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Lighting Research Center

Implementation of Decision-Making Tools that Address Light Pollution for Localities Planning Street Lighting

EFFICIENT STREET LIGHTING AND LIGHT POLLUTION

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SCOPE OF THIS PAPER

The intent of this document is to provide information to municipalities, specifiers, designers, and other lighting decision makers in the state of Connecticut about street lighting and light pollution. The document outlines the Connecticut legislation limiting the types of luminaires that may be used, defines light pollution and many of the issues that surround the topic, discusses lighting considerations that should be considered before embarking on a lighting project, and summarizes good lighting practice and how municipalities can work with designers or planners to ensure that their lighting installation meets the lighting objectives in their community. This white paper is intended to be used with companion documents that include a checklist and a design guide. The checklist helps decisions makers think about their street lighting objectives. The design guide provides illustrative examples of specific types of typical street lighting designs and presents alternative options. It is a tool to identify approaches to meet the design objectives with efficient street lighting.

INTRODUCTION

Undoubtedly, a significant amount of energy is wasted in many street lighting installations, but the reasons for this wasted energy are not always the same. Some of these installations might have light levels well above those recommended by organizations such as the Illuminating Engineering Society of North America (IESNA); others might be using lighting when in fact none is needed. Selection of ineffective and inefficient luminaires can also create glare, wasted uplight and light trespass in yet other installations. And sometimes, even light levels that are too low can result in wasted energy and light, because if such lighting is not sufficient for the tasks it is supposed to illuminate, users would be no worse off if the lighting were simply removed!

Different communities can have different objectives with respect to street lighting. Lighting can be installed primarily for the safety and visibility of drivers. This is certainly among the primary considerations set forth in recommendations of the IESNA for roadway lighting. It can also be installed to create a sense of security among neighbors. Or it can be installed near a playground, for example, for the safety of neighborhood children using the facilities at night. In many downtown urban areas, lighting is seen as an aesthetic element that can help attract shoppers and diners to area stores and restaurants.

All of these objectives can and should be met by communities while at the same time providing cost effective energy improvements, and using equipment that minimizes wasted light, light pollution, glare and trespass. Yet there is a dearth of useful, practical tools for street lighting decision-makers to help them not only in identifying and clarifying their objectives for street lighting, but also in selecting the lamps, luminaires and poles, as well as their layout, that will best meet those objectives while minimizing light pollution.

CONNECTICUT LEGISLATION FOR OUTDOOR LIGHTING

The state of Connecticut passed legislation (Public Act No. 01-134) that sets limits on outdoor lighting that uses state or municipal funds to install or replace permanent outdoor luminaires for roadway lighting. The law requires that the illuminance resulting from a luminaire must be equal to the minimum illuminance adequate for the intended purpose of the lighting. The law also requires that any luminaire with a rated output of more than 1800 lumens that is installed or replaced on a municipal or a state road must be a full cutoff luminaire. The definition of full cutoff in the text of the act is "a luminaire that allows no direct light emissions above a horizontal plane through the luminaire's lowest light-emitting part." The full text of Public Act No. 01-134 may be found at the following website: http://www.cga.state.ct.us/2001/act/Pa/2001PA-00134-R00HB-05449-PA.htm.

WHAT IS LIGHT POLLUTION?

Light pollution is an unwanted consequence of outdoor lighting and includes such effects as sky glow, light trespass, and glare. Sky glow is the brightening of the sky due to outdoor lighting and is usually objected to because it inhibits one's ability to see and appreciate the stars. A large amount of light and energy is wasted as a result of outdoor lighting. This fact is illustrated in Figure 1. Light trespass is light falling where it is not wanted or needed. Light from a streetlight or a neighbor's floodlight that illuminates your bedroom at night is an example. Glare is excessive brightness causing discomfort or visual disability and a good example is an unshielded luminaire where the lamp can be directly seen.

Figure 1. Credit: Data and image processing by NOAA's National Geophysical Data Center. DMSP data collected by US Air Force Weather Agency.

Concerns about light pollution and light trespass are growing throughout Connecticut. State and local legislation exists regarding how much light can be emitted by luminaires in the upward direction, or onto adjacent properties. Be sure your designer is aware of and understands them. In some areas, some light emitted in the upward direction might be acceptable, e.g., in a downtown, where low wattage sources are used on relatively shorter poles, and where it is desired to have some light on adjacent building surfaces to highlight architectural features or reduce shadows in pedestrian areas. However, it is probably always a waste of light and electricity to use luminaires that emit a large amount of light directly upward into the night sky, especially in suburban and rural areas where amateur astronomers might wish to view the stars.

The IESNA (1999) has developed a classification system for the distribution of light from outdoor lighting luminaires. The cutoff classification system limits the amount of light emitted directly above the horizontal and, in addition, limits the amount of light emitted between 80º and 90º from nadir. Angles referenced by the IESNA cutoff classifications are illustrated in Figure 2 .

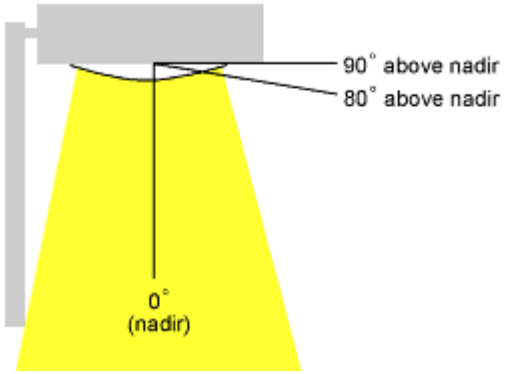

Figure 2. Angles referenced by the IESNA Cutoff Classifications.

The two most stringent classifications are cutoff and full cutoff luminaires. Full cutoff luminaires emit no light upward and tend to emit very little at angles near horizontal. Cutoff luminaires may emit some light upward and also tend to emit little light near horizontal. The semicutoff classification is the least stringent and usually permits more light upward and at angles near the horizontal. However, it is possible for a semicutoff luminaire to generate no upward light, if it exceeds certain limits for light near horizontal angles. This could lead to increased glare but might be suitable for environments when vertical illumination is desired for recognition of people or other vertically oriented objects. In general, municipalities should consider using full cutoff luminaires if they will accomplish the required objectives and goals. Less restrictive categories should be considered only when the required objectives cannot otherwise be met.

The term “full cutoff luminaire” is defined in Connecticut’s Public Act No. 01-134 as “a luminaire that allows no direct light emissions above a horizontal plane through the luminaire’s lowest light-emitting part.” This definition varies from the IESNA definition found in RP-33-99 which defines the distribution of a full cutoff luminaire as “a luminaire light distribution where zero candela intensity occurs at an angle of 90º above

nadir, and at all greater angles from nadir. Additionally, the candela per 1000 lamp lumens does not numerically exceed 100 (10 percent) at a vertical angle of 80º above nadir. This applies to all lateral angles around the luminaire."

The IESNA is aware of the confusion and inconsistencies with the cutoff classifications. In 2002, a new IESNA committee was chartered to address the issues.

In addition to legislation requiring a certain type of luminaire, there are a number of other ways that have been proposed (limiting to certain types might or might not actually limit it) to limit light pollution. Some examples to reduce light pollution include installing lighting only where it is needed, avoiding overlighting by choosing minimum light levels that will fulfill the lighting objectives, and installing appropriate controls such as motion sensors and timers or photosensors that turn lighting off when it is not needed.

It should be mentioned that there are a number of tradeoffs in regard to lighting. No one is in favor of light pollution and wasted energy. However, issues such as safety, security, cost, sky glow, and energy must all be considered when making lighting decisions.

REASONS FOR LIGHTING - IS LIGHTING REALLY NEEDED?

The topic of light pollution has received a lot of attention in the media of late. The Connecticut law requiring full cutoff luminaires is a result of this new public awareness of, and concern about, outdoor lighting. This coverage on light pollution often lacks discussion about why municipalities, businesses, or individuals choose to light in the first place. Although no one would agree that we should cause light pollution and waste energy, the question must be asked, why choose electric lighting? The easiest way to avoid light pollution is to eliminate lighting altogether. In short, we light our outdoor nighttime environment to meet certain societal goals. These include increasing safety and security, enhancing economic development, highlighting historic areas or landmarks of cities or towns, and sending messages.

Safety

While headlights on cars provide forward lighting for the driver, street lighting illuminates the roadway showing the driver changes in direction up ahead, obstacles in the way, and the roadway surface conditions. Street lighting lights more than just the road; walkways and adjacent areas to the road also benefit. Pedestrians, cyclists, children playing in the front yard, and other non-motorists are more readily seen with street lighting. The IESNA (1999 and 2000) has recommendations for lighting that illuminates intersections allowing oncoming drivers to see other vehicles, as well as pedestrians and cyclists. Street lighting helps to mitigate headlight glare as well.

Figure 3. Example of the lighting on a residential street in Connecticut.

Security

While there is controversy about whether electric lighting improves security (Painter, 2001, Boyce 1990, Tien 1979), there is no question that one feels safer walking or driving on well-lit streets and in well-lit parking lots. Boyce (1990) found that an illuminance of 1-3 footcandles provides the appearance of good security. Security may be thought of as freedom from worry in regard to the security of people and property. The purpose of security lighting is to deter the intruder, aid law-abiding citizens in recognizing danger, and to help law enforcement in the identification process after a crime has occurred. An intruder may be deterred if the criminal is easily seen at a distance and the victim is likely to be prepared. Brightness of the neighborhood, uniformity of the brightness of the area, and whether there is lighting outside of the area lit by security lighting are three factors that influence deterrence. In order for security lighting to be effective, minimum light levels that achieve the objectives of brightness and uniformity must be met (Boyce 2000, Rombauts 1989, Boyce 1990).

Economic Development

Exterior lighting has a significant impact on economic development (IESNA 2000). Lighting may draw people to a downtown area or a shopping area by making the shops and restaurants inviting. People may spend more time in a downtown area or shopping district if the lighting is inviting and there is a feeling of security (Boyce 2000).

The appearance of a space (during nighttime as well as daytime) is an important consideration for many areas, especially in historic areas where the lighting system not only illuminates roadways and sidewalks, but can also help draw attention to architecture and other aesthetic features such as parks, statues and other public areas. The appearance of the luminaire itself is often selected to harmonize with its surroundings. In addition, factors such as color appearance might be important. Leslie (1996) found that one's ability to identify colors is reduced with high pressure sodium illumination at light levels below 1 footcandle, while metal halide, fluorescent and incandescent lamps provide good color identification even at one-tenth this light level. This could be important for identifying one's parked car, for example.

Figure 4. Example of the lighting on a downtown street in Connecticut.

Aesthetics

Finally, lighting sends a message. “Look here.” “Walk down this street.” “Don’t walk down this street.” “Come and window shop.” Lighting conveys information to people. Lighting enhances historic areas or landmarks and helps to promote an image of the city or town.

Indeed there are many valid reasons where lighting is not only needed, but required. However, as in most things in life, understanding how much is enough is important. Awareness is the key to balancing the need for lighting while minimizing light pollution and increasing energy efficiency. Understanding the reason for lighting and the many

different ways lighting may be achieved is important in order to balance the need for lighting with its control to minimize light pollution.

Retail establishments use lighting to entice people to enter their property. All too often, the lighting level is much higher than necessary and the luminaires produce significant glare. An alternative approach to overlighting and glaring fixture choices may be to create ambience and sparkle by using shielded fixtures which allow for some sparkle, lighting to appropriate light levels, and possibly using targeted lighting. One study on gas station canopy lighting showed that the number of cars entering the gas station increased when cutoff fixtures with some sparkle were installed

LIGHTING CONSIDERATIONS

Before any decisions about lighting are made, the objectives of the community must be considered. Depending on the situation, sometimes lighting is not necessary. It is important to explore the options to meet the objectives of why lighting is being considered. Some questions to consider include:

- Does the street in question need lighting?
- Are there other ways to accomplish the goals without installing lighting?

Once lighting is deemed necessary to achieve the community objectives, these issues should be considered:

- Are minimum lighting levels being used to accomplish the objectives?
- Will the lighting installation minimize light pollution?
- Are efficient technologies being used?
- Have lighting controls such as motion sensors, timers, or photosensors been considered?
- Is a lighting curfew or a time period when the lighting is shut off or dimmed appropriate?
- Are full cutoff luminaires being used?

GOOD LIGHTING PRACTICE

Many installations of lighting on roadways fall short of recommendations by organizations such as the IESNA. Of course, vehicles are equipped with headlights designed to illuminate the roadway surface, but additional lighting can assist in making adjacent people and objects more visible. Reduced light levels and increased nonuniformities can result in dark areas and shadows that could make it difficult to see pedestrians and other objects along the road. When safety issues are of prime importance, consult the recommendations of the IESNA. These recommendations form the basis for what is considered to be "good practice" in street and roadway lighting.

Once the decision is made to embark on a street lighting project, carrying it through requires care and attention in order to avoid unwanted equipment costs, complaints about poor visibility, glare, unnecessary use of energy, and excessive maintenance costs. Once you've identified who will be designing your street lighting installation in order to meet your objectives, be sure to ask them the following questions. The answers you receive

will help you understand whether your designer understands what you want to accomplish, as well as how to most efficiently accomplish your objectives. Your designer can be any one of the following:

- in-house engineering staff
- manufacturers, or manufacturers' distributors
- electric utility specialists
- contractor

Regardless of who will ultimately design your street lighting installation, these issues will help to open the lines of communication that are important to a successful efficient street lighting project.

Planning

Before developing recommendations for the lighting installation, be sure that the designer knows what you what to achieve and what the characteristics of the project site are.

Understanding Objectives

Be certain that the designer is aware of the issues outlined in this document. Beware of bold promises to reduce crime or improve safety. Share the white paper, checklist, and design patterns, along with the resources listed at the end of this section with the designer.

Awareness of Existing Conditions

Be sure the designer has an accurate understanding of the area in question. Do they understand the traffic density, posted and typical driving speeds and accident history of the location? Is pedestrian traffic heavy throughout the day or only at certain times of the day (such as the start and end of the work day)? What types of buildings are found in the area--residences, offices, neighborhood businesses, schools, restaurants? All will have special considerations for lighting and different hours of active use. What is the crime history of the area? Is the location perceived as safe or unsafe? There are procedures given by the IESNA (199, 2000) for determining whether and how much lighting is appropriate for a location.

Lighting Criteria

Municipal officials will probably not be familiar with each of the issues that make a lighting installation successful. The role of the designer is to address the issues such as those listed below.

Use Efficient Technologies

There is not one single best technology for street lighting, but your designer should be aware of the relative benefits and drawbacks of different types of lamps and luminaires. Are efficient light sources and ballasts planned? Mercury vapor lamps are found in many older street lighting installations but these lamps are relatively inefficient and should not be used in any new or retrofit installations. Almost all lamps used in street lighting require a ballast to provide the proper voltage and current to the lamp; these will also use

some energy and impact the overall energy use. Are efficient ballasts going to be used? Finally, even the most efficient lamp and ballast can be made very inefficient by using luminaires that trap light inside. A luminaire that emits less than half of the light generated by the lamp and ballast should be avoided.

Use Appropriate Pole Heights

In different locations, different pole heights can be appropriate for the desired appearance and required lighting. The "cobra head" type of luminaire seen on many streets and roadways is often found on a 30-to-35 foot pole. Architectural or decorative types of luminaires might have a scale that requires shorter pole heights. At the same time, the use of high-wattage, very efficient light sources on lower poles could possibly lead to unwanted glare. These factors must be balanced. When existing utility poles are used, careful attention to luminaire selection is important so that it is suitable for the pole heights.

Use Appropriate Pole Spacings

The height of street lighting poles will impact how uniform the light levels are in the street and surrounding area. Visibility can sometimes be reduced if lighter and darker areas have large differences in light level. Ask whether the combination of luminaires and pole heights will result in sufficient uniformity. This issue can be especially important in a retrofit installation where existing pole mounting locations are going to be used with no additional pole mountings, or, as described above, when existing utility poles are to be used. Changes in luminaire type and pole height can also impact the uniformity.

Maintenance

Maintenance of Lighting Installation

Some luminaires have easy mechanisms for opening, removing lamps and ballasts, and cleaning. Find out if special tools or equipment will be needed for relamping. Understand the warranties of the components in the system, and who should be contacted if a given component does not meet warranty.

Life of Components

The environment in which a street lighting installation is located might have additional requirements for street lighting equipment. Some lamps have very stable light output over a long period of time; others become "dimmer" over a period of a few years. Is the area prone to flooding, pollution or other possible environmental factors? If so, the selection of equipment that will work throughout a range of conditions and with gasketed or watertight enclosures to prevent failure will be important. Other luminaires are available with heavy-duty, vandal-proof housings and lenses to deter destruction of these systems. Different pole materials also have different properties that might lend some materials to be more attractive in certain areas.

COMPANION DOCUMENTS

Companion documents were developed to go along with this white paper. They include a checklist and design patterns. The design checklist helps decision makers think about

their street lighting objectives. The design guide provides illustrative examples of specific types of typical street lighting designs and present alternative options. It is a tool to identify approaches to meet the design objectives with efficient street lighting.

REFERENCES

Boyce, P. R., Eklund, N. H., Hamilton, B. J., and Bruno, L. D., (2000) Perceptions of safety at night in different lighting conditions, *Lighting Research and Technology*, 32, 79-91.

Boyce, P. R. and M. S. Rea. 1990. Security lighting: Effects of illuminance and light source on the capabilities of guards and intruders. *Lighting Research and Technology* 22(2): 57-79.

Illuminating Engineering Society of North America (IESNA). 2000. *American National Standard Practice for Roadway Lighting*, RP-8-00. New York, NY: Illuminating Engineering Society of North America.

Illuminating Engineering Society of North America. 2000. *The IESNA Lighting Handbook*, 29-20 – 29-22.

Illuminating Engineering Society of North America (IESNA). 1999. *Recommended Practice for Lighting for Outdoor and Environmental Lighting*, RP-33-99. New York, NY: Illuminating Engineering Society of North America.

Painter, K. A. and D. P. Farrington. 2001. The financial benefits of improved street lighting, based on crime prevention. *Lighting Research and Technology* 33(1): 3-12.

Rombauts, P., Vandewyngaerde, H., and Maggetto, G., (1989) Minimum semi-cylindrical illuminance and modeling in residential lighting, *Lighting Research and Technology*, 21, 49-55.

Russell P. Leslie and Paula A. Rodgers. 1996. *The Outdoor Lighting Pattern Book*, McGraw-Hill.

Tien, J. M., V. F. O'Donnell, A. Barnett and P. B. Mirchandani. 1979. *National Evaluation Program Phase I Report: Street Lighting Projects*. Washington, DC: National Institute of Law Enforcement and Criminal Justice.

FURTHER READING

American Association of State Highway Transportation Officials, Joint Task Force for Highway Lighting of the AASHTO Highway Subcommittees on Design and Traffic Engineering. 1984. *Informational Guide for Roadway Lighting*, Washington, D.C.: American Association of State Highway Transportation Officials.

Edison Electric Institute, 1988. *Street Lighting Manual*, 3rd Edition, Street and Highway Lighting Task Force, Washington, D.C.: Edison Electric Institute.

He, Y., M. Rea, A. Bierman and J. Bullough. 1997. Evaluating light source efficacy under mesopic conditions using reaction times. *Journal of the Illuminating Engineering Society* 26(1): 125-138.

Illuminating Engineering Society of North America, Roadway Lighting Committee. 2000. *American National Standard Practice for Roadway Lighting*, ANSI/IESNA RP-8-00. New York, NY: Illuminating Engineering Society of North America.

Leslie, R. and P. Rodgers. 1996. *The Outdoor Lighting Pattern Book*. New York, NY: McGraw-Hill.

Lighting Research Center. 1993. *Parking Lot Luminaires. National Lighting Product Information Program Specifier Reports*. Troy, NY: Lighting Research Center, Rensselaer Polytechnic Institute.

Tien, J., V. O'Donnell, A. Barnett and P. Mirchandani. 1977. *National Evaluation Program, Phase I Final Report*. Washington, DC: National Institute of Law Enforcement and Criminal Justice.

IESNA (Illuminating Engineering Society of North America)
Lighting Handbook
RP-33-99 *Lighting for Exterior Environments*
RP-8-00 *Roadway Lighting*

CIE (Commission Internationale de l'Eclairage)
CIE *Collection on Glare 2002*
CIE Technical Report *Guidelines for Minimizing Sky Glow*
CIE Technical Report *Guide on the limitation of the effects of obtrusive light from outdoor lighting installations*, in press

IDA (International Dark-Sky Association)
www.darksky.org

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Institution of Lighting Engineers
www.ile.org.uk