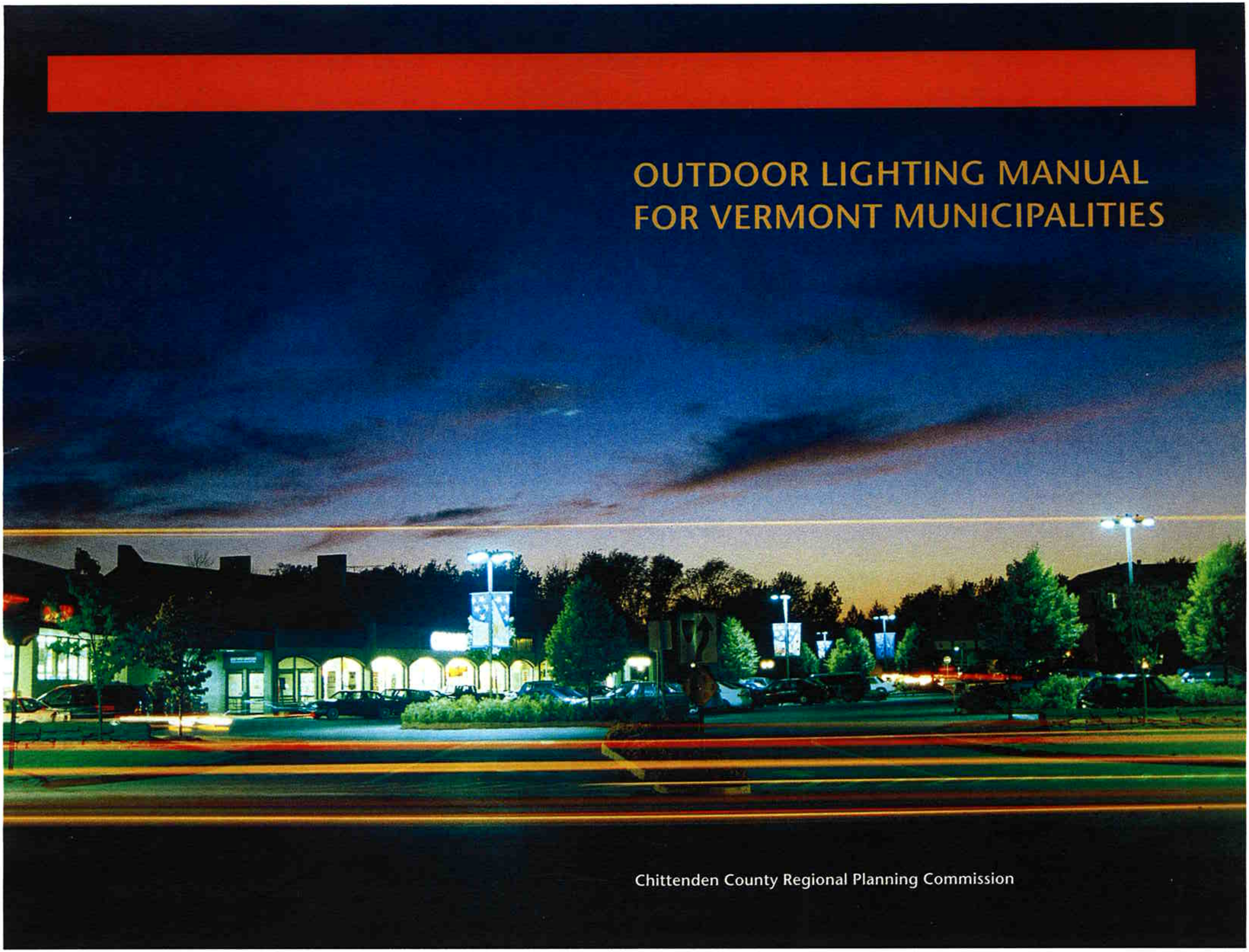
OUTDOOR LIGHTING MANUAL FOR VERMONT MUNICIPALITIES



Chittenden County Regional Planning Commission

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"Vermont Outdoor Lighting Study—Technical Report" (Order No. DG/95-308A);
"Vermont Outdoor Lighting Study—Proposed Ordinances" (Order No. DG/95-308B);
"Outdoor Lighting—Issues, Concepts and Design—A Slide Presentation" (Order No. DG/95-308C).

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INTRODUCTION

THE INCREASED DEVELOPMENT that has occurred in Vermont in recent decades has brought a corresponding increase in the use of outdoor lighting. From new parking lots and brighter street lighting in cities to floodlights and gas station canopies in small villages, the use and levels of exterior lighting are rapidly increasing. While some Vermonters see this increase as an inevitable result of growth, many are concerned with both the increased energy usage it represents and the changes this lighting brings to the nighttime character of our villages and town centers. In rural areas there is an additional concern for the visual effects on the night landscape and the skyglow that results in the loss of a star-filled sky, precious natural resources for our state.

In the first half of the century, when the incandescent bulb was the primary source of outdoor lighting, the impact of most lighting installations was minimal. With the advent and increased use of high intensity discharge (HID) lighting fixtures since the 1950s, commercial enterprises, municipalities, and even private citizens gained a powerful tool for shaping the night environment.

Some new lighting installations, well designed and executed, provide good night vision at reasonable light levels and blend well into their settings. Many do not. As a result, problems of glare, overlighting, light escalation, skyglow, and energy waste are increasingly common in both urban neighborhoods and rural villages throughout Vermont.

Concerned planning commissions are seeking methods to manage these environmental impacts. Though site lighting has long been a criterion for review under the "site plan review" process, most towns have lacked the information and expertise to set standards or review plans.

Goals and Methodology

The goal of this study is to help municipalities identify exterior lighting issues; understand basic lighting design concepts; and set sensible, clear, and meaningful lighting standards.

The year-long study that preceded this manual involved three Chittenden County communities representing rural, suburban, and urban municipalities in Vermont. Local lighting committees assessed exterior lighting in their towns and prioritized the issues they found. Based on work with the local committees, model lighting standards were developed for each municipality. Communities had the opportunity to adopt these standards as written or adapt them for use as lighting design guidelines.

The intent of the standards is to effectively communicate the site lighting goals of the community to planning applicants and to create consistent review criteria that will result in an expeditious review process and produce efficient, effective, and attractive outdoor lighting.

This manual was developed to provide all Vermont communities with the following:

- An understanding of site lighting issues and opportunities.
- Information on and interpretation of current research and technology.
- The basics and principles of good lighting design that will help officials make sound planning decisions on site lighting policy.
- The vocabulary and tools to discuss lighting.
- Assistance in crafting lighting policy and regulations to include in municipal plans and zoning ordinances.
- The ability to identify patterns in the use of outdoor lighting where energy conservation improvements can be made.

A BRIEF HISTORY OF EXTERIOR LIGHTING

ELECTRICALLY GENERATED outdoor light has been part of the built landscape for only about 100 years.

Before the advent of the electric light bulb, outdoor activities were illuminated by gas or oil lamps or by moonlight. In rural areas torches were used, and farm laborers sometimes built bonfires to light evening harvests. Although the limited sources for illumination restricted outdoor labor during the evening, they did not keep everyone at home. Commerce was encouraged by shop windows lit with oil and gas as early as the 1820s. Gas street lights guided the way for pedestrians and carriages in town. When weather permitted, moonlight and carriage lamps guided travel in the countryside.

Thomas A. Edison invented the first practical light bulb in 1881. By 1890 the first incandescent light was on the market, beginning to change the lives of many Americans. At first the incandescent lamp was used very pragmatically for interior applications, but at the World's Columbian Exposition in Chicago in 1893 and the Panama Pacific Exposition in San Francisco in 1915, lights were brought outside to illuminate buildings and walkways. These events were important tastemakers of their day.

Dramatic light displays on the grounds of the 1915 Panama Pacific Exposition demonstrated the potential of electric lighting for outdoor use.

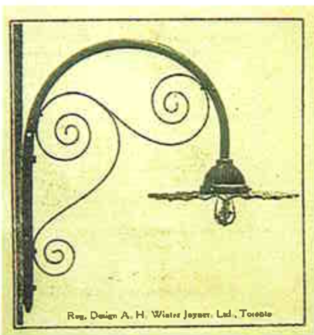
The World's Columbian Exposition in Chicago promoted the City Beautiful movement that shaped many of America's cities. Along with other architectural and planning influences, the fair created the concept of the Great White Way, a central boulevard lined with grand light fixtures borrowed from the European style. Many municipalities across the country, including Rutland, St. Albans, and Burlington, responded by introducing classically styled street lighting fixtures to light their Main Streets and public parks. Having their own White Way was an urban status symbol and considered necessary if a city was to compete economically.

Outdoor lighting applications increased rapidly, only slowing down slightly during WWI. The '20s brought the increased use of the automobile. Headlights, although weak by today's standards, brought additional illumination to city streets. Some communities, including Atlantic City, found the glare objectionable and required that automobile headlights be turned off when drivers went through town. Tiny lights were used to border theater marquees and the eaves of small gas station canopies.

Use of outdoor lighting on private property had also become commonplace. Entryways and yards of private residences were illuminated, and shop windows gleamed onto the sidewalks. Lighting engineers developed fixtures that shielded and reflected light to use it more effectively.

The incandescent lamp and the less popular arc lamp were still the only electric light sources for exterior use. Although a low-pressure sodium vapor lamp that efficiently generated large quantities of orange-hued light came briefly to the market in the 1930s, it did not catch on, due to its poor color-rendering qualities.

The fluorescent lamp, introduced about 1940, became widely used for interior applications, but was used on a limited basis outdoors, especially in northern climates where the cold affected its performance. The 1950s and 1960s saw the high intensity discharge (HID) lamp widely adopted for exterior lighting. Most popular was the mercury vapor lamp, which produced twice as much light as did an incandescent lamp using the same amount of electricity. The bluish cast it created was initially objectionable to many citizens, but considerations for cost savings prevailed in most communities, where the mercury vapor fixture became the standard



The radial wave fixture, still in use today, is an example of early luminaire design and engineering.

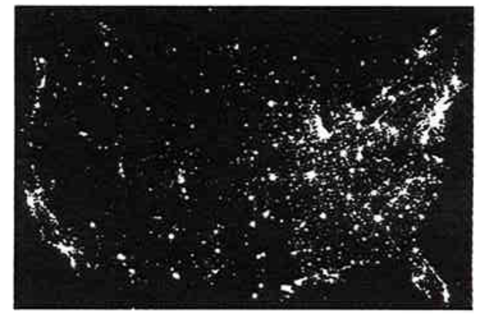
street light. Low-cost fixtures using this light source also became ubiquitous in parking lots and on the sides of commercial buildings and barns. Refractor lenses intended to control glare from the higher-powered lamps were used with limited success.

In the 1970s, both high pressure sodium (HPS) and metal halide (MH) lamps became broadly used. The improved technology increased lamp efficiency by about 50 percent over mercury vapor lamps. Although the HPS was slightly more efficient, its color-rendering properties were poor, casting an orange-yellow hue on illuminated objects. Metal halide lamps (originally developed for the TV tube) provided an icy white light and had better color-rendering qualities, but the difference in efficiency and the shorter lamp life influenced the "life cycle costing" accountants at most utility companies to pass it over in favor of high pressure sodium. The energy crisis of the early 1970s reinforced the rationale for using HPS. The low pressure sodium lamp also saw a brief resurgence in use during this period of rising electricity costs. As most American cities converted to the orange-yellow lamps of the high pressure sodium, the night landscape of urban areas dramatically changed. Higher-powered lamps brought a greater potential for glare and light trespass. Lighting engineers responded by developing even more sophisticated fixtures to control these problems.

During this century advances in lamp technology have prompted more new uses for outdoor lighting. As the U.S. has become a 24-hour society, more outdoor activities are lighted and extended into the night. The use of outdoor lighting nationally has increased at a more rapid rate than has the population.

The satellite photo of the United States (far right) reveals the distribution of outdoor lighting that has occurred across the country over the last 100 years.[1] It has been estimated that 30 percent of the light the camera has recorded is shining directly into the sky, serving no illuminating function.

This inexpensive mercury vapor fixture remains widely used today despite its poor light control.



Satellite photo (1978) showing the relative intensity and distribution of outdoor lighting across the country.

As we enter the second century of the electric light, it is time to think about the direction we are heading in the use of outdoor lighting. Technology in the lighting industry continues to improve the color and efficiency of lamps and create entirely new lighting tools. The nation's municipalities can take a proactive role in ensuring that outdoor lighting contributes positively to our nighttime environment. This manual is intended as a first step in that effort.

[1] Newsletter #24, May 1995, "Europe at Night Poster Etc." Re: Photo work of Woodruff Sullivan III and the Hanson Planetarium, International Dark-Sky Association, Tucson, Arizona.

VISION AND PHYSIOLOGY[1]

BECAUSE THE PURPOSE OF LIGHTING is to enable good vision, it is important to understand how the eye functions and becomes accommodated to the dimly lit night environment.

The workings of the human eye are often compared to those of a camera. Like the diaphragm of a camera, the iris responds to light by opening the pupil in dim light and closing it when brightness increases, thereby controlling the amount of light passing through the lens. The retina at the back of the eye is similar to the film in a camera. Light falling on the retina causes chemical reactions to take place, sending messages to the brain, where they are interpreted as images.

The two types of photoreceptors located at the retina are called *rods* and *cones*. The cones are capable of transmitting very sharp, detailed images to the brain. They perceive color but are not as sensitive at low light levels. The rods are more sensitive at low light levels, responding to movement and flicker. They are slow to respond to stimuli and slower in their recovery than are the cones. Rods are important for peripheral vision but do not afford distinct vision or respond to color.

In the night environment, when light levels fall below one foot-candle (twilight), the eye's perception of color begins to decrease. At one tenth of a foot-candle (full moonlight) strong colors can still be distinguished. Below one one-hundredth of a foot-candle color recognition is absent. Under low light conditions the rods become the dominant photoreceptors and aid in vision principally by distinguishing between light and dark and by recognizing movement. At brighter light levels the cones function to identify the subtleties of color and to perceive detail.

The inner eye contains a liquid medium called the vitreous humor. Although the liquid is clear, it contains impurities which reflect and scatter light, and, under certain lighting conditions, hinder vision. These conditions will be discussed further in the section on glare.

The eye is a living organ that adapts continuously and automatically to vastly different light levels throughout the day and night. Adaptation involves changes in the size of the pupil and corresponding photochemical changes on the retina. These changes are not always instantaneous. When going from a very bright interior to a dark exterior, it can take the eye several minutes to adjust. As a rule it takes the eye longer to adapt to a change from light to dark than from dark to light. Up to one half hour is sometimes needed for the eyes to fully adjust to a dark environment. Understanding the adaptation process and its limitations in outdoor lighting conditions is relevant to the design of exterior lighting installations.

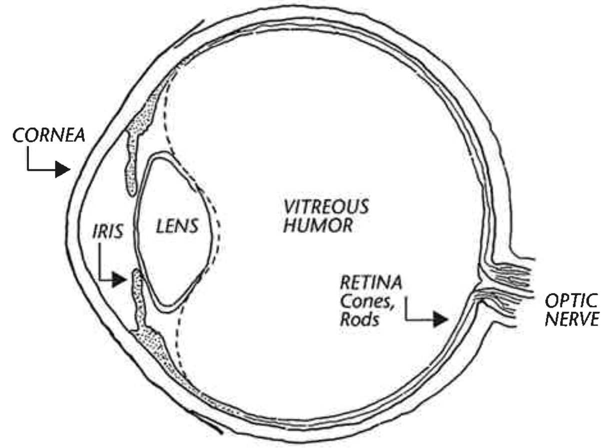


Diagram of the human eye.

[1] Nuckolls, James L., I.A.L.D., Interior Lighting for Environmental Designers. 2nd edition. John Wiley & Sons. Text based on Chapter 2, pp 12-17.

OUTDOOR LIGHTING ISSUES

LIGHT LEVELS

Light and Visibility

The purpose of an outdoor lighting installation is to enhance the visual process needed for the performance of a given task.

How we perceive a visual picture has to do with its brightness (luminance), size, and contrast, and how long we have to observe it. All of these factors are interrelated. To improve the visibility of an object we can use any of the following options: increase the size, such as making a sign or lettering larger; increase contrast, such as making the background darker to distinguish the foreground; increase the luminance, by lightening the color, changing the texture of the object to make it more reflective, or adding more light to the object; increase the length of time an object is visible, which could include making an object bigger or changing the object's location so it is seen from a greater distance.

The visibility of an object depends on many factors. Lighting can improve visibility by contributing to one of these: the brightness (luminance) factor.

Visibility and Light Level Adaptation

Using a large quantity of light does not guarantee good visibility. In fact, over-lighting is often the cause of glare and other problems that hinder good vision.

The cafe appears adequately lit until...

The brightly lit auto sales facility is built across the street.[1]

The eye can see in a wide range of lighting conditions from dim moonlight to bright sunlight. Table 1 shows a range of illuminance values to which the average eye can adapt and see fairly well.

While the human eye is very adaptable, it can adapt to only one light level at a time. We have all experienced being outside on a clear night when the moon is full. Once our eyes adapt we can see our surroundings quite well at this low light level, perhaps even read. But if a bright light is introduced in our viewing area, for instance, a flashlight is turned on to illuminate a map, we lose that broad visibility and see primarily what is directly illuminated by the bright light.

TABLE 1: ILLUMINANCE VALUES

Full Moonlight	.01 to 0.1 foot-candle
Predawn	0.1 to 1 foot-candle
Windowed Room on a Cloudy Day	6-8 foot-candles
Beach in Bright Sunlight	30,000 foot-candles

When the eye's nighttime view includes a range of light intensities, the eye adjusts to the brightest light level. As a result other areas look dark and shadowy.

To take advantage of the eyes' adaptability a good lighting installation will be designed with the following characteristics:

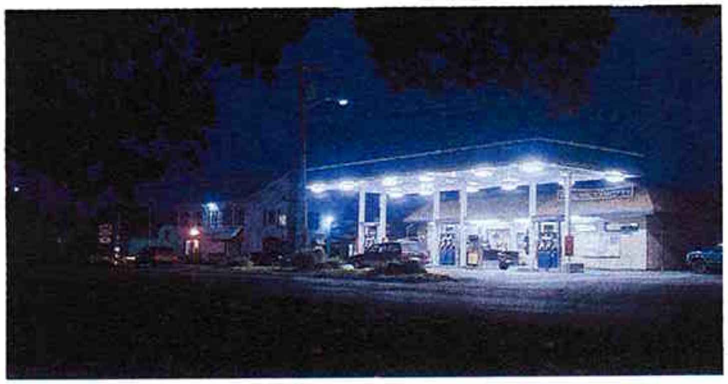
- Illumination levels appropriate for the visual task.
- Reasonably uniform illumination levels.
- Absence of glare.

Avoid Competing Light Levels

Lighting problems arise when neighboring properties are illuminated at very different levels. The two photographs illustrate this condition. The Lumen Cafe appears adequately lit until the brightly lit Candella Auto Sales is built across the street. The Cafe suddenly looks dark by comparison and will now need to add more lights. The new brighter lighting installation has begun a cycle of ratcheting up light levels. In the end, each business suffers by paying for more lighting equipment and higher electric bills.

Maintaining balanced light levels between neighboring properties within a village or downtown is important in several ways. In a uniform lighting environment the eye can adapt and see better. Less light is needed. Even lighting makes an area feel safer and

[1] See p. 21 for endnotes.



The bright light of this gas station canopy detracts from neighboring historic buildings and casts them in shadow. *(PHOTO: GARY CLAYTON HALL)*

The site lighting of this office complex serves the needs of users without impacting adjacent properties. *(PHOTO: GARY CLAYTON HALL)*

more comfortable for pedestrians. A light installation that is much brighter than its surroundings calls attention to itself and away from other properties. The brightly lit site may not represent the most attractive feature of the town and may distract and obscure parts of the town more worthy of the spotlight.

Design Light Levels for Conditions and Task

Ideally, light levels for a given installation are set by a lighting designer who carefully analyzes the site, the structures, vegetation, and surroundings. The designer can make use of building facades and canopies and the reflectant properties of surfaces to arrive at a lighting solution that allows adequate visibility and enhances both the site and its buildings.

Choosing the light level is the final step. Some tasks, such as walking in a park, do not need much light, and may, in fact, be best enjoyed with very little light. Other tasks, such as finding and unlocking a car in a commercial parking lot, need higher light levels. Using only the amount of light necessary saves energy, decreases skyglow, and avoids escalation of light levels in surrounding neighborhoods.

Light Level Guidelines

When specifying lighting, professionals in Vermont's lighting trade often rely on light level guidelines established by the Illuminating Engineering Society of North America (IESNA).

The IESNA *Lighting Handbook's* extensive reference material includes listings of recommended light levels for hundreds of typical outdoor tasks and activities. IESNA determines these figures by compiling research and technical information and by consensus of members of the organization's technical committees. The figures are meant to be used only as guidelines for the lighting community and should be adjusted for specific site conditions. Table 2 shows some examples of recommended levels from the current edition of the handbook.

TABLE 2: RECOMMENDED LIGHT LEVELS

Task/Site	Average Maintained Foot-candles
Amateur Tennis	20-30
Recreational Volleyball	10
Building Entry - active use	5
Commercial Parking Lot (medium activity level)	1.1
Collector Road (Commercial)	0.8 - 1
Local Road (Residential)	0.3 -0.4

It is important to understand that IESNA recommended guidelines are reached by consensus among IESNA committee members and are based on both visual performance research and other more subjective factors.[2]

A guideline established as a nationwide prescription may not be right for every Vermont setting. Just as prototype building and sign designs for national restaurant chains are not appropriate for most Vermont villages, so too a national recommended light level may not be appropriate for all of Vermont, especially in rural locations.

Town officials can and should look at the setting of their town, familiarize themselves with local lighting conditions, and make their own decisions as to what levels seem adequate. The basis for these decisions may be an assessment of how sites have historically functioned under existing light levels. They may decide that some areas of their town should remain lit only by the night sky.

Light Levels and Liability

DESIGN AND STANDARDS:
Issues of liability are a potential concern for communities, businesses, and utility companies that design and/or provide lighting installations. If an accident occurs on a street or a property during evening hours, there is always a risk that a negligence suit may be brought against the owner charging that the accident occurred because there was not "proper lighting."

In such a case the legal questions might be:

- Was the accident related to the injured's inability to see a given object or feature on the site?
- Was the lack of visibility due to poor lighting conditions rather than other factors?
- Was the defendant negligent in not illuminating that feature in a manner that allowed for reasonable visibility?
- What is a reasonable manner in which to illuminate the object?

Legally establishing the visibility of a feature in a given setting is a complex process that would include a discussion of size, luminance, contrast, and perhaps time. The level of lighting would certainly be an issue but in the end might not be the deciding factor.

In designing a lighting installation or adopting a lighting ordinance, there is a minimal risk of liability if standards are based on the best accepted current literature. In the field of lighting the most widely accepted reference is the IESNA guidelines. An ordinance can require that installations meet the minimum recommendations of this reference.

However, many streets and private properties in rural Vermont are illuminated at levels well below those recommended by IESNA. These communities may find national guidelines incompatible with the lighting environment of their town. In this case, town officials may establish their own standards if they are well reasoned and set down as a clearly articulated policy. Alternatively, informal lighting guidelines can be written to encourage a given direction for new lighting installations.

Many rural towns do not meet national standards in parts of their infrastructure. Narrow roadbeds and trees growing in the road right-of-way are two examples. A municipality must consider whether the benefit to the town of developing its own lighting standard outweighs the potential for increased liability.

Kennebunkport, Maine has a unique and stringent ordinance, written by a local lighting committee, that documents lighting design objectives tailored to their town's character and tourist-based economy.

LIGHTING AND LIABILITY INSURANCE:
Many businesses use lighting as part of a security system that protects their property during evening hours. During the permit process, zoning applicants sometimes maintain that certain lights are "required" by their insurance company to discourage burglaries or vandalism.

Inquiries revealed that commercial insurance policies in Vermont that cover liability and theft generally do not require or give discounts for a particular lighting installation. They may, however, give credit for security alarms, which are considered an effective deterrent to break-ins. An insurance company representative who surveys a facility before providing coverage might recommend lighting improvements; however, not all agents believe that lighting reduces that risk.[3]

Floodlights directed toward the road create glare for passing drivers. *(PHOTO: GARY CLAYTON HALL)*

These unshielded lights produce both glare and strong shadows around the building, diminishing their security function.

A cut-off fixture directs light downward, reducing glare.

GLARE

Glare is excess brightness that makes it difficult to see or causes discomfort. Glare is very common in the night environment and probably the most important lighting issue facing Vermont communities. Good visibility can be accomplished with less light where glare is controlled.

There are different types of glare. Discomfort glare produces physical discomfort but does not affect visibility. Disability glare reduces visual performance and may also be uncomfortable.[4] Both kinds of glare occur in outdoor lighting; sometimes together, but disability glare is more common.

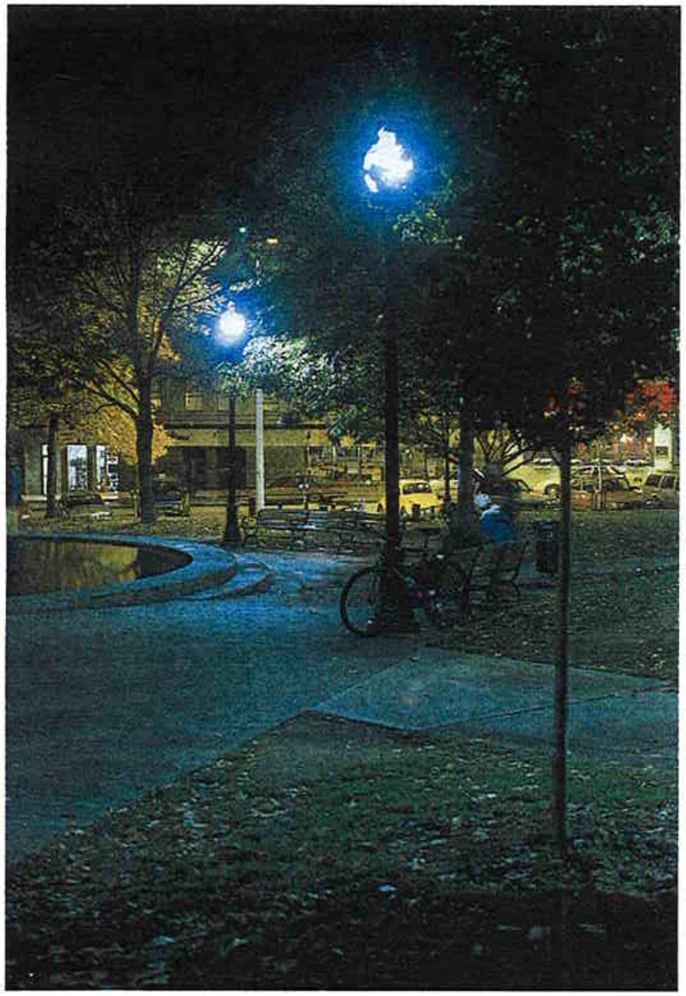
Disability glare (sometimes called veiling luminance) occurs when stray, misdirected light enters the eye and passes through the vitreous humor, a liquid in the inner eye. This medium contains impurities which scatter incident light and spread it across the retina like a veil, reducing contrasts and thereby reducing the visibility of images. As with sunlight on a computer screen, contrasts become washed out and images become hard to see. As the eye ages, disability glare becomes more of a problem. This is one reason older people sometimes find it difficult to drive at night.

If we are surrounded by sources of glare in our field of vision, our ability to see the "task surfaces," (such as objects in the road or sidewalk) even if they are lit at standard illumination levels, will be greatly impaired.

Glare is caused by light fixtures that do not control the light they emit. Instead of being directed toward the ground or toward the intended surface, part of the light shines directly into the viewer's eyes.

Common sources of glare include poorly designed fixtures with bright, exposed, or poorly shielded lamps; intensely lit signs; poorly designed "wall pacs" often used on commercial buildings; and misdirected floodlights.

The solution to reducing glare is to use light fixtures that direct light toward the ground or facade where it is needed and not toward the viewer. One type of fixture designed to control glare is called a "cut-off" fixture and is defined by IESNA specifications. The characteristics of these and other fixtures are discussed later in this document.



The metal halide lamps used to illuminate this park show colors quite accurately, especially the subtle shades of green in surrounding vegetation. *(PHOTO: GARY CLAYTON HALL)*

COLOR

Many types of lamps (bulbs) are used for exterior lighting. Objects illuminated under different lamps appear to be colored differently than they are in daylight. The ability of a lamp to show color accurately is known as its color-rendering ability. Certain lamps can significantly change the color and appearance of people, clothing, cars, vegetation, and even the night sky. Under light from some sources, it is difficult to distinguish one color from another.

Although there is no light source that perfectly replicates the way we see color by sunlight at mid-day, some lamps render color more accurately than others. The incandescent lamp, which has lit most of the evening hours in our homes, porches, and yards for years, is best for true color rendering. The color rendering index (CRI) for lamp types and wattages most often used for exterior lighting in Vermont are shown in Table 3.[5]

This table would seem to indicate that the incandescent lamp should be the lamp of choice where true color rendering is desired.

TABLE 3: LAMP CHARACTERISTICS

Lamp Type and Color	Common Wattages	Mean Lumens	Lumens per Watt Efficiency	Rated Avg Lamp Life Hours	CRI Color Rendering	CCT Color Temp
Incandescent warm white	100	1200	12	1000	100	2900
	150	2000	19	1000	100	2775
Compact Fluorescent cool green-white	16	600	38	10,000	82	2800
	28	1485	53	10,000	82	2700
Mercury Vapor cool blue-white	175	7200	47	24,000	50	3900
Metal Halide icy white	70	3400	78	12,000	70	3200
	175	12,100	94	15,000	75	4000
	250	15,000	100	15,000	70	3600
High Pressure Sodium yellow-orange	70	5050	85	24,000	22	1900
	150	13,500	100	24,000	22	2000
	250	23,400	110	24,000	22	2100
Low Pressure Sodium orange	35	4000	180	18,000	- 44	1800
	90	11,095	180	16,000	- 44	1800

CORRELATED COLOR TEMPERATURE

The Correlated Color Temperature (CCT) describes a characteristic of some lamps related to the appearance of the burning lamp, but it does not give information about the lamp's effects on an object's color. A lamp's CCT is stated in degrees Kelvin (K). Higher K numbers (3900K for mercury vapor) indicate a cool appearance and lower numbers (3200K for coated metal halide) a warm appearance. The importance of CCT relates to its use in making the best lamp selection once a given lamp type has been selected. For example, the cool characteristics of a metal halide lamp can be softened by selecting a metal halide lamp with a CCT at or below 3200K.[6]

Illuminated by metal halide lamps, the reds, whites, blues, and greens in this parking lot retain their distinction and contrast. *(PHOTO: GARY CLAYTON HALL)*

Under the light from high pressure sodium lamps, the white house, green tree, and brown church at this site all blend to a yellow hue. *(PHOTO: GARY CLAYTON HALL)*

Unfortunately, as indicated in the lumens per watt column, an incandescent lamp is also the least efficient. When energy efficiency becomes a factor, the selection process becomes more complicated.

The choice of lamp type must include consideration of the cost of installation and maintenance, the nature of the lighting task to be accomplished, and the visual effect of the light on its environment.

The Lamp Color and Cost Debate

Since the 1970s, when the energy crisis prompted large-volume users of electrical lighting to seek cost savings, most cities and many businesses in the U.S. have retrofitted their street lights and parking lots with high pressure sodium fixtures. This switch to an orange-yellow light source changed the color of the nighttime landscape across the nation. The change has been the subject of national debate within the lighting profession and among urban planners for the last 20 years.

Exceptions to the trend include Toronto, Ontario and Portland, Maine, two cities that have decided to use the white light of metal halide lamps to light their streets.

The light source debate divides like this:

HIGH PRESSURE SODIUM:

- More efficient use of energy.
- Color-rendering properties of light are not important because our eyes don't perceive color well at low light levels. (This is true for light levels below 0.1 foot-candle.)
- Produces a warm light that is desirable in the landscape, especially during the winter.
- Renders colors "close enough" that most colors are distinguishable. HPS renders colors sufficiently for criminal detection (except at the lowest light levels).
- Lamps last longer.

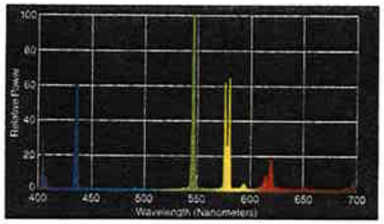
METAL HALIDE:

- Metal halide is only slightly less energy efficient than HPS for wattages commonly used in Vermont installation (below 400w).
- Our eyes do perceive and appreciate the color subtleties of illuminated areas at night.
- Better for security lighting because its color-rendering qualities allow more accurate witness identification.
- Allows better identification from a distance, which adds to a sense of security for pedestrians.[7]

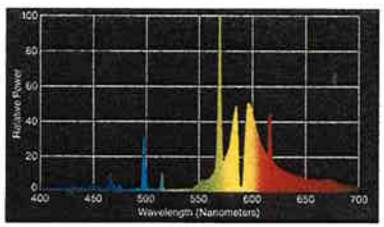
- Adds a feeling of security for pedestrians because the surroundings and people look familiar when illuminated in true colors. Orange light creates a more threatening "Road Warrior" setting.
- Creates skyglow similar to moonlight, rather than an orange wash in the sky.
- Visibility is better at low light levels with MH. (See below.)
- Lamps are less expensive (for 250-400w lamps).

Current Research Related to the Debate

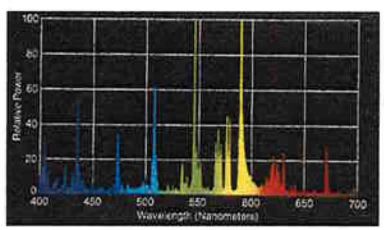
The Lighting Research Center at Rensselaer Polytechnic Institute is conducting research that is very pertinent to this topic. Findings of the study so far indicate that, at low light levels, cooler light sources (such as metal halide) that include the blue-green portion of the spectrum provide greater peripheral vision than light sources such as high pressure sodium lamps that are weak in the blue-green portion of the spectrum.[8] The results of this work have implications for all outdoor lighting, particularly street and parking lot lighting, where one's peripheral view of a car or pedestrian could prevent an accident. The results of this study imply that all lumens are not equal and that light generated by some lamps may provide better peripheral vision at low light levels.



Spectrum: Mercury vapor lamp. Emphasizes blue-green.



Spectrum: High pressure sodium. Emphasizes orange-red.



Spectrum: Metal halide. Good distribution. Slight emphasis on blue.

Lighting that makes our towns and cities comfortable and inviting at night also contributes to their economic viability.

Implications for Vermont Towns

Up until the 1980s, many District Act 250 Commissions, under the aesthetics criterion, have required applicants to use metal halide or other high color-rendering light sources such as incandescent or compact fluorescent for outdoor lighting. In the mid-'80s the Public Service Department urged the Commissions to permit high pressure sodium as well, recognizing its higher efficiency.

Vermont utilities have been following the national trend toward converting to HPS. Many, but not all, new commercial facilities are doing the same. However, businesses and retailers who are interested in displaying their buildings, property, logos, and products effectively invest in light sources that show truer color.

The public often voices a dislike for the blue-green hues produced by mercury vapor lights and the heavy yellow and orange effect of high pressure sodium lamps. Objections range from a general sense of uneasiness felt in these lighting environments to specific color distortions, inability to recognize colors, and the loss of visual enjoyment of the night landscape.

In the process of this study, which involved citizen lighting committees in all three case study communities, there was a clear agreement among members that the color-rendering properties of HPS did not produce the friendly night environment they wanted for their towns.

The financial choice of a light source that reduces the nighttime comfort and qualities of our towns and cities may be driven by a false economy. Merchants, residents, and property owners all have a stake in keeping our communities safe, inviting, and attractive. With increasing competition from malls and large suburban retailers, our town centers are at risk. Shopping malls, realizing the need to create a comfortable setting, do not illuminate their interior "streets" with orange light.

Lighting is more than a functional part of the infrastructure, it is a design tool that shapes the night landscape of our cities and countryside. Choosing a light source that preserves the livability of our towns makes sense from both a planning and an environmental perspective. Livable town centers that support both residential and commercial uses result in compact growth, efficient land use, and sound transportation patterns.

SKYGLOW

The term "skyglow" refers to the glow, visible in the night sky, over cities and brightly lit developed areas. In years past, skyglow was a phenomenon associated only with dense urban areas outside the state. But, with the increased use of outdoor lighting, the skies above Vermont cities such as Burlington and Rutland now emit an orange radiance that is far reaching. Even smaller communities such as Randolph and Morrisville now create their own distinct glow.

In Vermont this phenomenon, sometimes termed "light pollution," is not only a problem for amateur astronomers whose view of the galaxy is obscured. It is also a profound loss for the many Vermont children and adults who are denied the wonder and magic of seeing the Milky Way and a myriad of stars on a clear night. Under ideal conditions, about 2500 stars are visible in the night sky from horizon to horizon. Today, even in a moderately illuminated suburb where sky brightness has more than doubled, the number of visible stars is reduced to 200-300.[9] In some areas of Burlington only a few dozen stars are visible at night.

Throughout history, people have looked to the sky to seek answers to spiritual questions and to understand their place in the universe. The sky has also provided vital information for those creating calendars, growing crops, and navigating the seas. By obscuring night sky we cut ourselves off from a vast natural resource, a piece of the history of civilization, and a source of spiritual wonder.

Skyglow from Chittenden County's urban areas is visible from many miles away.
(PHOTO: GARY CLAYTON HALL)

Causes of Skyglow

Skyglow occurs when exterior light, shining into the sky, bounces off clouds, particles of moisture, or dust suspended in the atmosphere. The light may be shining directly into the sky from unshielded fixtures such as floodlights, or indirectly from reflectance off surface materials such as asphalt or snow.

The intensity of skyglow depends on several factors:

- The total light power of all the exterior lighting fixtures in a community.
- The proportion of that light spilling directly up into the sky.
- The nature of the surfaces that are being lit and their degree of reflectivity.
- Weather and atmospheric conditions.

In Vermont, where snow covers the ground for a good part of the year, reflectivity contributes significantly to winter skyglow. Table 4 shows the reflectivity of typical surface materials found in the landscape.

Although growth and development certainly contribute to an increase in skyglow, some experts believe that the amount of light that has been generated since the 1950s has increased much more dramatically than the population.[10] The invention of more powerful high intensity discharge (HID) lamps, the use of lighting on an expanded roadway system and in outdoor advertising, and the general fearfulness of the population that calls for more and brighter lighting have all fueled the growth in exterior lighting.

TABLE 4: REFLECTANCE FACTOR

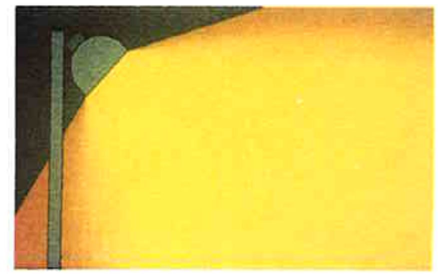
Percent of light reflected varies with type of surface.

	Percent
New snow	75
White painted surface	70
Concrete	40
Old asphalt	35
New asphalt	7
Grass	6

Reducing Skyglow

Skyglow cannot be eliminated, but implementation of the following general guidelines could significantly reduce skyglow in Vermont.

- Use only the amount of illumination needed to do the job. This will result in less light being reflected into the sky.
- Require that cut-off style fixtures meeting IESNA standards be installed for all new and replacement lighting installations. Most utility companies that supply roadway lighting in Vermont are now installing these fixtures. They direct light downward where it is needed, eliminating spill light.
- Require that "security" lighting meet cut-off requirements. Floodlights and non-shielded wall-mounted fixtures spill the most light and cause glare. If non-cut-off fixtures are used, require that they be motion sensor lights that turn on only when intruders are detected.
- Limit the use of "decorative" non-cut-off lighting to low light (lumen) levels.
- Require that sign lighting be kept to minimums needed to read signs and that signs be illuminated with downshielded lights installed above the sign.
- Discourage the "uplighting" of building facades.



A large portion of the light from this flood-type fixture shines directly toward the sky.

PRACTICAL ISSUES

Energy Savings

Most efforts to conserve energy for exterior lighting have focused on the use of more efficient lamps. Regulators and the industry have suggested that the best way to conserve energy is to use lamps that generate light using the least amount of electric power. In theory this would result in the use of lower wattage lamps and conserved energy.

In the area of exterior lighting this has not been the result. In the mistaken belief that more light is always better, and because electricity is relatively inexpensive, the tendency has been to use efficient lamps to increase light levels. The byproduct of this trend toward higher wattage lamps and more light has been an increase in glare and unbalanced illumination which then generates a pattern of further light escalation.

This manual addresses energy conservation by taking a broad look at exterior lighting in Chittenden County and identifying patterns of lighting practice where energy saving improvements can be made. The following list summarizes the recommendations of this report. Implementation of these recommendations would result in significant energy savings.

USE APPROPRIATE LIGHT LEVELS:
A well-designed lighting installation that uses only the amount of light needed for the task will eliminate overlighting.

REDUCE GLARE:
Reduced glare through the use of proper fixtures will result in improved visibility and the reduction of the light required for illumination.

REDUCE WASTED LIGHT:
Light that spills from fixtures up into the sky or toward a neighbor's window is wasted light energy. Cut-off fixtures that direct light properly conserve this light.

The amount of energy used for outdoor lighting is not trivial. The Vermont Comprehensive Energy Plan[11] provides the following estimates of electrical energy demand for Vermont for 1990 and 2000 (a linear interpolation generated 1995 estimates).

TABLE 5: TOTAL ELECTRICITY DEMAND

	TBTU*/Yr	$M/Yr
1990	16.96	468.20
1995	18.78	518.82
2000	20.61	569.44

*Trillion BTUs

Standard estimates hold that 25 percent of all electrical energy is used for lighting and of that amount 2.5 percent is used for exterior lighting[12]. Applying these percentages to the figures in Table 5 results in the following totals.

TABLE 6: TOTAL ELECTRICITY USED FOR EXTERIOR LIGHTING

	TBTU*/Yr	$M/Yr
1990	.11	2.92
1995	.12	3.24
2000	.13	3.56

*Trillion BTUs

The International Dark Sky Association estimates that 30 percent of all outdoor lighting is wasted due to the use of inefficient non-cut-off fixtures[13]. If overlit areas, signs, and floodlights are included, this 30 percent figure seems reasonable, and generates the following estimates of wasted energy in Vermont.

TABLE 7: TOTAL ELECTRICITY WASTED BY EXTERIOR LIGHTING

	TBTU*/Yr	$M/Yr
1990	.030	.88
1995	.036	.97
2000	.040	1.07

*Trillion BTUs

If, through improved lighting design, this waste could be eliminated, Vermonters would be able to save in the neighborhood of $1 million a year in electrical energy by the year 2000.

Cost Analysis

Saving costs through energy conservation is only one means of saving money on exterior lighting. A total cost analysis would examine the initial purchase and installation costs and the annual operating costs over the life of the installation. Various approaches to "life cycle costs" demonstrate that there are a wide range of variables to consider.

Initial costs include the cost of poles, brackets, ballasts, fixtures, lamps, control systems, and wiring and installation.

Annual operating costs depend on energy costs, cleaning and repair protocol, life of lamps, lamp replacement protocol (group replacement or as needed), number of fixtures, and anticipated vandalism or weather damage.

Every installation is unique. Each user will balance these variables according to his or her own priorities. For small businesses and many residential users, initial cost is most important. For large retailers, costs of use are important. Municipalities and utilities that provide street lighting are primarily concerned with electricity and maintenance costs. It is important that any proposed major lighting installation be subject to a life cycle cost analysis and that dollar costs take into account the quality of light provided and its impact on the surrounding areas.

SECURITY, CRIME, AND EXTERIOR LIGHTING

Security lighting can be broadly defined as lighting installed solely to enhance the protection of people and property.

Most lighting installations serve more than one function, but some lights that stay on after hours do so purely for security purposes. Security lighting is a significant source of glare and overlighting.

It is widely recognized by lighting professionals and those in the field of security that lighting in itself does not prevent crime.[14] All types of crime occur at all hours of the day and night. Despite the widespread use of security lighting and many studies on the subject, there is little definitive evidence that shows an increase in lighting to be a deterrent to crime.[15] One exception is street lighting, where recent studies in the U.S. and Great Britain link new installations with a reduction in some types of crime.

However, it is generally accepted among those in the field of crime prevention that lighting does play a *role* in both personal security and property security. That role is primarily one of facilitating surveillance.

Securing Property

Security lighting installed to protect property is only one part of a well-planned security system. A comprehensive and effective system will also consider gates, locks, detection devices, guards, or patrols to conduct surveillance and a form of response if suspicious activity is detected.

Crime is a complex social issue that includes many community factors. For a crime to occur there must be a "criminal opportunity," which consists of three elements: a suitable target, a motivated offender, and the absence of a witness.[16] Lighting can play a direct role in discouraging crime by increasing the "witness potential." The perception of visibility and the increased chance of being identified may make the criminal less motivated.

The goal of security lighting, then, is to increase the potential of a criminal being seen. Security lighting should therefore be designed to produce good visibility. Good visibility is best achieved with even light, bright enough to detect and identify a potential intruder. Lights that are too bright or glaring can create shadows and prevent good visibility. Light that renders color accurately allows for better witness identification of clothing and vehicles.

Risk of Crime

Crime rates in Vermont are relatively low. Vermont is reported to be the second safest state in the nation. Crime figures for burglary and larceny in Chittenden County declined between 1988 and 1994. Auto theft has remained fairly constant over that same period despite an increase in population.[17]

Although the burglary statistics in Table 8 have not been broken down by time of day, national figures indicate that 50 percent occur during the day.[18] Local police officials indicate that break-ins usually occur in residential areas during the day when no one is home and in business districts at night when buildings are unoccupied.[19]

TABLE 8: REPORTED CRIME RATES

Chittenden County	1988	1994
Burglary	1857	1190
Larceny	5636	5188
Auto Theft	319	332

Glare from unshielded wall-mounted fixtures, installed as security lighting, makes surveillance of this industrial building difficult. *(PHOTO: GARY CLAYTON HALL)*

Security Lighting That Saves Energy

LIGHTS OFF:
If a facility is located at a remote site where there is no guard, patrol, or evening neighbors, surveillance cannot take place and security lighting will not be an effective deterrent. It may be best for a business in a remote location to invest its security budget in an alarm system that notifies the local law enforcement agency.

SENSOR-CONTROLLED LIGHTS: Motion sensor- or heat sensor-controlled lights are an appropriate security lighting solution for many locations. They act as visual alarms, alerting those nearby and startling the intruder who comes within their range. Early versions were often inadvertently set off by animals and blowing branches, but newer models are more sophisticated and can be accurately aimed and adjusted to the proper sensitivity. Motion sensor lights must come on immediately and therefore require lamps that have no "warm up" time.

Sensor lights may overcome the problem of the visual desensitivity that results from overlighting. As areas of our communities become brighter at night, a business that is spotlighted for security no longer stands out because its neighbors have installed similar or brighter lighting. The patrol officer and the general public become immune to bright lights and no longer turn their heads as they drive or walk by. Neighbors pull their shades to keep out the glare of the street light or the floodlight shining from the garage next door.[20]

The use of sensor lights can improve surveillance by attracting attention to the business or residence only when necessary. Sensor lights save electricity and improve the night environment.

Street Lighting and Personal Security

Lighting plays an important part in raising the comfort level of those using the streets and public spaces of our towns and cities. By lighting both public and private spaces we invite more people to use our cities at night and as a result they become safer. Crime is less likely to occur where it can be witnessed. Well-designed lighting can become the catalyst for the increased safety of an actively used space.

The goal of encouraging the use of our public and private outdoor spaces suggests that we light these spaces in an inviting manner. Harsh and glaring light or lights that give the surroundings a vaguely unfamiliar color will discourage public use. Overlit streets have become associated with high crime areas. Studies have shown that even light levels, rather than high light levels, are more important for pedestrian comfort.[21] Pedestrians like to walk at night where there are other people, lighted store or residential windows, attractively lit buildings, and green and colorful vegetation.

When alone in an urban area at night people feel more comfortable if they can see their surroundings, see and judge the appearance of an approaching stranger, and have a clear view of alternative routes available if they wish to avoid a person or place. Dark corners can be viewed as threatening.

An individual's sense of danger is based on several factors, including his or her perception of the amount of crime in an area. This perception is balanced with the desire to take evening walks for enjoyment or the need to reach a destination. Also, personal attitudes about being in a nighttime environment vary greatly. Some find the evening itself romantic and inviting, others find it inherently threatening. Lighting designs can create a comfortable environment but cannot quell all fears.

[1] "The Moldcast Method," Manufacturer's brochure, 1988 Prescolite USI.

[2] Peter R. Boyce, "Illuminance Selection Based on Visual Performance—and Other Fairy Stories." In the proceedings of the 1995 Illuminating Engineering Society of North America, Annual Conference, 30 July 1995. pp. 562-577.

[3] Phone interview with David Slayton, Vermont Department of Banking and Insurance, 2 January 1996.

[4] Information Sheet, "Glare," Lighting Research Center, Rensselaer Polytechnic Institute, Troy, New York.

[5] CRI ratings are to be compared within the color temperature of lamp types. However, the hierarchy shown on this chart is useful as a general guide.

[6] The discussions of CRI and CCT are a simplification of a highly complex interaction. Those interested in a more detailed explanation should consult the IESNA Handbook and the references it includes.

[7] Peter R. Boyce, "Site, Perception, and Human Response in Street Lighting." A paper presented at City Light '94: New Challenges in Urban Lighting, Toronto, Ontario, Canada, 12 August 1994.

[8] Russell P. Leslie, "Lights Out," *Progressive Architecture,* November 1995, pp. 80-83.

[9] Arthur R. Upgren, "Starless Night," *Utne Reader,* March-April 1996.

[10] Scott Allen, "Blinded by the Light," *Boston Globe,* November 30, 1992. Based on an interview with Dave Crawford, International Dark-Sky Association.

[11] Vermont Comprehensive Energy Plan. 1991. (Vermont Department of Public Service). p. 37.

[12] Exterior Lighting Seminar, sponsored by the American Society of Landscape Architects, 1982, Chicago, Illinois.

[13] Information Sheet #3, "Why We Don't Like the 175 Watt Mercury Vapor Fixture." International Dark-Sky Association, Tucson, Arizona.

[14] Russell P. Leslie, "Lights Out," *Progressive Architecture,* November 1995, pp. 80-83.
Phone interview with Will Rykert, Director, National Crime Prevention Institute, Univ. of Louisville, Kentucky, January 1996.

[15] Information Sheet #51 (Edition No.1, April 1992) International Dark-Sky Association, Tucson, Arizona.
Phone interview with Will Rykert, Director, National Crime Prevention Institute, Univ. of Louisville, Kentucky, January 1996.

[16] Henri Berubé, "Security Lighting—A New Approach." A paper presented at City Light '94: New Challenges in Urban Lighting, Toronto, Ontario, Canada, 12 August 1994.

[17] Vermont Crime Report, 1994, (Department of Public Safety, Criminal Justice Services).

[18] Phone interview with Will Rykert, Director, National Crime Prevention Institute, Univ. of Louisville, Kentucky, January 1996.

[19] Interview with Bob Hawke, South Burlington Police Department, January 1996.

[20] Henri Berubé, "Security Lighting—A New Approach." A paper presented at City Light '94: New Challenges in Urban Lighting, Toronto, Ontario, Canada, 12 August 1994.

[21] James M. Tien, "Improving City Streets for Use at Night, The Norfolk Experiment," *Lighting Design and Application,* June 1974.

HOW CAN MUNICIPALITIES preserve the nighttime ambiance of their village centers and illuminate them for safety and convenience in a way that enhances the best qualities of their streets, architecture, and public spaces? Some of the solutions lie in making the community, businesses, and developers aware of lighting issues and in using planning tools which may already be available in some communities.

Lighting design, like architecture, is part science and part art. The best regulations will allow a designer to be creative within the framework of the community's lighting goals.

PLANNING TOOLS

Municipal Plans

Municipalities use their town plans to set goals related to the functioning and the livability of their towns. Broad goals and objectives for lighting and light levels can be part of this document.

Zoning Ordinances

A lighting section may be incorporated into a town's Zoning Ordinance to cover lighting installations in all parts or portions of the town. (See Municipal Regulation and Control section). Lighting plans, specifications for fixtures, and planned light levels can be reviewed in the Site Plan Review process. An informed planning staff and commission can be very successful in guiding lighting trends in their community. The review criteria should be based on the lighting goals of the town's master plan. Sign regulations can also specify lighting requirements.

Lighting Districts

Lighting Districts may be established which set lighting requirements for different areas of town. Residential areas can be assigned lower light levels and more restrictive glare limits. Commercial areas may be assigned higher light level limits, thereby restricting light escalation to a defined area. Illumination levels can be encouraged that reinforce and accentuate gateways and important civic spaces at the center of a town. The light levels of a town should parallel the hierarchy of land uses. The more densely developed and active commercial areas call for a slightly higher level of light than do quieter residential areas. Lamps with poor color-rendering qualities that are unappealing to pedestrians may be restricted to the industrial areas of town where there is no foot traffic at night.

Design Review

Towns that have a design review ordinance can review proposed lighting installations as part of that process. Criteria should be established. Lighting plans, levels, and specifications for fixtures should be reviewed. A knowledgeable design review board can be very successful in guiding lighting trends in a community.

Public Works Specifications

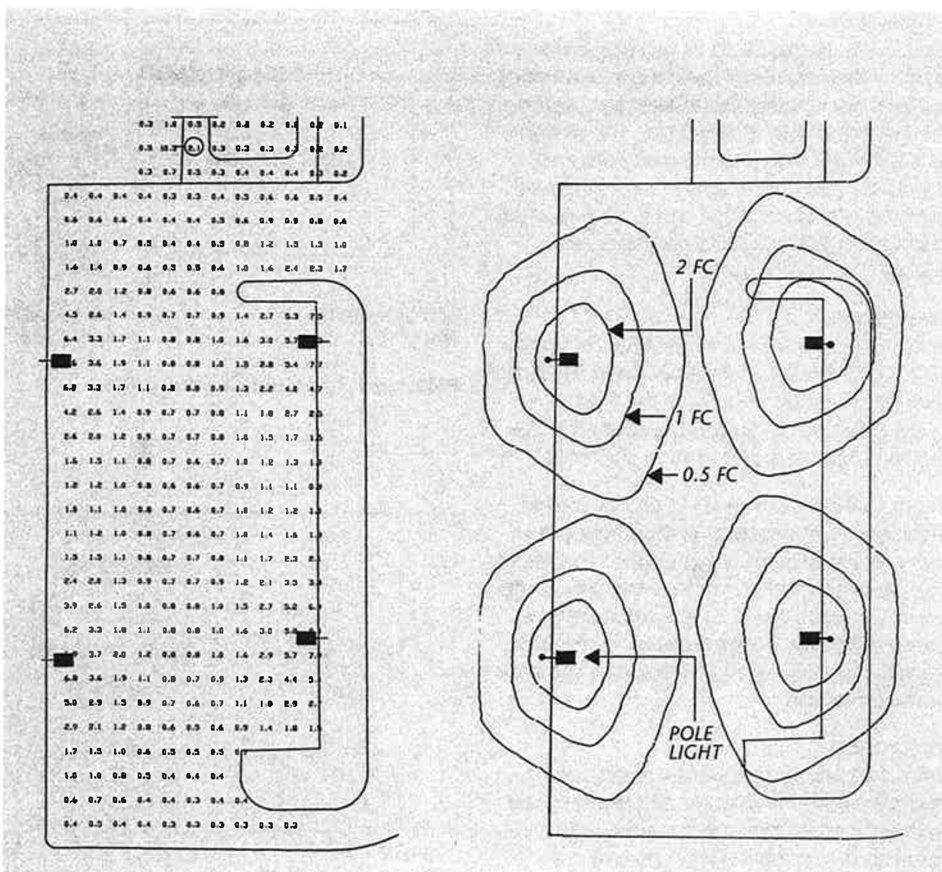
These regulations may establish street lighting requirements for new subdivisions. The requirements should reflect the goals of the master plan.

REQUIRING AND REVIEWING LIGHTING PLANS AND SPECIFICATIONS

A municipality requires basic application materials for issuance of a zoning permit. If the applicant plans to install outdoor lighting, the application should include enough information to clearly show the extent and impact of the new lighting improvements. The following should be included in the submittal requirements.

Lighting Plan

This plan should show locations of all pole-mounted and building-mounted fixtures and a numerical grid of lighting levels, in foot-candles, that the fixtures will produce on the ground (photometric report). For large projects this plan is usually developed by an electrical engineer as part of the design process. Even small projects (with four or five fixtures) can have a light level plan developed by the luminaire manufacturer at no cost. This plan will show light levels, evenness, and patterns of light distribution, and should also indicate the lamp type, wattage, and lamp loss factors applied.



PARKING LOT LIGHTING PLANS

1. Computer generated light level grid. Readings in tenths of foot-candles.

2. Iso-Illuminance circles. Each circle indicates an even light level. Readings in foot-candles.

Light levels and distribution patterns can also be shown on a site plan using circular patterns (iso-illuminance curves). This method of showing light levels uses concentric circular lines, each representing a constant illumination level. Iso-illuminance curves are used frequently in the early planning stages of a lighting design.

The photometric report will indicate the minimum and the maximum foot-candle levels within the lighted area of the site. The maximum level is usually close to the light fixture itself. The minimum (lowest number) is usually at the outer edges of the illuminated area or between two fixtures. As a general rule, the ratio of the highest and lowest light levels should not exceed 10:1. The average light level (often referred to in the regulations at the end of this manual) is determined by adding the foot-candle value of all the points in the grid and dividing by the total number of points. IESNA standards are usually based on this number. A ratio of average to minimum light levels is sometimes used as a measure of even illuminance within an installation.

The accuracy of computer printouts is exact within a range of approximately 10 percent depending on the validity of assumptions made in the modeling process. Printouts generally do not take into account such factors as light from neighboring properties and shadowing from trees.

Light level calculations usually consider a light loss factor (LLF) to account for normal light power loss over the life of the lamp. The LLF is a multiplier of about 0.6 or 0.7. Lamps will burn brighter when first installed, especially for the first 100 hours, when they are at their peak.

Building Elevations

Building elevations will show the location, height, and visibility of the fixtures, including the placement of all wall- or soffit-mounted lighting. Elevations may also be used to show the aiming point of pole-mounted floodlights. Interior lighting seen through windows will sometimes have significant visual impact on the streetscape and should be considered. The light from open parking garages can also have an effect on the character of a street and district.

Luminaire and Pole Specifications

Manufacturer's specifications on fixtures, poles, and lamps will provide information about the daylight character of the fixture and pole height, but more importantly will identify the potential for glare and determine color-rendering ability.

WHAT TO LOOK FOR

Overall Application and Approach

Some of the general design questions to ask may include:

Is the applicant clear about the lighting needs of the project? What are the outdoor tasks to occur on site in the evening? What area of the site is proposed to be lit? What light levels are appropriate and how will the proposed plan meet those needs? How does the proposed lighting plan relate to lighting in the surrounding area?

Is security lighting proposed? How will it function and is it part of an overall security plan? Have motion sensor lights been considered?

Light Levels and Distribution

Light levels should be appropriate for the proposed use of the site. Light levels appropriate for various uses are discussed in the last part of this manual. The applicant should be aware of the maximum, minimum, and average light levels that will be generated. These figures can be compared to IESNA guidelines, local standards, and other light levels in the vicinity of the site. Proposed light levels should be compatible with the neighborhood.

A foot-candle meter, about a $400 municipal investment, is worthwhile for helping board members acquire a sense of light levels in their town. A meter will also be useful for light level verification of new installations.

Pole Heights

Pole heights should be compatible with the scale of the surrounding architecture and the scale of the site. Lights on 25- to 30-foot poles create a high "ceiling" that shapes an outdoor space at night, giving it a grand scale. A large space can be lit more efficiently and evenly with high wattage lamps on fewer tall poles. Because high poles can be seen from broader vantage points, it is important that their luminaires have good cut-off qualities. Even with cut-off luminaires, if tall poles located on a rise are viewed from below (when driving up a steep hill, for example), they are likely to cause glare.

Lights on lower poles (10-18 feet) create a more intimately lighted space that is comfortable for pedestrians. When lower pole heights are used, lamp wattages are lowered accordingly to avoid "hot spots" of bright light at the foot of the pole.

Very low (42-inch) poles, called bollards, are often used for gardens and walkways. Where vandalism is a consideration, vandal-resistant models are available.

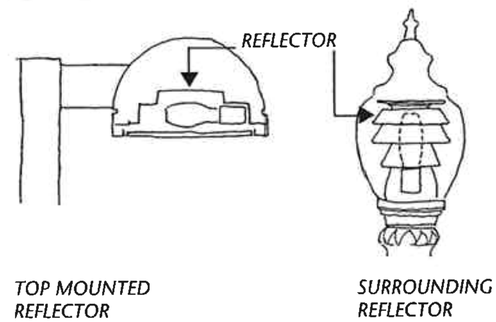
Luminaires

Luminaires are made up of receptacles for lamps, reflectors and/or refractors that control and direct light, and lenses that protect the lamp and may diffuse light. The design of a luminaire will determine its ability to distribute light evenly and to control glare. Luminaires may also have decorative qualities that add to their daytime character and appeal.

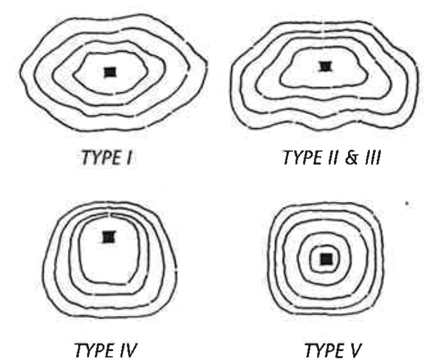
REFLECTORS:
Reflectors are mirrored enclosures within the housing of the luminaire that shield the lamp and, by reflection, distribute the light in a given direction. Reflectors are located in the top of the luminaire or around the lamp.

Some reflectors are carefully engineered to distribute light evenly in precise light patterns on the ground. The designer can select the pattern that best matches the area of the site to be illuminated. Some luminaires can accommodate a device called a "house side shield" that reduces light shining to the back of the luminaire.

REFRACTORS:
Refractors are glass or plastic enclosures that surround the lamp. Most refractors use prisms to direct and distribute the light. A refractor is generally less precise than a reflector. There are some highly engineered and crafted borosilicate glass refractors which do work well but are very expensive.



Reflectors shield and distribute light.



Luminaire distribution pattern options.

LENSES AND ENCLOSURES:

Lenses and enclosures are usually flat or box shaped. They primarily serve to protect the lamp but may also have minor light-diffusing properties.

Classification of Luminaires

CUT-OFF FIXTURES:

This type of fixture is the most effective in controlling glare and skyglow. Cut-off fixtures control glare by directing light well below the horizontal. The intent is to keep the light out of the viewer's line of sight. Specifications for cut-off fixtures have been established by IESNA.

Wall-mounted fixtures also are manufactured with cut-off features. Such fixtures shine light down and outward from a building wall.

SEMI-CUT-OFF FIXTURES:

In this classification of luminaire 20 percent of the light shines above the 80 degree line and 10 percent of the light shines above the horizontal. Because the lamp is only partially shielded, minimal glare control is provided.

NON-CUT-OFF FIXTURES:

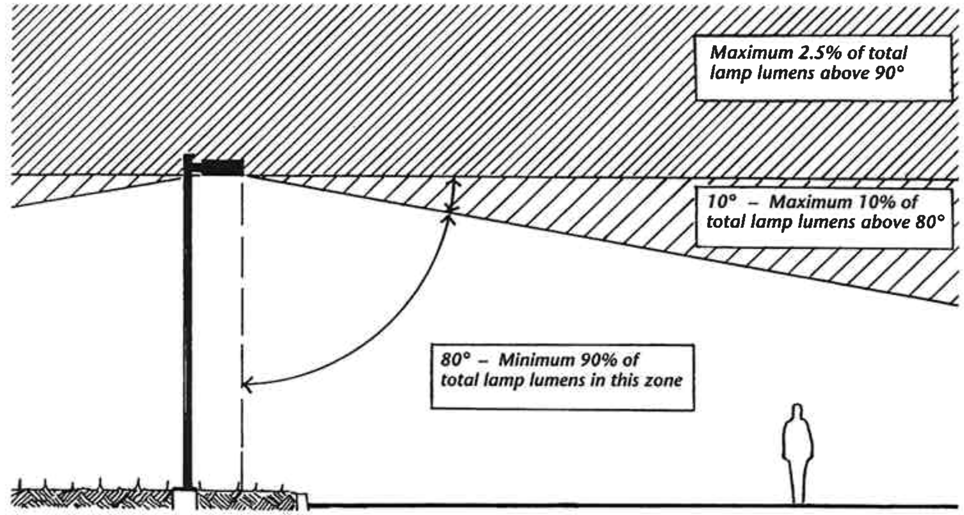
Some luminaires control brightness only through the use of a segmented lens surrounding or covering the lamp. These frosted or prismatic lenses diffuse some of the light, but few such lenses are effective against glare. Some luminaires in the non-cut-off category are designed to be decorative or historic. Many such fixtures are sold for residential or small-scale commercial use. If the luminance is low enough, the effect of glare will be minimal. The ordinances that follow recommend that such fixtures be permitted if lamps with low lumen power are used.

FLOODLIGHTS:

Floodlights are designed to create a controlled beam of light. Some fixtures provide a more narrow beam than others. Because they are installed on an angle and usually use high wattage lamps they have a very high capacity to create glare. Floodlights should not be installed where the "face" can be seen directly by pedestrians, drivers, and neighbors in the immediate vicinity of the fixture at night. In residential areas floodlights are likely to shine in homeowners' windows and cause light trespass problems. If viewed from the roadway, their glare can interfere with a driver's or pedestrian's vision. Most floodlights are designed with a "knuckle" that allows readjustment. This feature makes enforcement of floodlight installations difficult.

Lamps

Lamps used for outdoor lighting differ in wattage, efficiency, lamp life, color rendering, and cost. Table 9 shows some characteristics of lamps commonly used for outdoor lighting in Vermont.



Cut-off fixture as defined by IESNA.

TABLE 9: WATTAGE RANGE AND COLOR

Lamp Type	Wattage Range	Color	Notes
Incandescent*	25-1000	Warm white	Warm white good for small-scale installations. Instant-on.
Compact fluorescent*	7-28	Cool green-white	Loses light output at low temperatures.
Mercury vapor	75-400	Cool blue-white	Installed infrequently today but still available.
Metal halide*	32-1000	Icy white	Lamps below 3200 K have best CRI.
High pressure sodium	35-400	Yellow-orange	Color corrected lamps available.
Low pressure sodium	90-180	Deep orange	Rarely installed today except for internal security.

*Lamps with high color-rendering qualities, 65 CRI or above.

MUNICIPAL REGULATION AND CONTROL

IN VERMONT, the basic mechanism of regulating outdoor lighting is the local zoning ordinance, which includes regulations for various aspects of development. This part of the manual assumes that a municipality desires to include an outdoor lighting section in its zoning regulations.

The "Vermont Outdoor Lighting Study" identified nine types of outdoor lighting installations that municipalities may wish to regulate. Some communities may not choose to address them all. Other communities may identify types not described here. In this section we present an approach to regulation of outdoor lighting that can be used regardless of what installations are addressed. Since lighting technology is always evolving, the approach tends toward establishment of performance standards within which numerous design solutions are possible. The approach illustrated here is intended to provide a sound starting point for municipalities striving to develop their own unique regulations. As such, the numerical values may be adjusted to reflect local circumstances. The nine types of installations to be addressed are:

- Parking Lot Lighting
- Street Lighting
- Lighting of Gasoline Station Aprons/Canopies
- Lighting of Exterior Sales Areas
- Lighting of Exterior Sports/Performance Facilities
- Security Lighting
- Illuminated Building Facades and Landscaping
- Illuminated Signs
- Illuminated Walkways and Park Areas

Regulatory approaches for each of these will be discussed, along with prototypical regulations for communities to adopt or adapt to their own needs.

Drafting Lighting Regulations

The first part of an outdoor lighting section should specifically state that outdoor lighting installations will require a zoning permit, set forth the review process to be followed, and establish some general lighting standards to be met by all outdoor lighting installations. Desired lighting levels may vary from one section of a municipality to another. A municipality may wish to create "lighting districts" that have different lighting regulations. A lighting district might be a zoning district or several zoning districts that have similar lighting needs and requirements. If the municipality wishes to establish lighting districts, they should be defined in the first part of the lighting section.

A sample of general provisions is provided below. It would be followed by subsections directed to specific types of installations.

SAMPLE ZONING LANGUAGE

OUTDOOR LIGHTING:

The residents of ________ value the town's rural qualities, including the ability to view the stars against a dark sky. They recognize that inappropriate and poorly designed or installed outdoor lighting causes unsafe and unpleasant conditions, limits their ability to enjoy the nighttime sky, and results in unnecessary use of electric power. On the other hand, it is also recognized that some outdoor lighting is appropriate in areas such as village centers. To ensure appropriate lighting while minimizing its undesirable side effects, the following regulations are established.

A. Permit Required:

On all properties except those of one- and two-family residential structures and active farms, the installation or replacement of any outdoor lighting fixtures shall require a zoning permit. Said permit may not be issued unless the proposed installation is found (by the Planning Commission or the Zoning Administrator) to conform to all applicable provisions of this section.

B. Creation of Lighting Districts:

For the purposes of this section, the zoning districts established elsewhere in these regulations are consolidated into lighting districts, as follows:

i. Lighting District 1 shall consist of the industrial districts and the high-density commercial districts.

ii. Lighting District 2 shall consist of the low-density commercial districts.

iii. Lighting District 3 shall consist of the higher-density residential districts.

iv. Lighting District 4 shall consist of the low-density residential districts, the rural and agricultural districts, and the forestry or conservation districts.

C. General Requirements:

i. When the outdoor lighting installation or replacement is part of a development proposal for which site plan approval is required under these regulations, the Planning Commission shall review and approve the lighting installation as part of its site plan approval.

ii. Outdoor lighting installations involving the installation or replacement of two or fewer lighting fixtures (free standing or facade mounted) may be approved by the Zoning Administrator, provided that no single lamp (bulb) exceeds 150 watts, and that the total wattage of all bulbs in all fixtures does not exceed 300. All other installations must be approved by the Planning Commission.

iii. The applicant shall submit to the Town sufficient information, in the form of an overall exterior lighting plan, to enable the Town to determine that the applicable provisions will be satisfied. The lighting plan shall include at least the following:

- A site plan, drawn to a scale of one inch equaling no more than twenty (20) feet, showing buildings, landscaping, parking areas, and all proposed exterior lighting fixtures;
- Specifications for all proposed lighting fixtures including photometric data, designation as IESNA "cut-off" fixtures, Color Rendering Index (CRI) of all lamps (bulbs), and other descriptive information on the fixtures;
- Proposed mounting height of all exterior lighting fixtures;
- Analyses and illuminance level diagrams showing that the proposed installation conforms to the lighting level standards in this section; and

SAMPLE ZONING LANGUAGE

- Drawings of all relevant building elevations showing the fixtures, the portions of the walls to be illuminated, the illuminance levels of the walls, and the aiming points for any remote light fixtures.

iv. Wherever practicable, lighting installations shall include timers, dimmers, and/or sensors to reduce overall energy consumption and eliminate unneeded lighting.

v. When an outdoor lighting installation is being modified, extended, expanded, or added to, the entire outdoor lighting installation shall be subject to the requirements of this section.

vi. Expansions, additions, or replacements to outdoor lighting installations shall be designed to avoid harsh contrasts in color and/or lighting levels.

vii. Electrical service to outdoor lighting fixtures shall be underground unless the fixtures are mounted directly on utility poles.

viii. Proposed lighting installations that are not covered by the special provisions in this section may be approved only if the Commission finds that they are designed to minimize glare, do not direct light beyond the boundaries of the area being illuminated or onto adjacent properties or streets, and do not result in excessive lighting levels.

ix. For the purposes of these regulations, the mounting height of a lighting fixture shall be defined as the vertical distance from the grade elevation of the surface being illuminated to the bottom of the lighting fixture (i.e. luminaire).

x. Holiday lighting during the months of November, December, and January shall be exempt from the provisions of this section, provided that such lighting does not create dangerous glare on adjacent streets or properties.

xi. The Planning Commission may modify the requirements of this section if it determines that in so doing, it will not jeopardize achievement of the intent of these regulations.

A Basis for Specifying Lighting Levels

Light levels on illuminated surfaces such as parking lots, roads, or walkways are generally described (in foot-candles) by one or more of three measures of illuminance.

- Maximum light level: The brightest point on the surface of the illuminated area.
- Minimum light level: The dimmest point on the surface of the illuminated area.
- Average light level: The overall average of all points on the surface of the illuminated area including the brightest and dimmest points.

Guidelines or regulations generally specify one or more of these three interrelated measurements.

For example, the IESNA guidelines for parking area lighting suggests that a minimum light level for an illuminated parking lot should not fall below 0.2 foot-candles. Additionally, in order to prevent undue contrast between dim and bright areas, IESNA specifies a uniformity ratio that should be maintained between the average light level and the minimum light level. For parking lots the recommended ratio is 4:1.

Continuing with the parking lot example, if the minimum light level is 0.2 foot-candles, and the average to minimum ratio is 4:1, the average level of illumination will not exceed 0.8 foot-candles. The light level at the brightest point, the maximum light level, is not directly limited, but is indirectly controlled by the 4:1 ratio.

The IESNA guidelines are written to establish minimum light levels and to recommend ratios that will create even lighting. They do not establish upper limits for any of the three measures of illumination listed above. In fact, many installations provide light levels far in excess of the IESNA guidelines.

However, for municipalities that want to discourage excessive light levels, the IESNA guidelines can be useful. They can establish a baseline set of accepted minimum light levels. The municipal ordinance can require that these minimum light levels are not exceeded, or not exceeded by more than a specified amount.

Using the parking lot example above, where the IESNA minimum is 0.2 foot-candles, a town's ordinance may state that the minimum lighting level in the lot must not exceed IESNA minimum guidelines by more than 0.2 foot-candles—an "upper value" for the minimum of 0.4 foot-candles. If the average to minimum ratio is also specified as 4:1, then the average level of illumination on the surface of the lot will not exceed 1.6 foot-candles. Again, the maximum is controlled indirectly by the uniformity ratio. By holding down the minimum, the ordinance controls illumination measurements over the whole lot.

A similar approach could be applied to the average illumination level measurement. If IESNA specifies an average illumination level together with an average to minimum ratio, the municipal ordinance may require that the average not be increased by more than a specified amount in foot-candles. When the average to minimum ratio is applied, overall light levels will be controlled.

PARKING LOT LIGHTING

Lighting is helpful in allowing people to quickly identify and locate their vehicles, locate keys and fit them to locks, and perceive pavement irregularities which might cause a stumble. Lighting can also add to a sense of comfort and security by making it possible to see vehicles and other people in the area.

Operators of retail facilities often feel that having a brightly illuminated parking area calls attention to their facilities. Indeed, if a parking area is significantly brighter than neighboring properties, it not only calls attention to itself, it can limit visibility into neighboring establishments. This leads to ever-increasing levels of illumination in parking areas.

The IESNA *Lighting Handbook*[1] includes lighting guidelines for parking areas, both open and enclosed. The guidelines for open parking facilities suggest that a basic minimum level of illumination (at the darkest point of the lot) of 0.2 foot-candles is necessary to provide adequate visibility in areas of low nighttime activity. As the activity level increases, the minimum level of illumination should also increase. In Vermont, where background lighting levels are generally low, the necessary minimum level of illumination need not be high, and should rarely go above 0.6 foot-candles.

In order to prevent severe contrasts in illumination levels at various points in the parking area, the IESNA guidelines suggest that a uniformity ratio, defined as the ratio of the average level of illumination to the minimum level of illumination, not exceed 4:1 (3:1 in medium-use situations). This, in conjunction with a minimum illumination level of 0.6 foot-candles, would yield an average level of illumination no higher than 2.4 foot-candles.

The IESNA guidelines are intended to serve as a basis for design. The designer is advised to take into account such external factors as the level of background lighting, lighting from other sources, and characteristics of the surrounding area. The guidelines, by themselves, do not address off-site community impacts of lighting—particularly when levels in excess of the suggested values are provided. In particular, issues associated with excessive lighting levels, glare, color, and skyglow are not specifically addressed. It is these issues that communities may wish to address via local control and regulation.

The even lighting in this parking lot facilitates visibility. Designating average to minimum light level ratios discourages severe lighting contrasts. *(PHOTO: GARY CLAYTON HALL)*

Parking Lot Lighting Issues

EXCESSIVE LIGHTING LEVELS:
Municipalities may prevent excessive lighting levels in parking areas by adopting standards that are similar to the IESNA guidelines, but that also provide some upper limit to lighting levels. As suggested above, this can be done by specifying an upper limit to the illumination level of the darkest point on the parking area (minimum illumination level), along with a maximum uniformity ratio which limits the average illumination level for the entire parking area. With these limits in place, there may be bright spots on the parking area, but they will be restrained by the need to keep the average below the specified level.

Some municipalities have suggested that it is not their position to require that parking areas be illuminated, and that setting a required minimum level of illumination essentially establishes that requirement. An alternative is to require, if the Planning Commission and the applicant agree that a parking area is to be illuminated, that the lighting level of the darkest point (minimum illumination level) may not exceed the specified level, and that the uniformity ratio may not exceed a specified value.

The designated level of illumination in parking areas may vary from neighborhood to neighborhood. In some neighborhoods, such as rural or very low density single-family residential areas, illuminated parking lots might be discouraged. Other neighborhoods may justify moderate illumination levels. Neighborhoods characterized by heavy traffic on roads, regional shopping facilities, high rates of parking turnover, etc., might need higher lighting levels in parking areas. These varying needs should be reflected in the creation of the lighting districts.

Where parking lots of adjacent facilities are close together, high ambient lighting levels may add to the lighting levels in the parking areas. This should be considered when calculating the minimum and average lighting levels for new installations.

GLARE:
Municipalities may reduce glare from parking lot lighting by requiring the use of "cut-off" fixtures (described earlier), and by specifying maximum mounting heights.

While the use of cut-off fixtures is effective in controlling glare, there may be certain installations in which "designer" or "period" design light fixtures not meeting cut-off criteria are desired in order to create a certain visual character. Such fixtures can play an important role in the overall design of an area, and should not be discouraged. If they are not significantly brighter than the background against which they will be seen, they probably will not create glare problems. A light source equivalent to a 150-watt incandescent bulb is rarely objectionable unless viewed against a dark background. This is approximately 2000 initial lumens. Non-cut-off fixtures having light sources of no more than 2000 initial lumens can be allowed as alternatives or supplements to lighting provided by more conventional cut-off fixtures, but the illumination level should still fall at or below the specified upper limits for parking areas.

COLOR:
A community may regulate the color impacts of parking lot lighting by specifying a minimum Color Rendering Index (CRI) value. This allows some discretion to the designer, as well as the ability to accommodate evolving technology. A minimum CRI of 65 would require the better color corrected high pressure sodium (HPS) lamps or most metal halide lamps, while a minimum CRI of 70 would require metal halide lamps, certain fluorescent lamps, or incandescent lamps.

There may be some areas in a community in which color rendering is not so important. If color is definitely not a concern, setting a minimum CRI of 20 would allow virtually all HPS and mercury vapor lamps. The lighting districts would allow for these variations.

SKYGLOW:
Requiring the use of cut-off fixtures and limiting the illumination levels will also reduce the amount of light being directed or reflected to the sky, thus reducing the contribution to skyglow.

ENERGY EFFICIENCY/COST:
Parking lot lighting standards that discourage lighting where it is not needed, reduce lighting levels, and minimize the amount of waste light directed toward the sky should reduce lighting energy use and associated operating costs. On the other hand, standards that specify minimum CRI values may result in the use of light sources that are somewhat less efficient in terms of lumens per watt. Some form of trade-off will be necessary to achieve all of the varied lighting objectives.

What follows is prototypical language on parking lot illumination, suitable for incorporation into municipal zoning regulations. The specific values shown may be adjusted to meet the unique needs of a particular community and/or neighborhood.

SAMPLE ZONING LANGUAGE

D. Parking Lot Lighting:
Parking lot lighting shall be designed to provide the minimum lighting necessary to ensure adequate vision and comfort in parking areas, and to not cause glare or direct illumination onto adjacent properties or streets.

i. All lighting fixtures serving parking lots shall be cut-off fixtures as defined by the Illuminating Engineering Society of North America (IESNA).

ii. Alternatives: The design for an area may suggest the use of parking lot lighting fixtures of a particular "period" or architectural style, as either alternatives or supplements to the lighting described above.

a) If such fixtures are not "cut-off" fixtures as defined by IESNA, the maximum initial lumens generated by each fixture shall not exceed 2000 (equivalent to a 150-watt incandescent bulb).

b) Mounting heights of such alternative fixtures shall not exceed fifteen (15) feet.

iii. Parking area lighting standards in the various lighting districts are as shown in Table 10. (Note: The table is a prototype. District names and actual values should be determined by each town.)

iv. Parking area lighting in the low-density rural district: Parking areas in the low-density rural district shall not be illuminated unless there exist specific hazardous conditions which make illumination necessary. In such cases, the lighting shall meet the standards for the next higher lighting district.

TABLE 10: PARKING LOT LIGHTING STANDARDS

	District 1 Industrial/ Commercial	District 2 Town Center	District 3 High-Density Residential	District 4 Rural
Mounting Height (Maximum)*	25 ft	20 ft	20 ft	Discouraged
Minimum Illumination Level (at darkest spot on the parking area)	no less than 0.3 fc no more than 0.5 fc	no less than 0.2 fc no more than 0.3 fc	no less than 0.2 fc no more than 0.3 fc	Discouraged
Uniformity Ratio **	4:1	4:1	4:1	Discouraged
Minimum CRI ***	20	65	70	Discouraged

* Mounting height is the vertical distance between the surface being illuminated and the bottom of the lighting fixture.
** Uniformity ratio is the ratio of average illumination to minimum illumination.
*** CRI is the Color Rendering Index.

STREET LIGHTING

Street lighting is generally necessary to allow people to see comfortably and to illuminate hazards along or on the roadway. In rural areas and many low-density residential areas, street lighting may not be necessary except at intersections, sharp curves, or other hazardous locations. In some highly urban locations, street lighting is also used to assure people that it is safe to walk or drive on streets at night, and to discourage vandals or burglars. With very few exceptions, vandalism and burglary are unlikely events in Vermont. The real issue is the degree of lighting that is needed to accommodate pedestrians and motorists without causing adverse impacts on surrounding properties.

IESNA has established lighting guidelines for roadways. These guidelines recognize different types of roadway (Freeway, Expressway, Major [or Arterial] Roadway, Collector Roadway, and Local Roadway) and different types of adjacent development (commercial, intermediate [mixed], and residential). The guidelines recommend values for the average level of illumination on the roadway, along with uniformity ratios (defined as the ratio of the average level of illumination to the minimum level of illumination).

The IESNA guidelines and suggested design approach are widely accepted as appropriate for establishing the basic levels of illumination on roadways. They do not explicitly take into account the community concerns described above, such as excessive lighting levels, glare, color rendering, or skyglow.

In Vermont, most street lighting is owned by utility companies and provided to municipalities under lease arrangements. As such, street lighting does not readily fall under the jurisdiction of zoning regulations. In some cases, street lighting in new developments might be subject to subdivision regulations, but only insofar as the subdivision regulations set parameters which developers then impose on the utility. Thus, regulation of street lighting is probably best accomplished through the municipal public works specifications, and should be drafted after extensive discussions with the utility.

Street Lighting Issues

EXCESSIVE LIGHTING LEVELS:
An urban or suburban municipality can prevent excessive street light illumination by adopting standards similar to the IESNA guidelines, with the added provision that the average illumination level cannot exceed the IESNA recommended level by more than 0.2 foot-candles. Specifying maximum mounting heights is also helpful.

IESNA guidelines work well for urban areas where the character of neighborhoods may change frequently. In smaller communities or in rural areas, it may make sense to use the lighting district approach, and to specify illumination levels for each district.

In some rural or very low density residential areas, street lighting might be discouraged except at intersections or special hazards such as sharp curves. In such areas, specifying illumination levels for the entire roadway may not be appropriate. Instead, a "pool of light" concept may be more consistent with the overall character of the area. Effective pools of light can be achieved by specifying mounting heights, approximate spacing, and maximum initial lumens per fixture.

GLARE:
Glare from street lighting installations can be reduced by requiring the use of "cut-off" fixtures. The lighting industry has designed supplementary "house side shields" intended to prevent light from being directed to the rear of the fixtures.

Even when cut-off and shielded fixtures are required, it is still important to consider the effects of mounting height and the elevation of potential viewers. If an adjacent walkway or structure is substantially lower in elevation than the street, or if very high mounting heights are used, even cut-off or house-side-shielded fixtures may cause annoying glare.

While the use of cut-off fixtures is effective in controlling glare, there may be certain installations in which "designer" or "period" design light fixtures not meeting cut-off criteria are desired in order to create a certain visual character. Such fixtures can play an important role in the overall design of an area, and should not be discouraged. If they are not significantly brighter than the background against which they will be seen, they probably will not create glare problems. A light source equivalent to a 150-watt incandescent bulb is rarely objectionable unless viewed against a dark background. This is approximately 2000 initial lumens. Non-cut-off fixtures having light sources of no more than 2000 initial lumens can be allowed as alternatives or supplements to lighting provided by more conventional cut-off fixtures, but the illumination level should still fall at or below the specified upper limits for the roadway.

COLOR:
A community may control color impacts from street lighting by simply specifying that only a certain type of light source (lamps or bulbs) may be used. Kennebunkport, Maine, requires incandescent, while Stowe, Vermont, allows only metal halide lamps.

A community could also specify a minimum CRI value, allowing some discretion to the designer as well as the ability to accommodate evolving technology. A minimum CRI of 65 would require the better color-corrected high pressure sodium (HPS) lamps or most metal halide lamps. A minimum CRI of 70 would require metal halide lamps, certain fluorescent lamps, or incandescent lamps.

There may be some areas in a community in which color rendering is not so important. If color is definitely not a concern, setting a minimum CRI of 20 would allow virtually all HPS and mercury vapor lamps. Lighting districts would allow for these variations.

Note: Many Vermont utilities do not currently offer alternatives to high pressure sodium street lighting. Municipalities should discuss any CRI regulations with their utility companies.

SKYGLOW:
Street lighting standards that require the use of cut-off and shielded fixtures and that limit illumination levels will also reduce the amount of light being directed or reflected to the sky, thus reducing the contribution to skyglow.

ENERGY EFFICIENCY/COST:
Street lighting standards that reduce lighting levels and minimize the amount of waste light directed toward the sky should also reduce lighting energy needs and associated operating costs. On the other hand, standards that specify minimum CRI values may result in the use of light sources that are slightly less efficient in terms of lumens per watt. Some form of trade-off will be necessary to achieve all of the varied lighting objectives.

What follows are general standards for street lighting installations, intended to be incorporated into a municipality's zoning ordinance or public works specifications. Two sets of standards are offered. The first, for more urban areas, essentially incorporates the IESNA guidelines with an upper limit to the average illumination level. The second, for more rural areas, calls for widely spaced fixtures and limits the maximum initial lumens per fixture.

1A. General Street Lighting Standards (Alternative for Urban Areas):

A. General levels of illumination shall be consistent with guidelines published by the Illuminating Engineering Society of North America (IESNA), provided that the average illumination level may not exceed that specified in those guidelines by more than 0.2 foot-candles.

B. The uniformity ratio shall not exceed that suggested by the IESNA guidelines.

C. Lamps shall have a Color Rendering Index (CRI) of no less than ——.

D. Mounting heights shall not exceed thirty (30) feet.

1B. General Street Lighting Standards (Alternative for More Rural Areas):

A. General standards for mounting height, spacing, maximum initial lumens per fixture, and minimum Color Rendering Index, for the various lighting districts, shall be as set forth in Table 11.

2. Fixtures

All street lighting fixtures shall be "cut-off" fixtures as defined by IESNA. If necessary, fixtures shall include "house side shields" to minimize light directed to the rear of the fixtures.

Alternatives: The design for an area may suggest the use of street lighting fixtures of a particular "period" or architectural style, or there may be existing historical fixtures to be retained. In such cases, the non-cut-off fixtures may be used either as alternatives or supplements to street lighting described above.

MODEL PUBLIC WORKS SPECIFICATIONS

A. For fixtures that do not meet the "cut-off" criteria, the maximum initial lumens generated by each fixture shall not exceed 2,000 (equivalent to a 150-watt incandescent bulb).

B. Mounting heights of such fixtures shall not exceed fifteen (15) feet for new fixtures. Where historic fixtures are being retained (and/or extended) mounting height shall be that of the existing fixtures and every effort shall be made to use brackets that match existing brackets.

3. Location

A. Street lights shall be located in the public right-of-way.

B. If the street has a sidewalk along one side, the street lights shall generally be located on the sidewalk side of the street.

TABLE 11: STREET LIGHTING STANDARDS

	District 1 Industrial/ Commercial	District 2 Town Center	District 3 High-Density Residential	District 4 Rural
Mounting Height (Maximum)*	30 ft	30 ft	30 ft	Discouraged
Spacing	600 ft and at intersections	Main street: 300 ft Elsewhere: 600 ft and at intersections	At intersections only	Discouraged
Maximum Initial Lumens **	15,000	15,000	15,000	Discouraged
Minimum CRI ***	20	65	70	Discouraged

* Mounting height is the vertical distance between the surface being illuminated and the bottom of the lighting fixture.
** Maximum of 15,000 initial lumens is the equivalent of a 175-watt metal halide lamp, a 250-watt mercury vapor lamp, or a 150-watt high pressure sodium lamp.
*** CRI is the Color Rendering Index.

LIGHTING OF GASOLINE STATION/CONVENIENCE STORE APRONS/CANOPIES

The lighting of gasoline station and/or convenience store aprons has become a widespread lighting problem. These facilities have carried to the extreme the notion that being more brightly illuminated than neighboring properties attracts attention and business. This is particularly true when canopies over gasoline pump islands are installed. Lighting fixtures in the canopies produce very intense light (measured at over 100 foot-candles). In addition to excessive illumination levels, the light fixtures are frequently not adequately shielded, so that glare is produced which hinders visibility for drivers and pedestrians on nearby roadways. By addressing the problems of excessive illumination levels and glare, municipalities will also achieve positive impacts in terms of skyglow and energy efficiency/cost.

Gasoline Station/Convenience Store Lighting Issues

EXCESSIVE LIGHTING LEVELS:

In most gasoline station/convenience store situations, the apron consists of two parts: the area immediately around the gasoline pumps (and under the canopy if there is one), and the more remote area around the periphery of the apron. The former area is where more detailed vision is required for tending to the vehicle, operating the pumps, etc., and this may justify a higher level of illumination than needed in the outlying areas. The outlying areas are essentially used for vehicle storage or parking, and require levels of illumination equivalent to that used in parking lots.

Research on gasoline station lighting suggests that average illumination levels in excess of 10 foot-candles serve no purpose other than attracting attention to the site[2]. The lighting guidelines offered by IESNA[3] suggest an average illuminance level of 20 foot-candles.

Another source of excessive lighting is the illumination of canopy fascias at levels well above background levels. In a sense, this is an attempt to use the fascia as a large illuminated sign or billboard.

GLARE:

Glare from canopy lighting is caused primarily by ceiling-mounted light fixtures in which the diffusing lens projects below the bottom edge of the canopy. A solution is to require recessed fixtures so that the rim of the fixture and/or the edge of the canopy serve as shields to confine direct light to a cone no more than 85 degrees from the vertical.

Glare coming from light fixtures serving the remote areas of the apron can be controlled by requiring the use of cut-off fixtures designed to direct light onto the paved apron and not onto adjacent properties.

COLOR:

Most owners and operators of gasoline stations and convenience stores recognize that white light is more inviting than yellow light, and generally do not use HPS lighting. Thus, poor color rendering is rarely a problem. If necessary, regulations could specify either the type of light sources permitted or a minimum CRI level.

SKYGLOW:

By reducing the lighting levels and controlling glare, much light directed skyward will be eliminated, thus reducing the contribution to skyglow. There will still be reflected light, but even that will be reduced by controlling the light levels.

ENERGY EFFICIENCY/COST:

The primary impact of the suggested regulations on energy efficiency/cost will be the reduction of overall illumination levels and the corresponding reduction in energy consumption. While recessed fixtures may be more expensive than surface-mounted fixtures, there may be fewer fixtures required.

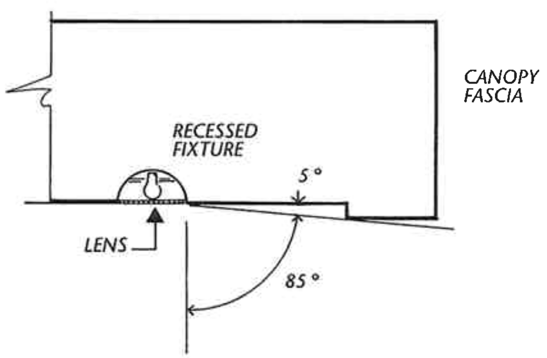
What follows is some suggested language to be incorporated into an outdoor lighting section of local zoning regulations for controlling lighting of gasoline station/convenience store aprons and canopies.

SAMPLE ZONING LANGUAGE

E. Lighting of Gasoline Station/Convenience Store Aprons and Canopies: Lighting levels on gasoline station/ convenience store aprons and under canopies shall be adequate to facilitate the activities taking place in such locations. Lighting of such areas shall not be used to attract attention to the businesses. Signs allowed under the appropriate section of these regulations shall be used for that purpose.

i. Areas on the apron away from the gasoline pump islands used for parking or vehicle storage shall be illuminated in accordance with the requirements for parking areas set forth elsewhere in this section. If no gasoline pumps are provided, the entire apron shall be treated as a parking area.

ii. Areas around the pump islands and under canopies shall be illuminated so that the minimum horizontal illuminance at grade level is at least 1.0 foot-candle and no more than 5.5 foot-candles. The uniformity ratio (ratio of average to minimum illuminance) shall be no greater than 4:1, which yields an average illumination level of no more than 22.0 foot-candles.



Gas pump canopy.

By using indirect lighting techniques, this gas station canopy provides adequate light levels without glare. *(PHOTO: GARY CLAYTON HALL)*

SAMPLE ZONING LANGUAGE

iii. Light fixtures mounted on canopies shall be recessed so that the lens cover is recessed or flush with the bottom surface (ceiling) of the canopy and/or shielded by the fixture or the edge of the canopy so that light is restrained to no more than 85 degrees from vertical, as shown in the sketch at left.

iv. As an alternative (or supplement) to recessed ceiling lights, indirect lighting may be used where light is beamed upward and then reflected down from the underside of the canopy. In this case light fixtures must be shielded so that direct illumination is focused exclusively on the underside of the canopy.

v. Lights shall not be mounted on the top or sides (fascias) of the canopy, and the sides (fascias) of the canopy shall not be illuminated.

LIGHTING OF EXTERIOR SALES/DISPLAY AREAS

Some types of commercial establishments rely heavily on outdoor sales and display areas. Examples include heavy equipment sales, recreational vehicle sales, automobile sales, and sales of building materials. Most such establishments do not operate at night, and do not require significant lighting of the outdoor sales or display areas. A noteworthy exception is automobile sales areas. Automobile dealers have noted that many people examine cars during off-hours. In addition, dealers have recognized that illuminating the automobile lot to very high levels tends to call attention to the lot.

Very high lighting levels on automobile sales lots cause a variety of community problems, such as excessive overall ambient light levels, contribution to the upward ratcheting of lighting levels as neighboring properties react by installing additional lighting, glare, increased skyglow, and increased community energy consumption.

Exterior Sales/Display Area Lighting Issues

EXCESSIVE LIGHTING LEVELS:

The illumination level of exterior sales and display areas need not match that of interior spaces since the level of detail being examined and the duration of examination are both lower. In addition, for much of the time, after-hours shopping is done without benefit of a salesperson, and the vehicles are locked so interior examination is not possible. An average illumination level of 5.0 foot-candles is generally adequate for these tasks. Illumination levels above 5.0 foot-candles are needed only for advertising purposes, essentially turning the display lot into a giant billboard.

In regulating illumination levels in outdoor display areas, the first step is to distinguish between areas actually used for parking and passive vehicle storage and the area actively used as a sales/display area. Lighting of the parking/storage areas should meet the standards described earlier.

Lighting levels in the active sales/display area should be limited by establishing an upper boundary to the average level of illumination, using only the active sales/display area as the basis for computing the average. A uniformity ratio of no more than 4:1 should be established to prevent extremely bright areas within the overall average.

GLARE:

Extremely high illumination levels on outdoor automobile sales/display areas cause significant glare problems if the lighting is provided by unshielded or non-cut-off light fixtures. Requiring the use of cut-off fixtures and/or fixtures that are aimed and shielded so that light is not directed away from the display area will greatly reduce the amount of glare produced. If lighting fixtures are directed away from adjacent streets, the problem of glare causing dangerous loss of vision for drivers will be reduced, possibly at the expense of neighboring properties.

COLOR:

Most merchants recognize that the ability to correctly discern color is important to effective outdoor display of merchandise. Thus, most lighting of outdoor display/sales areas uses either color-corrected HPS lamps or metal halide lamps. In order to ensure that these lamp types are used, regulations could specify a minimum CRI of 70.

SKYGLOW:

The use of very high levels of illumination and the use of non-cut-off and unshielded lighting fixtures result in the release of a great deal of direct and reflected light toward the sky. Requiring significantly lower illumination levels and the use of shielded and/or cut-off fixtures will greatly reduce the amount of misdirected light. Even so, illumination of shiny surfaces such as automobile bodies will always reflect light toward the sky.

ENERGY EFFICIENCY/COST:

The primary impact of the suggested regulations on energy efficiency/cost will be the reduction of overall illumination levels and the corresponding reduction in energy consumption.

Presented below are some suggested regulations that might be incorporated into an outdoor lighting section of local zoning regulations if a community feels that illuminated exterior display/sales areas are current or potential problems.

SAMPLE ZONING LANGUAGE

F. Lighting of Exterior Display/Sales Areas:
Lighting levels on exterior display/sales areas shall be adequate to facilitate the activities taking place in such locations. Lighting of such areas shall not be used to attract attention to the businesses. Signs allowed under the appropriate section of these regulations shall be used for that purpose. The applicant shall designate areas to be considered display/ sales areas and areas to be used as parking or passive vehicle storage areas. This designation must be approved by the Planning Commission.

i. Areas designated as parking or passive vehicle storage areas shall be illuminated in accordance with the requirements for parking areas suggested elsewhere in this section.

ii. Areas designated as exterior display/sales areas shall be illuminated so that the average horizontal illuminance at grade level is no more than 5.0 foot-candles. The uniformity ratio (ratio of average to minimum illuminance) shall be no greater than 4:1. The average and minimum shall be computed for only that area designated as exterior display/sales area.

iii. Light fixtures shall meet the IESNA definition of cut-off fixtures, and shall be located, mounted, aimed, and shielded so that direct light is not cast onto adjacent streets or properties.

iv. Fixtures shall be mounted no more than twenty-five (25) feet above grade, and mounting poles shall be located either inside the illuminated area or no more than ten (10) feet away from the outside edge of the illuminated area.

LIGHTING OF EXTERIOR SPORTS/PERFORMANCE FACILITIES

There are many types of outdoor sports/performance facilities that might be illuminated for nighttime use. The following are some general categories.

- Local recreation facilities (tennis courts, ice skating rinks) intended for use by participants and few, if any, spectators.
- Sports facilities designed not only for the participants but also significant numbers of spectators (major or minor league ball parks and high school ball fields).
- Facilities for outdoor stage presentations (amphitheaters, outdoor concert facilities, and open air theaters) which include space for performers and spectators.

Each of these has its own unique lighting needs, and it is not practicable to attempt to address them all in local regulations. The IESNA *Lighting Handbook*[4] has devoted an entire chapter to lighting outdoor sports and recreational areas, and even this reference acknowledges that it is a highly specialized, technical field. Important variables include whether spectators need to see not only the playing field but also the players, whether the game is played at or very near the playing surface (ice hockey) or substantially above it (basketball), the size of the playing area, and whether players typically look in few or all directions.

Lighting of these types of facilities can be highly visible. If not carefully designed, it can contribute to elevated general illumination levels in surrounding areas, create glare, and contribute to skyglow. Careful design by qualified designers can ensure adequate but not excessive light levels, minimal external effects of glare and light trespass, and overall energy and cost efficiency.

With this in mind, local regulations should require the submission of a lighting plan, prepared by a qualified lighting designer, which explicitly documents the need for the level of lighting provided; demonstrates that the location, selection, and aiming of all lighting fixtures will focus light on the playing areas; minimizes glare and visibility from neighboring areas; minimizes contributions to skyglow; and provides an energy- and cost-efficient overall system.

Sports facilities can be adequately lit using non-glare cut-off fixtures.

The following language is intended to be incorporated into an outdoor lighting section of a local zoning ordinance.

SAMPLE ZONING LANGUAGE

G. Lighting of Outdoor Performance Facilities:
Outdoor nighttime performance events (concerts, athletic contests, etc.) have unique lighting needs. Illumination levels vary, depending on the nature of the event. The regulations in this section are intended to allow adequate lighting for such events while minimizing skyglow, reducing glare and unwanted illumination of surrounding streets and properties, and reducing energy consumption.

i. Design Plan: A lighting design plan shall be submitted which shows in detail the proposed lighting installation. The design plan shall include a discussion of the lighting requirements of various areas and how those requirements will be met.

ii. Dual System: The main lighting of the event (spotlighting or floodlighting, etc.) shall be turned off no more than forty-five (45) minutes after the end of the event. A low level lighting system shall be installed to facilitate patrons leaving the facility, cleanup, nighttime maintenance, etc. The low level lighting system shall provide an average horizontal illumination level, at grade level, of no more than 3.0 foot-candles with a uniformity ratio (average to minimum) not exceeding 4:1.

iii. Primary Playing Areas: Where playing fields or other special activity areas are to be illuminated, lighting fixtures shall be specified, mounted, and aimed so that their beams fall within the primary playing area and immediate surroundings, and so that no direct illumination is directed off the site.

iv. Parking Areas: Lighting for parking areas shall meet the requirements suggested elsewhere in this section.

v. Pedestrian Areas: Areas intended solely for pedestrian circulation shall be provided with a minimum level of illumination of no less than 0.1 foot-candles and no more than 0.2 foot-candles. A uniformity ratio of average illumination to minimum illumination shall not exceed 4:1.

vi. Security Lighting: Security lighting shall meet the requirements suggested elsewhere in this section.

SECURITY LIGHTING

For the purposes of this discussion, security lighting is defined to include the following:

- Lighting intended to reduce the risk (real or perceived) of personal attack. Such lighting is usually provided where the risk of such attack is perceived as high. Reducing the risk is achieved by providing a level of lighting adequate to allow the perception and identification of other persons in the area at a distance sufficient to allow evasive action, by ensuring that there are no dark spots or shadows in which potential attackers might hide, and by illuminating potential escape routes.[5]
- Lighting intended to discourage intruders, vandals, or burglars. This is generally applied in commercial and industrial areas, but sometimes appears at institutions such as schools or large housing projects in high crime areas. Areas to be secured are illuminated so that the intruder is extremely visible to either occupants of the structures or observers from surrounding areas. This may be counter-productive if there is no one around to observe—the security lighting may simply provide light for the intruder to do what he/she wishes to do.
- Lighting intended to facilitate active surveillance of an area by designated surveillance personnel or by remote camera. To be effective as a deterrent, it must be evident that surveillance is actually occurring.

The very nature of security lighting brings it into conflict with concerns about excessive illumination levels, glare, color, skyglow, and energy conservation/cost.

Security Lighting Issues

EXCESSIVE LIGHTING LEVELS:
There is a prevailing belief regarding security lighting that brighter is better. The limited available research on this subject suggests that this is not the case. A study of perceptions of observers of high-risk urban streets indicates that the perception of security increases as lighting levels increase up to an average illumination level of approximately 3.0 foot-candles, beyond which there is little sense of additional security.[6] In addition, lighting levels significantly higher than those of surrounding areas may actually limit visibility into the area from outside until the eye is able to adapt to the contrast. This reduces the effectiveness of potential surveillance. Placing upper limits on security lighting levels may actually increase its effectiveness.

Security lighting generally includes illumination of both horizontal (grade) and vertical (wall) surfaces. Limitations should be placed on both. In addition, it is appropriate to limit the amount and location of vertical surface that can be illuminated, since it is only necessary to illuminate that portion in front of which an intruder might be walking or standing.

GLARE:
The primary cause of glare is the use of lighting fixtures that are improperly located, mounted, or shielded, so that the source of light (lamp or lens) is directly visible from adjacent roads, walkways, or structures. General floodlight fixtures are frequently used which illuminate large areas of lawn, and which often shine directly onto nearby roads, walkways, and other properties. Security lighting systems should be designed so that light is directed only toward the area to be secured, and proper fixtures and shielding should be used to prevent glare on surrounding areas.

COLOR:
The need for energy efficiency in security lighting has resulted in the common use of HPS lamps, which generate an orange color. Light sources that render color poorly may prevent accurate identification of intruders. In many places, such as remote locations or in industrial areas, color rendering may not be particularly important. In other places, such as village centers, downtown commercial areas, and other prominent retail areas, the desired visual qualities may suggest that white light is important. The use of lighting districts can reflect this variation by specifying different minimum CRI levels for security lighting in different areas.

SKYGLOW:

Security lighting, because of the tendency toward high illumination levels and the use of unshielded fixtures, directs a great deal of illumination toward the sky—either directly or as reflected light. Limiting illumination levels and requiring appropriate shielding will do much to correct this problem.

ENERGY CONSERVATION/COST:

The tendency toward very high illumination levels in combination with the general practice of leaving security lighting on continuously during dark periods means that energy efficiency is very important. While the use of HPS lamps is efficient, further energy savings can be achieved by installing sensors that allow the lights to be out unless activated by an intruder. This has the added advantage that surveillance personnel know they should pay particular attention to an area where the lights are on.

What follows are prototypical regulations for security lighting, intended to become a sub-section of an outdoor lighting section of local zoning regulations. The approach includes the concept of lighting districts with somewhat different threshold levels intended to achieve different visual objectives.

SAMPLE ZONING LANGUAGE

H. Security Lighting:

The purpose of and need for security lighting (i.e. lighting for safety of persons and property) must be demonstrated as part of an overall security plan which includes at least illumination, surveillance, and response, and which delineates the area to be illuminated for security purposes. To the extent that the designated area is illuminated for other purposes, independent security lighting installations will be discouraged.

i. In addition to the application materials set forth in the general provisions of this section, applications for security lighting installations shall include a written description of the need for and purposes of the security lighting, a site plan showing the area to be secured and the location of all security lighting fixtures, specifications of all fixtures, the horizontal and vertical angles in which light will be directed, and adequate cross-sections showing how light will be directed only onto the area to be secured.

Excellent visibility for security surveillance is provided at this industrial park facility by pole-mounted cut-off fixtures and interior doorway lights. *(PHOTO: GARY CLAYTON HALL)*

SAMPLE ZONING LANGUAGE

ii. All security lighting fixtures shall be shielded and aimed so that illumination is directed only to the designated area and not cast on other areas. In no case shall lighting be directed above a horizontal plane through the top of the lighting fixture, and the fixture shall include shields that prevent the light source or lens from being visible from adjacent properties and roadways. The use of general flood-lighting fixtures shall be discouraged.

iii. Security lighting may illuminate vertical surfaces (e.g. building facades and walls) up to a level eight (8) feet above grade or eight (8) feet above the bottoms of doorways or entries, whichever is greater.

iv. Security lighting fixtures may be mounted on poles located no more than ten (10) feet from the perimeter of the designated secure area.

v. Security lights intended to illuminate a perimeter (such as a fence line) shall include motion sensors and be designed to be off unless triggered by an intruder located within five (5) feet of the perimeter.

vi. Security lighting standards in the various lighting districts are as shown in Table 12.

vii. Security lighting in low-density residential and rural areas: Security lighting shall be allowed in low-density residential and rural areas only if unusual hazardous conditions make it necessary. In such cases, indirect and reflected lighting techniques shall be used to provide soft lighting under canopies, entry porches, or soffits. Lighting levels shall not exceed the standards established for the next higher density residential area.

TABLE 12: SECURITY LIGHTING STANDARDS

	District 1 Industrial/ Commercial	District 2 Town Center	District 3 High-Density Residential	District 4 Rural
Mounting Height (Maximum)*	25 ft	20 ft	20 ft	Discouraged
Average Horizontal Illumination Level on Ground	No more than 1.5 foot-candles	No more than 1.0 foot-candle	No more than 0.5 foot-candle	Discouraged
Average Illumination Level on Vertical Surface	No more than 1.5 foot-candles	No more than 1.0 foot-candle	No more than 0.5 foot-candle	Discouraged
Minimum CRI **	20	65	70	Discouraged

* Mounting height is the vertical distance between the surface being illuminated and the bottom of the lighting fixture.
** CRI is the Color Rendering Index.

ILLUMINATION OF BUILDING FACADES

The illumination of building facades, if done well, can add a great deal to the overall visual qualities of an area. The facades of public or symbolic (e.g. religious) buildings, if subtly illuminated, can become major features of traditional villages and town centers. Historic downtown areas can be made even more interesting by illuminating architectural highlights of building facades. On the other hand, lighting unexceptional buildings can have a detrimental effect, as can facade lighting that is poorly designed or implemented. Lighting levels on facades may be so high that the entire facade becomes a major source of reflected light much brighter than the surrounding area. Light fixtures may be located and aimed so that they cause glare on nearby properties and roadways, or direct significant amounts of light toward the sky. Just as is the case for security lighting, it is important that facade lighting be limited to places where it is justified, and that it be done according to a well-developed plan that minimizes negative impacts.

In small towns and rural areas it may be appropriate to limit facade lighting to public buildings, structures with strong symbolic importance to the community, or significant historic structures with architectural merit. In a densely developed downtown area, it may be appropriate to allow more structures to be illuminated if doing so adds to the overall visual qualities of the area, and does not generate negative impacts such as glare, skyglow, or excessive general levels of illumination. In any case, it may be appropriate to require that facade lighting be turned off after 11:00 p.m. (or some other appropriate hour) when people are not likely to appreciate the lighting effects.

In some cases it may be appropriate to illuminate landscaping features, but only if the lighting is part of an overall landscaping design and if there is a well-developed plan that demonstrates that the lighting will not contribute excessive lighting, glare, or skyglow.

Chapter 22 of the IESNA *Lighting Handbook*[7] is devoted entirely to exterior lighting and provides some general design principles. Chapter 22 also includes a good discussion of "softscape lighting," which addresses lighting of landscape features.

What follows is some suggested language which might become a subsection of an outdoor lighting section of municipal zoning regulations. The general concept might be modified to reflect slightly different needs of different neighborhoods or lighting districts.

SAMPLE ZONING LANGUAGE

I. Lighting of Building Facades and Landscaping:
With the exception of structures having exceptional symbolic (i.e. churches and/or public buildings) or historic significance in the community, exterior building facades shall not be illuminated. When buildings having symbolic or historic significance are to be illuminated, a design for the illumination shall be approved by the Planning Commission and the following provisions shall be met:

i. The maximum illumination on any vertical surface or angular roof surface shall not exceed 5.0 foot-candles.

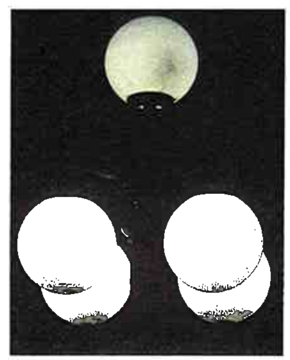
ii. Lighting fixtures shall be carefully located, aimed, and shielded so that light is directed only onto the building facade. Lighting fixtures shall not be directed toward adjacent streets or roads.

iii. Lighting fixtures mounted on the building and designed to "wash" the facade with light are preferred.

iv. To the extent practicable, lighting fixtures shall be directed downward (i.e. below the horizontal) rather than upward.

v. When landscaping is to be illuminated, the Commission shall first approve a landscape lighting plan that presents the purpose and objective of the lighting, shows the location of all lighting fixtures and what landscaping each is to illuminate, and demonstrates that the installation will not generate excessive light levels, cause glare, or direct light beyond the landscaping into the night sky.

Indirect lighting on the facade of this commercial building provides an inviting appearance for evening shoppers and security light for after hours. *(PHOTO: GARY CLAYTON HALL)*



Regulations should allow for the use of historic and decorative fixtures.

ILLUMINATED SIGNS

Illuminated signs are one way in which light is used for advertising. Externally illuminated signs may be illuminated too brightly so that the reflection from the sign surface causes glare and illuminates surrounding areas. The lights may be improperly aimed and/or shielded so that they radiate directly into the eyes of passing drivers or pedestrians, or onto adjacent properties. Internally illuminated signs may be too bright and create similar problems.

Local sign regulations can include standards which limit the vertical illuminance of externally illuminated sign surfaces. In addition, standards can be established requiring the lights to be properly aimed and shielded. This will probably require the submission of sign lighting designs and specifications.

Sign lights should be carefully located and aimed to prevent glare. *(PHOTO: GARY CLAYTON HALL)*

Internally lit signs, though not suited to all locations, can be artfully designed. *(PHOTO: GARY CLAYTON HALL)*

Internally illuminated signs having light lettering on a dark background are generally less obtrusive and more effective than those with dark lettering on a light background. The lightness or darkness is determined largely by the light transmission coefficients of the material used (manufacturers can provide these data), and, of course, the internal light source (which is usually incandescent or fluorescent). Municipalities can establish sign lighting standards that: a) require light lettering on a dark background; b) specify a range of transmission coefficients for lettering and background; and c) provide upper limits to the number and wattage of light sources.

The following language is suggested for inclusion in a local sign ordinance, if there is one, or inclusion in the sign section of local zoning regulations. There should also be a brief provision in the outdoor lighting section of the zoning regulations noting that illuminated signs are subject to the provisions set forth in the sign section.

SAMPLE ZONING LANGUAGE

1. Illuminated Signs:
Signs may be illuminated only during those hours that the business being advertised is open for business. It is the intent of this section to allow illuminated signs but to ensure that they do not create glare or unduly illuminate the surrounding area. The applicant shall provide the Planning Commission with sufficient technical and design information to demonstrate that the following provisions are met.

A. Externally Illuminated Signs:

i. The average level of illumination on the vertical surface of the sign shall not exceed 3.0 foot-candles, and the uniformity ratio (the ratio of average to minimum illumination) shall not exceed 2:1.

ii. Lighting fixtures illuminating signs shall be carefully located, aimed, and shielded so that light is directed only onto the sign facade. Lighting fixtures shall not be aimed toward adjacent streets, roads, or properties.

iii. Light fixtures illuminating signs shall be of a type such that the light source (bulb) is not directly visible from adjacent streets, roads, or properties.

iv. To the extent practicable, fixtures used to illuminate signs shall be top mounted and directed downward (i.e. below the horizontal).

B. Internally Illuminated Signs: [Note: It is possible to prohibit internally illuminated signs. If that is done, this section is not necessary.] Internally illuminated signs are allowed only in (specify zoning districts or lighting districts). In order to prevent internally illuminated signs from becoming light fixtures in their own right, it is the intent of this section that such signs consist of light lettering or symbols on a dark background. The lightness or darkness is a function of the luminous transmittance of the translucent surface material, and the light source. The higher the luminous transmittance, the lighter the color.

i. The lettering or symbols shall constitute no more than forty (40) percent of the surface area of the sign.

ii. The luminous transmittance for the lettering or symbols shall not exceed thirty-five (35) percent.

iii. The luminous transmittance for the background portion of the sign shall not exceed fifteen (15) percent.

iv. Light sources shall be fluorescent tubes, spaced at least twelve (12) inches on center, mounted at least 3.5 inches from the translucent surface material.

LIGHTING OF WALKWAYS AND PARK AREAS

In some cases it may be desirable to illuminate walkways (or bikeways) and portions of parks that are to be used after dark. These areas should be illuminated sufficiently to allow identification of hazards on the walkway surface. The IESNA *Lighting Handbook*[8] suggests an average horizontal level of 0.5 foot-candles at grade, and this should be seen as an upper limit to the average level of illumination. In addition, identification of other pedestrians requires illumination on the vertical plane of 0.3 to 0.5 foot-candles at a height of about 5 feet. Low-level lighting should extend several feet on either side of the walkway or path in order to provide good definition of path edges. Lighting should be provided at specific hazardous locations such as sharp turns and intersections.

In order to prevent glare and skyglow, fixtures should be cut-off or shielded and mounted relatively low at a pedestrian scale. Lights of less than 1,000 initial lumens might be acceptable, even if they are not cut-off or shielded fixtures. Walkways along streets may be illuminated by street lights, although small fixtures at low mounting heights might make the area seem more pedestrian friendly.

In many cases, parks and walkways are provided as public facilities, and may not be subject to zoning requirements. If this is the case, standards may be included in the public works specifications.

The following language is suggested for inclusion either in municipal public works specifications or in an outdoor lighting section of local zoning regulations.

SAMPLE ZONING LANGUAGE

J. Lighting of Walkways/Bikeways and Parks:
Where special lighting is to be provided for walkways, bikeways, or parks, the following requirements shall apply.

i. The walkway, pathway, or ground area shall be illuminated to a level of at least 0.3 foot-candles and no more than 0.5 foot-candles.

ii. The vertical illumination levels at a height of five (5) feet above grade shall be at least 0.3 and no more than 0.5 foot-candles.

iii. Lighting fixtures shall be designed to direct light downward, and light sources shall have an initial output of no more than 1000 lumens.

iv. In general, lighting shall be consistent with the guidelines presented in the IESNA *Lighting Handbook*, 8th Edition.

[1] *Lighting Handbook*, Illuminating Engineering Society of North America, 8th Edition.

[2] Telephone conversation with Will Rykert, University of Louisville, January 5, 1996.

[3] *Lighting Handbook*, op. cit., pg. 471.

[4] *Lighting Handbook*, op. cit., pp. 723 - 749.

[5] "Lights Out," Russell P. Leslie, *Progressive Architecture*, November, 1995, pp. 80 - 83.

[6] "Lights Out," op. cit.

[7] *Lighting Handbook*, op. cit., pg. 711.

[8] *Lighting Handbook*, op. cit., pg. 720.

GLOSSARY

Candela - A measure of luminous intensity in a certain direction. Useful in determining how much light is shining out of a fixture and in what direction.

Candela Diagram - Diagram of light power produced by a source and the value of luminous intensity in given directions. A picture of how much light is shining out of a fixture and in what direction.

Color Rendering Index (CRI) - A measurement of the amount of color shift that objects undergo when lighted by a light source as compared with the color of those same objects when seen under a reference light source of comparable color temperature. CRI values generally range from 0 to 100.

Cones - Photoreceptor cells located in the fovea of the retina and responsible for color (photopic) vision.

Contrast - The ratio of the luminance of an object to that of its immediate background.

Cut-off Angle - The angle between the vertical axis of a luminaire and the first line of sight (of a luminaire) at which the light source is no longer visible.

Efficacy - A measurement of the ratio of light produced by a light source to the electrical power used to produce that quantity of light, expressed in lumens per watt. Efficacy is an important determinant of energy efficiency in lighting equipment.

Efficiency - See efficacy; also, refer to luminaire efficiency.

Floodlight - A light fixture designed to light a scene or object to a luminance greater than its surroundings. The beam spread of floodlights may range from narrow field angles of 10 degrees to wide angles (more than 100 degrees).

Fluorescent Lamp - A lamp that produces light by means of an electric arc that excites a phosphor coating deposited on the inside of the glass bulb. Compact fluorescents are in this category.

Flush Mounted or Recessed Luminaire - A luminaire that is mounted above the ceiling (or behind a wall or other surface) with the opening of the luminaire level with the surface.

Foot-candle - A measure of light falling on a given surface. One foot-candle is equal to the amount of light generated by one candle shining on a square foot surface one foot away. Foot-candles can be measured both horizontally and vertically by a foot-candle or light "meter." Light meters are readily available at a cost of a few hundred dollars.

Footlamberts - A measure of brightness from a surface. Or "the uniform luminance of a perfectly diffusing surface emitting or reflecting light at the rate of one lumen per square foot." The equipment required to measure luminance in footlamberts is not readily available.

Glare, Direct - Glare resulting from insufficiently shielded light sources or areas of excessive luminance within the field of view.

Glare, Disability - The effect of stray light in the eye whereby visibility and visual performance are reduced.

Glare, Discomfort - Glare producing discomfort. It does not necessarily interfere with visual performance or visibility.

HID (High Intensity Discharge) Lamp - A lamp that generates large quantities of light with electric arches through small tubes. The tubes also contain phosphors that generate additional light output and color.

Illuminance - The amount of light falling on a surface—measured in lux (lx) or foot-candles (fc).

Illuminating Engineering Society of North America (IESNA) - An association of professionals in the field of lighting and related professions. Its membership is made up of engineers, architects, designers, manufacturers, contractors, distributors, utility personnel educators, students, and scientists. This forum, organized for the exchange of ideas and information, has been in existence for over 80 years.

Iso-foot-candle line - A line plotted on a set of coordinates to show all points on a surface where equal illuminances occur. Also called isodiagrams. Drawn as single line circular patterns or, more commonly, computer generated spot readings in a grid pattern on a site plan. In both cases the intent of the diagram is to show the level and evenness of a lighting design. Lighting designers and manufacturers can easily generate such diagrams to show how light fixtures will perform when installed on a given site.

Lamp - A bulb. An outer glass envelope and metal base enclosing a filament or arctube and electrodes.

Lens - Glass or plastic element used in luminaires to change the direction and control the distribution of light rays; also, that part of the eye which focuses light rays—the images are received on the retina.

Light Meter - A device that measures the amount of light energy falling on a given surface.

Lighting Plan - A plan used for an approval process or construction indicating all site improvements and the number, location, type of fixture, and manufacturer's data on all the proposed lighting, both pole and building mounted.

Luminaire - A complete lighting unit, consisting of a lamp(s), reflector, refractor, or lens, wiring, and sockets. Often referred to as a "fixture."

Luminaire efficiency - The ratio of lumens exiting a luminaire to the total lumens emitted by that luminaire's lamps; expressed as a percentage.

Luminance - What we commonly call brightness or the light coming from a surface. The proper term is "photometric brightness." Luminance is composed of the intensity of light striking an object or surface and the amount of that light reflected back toward the eye. Luminance is measured in footlamberts. All surfaces have some reflecting qualities and therefore have luminance, light surfaces being more reflective than dark surfaces. The luminance of asphalt pavement and the moon can both be measured.

Lux - A measurement of light falling on a given surface. A metric measurement that is the equivalent of the amount of light generated by one candle falling on a square meter surface one meter away. For an approximate conversion from lux to foot-candles, divide by 10.

Lumen - A measure of light energy generated by a light source. Manufacturers list lumen ratings for all their lamps. Average lumen ratings are slightly lower than initial lumen ratings.

Mounting Height - The vertical distance between the surface to be illuminated and the bottom of the light source.

Photopic Vision - Vision produced by the cone receptors in the retina. Responsible for color vision.

Retina - A membrane lining the posterior part of the inside of the eye. It is composed of photoreceptors (cones and rods) that are sensitive to light, and nerve cells that transmit to the optic nerve the responses of the receptor elements.

Rods - Photoreceptor cells located in the retina, very responsive to levels of light.

Scotopic Vision - Vision produced by the eye's rod receptors. Enables the eye to discern black and white contrast. Also referred to as night vision.

Uniformity Ratio - The ratio of average illumination to minimum illumination.

Vertical Foot-candles - A measurement of illuminance intensity on a vertical surface, such as a wall or billboard.

Watt (w) - A unit used to measure electric power. One watt equals one joule/second.

BIBLIOGRAPHY

Berman, S.M. et al. "An Objective Measure of Discomfort Glare." Journal of the Illuminating Engineering Society of North America, Summer 1994.

Berubé, Henri. "Security Lighting: A New Approach." A paper presented at "Citylight '94: New Challenges in Urban Lighting," Toronto, Ontario, Canada, 12 August 1994.

"Blinded by the Light: 'Dark Sky' Proponents Say We've Lost Night's Glory." The Boston Globe, 30 November 1992, p.1.

Boyce, Peter R. "Illuminance Selection Based on Visual Performance—and Other Fairy Stories." In the Proceedings of the 1995 Illuminating Engineering Society of North America Annual Conference, 30 July 1995, pp. 562-577.

______."Site, Perception and Human Response in Street Lighting." A paper presented at "Citylight '94: New Challenges in Urban Lighting," Toronto, Ontario, Canada, 12 August 1994.

"Europe at Night Poster, Etc." International Dark-Sky Association Newsletter, 24 May 1995.

Illuminating Engineering Society of North America. Lighting Handbook: Reference and Application, 8th ed. (edited by M.S. Rea, New York: Illuminating Engineering Society of North America, 1993).

"Lighting and Crime." Information Sheet 51, Ed. No. 1, Tucson, AZ: International Dark-Sky Association, April 1992.

Hawke, Lt. Bob, So. Burlington, Vermont Police Department. Interview by Debra L. Sachs, 4 January 1996.

Leslie, Russell. "Lights Out," Progressive Architecture, November 1995, 80-83.

Nuckolls, James L. Interior Lighting for Environmental Designers, 2nd ed. John Wiley & Sons, Chapter 2, pp. 12-17.

Rykert, Will, Director, National Crime Prevention Institute, University of Louisville, KY. Interview by Debra L. Sachs, 5 January 1996.

Slayton, David, Vermont Department of Banking and Insurance. Interview by Debra L. Sachs, 2 January 1996.

"The Moldcast Method," Manufacturer's brochure. Prescolite, USI, 1988.

Tien, James M. "Improving City Streets for Use at Night," Lighting Design & Application, June 1974, pp. 22-30.

Vermont Comprehensive Energy Plan, 1991, Vermont Department of Public Service, p. 37.

"Why We Don't Like the 175 Watt Mercury Fixture." Information Sheet 3, Tucson, AZ: International Dark-Sky Association.

Upgren, Arthur R. "Starless Night," Utne Reader, March-April 1996.