cutoff—The luminous intensity (in candelas) at or above an angle of 90° above nadir does not numerically exceed 2.5% of the luminous flux (in lumens) of the lamp or lamps in the luminaire, and the luminous intensity (in candelas) at or above a vertical angle of 80° above nadir does not numerically exceed 10% of the luminous flux (in lumens) of the lamp or lamps in the luminaire.
- Semicutoff—The luminous intensity (in candelas) at or above an angle of 90° above nadir does not numerically exceed 5% of the luminous flux (in lumens) of the lamp or lamps in the luminaire, and the

luminous intensity (in candelas) at or above a vertical angle of 80° above nadir does not numerically exceed 20% of the luminous flux (in lumens) of the lamp or lamps in the luminaire.

- Noncutoff—There is no candela limitation in the zone above maximum candela.

Figure 11. Angles referenced by the IESNA cutoff classifications



Source: Adapted from Bullough 2002
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Are the IESNA cutoff classifications a good indicator of direct uplight?

Except for the **full cutoff** designation, the Illuminating Engineering Society of North America (IESNA) **cutoff classifications** are not a good indicator of **direct uplight**, because **glare** control was the original reason they were developed. A luminaire that has the IESNA full cutoff classification does not have any light going directly upward from the luminaire and will not, if mounted correctly, emit light directly into the sky. The direct uplight from a **cutoff** luminaire can vary from 0% to 16% of the light output of the lamp(s) in the luminaire, and the uplight from a semicutoff luminaire can vary from 0% to 31% of the lamp light output.

However, careful consideration of these classification definitions can be very important when evaluating outdoor luminaires for their potential to cause **light trespass** or glare. Please read the following sentence carefully:

The definitions are given in terms of *luminous intensity* (in **candelas**), but the values are made in reference to *luminous flux* of the light source (in **lumens**).

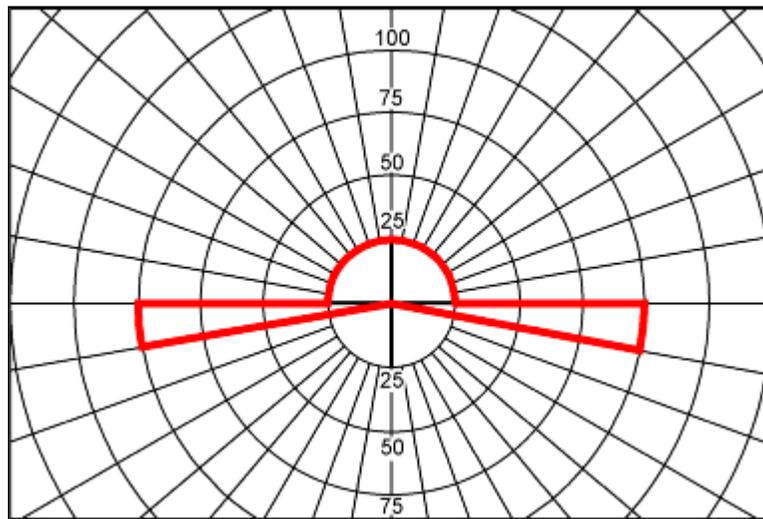
Casually skimming these definitions could lead to the assumption that for a cutoff luminaire, no more than 10% of the lamp luminous flux is emitted between 80° and 90° from nadir, or that no more than 2.5% of the lamp luminous flux is emitted above 90° from nadir. In fact, neither of these assumptions is correct. The following is a technical discussion of these discrepancies.

Bullough states the following:

Consider the hypothetical luminous intensity distribution [shown in Figure 12] for a luminaire equipped with a 1000-lumen lamp. The luminous intensity at any angle between and including 80° and 90° from nadir is 100 candelas, which is 10% of the numerical value of the lamp lumens. The luminous intensity 90° from nadir and at any angle above is 25 candelas, which is 2.5% of the numerical value of the lamp lumens. [The distribution of the remaining 73% of lamp lumens at angles below 80° from nadir does not affect the cutoff classification of the luminaire and, thus, is not shown in Figure 12.] This hypothetical luminaire can be classified as a cutoff luminaire.

Interestingly, a luminaire with this distribution would emit 11% of the lamp lumens between 80° and 90° from nadir, and nearly 16% of the lamp lumens above 90° from nadir. (Bullough 2002, reprinted with permission from IESNA)

Figure 12. Hypothetical luminous intensity distribution at 80°–180° for a cutoff luminaire containing a 1000-lumen lamp (units are in candelas)



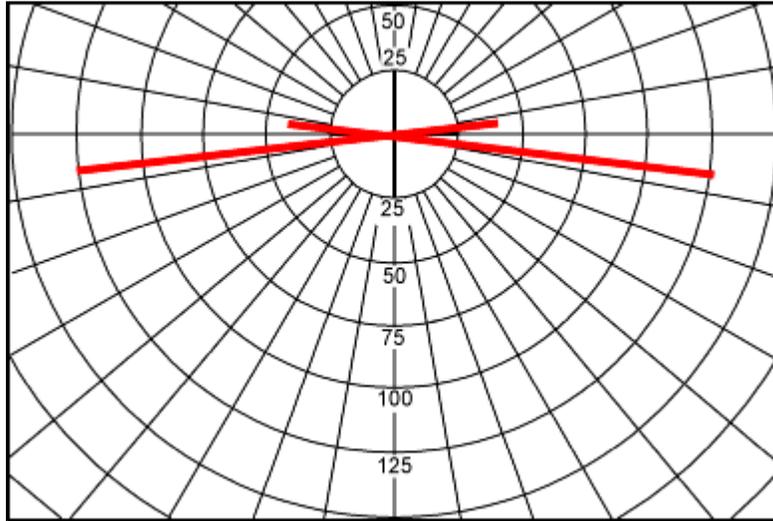
Source: Bullough 2002, © IESNA, used with permission

The quantity of lumens emitted above 90° from nadir is calculated by multiplying the maximum allowable intensity value, 25 candelas, by the solid angle over which they are emitted, 2π **steradians**, totaling 157 lumens or 16% of the 1000 lumens emitted by the lamp. For the percentage of lamp lumens in the glare zone, the solid angle from 80° to 90° is approximately 1 steradian. Multiplying the solid angle, 1 steradian, by the maximum allowable intensity value, 100 candelas, the total allowable lumens in the glare zone is 109 lumens or 11% of the 1000 lumens emitted by the lamp.

Bullough further explains:

Conversely, consider another hypothetical luminous intensity distribution [shown in Figure 13], also for a luminaire equipped with a 1000-lumen lamp. The luminous intensity at one angle between 80° and 90° from nadir is 125 candelas, exceeding 10% (100 candelas) of the numerical value of the lamp lumens. The luminous intensity at one angle above 90° from nadir is 40 candelas, exceeding 2.5% (25 candelas) of the numerical value of the lamp lumens. Such a luminaire would emit only 3% of the lamp lumens between 80° and 90° from nadir, and about 1% of the lamp lumens above 90° from nadir. [As in the example above, the distribution of the remaining 96% of lamp lumens at angles below 80° from nadir does not impact the luminaire's cutoff classification and, thus, is not shown in Figure 13.] Because of its luminous intensity values, this luminaire cannot be classified as a cutoff luminaire even though it emits significantly less light upward than the [previously shown] hypothetical luminaire [Figure 12]. Indeed, even if this same luminaire were fully shielded so that it emitted no light above 90°, it could not be considered a full cutoff or even a cutoff luminaire, because of its higher-than permitted intensity at one angle between 80° and 90°. (Bullough 2002, reprinted with permission from IESNA)

Figure 13. Hypothetical luminous intensity distribution at 80°–180° for a luminaire containing a 1000-lumen lamp failing to meet the cutoff classification (units are in candelas)



Source: Bullough 2002, © IESNA, used with permission

Certainly, these luminous intensity distribution examples represent extreme cases. They do, however, serve to emphasize the caution that is required when interpreting the various cutoff classifications. If, for example, one is concerned about minimizing direct uplight from a luminaire, it is not necessarily true that a cutoff luminaire will emit a smaller proportion of its luminous flux upward than a semicutoff (or even a **noncutoff**) luminaire, even if the luminaires are equipped with the same lamp. A full cutoff luminaire, on the other hand, will never emit direct uplight.

The best way to estimate the luminous flux emitted directly upward by a particular luminaire is to consult a zonal luminous flux summary prepared by the luminaire's manufacturer.

Continuing with the logic above and generalizing for each cutoff classification, ranges of lamp lumen percentage are shown in Table 5 in terms of uplight and lamp lumens in the glare zone. The direct uplight of a luminaire that has the IESNA semicutoff classification theoretically can vary from 0% to 31% of the total lamp lumens and the lamp lumens in the glare zone can vary from 0% to 22%.

Table 5. Allowable range of the lamp lumens being emitted up and in the glare zone

Luminaire classification	Range of allowable lamp lumens emitted upward	Range of allowable lamp lumens emitted between 80° and 90°
Full cutoff	0	0 - 11%
Cutoff	0 - 16%	0 - 11%
Semicutoff	0 - 31%	0 - 22%

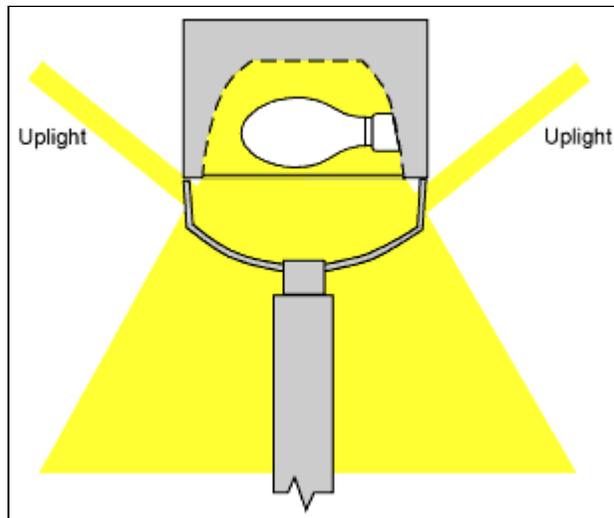
What is the difference between full cutoff and fully shielded?

The term **full cutoff** has and is being used to describe luminaires that have no **direct uplight** (no light emitted above horizontal). However, in addition to that limitation, the Illuminating Engineering Society of North America (IESNA) definition also requires luminaires to comply with the **glare** requirement limiting intensity of light from the luminaire in the region between 80° and 90°.

The term full cutoff is often substituted for the term **fully shielded**. The terms are not equivalent. Fully shielded luminaires emit no direct uplight, but have no limitation on the intensity in the region between 80° and 90°. Luminaires that fall under the IESNA full cutoff, **cutoff**, **semicutoff**, and **noncutoff** definitions, may also qualify as fully shielded. It may be obvious that a luminaire that is characterized as an IESNA full cutoff luminaire is fully shielded, but not as obvious when luminaires with other IESNA classifications may also qualify. Consider a semicutoff luminaire containing a 1000 lumen lamp that has no direct uplight but a **candela** value of 150 between 80° and 90°. This luminaire is considered to be fully shielded. However, if it were mistakenly labeled a full cutoff luminaire, this can become quite confusing. In 2002, the IESNA chartered a new committee to address the inconsistencies and confusion.

There is also a confusing assumption that a luminaire with a flat lens qualifies as a full cutoff luminaire. While this may be true sometimes, it is not always the case. Depending on the structure of the luminaire, reflections off the housing may result in some amount of direct uplight from the luminaire. Consider the hypothetical luminaire in Figure 14. Reflections from below the lens may result in some direct uplight from the luminaire. The IESNA full cutoff classification also has a limitation on light in the glare zone between 80° and 90°. A flat lens on a luminaire does not guarantee that this requirement is met.

Figure 14. Example of a flat lens luminaire that may have some uplight reflected from the mechanical structures below the lens



Resources

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For more information

Many other resources provide information about light pollution. The following is not intended to be a complete list of additional resources; numerous regional and international organizations disseminate information about this topic.

- Commission Internationale de l'Eclairage (CIE): Technical reports 146:2002/147:2002 *CIE Collection on Glare 2002*. Accessed on 31 March 2003 at <http://www.cie.co.at/cie/framepublications.html>
- International Dark-Sky Association (IDA): <http://www.darksky.org>
- Lighting Research Center (LRC): <http://www.lrc.rpi.edu>
- Institution of Lighting Engineers (ILE): <http://www.ile.org.uk>
- National Electrical Manufacturing Association (NEMA): *Statement of Principles on Outdoor Lighting Codes of the Luminaire Section of the National Electrical Manufacturers Association*. Accessed on 11 March 2003 at http://www.nema.org/index_nema.cfm/563/?pos=2&type=standard&pageid=6EC0CFDE-EA6A-48E8-A3CA2C05333EA600&node=534

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Glossary

Candela	The Systeme International d'Unities (SI) of luminous intensity. One candela is one lumen per steradian. Formerly, candle.
Cutoff angle	The angle of light distribution from a luminaire, measured upward from nadir, between the vertical axis and the first line at which the bare source (lamp) is not visible.
Cutoff classification	The classification system of the Illuminating Engineering Society of North America (IESNA) that describes the light distribution of an outdoor luminaire. Cutoff classifications define the luminous intensity limits in two illumination zones that occur within the range of 80° to 180° above nadir. North America (IESNA) that describes the light distribution of an outdoor luminaire. Cutoff classifications define the luminous intensity limits in two illumination zones that occur within the range of 80° to 180° above nadir.
Cutoff luminaire	IESNA classification that describes a luminaire having a light distribution in which the candela per 1000 lamp lumens does not numerically exceed 25 (2.5%) at or above an angle of 90° above nadir, and 100 (10%) at or above a vertical angle of 80° above nadir. This applies to all lateral angles around the luminaire.
Direct uplight	Light emitted upward by a luminaire.
Disability glare	A type of glare that causes a loss of visibility from stray light being scattered within the eye.
Discomfort glare	The sensation of annoyance or even pain induced by overly bright sources.
Fixture	A complete lighting unit consisting of lamp or lamps and the parts designed to distribute the light, position and protect the lamp(s), and connect the lamp(s) to the power supply. (Also referred to as luminaire.)
Footcandle (fc)	A measure of illuminance in lumens per square foot. One footcandle equals 10.76 lux, although for convenience 10 lux commonly is used as the equivalent.
Full cutoff luminaire	IESNA classification that describes a luminaire having a light distribution in which zero candela intensity occurs at or above an angle of 90° above nadir. Additionally, the candela per 1000 lamp lumens does not numerically exceed 100 (10%) at or above a vertical angle of 80° above nadir. This applies to all lateral angles around the luminaire.
Fully shielded luminaire	A luminaire that emits no direct uplight, but which has no limitation on the intensity in the region between 80° and 90°.
Glare	The sensation produced by luminances within the visual field that are sufficiently greater than the luminance to which the eyes are adapted, which causes annoyance, discomfort, or loss in visual performance and visibility.
Illuminance	The amount of light (luminous flux) incident on a surface area. Illuminance is measured in footcandles (lumens/square foot) or lux (lumens/square meter). One footcandle equals 10.76 lux, although for convenience 10 lux commonly is used as the equivalent.
Light trespass	A undesirable condition in which spill light is cast where it is not wanted.
Lumen (lm)	A unit measurement of the rate at which a lamp produces light. A lamp's light output rating expresses the total amount of light emitted in all directions per unit time. Ratings of initial light output provided by manufacturers express the total light output after 100 hours of operation.

Luminous flux	The rate of flow of light, measured in lumens. The overall light output of a lamp
Luminous intensity	The luminous flux on a small surface centered on and normal to the direction divided by the solid angle (in steradians) that the surface subtends at the source. Luminous intensity can be expressed in candelas or in lumens per steradian.
Lux (lx)	A measure of illuminance in lumens per square meter. One lux equals 0.093 footcandle.
Nadir	In the lighting discipline, nadir is the angle pointing directly downward from the luminaire, or 0°. Nadir is opposite the zenith.
Noncutoff luminaire	IESNA classification that describes a luminaire light distribution in which there is no candela limitation in the zone above maximum candela. (See also cutoff classification and cutoff angle.)
Semicutoff luminaire	IESNA classification that describes a luminaire light distribution in which the candela per 1000 lamp lumens does not numerically exceed 50 (5%) at or above an angle of 90° above nadir, and 200 (20%) at or above a vertical angle of 80° above nadir. This applies to all lateral angles around the luminaire.
Sky glow	Brightening of the sky caused by outdoor lighting and natural atmospheric and celestial factors.
Spill light	Light that falls outside of the area intended to be lighted.
Steradian (sr)	A unit of measure equal to the solid angle subtended at the center of a sphere by an area on the surface of the sphere equal to the square of the sphere radius.
Uplight	Light directed upward at greater than 90° above nadir. The source of uplight can be from a combination of direct uplight and reflected light.
Zenith	In the lighting discipline, zenith is the angle pointing directly upward from the luminaire, or 180°. Zenith is opposite nadir. In astronomical usage, zenith is the highest point in the sky, directly above the observation point.

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