LIGHTING FOR

SAFETY AND SECURITY
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INTRODUCTION

This guide has been prepared to give nontechnical readers important information about lighting and its ability to enhance human security and safety. Although some of the discussion relates to indoor lighting, most of it focuses on outdoor lighting, because outdoor lighting is the most effective and least expensive form of security. Unlike security personnel, closed-circuit television, sensors and detectors, and other security systems and devices, electric illumination is highly visible. Just a single light can in some cases be seen miles away. Up close, a few strategically located fixtures can be enough to discourage would-be vandals, thieves, or muggers. These are the kinds of people who need darkness. Lighting denies it to them. Facade lighting can make it impossible to avoid detection near windows and doors. Parking lot lighting can make auto break-ins unwise.

Effective security lighting is a deterrent. It creates a threat to those who would threaten others' property.

What is "security lighting"? Does it use special lamps or fixtures? Special poles? No. It is lighting which uses conventional equipment and materials to achieve a given effect. Security. But security is seldom the only effect. Outdoor lighting can also have an impact on safety, appearances, the extent to which a given facility or area can be readily identified, and other factors. These other effects occur whether or not they are intended. If they are not intended, the results will probably be negative. On the other hand, when all the various effects are considered in design, chances are they can be accomplished well to derive far more value from outdoor lighting.

THE FUNCTIONS OF OUTDOOR LIGHTING

Outdoor lighting provides security at night by denying burglars, vandals, muggers, and other "perpetrators" the shroud of darkness they need to pursue their goals. Safety is something else effective outdoor lighting can deliver, and not just in the sense that an area can be rid of muggers or that people can see others far enough ahead to take evasive actions when merited. Safety also means being able to see steps in a path leading from a parking lot to a building. It can also mean walkway illumination such that puddles left by a rain storm can be avoided, along with fallen slippery leaves and branches. Safety can also be improved when drivers are better able to see pedestrians or other vehicles while backing a car out of a parking space. A lighting system designed to provide security can be designed to provide safety at the same time.

Identification is another function of effective outdoor lighting, because it can cause a building or other structure to stand out. Facade lighting can be used to do this by illuminating windows, doorways, and other potential entrances. This makes it far easier to see someone attempting an unlawful entry, thus establishing both a preventive and a means for catching someone in the act or at least for providing effective identification. Facade lighting can also result in tell-tale shadows being cast when someone who should not be on the grounds walks between the luminaires — lighting fixtures — and the facade of the illuminated building. Identification is also enhanced by lighting that creates different color effects, so one building is easily differentiated from another or to indicate different pathways or walkways, to help eliminate the confusion or disorientation that can occur after the sun goes down. All outdoor security lighting provides some identification at night. How much it provides, and how well, depends on how effectively the function is considered in design.
Environment integration is an outdoor lighting effect that connotes lighting's ability to act as a unifying force, typically among separate buildings that do not appear to work together during the day. For example, many college campuses are showcases for the work of many architects active in different periods. In some cases the variety can create disharmony during the day. At night, when a common system of lighting is applied, all can be brought together into an instantly recognizable whole. The sense of security people also derive from such lighting is no accident. In fact, security may be the primary purpose of lighting that also integrates an environment.

Beautification is a particularly pronounced effect of outdoor lighting. Effective designers can use electric illumination much as artists use paint, to highlight selected portions of man-made and natural elements and thereby create appearances impossible to achieve during the day. It is for this reason that many who have been to our nation's capital report that it is far more elegant at night, because lighting is used to call people's attention only to the most important and most beautiful. It is used, too, to emphasize certain colors or textures, shapes or forms. In a sense, darkness is used as well, to eliminate clutter and some of the less graceful aspects of urban settings. But make no mistake about it: The same lighting used to beautify our environment can also provide security, safety, and the many other benefits of effective lighting.

Attraction also is a function of effective outdoor lighting, often coming as a byproduct of other effects. In the case of a motel, for example, lighting can help attract a potential patron by communicating that the facility is secure, and by making the establishment visible, identifiable, and pleasant to look at. For similar reasons, lighting can boost retail sales by attracting shoppers to safe, secure, and inviting shops and centers at night.

Recreation is yet another aspect of outdoor lighting, permitting use of areas that would otherwise go unused at night. At an apartment complex, for example, lighting can permit people to use large grassy areas, be it for games such as volleyball, badminton, or croquet, or just for informal get-togethers. And the same light which opens up the area also helps make that area and others more secure.

As valuable as the many effects of lighting are, many remain unattained because people forget that more than security is involved. Don't make the same mistake. The same lighting needed to provide security and safety can be used to provide identification, environment integration, beautification, attraction, and even recreation. The value derived from these additional benefits can be substantial; many times greater than whatever additional cost — if any — is invested to achieve them.
Economic analysis is as valid for evaluating security lighting alternatives as it is for evaluating any other investment. The key to making an effective analysis is considering all the major factors. Too often decisions are based on energy considerations alone. This can be a serious mistake, especially so since the system which consumes the least amount of energy may be incapable of achieving the purpose for which it was installed.

Lighting is not installed to consume energy. It is installed to fulfill security, safety, identification, attraction, and other needs. Each of these has a value connected with it, at least to the extent that one can prevent a costly loss. The best lighting system is the one that creates the most value.

The following discussion of lighting's many bottom-line benefits is comprehensive. Identify those which apply to your situation. Select a lighting system that can help you fulfill all your objectives, not just those associated with light.

FEWER SECURITY-RELATED PROBLEMS

Effective security lighting can help prevent a number of security-related problems by displacing the activity that gives rise to these problems. After all, why should those who want to perform an idle act of vandalism do so in a well-illuminated area — where they may be detected and identified — as opposed to an area hidden in darkness? The direct problems that can be avoided include vandalism: spray painting of walls, breaking of windows, destruction of shrubs, knocking over containers of different types, and otherwise making an embarrassing mess. Effecting repairs can be aggravating, time consuming, and costly. Many owners would rather not report the minor damage to an insurer for fear of higher premiums or policy cancellation. The ugliness must be cleaned quickly in those circumstances where it could otherwise affect business or create a negative image; possibly one which says, “This area is dangerous.”

As those with experience will relate, vandalism may be the least serious problem. Others include break-ins and assaults. Assaults may lead to a legal action in some cases, a problem discussed below. Break-ins can lead to significant losses when the material taken is irreplaceable or uninsured, or when it consists of data stored in a computer. The value of such losses can be huge. A number of security procedures and services can be used to prevent them. These include security patrols, sensors of all types, and closed-circuit TV (CCTV), among others. Of them all, however, only lighting can be seen from a distance to create a significant deterrent effect. That does not mean that you should rely on lighting only. But it does point out the danger of underrelying on lighting. Electric illumination is among the least costly of all security measures and is also the most effective.
MAINTENANCE OF IMAGE

Facilities that are well-illuminated not only look good; they will often gain a reputation for being safe and secure. And deservedly so. High levels of illumination are for many people synonymous with safety and security. But think about the downside. Whenever security breaks down — when someone is assaulted in a parking lot or on a walkway between a parking lot and a building — there always is a potential for damaging publicity. While lighting cannot under any circumstances guarantee security for an area, more lighting almost always is better lighting insofar as security is concerned. To the extent that effective lighting can make any unfortunate nighttime occurrence less likely, one has that much more of an assurance that a facility's image will not be tarnished.

AVOIDANCE OF LEGAL PROBLEMS

Sometimes an unfortunate event goes virtually unnoticed by the news media until an injured party institutes a lawsuit whose size seems to be newsworthy. No matter that a $25 million claim may be settled for $1,000. The claim can make headlines while the settlement goes unnoticed. The real legal problems are not those associated with the negative publicity, however; those are image problems. The legal problems are those associated with cost. Insurance almost never covers all the costs. A deductible usually must be satisfied and, until it is, one has to pay attorneys, expert witnesses, and private investigators. There is also the matter of time lost to review files, answer interrogatories, participate in depositions, and confer with attorneys. In fact, having to deal with a claim resulting from an assault or accident of some kind can easily create an unreimbursable cost of $25,000 or more, not including the financial impact of the negative publicity that might result. To the extent that effective security lighting can make such claims unlikely, it can save tremendous amounts of money. And to the extent that an owner can demonstrate concern through investing in effective security lighting, it makes claims that much easier to defend. The real problems can arise when it is argued that an owner was negligent for failure to provide more or better lighting, or to maintain the existing system well.

REDUCED SECURITY COSTS

Many facilities employ a variety of security measures. On college campuses, for example, it is common to employ lighting, CCTV, and security patrols. By increasing reliance on any one of these, it often is possible to reduce reliance on others. Effective measures that are comparatively low in cost are those that merit emphasis. In security, the most expensive tool usually is personnel and the least expensive is usually lighting. Documented cases show how reliance on more and better lighting can permit less reliance on security forces to create significant savings. Lighting can do this, without compromising safety, because of its deterrent aspects and because it permits security personnel to see faster and more accurately. In many cases lighting can also attract more people to illuminated areas, something else which in and of itself can enhance security.

MORE USE FROM EXISTING AREAS

Particularly in the case of campus-type layouts — e.g., those of colleges, universities, and multifamily residential communities — lighting can be used to make areas usable at night. For example, security lighting concerns may suggest that lighting should be installed in a certain area to provide 0.5 footcandles of illumination. If more lighting is installed, however, that area could be used at night to gain lighting's recreation effects. Particularly in areas where there is strong competition, any such advantage can be of great value. Besides, with effective lighting controls, it is possible to provide the additional light only when it can be used, i.e., it would be reduced after midnight and could be kept relatively low when the weather is unpleasant.
CURBSIDE APPEAL

Seeing people enjoying a facility's grounds at night usually can enhance the facility's curbside appeal. Curbside appeal also is improved by lighting that makes a building look better and/or that attains environment integration, while also creating a sense of safety and security. Increasing curbside appeal can create other benefits, too, such as more shopping for retail facilities or more rentals for apartment communities.

MORE RETAIL SALES

Because more people work during the day, more shopping is being done at night. Because America's population is aging, more shoppers are older citizens. While security is a concern to all, it is of particular importance to older people because they are the ones who are least able to run or to defend themselves. Effective lighting creates a sense of security which in itself is an important consideration to shoppers. It also provides safety, attraction, and identification. Precisely because of these benefits, National Lighting Bureau case histories point out, better security lighting can attract more shoppers and thus contribute directly to more retail sales and profits.

Also consider those establishments which display their wares out of doors, as is the case with an automobile sales center. Effective security lighting can and should also serve as effective display lighting, to add sparkle to the vehicles on the grounds. Particularly for those facilities located on somewhat busy roads, the security lighting system alone may be able to initiate sales to passers-by who are able to get a quick glimpse of the car of their dreams.

In some cases the beautification aspect of security lighting also can result in more sales. This can be the case when an apartment community is offering units. Beautiful outdoor lighting enhances the appearance and provides obvious safety, something that many people are looking for. The fact that this lighting also supports later hours for the leasing office helps mesh sales activities with many prospects' lifestyles and what they want from a lifestyle. In essence, as more people begin to rely on the nighttime to take care of personal business, effective lighting can help determine where that personal business will be conducted.

CASE IN POINT

New Lighting Revives Shopping Mall

Carmillus, NY — Inadequate lighting in the parking lot was creating a serious problem for the owners of Fairmount Fair Mall, a major retail facility located in a suburb of Syracuse. Shoppers were concerned about their cars being broken into. Both pedestrians and drivers said they were being made uncomfortable by glare. Neighboring land owners were complaining about "light trespass." Convinced that improvements were needed, the mall's manager conducted a survey among shoppers to determine what they liked and disliked about the lighting at Fairmount and other centers they patronized.

After analyzing survey responses, management decided to install a new outdoor lighting system that relied on metal halide lamps, combining good color-rendering properties with high efficiency and relatively long life. Energy was not a major issue. In fact, based on the value of energy savings alone, the new system would have to have operated more than 400 years in order to pay for itself. Payback was achieved in months, however, because of the other benefits derived.

A principal concern was reducing vandalism, especially during the Christmas season when the parking lot was filled with cars. During the first Christmas under the new lighting, vandalism was almost eliminated. And because the lighting provided such effective security, it was possible to reduce the extent of security patrols, saving $5,000 per year. The new lighting also permitted faster snow removal in the parking lot, saving another $1,500 annually. Because the lighting also called shoppers' and prospective shoppers' attention to the new parking area safety and security, traffic and sales increased, generating $90,000 annually in additional rent for the mall's owner, and about $2.5 million in increased sales for retailers.
HIGHER OCCUPANCY RATES/LESS TURNOVER

While better outdoor lighting will not necessarily increase occupancy rates or reduce turnover, it can be a significant factor in preventing problems in these key areas. Stated simply, effective lighting can help assure that people do not leave multifamily residential or commercial complex because of a lack of effective security lighting. To the extent that security lighting achieves other goals — beautification, environment integration, and so on — it can help maintain the highly positive attitudes needed to maintain high occupancy rates.

BEAUTIFICATION

As already noted, many if not most buildings and other structures can appear more handsome at night because lighting can be used to select what will and will not be seen and how the visible portions will be perceived. Beauty is not limited to buildings or other manmade structures, of course. Lighting can be integrated with grounds to create special effects on flowers, shrubs, and trees. As beautiful as this lighting can be, it can also enhance security. It can be used, too, for identification and attraction such that sales or occupancy are increased. In essence, something that is more beautiful is almost always more valuable. The cost of attaining beauty with light often is a tiny fraction of the value that light can create.

ENHANCED BUILDING VALUE

Shopping centers that do more business usually have higher occupancy rates, derive higher rents, and are more valuable and more easily sold. Apartment buildings that enjoy higher occupancy rates and experience less turnover also are more valuable and more saleable. Office buildings which are well-known as prestigious addresses often have higher occupancy rates and more value than otherwise. Effective outdoor lighting systems can be important factors that contribute to greater value. The value added through better lighting can easily be ten, twenty, one hundred, or more times the cost of the new or improved lighting.
INSURANCE ADVANTAGES

Most building owners are familiar with the myriad insurance problems that have gripped the United States since the mid-1980s. Insurance has been difficult to obtain at times, very costly, and — more often than not — less comprehensive in coverage. Effective security lighting helps minimize risks associated with accidents and assaults, reducing the likelihood that insurance will have to be called upon to satisfy a claim. Furthermore, by pointing out to an agent or underwriter the effectiveness of lighting, and one’s investment in it, it may be possible to obtain coverage when some others cannot, and/or to obtain coverage at more favorable rates. As most risk management professionals will say, however, risk avoidance would be a far more effective option than insurance were either — but not both — available.

IMPROVED MORALE

Particularly in those instances where a building is located in something other than a “totally safe neighborhood,” or when there have been problems in a parking lot or around a structure, the installation of security lighting — or enhancement of what already exists — can improve employee morale. In essence, effective security lighting can stand as an obvious statement of management’s commitment to the safety and well-being of employees.

Note, too, that more than employee morale is involved. In cases cited in a federal study, installation of effective security lighting in inner city areas resulted in more police reports and apprehensions. It was said that one cause of this was better visibility; criminal activities could be seen better and perpetrators could be described more accurately. It was also noted that the installation of lighting was taken by some residents as a demonstration of “city hall’s” concern, thus encouraging them to reciprocate by reporting what they had seen.

INCREASED PRODUCTION

As the United States economy becomes steadily more service-based, working late at the office has become part of many persons’ normal routines. Continually more of these persons are women. As equal as they may be in a work setting, outdoors at night they can become victims of attackers who are larger and stronger. For many, inadequate lighting in a parking lot — indoors or outside — can mean a somewhat fearful conclusion to a long day’s work. For some it can encourage leaving the office earlier than otherwise or it might mean less productivity as the day wears on, due to mounting apprehension. Just as installation of new security lighting or enhancement of an existing system can improve morale, so can it reduce anxiety and thus support later working hours and a relaxation of some of the stress that might otherwise prevail. As an example of the impact involved, consider a situation where the improvement consists of installing eight 400-watt high-pressure sodium (HPS) fixtures that are operated an average of 42 hours each week. If the installation encouraged just one $20,000-per-year employee to put in an average of 15 extra minutes each day, the annual value derived from that extra work would exceed the annual cost of the energy consumed to operate the lighting, assuming an average cost of $0.08 per kilowatt-hour (kWh).
MORE PROFITABILITY

When profit-making organizations invest in effective security lighting, they do so to cut actual or prospective losses. Thus, while the lighting may be an expense, it can help reduce the lost profits which can result when safety is somehow breached. When a comprehensive analysis is performed, however, so that all of lighting's effects are considered and steps are taken to derive more benefit from each, a different scenario emerges. Of course, there is nothing wrong with lighting that helps assure profitability by preventing losses. Consider, however, that the same lighting system can do so much more, by maintaining or enhancing image, improving curbside appeal, increasing building value, and so on. It should be noted, too, that these other benefits are very real and can be obtained with relative ease . . . providing they are sought.

In the case of public or other not-for-profit entities, profit is not the appropriate word, at least not in the business sense. However, in the sense that profit means benefit, the same basic concepts apply. In essence, one can realize tremendous benefit from security lighting. But even more significant benefit can be derived when the lighting installed for security is used also to achieve the many other bottom-line benefits lighting can provide.

CASE IN POINT

Lighting Replaces Labor at CMU

Mount Pleasant, MI — Determined to provide the best possible security for students and faculty, Central Michigan University was spending about $50,000 annually on security patrols in certain areas of its campus. The school had also invested heavily in outdoor lighting, but it was time for a change. Its system relied on mercury vapor lamps which are far more costly to operate than alternatives such as high-pressure sodium (HPS). And HPS is exactly what CMU decided to use in order to increase lighting levels while reducing annual expenditures for operation and maintenance (O&M).

In one area, where CMU had installed 244 high-security walkway fixtures, two options were available. One was to replace the existing 250-watt mercury vapor fixtures with retrofits using 150-watt HPS lamps. The change would have boosted light output by almost 30 percent while cutting O&M costs by one-third. Instead, CMU physical plant staff decided to rely on the second option, converting to 250-watt HPS lamps. This strategy more than doubled light output but it also resulted in O&M costs which exceeded those associated with the old mercury vapor system. Was it a wise decision? Absolutely! While the University had to spend a few dollars more on lighting, it was able to reduce the extent of its security patrols without compromising safety or security. The labor savings created a benefit worth $10,500 in the first year alone. ▶
UNDERSTANDING THE ROLE OF QUALITY

Discussions of lighting issues frequently center on the cost of energy consumed or the cost of the equipment used. The reasons for this are readily understandable. Facility managers, property managers, owners, developers, and others must contend with budgets and, for the most part, these are oriented to the expense side. The more one can hold down expenses, of course, the better off one is. But subscribing to that commonly held belief can at times lead to problems, because it can encourage reliance on the cheapest way of doing things as opposed to the best. In fact, the least expensive way of doing something over the long term almost always is the most quality-conscious way. Sacrificing quality in order to lower initial and/or operating and maintenance (O&M) costs almost always leads to higher costs “down the road.”

Some of the key factors which relate to attaining quality are lighting function, illuminance, uniformity, glare, light trespass, color rendition, and energy efficiency.

LIGHTING FUNCTION

Lighting function refers to the purpose of the lighting under consideration. Although the purpose may seem self-evident, it often is not. As already noted, lighting installed solely for purposes of security will do more than provide security. How well it performs these additional functions will depend on the degree to which they are considered in design. The more narrowly you can identify what it is lighting should do, the more guidance you will provide to those designing the system, and the more likely it is your goal will be achieved. For example, if you are looking to prevent vandalism, ask where and to what extent. How important is it to protect shrubs and newly planted saplings? Is there a need to discourage people from spraying graffiti on building walls or other surfaces? In the past, what problems have occurred at the site or others like it? What may happen given changes you are making?

Try to identify everything you want your lighting system to do in each definable area where lighting will or may be used. Also try to rate each function, using something such as a ten (extremely important) to zero (not important) scale, as shown in Figure 1. In that way, should there be conflict between achieving two objectives, the lighting designer will have a better indication of which is the more important. Possibly several people can be queried, to take advantage of different points of view and experience. Consider the case of a hotel, for example. The lighting in a certain area not generally visible to the public may not be particularly important from an aesthetic point of view. However, because staff may take their break there, it will be important to provide ample security. If it will not cost appreciably more to also enhance aesthetics, creating an attractive and secure outdoor rest and relaxation area that improves staff morale would likely be worthwhile. The same might apply to a hospital or similar facility where people work after dark and the effectiveness of a break is important.

Do not assume that you or any other single individual knows the answer. A director of housekeeping may have important insights that you do not have, simply because of differences in experience.
ILLUMINANCE

Illuminance is a measure of the amount of light that exists in a given area or at particular points in an area. It is measured in footcandles or lux (the metric equivalent). Although there are major differences between lighting quantity and lighting quality, quantity is an intrinsic quality factor. It is impossible to have quality lighting when the illumination system fails to deliver the quantity of light needed to achieve the primary purpose.

Table 1 provides some recommended illuminances for specific types of areas. These are the footcandle levels recommended by the Illuminating Engineering Society of North America. They are the only recommendations that have been developed using a consensus approach and that are backed by almost a half-century of research and experience.

As indicated in the glossary included in this publication, several quantity measurements are used. As a result, saying that a system provides 50 or 100 footcandles — abbreviated as fc — does not really convey much information to the experienced ear. Are they vertical footcandles or horizontal? Are they initial or maintained? These and many other questions must be answered in order to provide specificity, and to help assure that important concerns are addressed in design.

Good design is not enough. Good maintenance also is needed if the functions of lighting are to be achieved. This is particularly true as it relates to security. The light output of most lamps decreases over time, even when the lamp and luminaire are cleaned on a regular basis. Often they are not cleaned, however, and that can aggravate light loss problems. Effective maintenance of your security lighting system is fundamental to the maintenance of security: Even the best-designed system will fail to achieve its goals if it is neglected. And recognize that, outdoors, more than lighting can be involved. Trees and shrubs grow and are subject to natural phenomena which can create new demands on the

FIGURE 1: The type of form that could be developed for use by various department heads, after the meaning of the purpose listed is explained.

AREA 8: LIGHTING NEAR KITCHEN ENTRANCE

<table>
<thead>
<tr>
<th>Purpose</th>
<th>How Important (10-to-0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security (Vandalism)</td>
<td>10 9 8 7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>Security (Break-ins)</td>
<td>10 9 8 7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>Security (Assaults)</td>
<td>10 9 8 7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>Safety (Pedestrian)</td>
<td>10 9 8 7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>Safety (Vehicle)</td>
<td>10 9 8 7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>Beautification</td>
<td>10 9 8 7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>Environment Integration</td>
<td>10 9 8 7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>Attraction</td>
<td>10 9 8 7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>Identification</td>
<td>10 9 8 7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>Recreation</td>
<td>10 9 8 7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>Other</td>
<td>10 9 8 7 6 5 4 3 2 1 0</td>
</tr>
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<td></td>
<td>10 9 8 7 6 5 4 3 2 1 0</td>
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<tr>
<td></td>
<td>10 9 8 7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td></td>
<td>10 9 8 7 6 5 4 3 2 1 0</td>
</tr>
</tbody>
</table>

FORM COMPLETED BY:

Name

Title

12
illumination system. As such, a program of regular inspection is needed, supplemented by special reviews after particularly severe windstorms, snows, etc. These inspections should be performed at night, when it will be far easier to determine if aiming patterns have been changed for some reason, or should be.

**UNIFORMITY**

Average illuminance can be a misleading indicator of lighting quantity (and its quality implications) because average virtually presupposes uniformity. If it is important to achieve, say, 30 fc in a large area, doing so by providing 50 fc in some parts and 10 fc in others will not attain lighting goals.

With respect to any area illuminated for security purposes, it is essential to permit those using or traversing the area to see ahead and to the sides. This means that there should be an absence of dark areas, such as those caused by shadows. Areas adjacent to those which are the most highly illuminated should be illuminated by gradually less light. For example, it will not do much good to have a security walkway well-illuminated, only to furnish no illumination on immediately adjacent areas. This would permit someone to rush a pedestrian, by jumping out from the dark.

### TABLE I: Outdoor lighting illuminances recommended by the Illuminating Engineering Society of North America.

<table>
<thead>
<tr>
<th>Building exteriors</th>
<th>FC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entrances</td>
<td>5</td>
</tr>
<tr>
<td>Active (pedestrian and/or conveyance)</td>
<td>5</td>
</tr>
<tr>
<td>Inactive (normally locked, infrequently used)</td>
<td>1</td>
</tr>
<tr>
<td>Vital locations or structures</td>
<td>5</td>
</tr>
<tr>
<td>Building surrounds</td>
<td>1</td>
</tr>
<tr>
<td><strong>Buildings and monuments, floodlighted</strong></td>
<td><strong>FC</strong></td>
</tr>
<tr>
<td>Light surfaces</td>
<td>15</td>
</tr>
<tr>
<td>Medium light surfaces</td>
<td>20</td>
</tr>
<tr>
<td>Medium dark surfaces</td>
<td>30</td>
</tr>
<tr>
<td>Dark surfaces</td>
<td>50</td>
</tr>
<tr>
<td><strong>Dark surroundings</strong></td>
<td><strong>FC</strong></td>
</tr>
<tr>
<td>Light surfaces</td>
<td>5</td>
</tr>
<tr>
<td>Medium light surfaces</td>
<td>10</td>
</tr>
<tr>
<td>Medium dark surfaces</td>
<td>15</td>
</tr>
<tr>
<td>Dark surfaces</td>
<td>20</td>
</tr>
<tr>
<td><strong>Gardens</strong></td>
<td><strong>FC</strong></td>
</tr>
<tr>
<td>General lighting</td>
<td>0.5</td>
</tr>
<tr>
<td>Path, steps, away from house</td>
<td>1</td>
</tr>
<tr>
<td>Backgrounds – fences, walls, trees, shrubbery</td>
<td>2</td>
</tr>
<tr>
<td>Flower beds, rock gardens</td>
<td>5</td>
</tr>
<tr>
<td>Trees, shrubbery, when emphasized</td>
<td>5</td>
</tr>
<tr>
<td>Focal points, large</td>
<td>10</td>
</tr>
<tr>
<td>Focal points, small</td>
<td>20</td>
</tr>
<tr>
<td><strong>Loading and unloading platforms</strong></td>
<td>20</td>
</tr>
<tr>
<td>Freight car interiors</td>
<td>10</td>
</tr>
<tr>
<td><strong>Lumber yards</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>Parking areas</strong></td>
<td><strong>FC</strong></td>
</tr>
<tr>
<td>Self-parking area</td>
<td>1</td>
</tr>
<tr>
<td>Attendant-parking area</td>
<td>2</td>
</tr>
</tbody>
</table>

| **Piers** | **FC** |
| Freight   | 20 |
| Passenger | 20 |
| Active shipping area surrounds | 5 |
| **Quarries** | 5 |
| **Service station (at grade)** | **FC** |
| Dark surrounding | 3  |
| Approach     | 1.5 |
| Driveway     | 1.5 |
| Pump island area | 20 |
| Building faces (exclusive of glass) | 10* |
| Service areas | 3  |
| Landscape highlights | 2  |
| Light surrounding | 3  |
| Approach     | 3  |
| Driveway     | 5  |
| Pump island area | 30 |
| Building faces (exclusive of glass) | 30* |
| Service areas | 7  |
| Landscape highlights | 5  |
| **Ship yards** | **FC** |
| General     | 5  |
| Ways        | 10 |
| Fabrication areas | 30 |
| **Storage yards** | **FC** |
| Active      | 20 |
| Inactive    | 1  |

*Vertical
GLARE

Glare occurs when a bright light source appears against a dark background. It can create a sense of mild discomfort or, in some cases, it can be powerful enough to cause observers to avert their eyes. A typical example of glare is the visual effect created by an oncoming vehicle's high beams at night.

Many people associate glare with too much light. Thus, if they feel discomforted by the illumination they may say, “There's too much light here.” But in many cases it is not the quantity of light that's causing the glare. Instead, quality factors are at issue. And these are the same factors which result in an oncoming vehicle's high beams creating no glare problem during the day, while being blinding at night. The quantity of the headlamps’ light output does not change from day to night. What changes is the amount of light surrounding the headlamps.

A quality lighting system is often thought of as one which does not create glare. Absence of glare does not come about by accident, however. It is achieved as a consequence of careful planning, by considering where the light should be placed, typical angles of view, type of lamp and luminaire, mounting height, and related factors. In short, a range of significant variables must be considered. The importance of such a review cannot be overemphasized. Lighting that is supposed to achieve aesthetic effects cannot do so when it creates glare. Lighting that should help enhance vehicular safety cannot do so when drivers must avert their eyes. In fact, owners have been sued because the glare created by their lighting systems allegedly resulted in an accident.

Note that glare is sometimes a desirable element in a security lighting system. As an example, some security specialists say that the lighting used for automated teller machines — ATMs — should create glare aimed at anyone entering the ATM enclosure. In that way, those entering are not only slowed down due to the glare; they are also bathed in light, enhancing security for anyone inside the enclosure. Putting a high level of light inside the enclosure, which some do, can lead to problems because it makes the person inside highly visible while making it far more difficult to see anyone outside or on their way in.

In all cases, lighting should be designed for the specific facility and set of circumstances involved. As such, glare can at times be used to help improve security. When it is present, however, it should be achieved through purpose, not inadvertence.

LIGHT TRESPASS

Light trespass is the situation which occurs when lighting from one owner's property trespasses onto someone else's property, where it is not wanted. In many cases the problem is minor and the affected party doesn’t care. In some cases, however, the unwanted lighting can create significant interference with someone else’s preferences and changes must be made. In all cases, light trespass results in a waste of energy and also signifies either an inadequate design or an adequate design that has become inadequate in performance, due to damage to the luminaire or for other reasons.

Where light is directed is not something that should be left to chance, nor does it have to be. Relying on a variety of sophisticated computer programs, lighting designers, manufacturers' application engineers, and others can determine precisely where light beams will be directed given the specific luminaire involved, its direction and angle, height from the ground, and similar factors. Where light trespass may be a problem, specialized luminaires can be used so that light above a certain angle is cut off or otherwise controlled to prevent problems.
COLOR RENDITION
Color-related issues are discussed more fully later in this guide, with respect to lamps. In essence, depending on the gases and coatings used in the manufacture of a lamp, it will radiate more in some areas of the spectrum than others. As a result, some lamps emphasize reds or blues—among other colors—more than others.

With respect to security lighting, it is important to recognize that identification of persons can be critical in some instances, thus making it important to consider the degree to which a light source might distort colors. If color is of no importance with respect to aesthetics, it may be important to other concerns, for example, its ability to complement certain finishes.

ENERGY EFFICIENCY
Energy efficiency is an important quality issue because quality lighting does not waste energy. Recognize, however, that there is a major difference between using energy and wasting it. In fact, a system that consumes 500,000 kWh each year may waste far more energy than one which consumes twice as much.

Energy efficiency is achieved through effective design which minimizes the amount of energy needed to get the job done. In all cases, however, the job does get done. If the job does not get done, if the lighting fails to achieve its purpose, then all the energy used is wasted. This underscores why in this discussion of quality issues energy efficiency is discussed last—it should be considered last. To consider it first places undue emphasis on the energy issue. Bear in mind that the cost to medically treat a broken ankle is probably 50 times the cost of the energy needed to operate the more effective lamp/luminaire that could have made the hazard more visible and, thus, avoidable. In all cases, use as much energy as needed to get the job done well, and design and operate the system so that energy waste is eliminated.
Achieving quality in a security lighting system depends on far more than a skillful lighting design. When security and safety are involved, other concerns also must be addressed. The interrelationships between these concerns must be reviewed carefully to help assure overall objectives are realized. This concept applies to new construction as well as existing. In either case, the investment in new lighting — and overall safety and security efforts — will last a long while; often a decade, two decades, or more.

IDENTIFY THOSE WHO SHOULD BE INVOLVED

In order to identify the functions lighting should perform, it is essential to identify those whose guidance should be sought. The needs will vary depending on the nature of the facility in question. In most instances, however, needs can be divided between internal personnel and external.

Internal personnel include those who have or are responsible for safety and security issues, or who may be affected by them. In larger organizations, this may mean department heads. Overlook no one, because safety and security concerns affect virtually all staff and all persons who go into or out of a building, especially when it is near or after normal closing hours.

In the case of an office building, for example, those involved with human resources management should be contacted because safety and security affect morale. They may also affect one's willingness to put in overtime hours either before or after the close of the regular business day. Depending on circumstances, a building's leasing agent should be queried because safety and security issues affect leasability of space and its cost.

If the building involved offers food service, the person who directs foodservice activities might be contacted. Is lighting needed to illuminate dumpsters which may otherwise attract unwelcome visitors, including those of the four-legged variety?

The director of building and grounds should be queried about suggestions or needs. A review of records could reveal that some areas are more prone to problems than others; be it in the form of vehicular accidents, slips and trips, vandalism, etc.

The more people who are contacted, the better, if only because they will be given the opportunity to influence an extremely important element of their environment.

The outside personnel who may be relied upon include those who will provide guidance over the long term. This might include design professionals such as an illuminating engineer, architect, landscape architect, or electrical engineer. It may also be appropriate to rely on a security specialist and/or those who specialize in certain areas of security, such as closed-circuit television (CCTV), remote sensors, actuators and controls, and integrated systems either for local (on-site) or remote monitoring. Bear in mind that fire safety needs usually must be addressed as well, and that at times fire safety requirements and security recommendations may be at odds. For example, it might be best to keep a given door locked for security purposes, and unlocked/operable for fire safety purposes. Given today's array of equipment, control and monitoring strategies, etc., it is possible to achieve reasonable solutions that satisfy different needs. The critical issue: You must know what these needs are. This leads to another area of concern, that is, the need to identify and understand all applicable codes and standards. Some of these may affect the degree to which security and fire safety systems may be integrated or they might limit the height of
lighting poles, or they may prescribe certain minimums. Do not assume that a specific need has been satisfied simply because a code requirement has been met. Codes and standards define what is least acceptable. The minimum may not be enough to meet your needs.

In all cases the overall team should include the property or facilities manager. These people tend to be highly effective generalists with respect to real property. As such, they can identify a variety of issues which others may overlook, and frequently can identify valuable sources of assistance. Recognize, too, that guidance and other assistance may be available from lighting manufacturers, insurers and their agents, your local electrical utility, the local police and fire departments, and associations which cater to the needs and interests of the profession, product, or service involved, as well as the building type — multifamily residential, commercial, retail, etc.

CASE IN POINT

New Lighting Eliminates Assaults, Vandalism at Apartment Community

Toledo, OH — Owners of the Heather Hills Apartments were spending more than $2,100 each year to operate and maintain incandescent carriage lamps placed on either side of doorways and at other locations. The annual expenses included a $300 allowance for vandalism. A dollar value could not be placed on the assaults that were occurring, but it was quickly recognized that something had to be done. A local electrical contractor was called in. After analysis he recommended conversion to 35-watt high-pressure sodium (HPS) fixtures using vandal-resistant plastic lenses. After the new lighting was installed, vandalism, auto break-ins, and assaults were all but eliminated. The value of these savings combined with the value of operating and maintenance cost reductions led to a simple pay-back of 2.3 years.

ESTABLISH LOCATIONS

Where in and around a facility do safety and security needs arise? Many of these already have been alluded to: parking areas, accessways between a parking area and the building, at points of normal (doors) and abnormal (windows) ingress/egress, and indoors, in hallways, stairways, and so on.

The next step usually is to determine what the overall protection philosophy will be. Guidance on this area of concern is available from a number of sources, including some of the Electrical Design Library publications produced by the National Electrical Contractors Association. Is there to be perimeter protection? If so, in what form? Will the facility rely on a fence? If so, what kind? How tall? Will it rely instead or in addition on CCTV? If so, what kind of lighting will be needed? Would it be appropriate to use “invisible light,” i.e., infrared? In some cases this may be preferred to normal lighting. In other instances the decision may come down to cost factors. Recognize, however, that use of infrared may require reliance on a different type of camera; one that is more expensive than others.

Maintenance issues also may arise.

The type of access controls employed also is an important issue. A wide variety is available, including those that respond to different sounds as opposed to motion or physical disturbance.

To the extent that any given option necessitates reliance on some other option, all the interrelationships should be made known to help assure effective decision-making. A multidisciplinary approach is particularly important in this respect, because of the variety of options. As an example, in designing stairways with safety issues in mind, it is appropriate to use a tread and riser whose colors contrast, to help create more visibility and thus reduce the potential for a slipping/tripping hazard. In such cases, 3fc or so of light might be sufficient. However, if security is also a concern, it would be wise to provide 30fc of light, because security needs are so different from safety needs.

With lighting, as with other tools, merely having it is not enough. The right type of light needs to be used, along with the right amount in the proper location.

ATTEND TO OTHER ISSUES

A number of other issues need to be considered once locations are known. One of these relates to separate wiring. Due in particular to the needs of fire safety, it usually is wise to have all exit lighting on separate circuits so it will remain on despite a power outage. This type of wiring is often required by code and code may also dictate use of an emergency standby power system which would operate these lights.

Another concern might be systematic interrelationships. For example, the occupancy sensors used to detect the presence of intruders after hours might also be wired to cause all lighting in an affected area to turn on when activated, in addition to sounding a local and/or remote alarm. Alternatively, the occupancy sensors used in some areas to activate and deactivate lighting during the day could be used for security purposes at night.

The list that can be created is huge, given all the different types of facilities there are. By relying on a multidisciplinary team, most of those germane to your facility can be identified.
IDENTIFY WHAT ELSE LIGHTING COULD DO

Once a general approach to safety and security lighting has been identified, along with whatever options may exist, it would be wise to solicit and consider comments about other objectives the lighting can achieve. This is particularly the case outdoors, of course, and many issues often are involved. The premium required to achieve those other objectives — beautification, environment integration, attraction, etc. — is often relatively small. At this time, however, budget is not an issue. Encourage people to develop a wish list — from internal personnel to the consultants being used.

EVALUATE THE OPTIONS

How worthwhile will it be to make the additional investment which better lighting may require? If any type of prior analysis has been conducted, such as that to establish function, the answer should be immediately evident. Otherwise it would be worthwhile to consider the form shown in Figure 2. Minimize assumptions by obtaining competent guidance. In most instances, however, you will discover that just a little lighting can go a long way, principally because the value of lighting’s service is so disproportional to the small premium paid to install, operate, and maintain the better lighting needed to obtain these values.

![Figure 2: A form for use as a checklist to identify the value of lighting benefits. A far more detailed checklist might be appropriate for your facility.](image)

<table>
<thead>
<tr>
<th>BENEFIT</th>
<th>ESTIMATED ANNUAL VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less Vandalism (Buildings)</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Less Vandalism (Grounds)</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Fewer Building Break-Ins</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Fewer Auto Break-Ins</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Less Likelihood of Assaults</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Image Maintenance</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Annualized Value of Legal Savings</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Ability to Use More Areas</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Improved Curbside Appeal</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Increased Retail Sales</td>
<td>$_____________________</td>
</tr>
<tr>
<td>More Rent</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Less Turnover Costs</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Beautification</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Increased Building Value</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Insurance Savings</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Improved Morale</td>
<td>$_____________________</td>
</tr>
<tr>
<td>Improved Productivity</td>
<td>$_____________________</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$_____________________</td>
</tr>
</tbody>
</table>
For example, if better quality lighting will lead to circumstances which together result in an office building's value being increased by one-tenth of one percent, the value generated may be $25,000. But one-tenth of one percent often is unrealistically low, as when lighting contributes to factors such as enhanced curbside appeal, longer tenancies, less turnover, and more profitability.

Bear in mind, too, that just as more lighting can often lead to more safety, so can more lighting in some cases pay for itself by substituting for some other option. For example, maintaining higher lighting levels may permit reliance on fewer or lower cost CCTV cameras, or fewer security guards because central station monitoring becomes more effective. Also recognize lighting's deterrent benefits, since it is the most conspicuous form of security.

**UNDERSTAND PROCUREMENT**

In evaluating the cost-effectiveness of lighting, consider the various lighting procurement options. While a direct purchase is the most common option, it is not the only one. Outdoor lighting in particular may be leaseable, thus reducing capital outlay requirements. Lease arrangements may be available from electrical contractors, the local electrical utility, or other sources, including companies that will lease almost anything.

Third-party providers may also be able to help, especially in those cases where a new system is replacing an old one. In these instances some providers obtain payment by sharing the dollar value of energy savings. As a consequence, the facility owner can obtain the new lighting without any investment.

In cases where leasing the entire system is not practical, leasing at least part of it may be worthwhile, because it frees up capital that then can be used to enhance the system.

Recognize, too, that some local utilities may have special programs available because they want to encourage more use of nighttime lighting. This permits them to sell more electricity at night, thus making more efficient use of generating equipment that would otherwise be idle. (Daytime power requirements in most areas of the nation are far more substantial than nighttime's.)

What's available in your area? All the options should be identified and discussed.

**SELECT THE MOST COST-EFFECTIVE ALTERNATIVES**

The most cost-effective alternative seldom is the one which consumes the least amount of energy. Rather, it is the one that produces the most benefits. As such, to establish cost-effectiveness, it is critically important to identify the types of benefits which different types of lighting can provide, the extent to which a given approach can deliver a benefit, and the values involved. In the case of a shopping center, for example, lighting can provide so many benefits there is no point in skimping anywhere. This does not mean that lighting should be wasted. But it does mean that it should be used unsparingly, accompanied by energy-efficient design.

Which approach is best? Very often this will be determined by "the numbers." One of the most widely used approaches calls for calculation of *simple payback*. This is determined as:

\[
Simple\ Payback = \frac{Initial\ Cost}{Annual\ Savings}
\]

This approach would be used to compare a more expensive system to a less expensive one, or to consider the financial wisdom of adding a given option to a system.
As an example, assume System A costs $25,000 to install and will cost $5,000 per year to operate and maintain. System B costs $28,000 to install and will cost $5,500 per year to operate and maintain, but should increase retail sales enough to generate an additional $1,500 per year in profits. As such, System B's installed cost (premium) is ($28,000 − $25,000 = $3,000, and its annual benefit is ($5,000 − $5,500 + $1,500 = $1,000. Accordingly, the payback for investing the additional money in System B would be:

$$\frac{3,000}{1,000 \text{/yr}} = 3.0 \text{ years}$$

Similarly, if a given control system added to the system costs $2,500, but will shave the utility bill by $900 per year, the simple payback would be ($2,500 ÷ $900/yr = ) 2.8 years.

Another method of evaluating payback period relies on its reciprocal, simple return on investment (SROI):

$$SROI \ (%/\text{Year}) = \frac{\text{Annual Savings}}{\text{Initial Cost}}$$

or

$$SROI \ (%/\text{Year}) = \frac{1}{\text{Simple Payback (Years)}}$$

Accordingly, a system which costs $3,000 more than another, and which will generate an annual benefit of $1,000, will have a SROI of ($1,000/yr ÷ $3,000 = ) 33.3%/year.

Another method sometimes employed to compare alternative investments involves present value analysis. This approach holds that one dollar received one year from now is not as valuable as one dollar received today, because today's dollar can be invested without risk to generate a given rate of return. If it is assumed that this rate of return is 10 percent, one dollar received today would be worth ($1 \times 1.1 = $1.10 in one year, or $0.10 more than one dollar received one year from now. One dollar received today would be worth ($1 \times 1.1 \times 1.1 = $1.21 in two years, or $0.21 more than one dollar received two years from now.

To determine today's value (the present value) of a dollar received one year in the future, the above approach is reversed, to derive ($1 ÷ 1.1 = $0.909). One dollar received two years from now would have a present value of ($1 ÷ 1.1 ÷ 1.1 = $0.826.

Present value analysis can be particularly beneficial when somewhat complex factors must be evaluated. For example, assume you must decide between Option A and Option B, where Option A costs $4,000 to install, saves $1,500 annually, but will have to be replaced in five years. By contrast, Option B costs $5,000 to install, saves $1,000 annually, but will last ten years. Which is the better investment?

If one were to apply simple payback, which does not consider the "time value" of money, the total ten-year investment for Option A would be ($4,000 \times 2 = $8,000, creating a simple payback of ($8,000 ÷ $1,500/yr = ) 5.33 years. Option B would appear to be superior, with a simple payback of ($5,000 ÷ $1,000/yr = ) 5.0 years.

When present value analysis is applied, a different picture emerges. The present value of Option A's $1,500 annual energy savings over the next ten years is $9,217. The present value of the $4,000 which will have to be invested five years hence is $2,484.

As a result, the net present value of Option A over the next ten years is ($9,217 − $2,484 = ) $6,733. As such, Option A presents a savings-to-investment ratio (SIR) of ($6,733 ÷ $4,000 = ) 1.68.
The present value of Option B's $1,000 annual energy savings over the next ten years is $6,145, resulting in a SIR of ($6,145 ÷ $5,000 = ) 1.23. Thus, although investing in either option would be better than simply "banking" the investment money at 10 percent, Option A is by far the better of the two.

Engineering economics texts provide far more detailed explanations of present value analysis, as well as tables and charts of factors to apply assuming different basic rates of return. Assistance in making these and other calculations is available from many of the sources cited below.

OBTAIN GUIDANCE

Particularly when it comes to design guidance, it seldom is wise to select an individual or firm based on low bids. Bidding generally encourages someone to do something the least expensive way possible. As a consequence, the need to make a profit can become more important than the need to satisfy a client. When everyone is bidding to fulfill the same plan, such that each bidder's results would be about the same and could readily be evaluated by a common yardstick, bidding makes sense. But when design is involved, the client is relying on professional judgment. No two providers would produce identical results. Given the importance of design input, and given its long-term value, it is generally advised that clients should select on the basis of competence, e.g., the designer's experience with similar projects, the satisfaction of other clients, and so on.

A growing number of people are recommending that contractors also be selected on a negotiated basis, because this process can affect the quality of their work, too. It permits them to become involved earlier, so they can provide guidance or comments during design. They also may be more aware of certain issues than others, such as the availability of certain products in the local area, similar systems that have been used and who to contact for details, etc. In addition, whenever contractors or other businesses are retained on a negotiated basis, those involved recognize — or certainly should recognize — that their retention for the next project will depend on how well they perform this time, not how low they bid next time.

Once again, the watchword is quality. It is not achieved by accident, nor is it achieved by encouraging cheapened performance or materials. It costs more... and it just about always provides more.
LIGHTING SYSTEM COMPONENTS AND APPLICATION OPTIONS

Lighting system components include lamps, luminaires, shielding media, ballasts, controls, and poles. Although each should be considered separately, decisions should be based on the interrelationships that result in a system. If a system is to attain objectives, its various components must be compatible with one another. Recognize that effective illumination is derived through lighting management. The principal design consideration should always be the function lighting is to perform, not the amount of energy required. Through careful specification of system components you can maximize lighting’s ability to perform its function while minimizing energy consumption. The value of the benefits derived by enhancing electric illumination’s functional performance almost always exceeds whatever savings may result from increased efficiency.

LAMPS

Six “families” of lamps are commonly used for conventional lighting applications: incandescent, fluorescent, mercury vapor, metal halide, high-pressure sodium, and low-pressure sodium. All except incandescent use a gas-discharge principle that produces light when an electric current passes through a vapor or gas. Gas-discharge lighting needs a ballast to control the amount of voltage and current supplied to the lamps. Incandescent lamps do not because they convert electricity to light by heating a tungsten filament to the point of incandescence (glowing with white heat). Generating light in this manner results in low efficiency since 90 percent of the energy consumed creates heat while only 10 percent creates light. Incandescent lamps also have a short life, typically 750 to 3,500 hours.

Tungsten-halogen or quartz-halogen lamps also operate on the incandescent principle. Their bulbs are filled with halogens which, among other things, help retard bulb wall discoloration. Compared to standard incandescent lamps, tungsten-halogen generally are more efficient, have longer lives, produce whiter light, and do not darken as quickly.

Several key factors should be considered when selecting lamps. Among them are those listed below:

Efficacy

Efficacy is a technical term for lamp efficiency measured in terms of lumens (light output) per watt (power required to operate the lamp). The efficacies of the six basic lamp families is indicated in Table 2. Although the lumens-per-watt rating seems similar to a miles-per-gallon rating, there is a major difference. Miles-per-gallon efficiency is determined considering all automobile components working together. By contrast, a lamp is only one component of a system. Specifying higher-efficiency lamps does not necessarily result in an efficient system.
TABLE 2: Efficacies of Six Basic Lamp Families

<table>
<thead>
<tr>
<th>TYPE OF LAMP</th>
<th>WATTAGE RANGE</th>
<th>INITIAL LUMENS PER WATT INCLUDING BALLAST LOSSES</th>
<th>AVERAGE RATED LIFE (HOURS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-Pressure Sodium</td>
<td>18-180</td>
<td>62-150</td>
<td>12,000-18,000</td>
</tr>
<tr>
<td>High-Pressure Sodium</td>
<td>35-1,000</td>
<td>51-130</td>
<td>7,500-24,000+</td>
</tr>
<tr>
<td>Metal Halide</td>
<td>70-2,000</td>
<td>69-115</td>
<td>5,000-20,000</td>
</tr>
<tr>
<td>Mercury Vapor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>40-1,000</td>
<td>24-60</td>
<td>12,000-24,000+</td>
</tr>
<tr>
<td>Self-Ballasted</td>
<td>160-1,250</td>
<td>14-25</td>
<td>12,000-20,000</td>
</tr>
<tr>
<td>Fluorescent</td>
<td>4-215</td>
<td>14-95</td>
<td>6,000-20,000+</td>
</tr>
<tr>
<td>Incandescent</td>
<td>15-1,500</td>
<td>8-24</td>
<td>750-3,500</td>
</tr>
</tbody>
</table>

NOTES
1. Data are based on the more commonly used lamps and are provided for comparison purposes only. Actual results may vary depending on factors unique to the specific product and installation involved. Consult manufacturers for guidance.
2. Lumen output per watt of power input is a common measure of lamp efficiency (efficacy). Initial lumen-per-watt data are based upon the light output of lamps when new. The light output of most lamps declines with use. The actual efficiency to be derived from a lamp depends on factors unique to the installation. Therefore, the actual efficiency of a lighting system depends on far more than the efficiency of lamps alone. More than efficiency should be considered when evaluating a lighting system.

Rated Life

Rated life is established as the amount of time that elapses before half the lamps of a large test group fail. Rated life is an important factor given the cost of replacement lamps as well as the cost of labor and equipment needed to replace them. Manufacturers indicate rated life data in their catalogs.

Lamp Lumen Depreciation (LLD)

Most manufacturers of gas discharge lamps rate their lamps' light output after the first 100 hours of operation, the "initial burn-in." Thereafter the light output of most lamps slowly diminishes due to a process called lamp lumen depreciation (LLD). Since energy consumption remains constant during this process, the lamps become steadily less efficient. Low-pressure sodium lighting is an exception, because its light output remains constant. However, the energy consumption of low-pressure sodium lamps increases over time, so they, too, become less efficient. As such, the cost per lumen of light of virtually all lamps ultimately becomes so high it is economical to install new lamps even though the old ones still operate. Figure 3 illustrates typical LLD curves for commonly used lamps.

FIGURE 3: Lamp Lumen Depreciation (LLD) of Commonly Used Lamps
### Table 3: Interchangeability of Several Selected Lamps

<table>
<thead>
<tr>
<th>Standard Lamp</th>
<th>Replacement Lamp</th>
<th>Wattage Savings¹</th>
<th>Comparative Light Output of Replacement Lamp¹</th>
<th>Value of Energy Savings Over Life of Replacement Lamp at $0.08/kWh</th>
<th>Other Benefits²</th>
</tr>
</thead>
<tbody>
<tr>
<td>60W Incandescent</td>
<td>55W Reduced-Wattage Incandescent</td>
<td>5</td>
<td>=</td>
<td>$0.40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13W TT Compact Fluorescent with Ballast Adapter</td>
<td>44.5</td>
<td>+</td>
<td>$35.40</td>
<td>×</td>
</tr>
<tr>
<td>75W Incandescent</td>
<td>70W Reduced-Wattage Incandescent</td>
<td>5</td>
<td>=</td>
<td>$0.40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>22W Circline Fluorescent</td>
<td>45</td>
<td>=</td>
<td>$43.20</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>18W Compact Fluorescent</td>
<td>57</td>
<td>=</td>
<td>$24.20</td>
<td></td>
</tr>
<tr>
<td>100W Incandescent</td>
<td>95W Reduced-Wattage Incandescent</td>
<td>5</td>
<td>=</td>
<td>$0.40</td>
<td></td>
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<tr>
<td></td>
<td>44W Circline Fluorescent</td>
<td>56</td>
<td>=</td>
<td>$33.60</td>
<td>×</td>
</tr>
<tr>
<td>75W PAR-38 Spot or Flood Incandescent</td>
<td>65W PAR-38 Spot or Flood Incandescent</td>
<td>10</td>
<td>=</td>
<td>$1.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>45W Incandescent (Halogen)</td>
<td>30</td>
<td>=</td>
<td>$4.80</td>
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</tr>
<tr>
<td>150W R-40 Flood Incandescent¹</td>
<td>75W ER-30 Incandescent²</td>
<td>75</td>
<td>=</td>
<td>$12.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>120W ER-40 Incandescent²</td>
<td>30</td>
<td>+</td>
<td>$4.80</td>
<td>×</td>
</tr>
<tr>
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<td>90W PAR-38 Spot or Flood Incandescent (Halogen)</td>
<td>60</td>
<td>=</td>
<td>$9.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>120W PAR-38 Incandescent</td>
<td>30</td>
<td>=</td>
<td>$4.80</td>
<td></td>
</tr>
<tr>
<td>300W R-40 Flood Incandescent¹</td>
<td>120W ER-40 Incandescent³</td>
<td>180</td>
<td>=</td>
<td>$28.80</td>
<td></td>
</tr>
<tr>
<td>500W Incandescent</td>
<td>450W Self-Ballasted Mercury Vapor⁴</td>
<td>50</td>
<td>*</td>
<td>$64.00</td>
<td></td>
</tr>
<tr>
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<td>750W Self-Ballasted Mercury Vapor⁴</td>
<td>250</td>
<td>−</td>
<td>$320.00</td>
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</tr>
<tr>
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<td>7</td>
<td>=</td>
<td>$11.20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F-40 Reduced-Wattage, High-Efficiency, Cathode-Disconnect Fluorescent</td>
<td>9.5</td>
<td>=</td>
<td>$15.20</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>F-40 Reduced-Wattage, High-Efficiency, Color-Improved Fluorescent</td>
<td>7</td>
<td>*</td>
<td>$11.20</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>F-40 Reduced-Wattage, High-Efficiency, Color-Improved Cathode- Disconnect Fluorescent</td>
<td>9.5</td>
<td>*</td>
<td>$15.20</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>F-40 High-Brightness Fluorescent</td>
<td>0</td>
<td>+</td>
<td>$0.00</td>
<td>×</td>
</tr>
<tr>
<td>F-40 Fluorescent (U-Shape)</td>
<td>F-40 Reduced-Wattage, High-Efficiency Fluorescent (U-Shape)</td>
<td>7</td>
<td>=</td>
<td>$11.20</td>
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<tr>
<td>F-96 Fluorescent</td>
<td>F-96 Reduced-Wattage, High-Efficiency Fluorescent</td>
<td>17.5</td>
<td>*</td>
<td>$16.80</td>
<td></td>
</tr>
<tr>
<td>F-96 HO Fluorescent</td>
<td>F-96 HO Reduced-Wattage, High-Efficiency Fluorescent</td>
<td>21</td>
<td>*</td>
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<td></td>
</tr>
<tr>
<td>F-96 1,500 MA Fluorescent</td>
<td>F-96 1,500 MA Reduced-Wattage, High-Efficiency Fluorescent</td>
<td>25</td>
<td>*</td>
<td>$20.00</td>
<td></td>
</tr>
<tr>
<td>175W Mercury Vapor</td>
<td>150W Retrofit High-Pressure Sodium</td>
<td>40</td>
<td>+</td>
<td>$38.40</td>
<td>×</td>
</tr>
<tr>
<td>250W Mercury Vapor</td>
<td>215W Retrofit High-Pressure Sodium</td>
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<td>×</td>
</tr>
<tr>
<td>400W Mercury Vapor</td>
<td>325W Retrofit Metal Halide</td>
<td>70</td>
<td>+</td>
<td>$112.00</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>400W Retrofit Metal Halide</td>
<td>0</td>
<td>+</td>
<td>$0.00</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>360W Retrofit High-Pressure Sodium</td>
<td>60</td>
<td>+</td>
<td>$70.80</td>
<td>×</td>
</tr>
<tr>
<td>1,000W Mercury Vapor</td>
<td>880W Retrofit High-Pressure Sodium</td>
<td>160</td>
<td>+</td>
<td>$204.00</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>950W Retrofit Metal Halide</td>
<td>50</td>
<td>+</td>
<td>$48.00</td>
<td>×</td>
</tr>
</tbody>
</table>

**Notes:**

1. This table does not indicate all possible lamp replacement options and, in some cases, replacing the ballast and lamp, or relying on a new fixture, ballast and lamp will provide better overall performance and energy management than the replacement shown. All numbers reported in the table are approximations, and in certain cases assumptions are made about the types of fixtures and other conditions involved. Consult manufacturers for accurate data relative to direct replacements possible for a given installation as well as any ballast operating temperature or other restrictions which may apply.

2. Wattage savings include ballast losses, where applicable, assuming use of a standard ballast. Actual ballast losses to be experienced depend on the specific type of ballast involved and operating conditions which affect its performance. In those cases where wattage savings exceed the difference in lamp wattage (if any), operation of the replacement lamp also has the effect of reducing ballast losses.

3. Symbols used indicate the following: + (substantially more) + (more) = (about the same) " (less) — (substantially less). Consult manufacturers for accurate information relative to conditions unique to the lamps and installations involved.

4. Other benefits typically provided by retrofit lamps include: maintenance costs due to longer lamp life; improved productivity, safety/security, quality control, etc., due to higher light output; ability to reduce the number of lamps installed systemwide due to higher output of retrofit lamps; and improved color rendition.

5. When installed in a recessed downlight.

6. For high voltage only.
Chromaticity and Color Rendition

Each type of lamp has a different spectral distribution and thus tends to emphasize or deemphasize some colors more than others. Chromaticity refers to the whiteness of light, e.g., how warm (yellow) or cool (blue) neutral surfaces appear when illuminated by that light. Color rendition refers to the manner in which a lamp’s light output affects human perceptions of an object’s coloration or pigmentation.

Incandescent lighting and some types of daylight are often considered “standards” of color condition. Thanks to new phosphors and new techniques for applying them to bulb walls, some fluorescent lamps provide excellent color rendition. Certain metal halide lamps provide the same warm chromaticity as incandescent while affording vastly superior efficacy and rated life.

High-pressure sodium (HPS) lamps, which are used extensively outdoors, have a chromaticity that is often referred to as “golden white.” Although it causes some “color-shifting” (e.g., reds take on a brownish hue), colors illuminated by HPS lamps remain recognizable. Color-improved HPS lamps also are available. Their color-rendering properties are similar to metal halide’s, but they appear warmer. They do not last as long as their standard HPS counterparts, and they are not as efficient.

Low-pressure sodium lamps are the most efficient of all but they produce all their light in the yellow portion of the visible spectrum. As a result, all colors they illuminate appear as shades of yellow or grey. Low-pressure sodium lighting is suited for applications where color recognition and human appearance are of no importance (e.g., in warehouses where “picking” is not color-dependent) or where it can be mixed with other types to enhance overall system efficiency while minimizing color impacts. Low-pressure sodium light can also be used to provide illumination for use with black and white television surveillance systems.

Strike/Restrike Time

The three types of high-intensity discharge (HID) lamps—mercury vapor, metal halide, and HPS—take several minutes to attain full light output. If they are turned off accidentally even more time is required before full light output is restored, because the lamps must first cool down before their arcs can restrick (restart). Manufacturers can provide information on warm-up and restrick times. Note that options are available to prevent accidental turn-off. In addition, devices can sometimes be built into or added to an existing luminaire to shorten or eliminate restrick time.

Luminaire Compatibility

A lamp's compatibility with a luminaire is important when luminaire selection is restricted. This sometimes is the case in modernization projects when existing fixtures are reused for purposes of economy or authenticity.

In some cases an existing luminaire can be reused “as is” by installing a lamp which is far more energy efficient or which provides far more light than the lamp for which the luminaire originally was designed, as shown in Table 3. Always rely on a knowledgeable person to evaluate such plans before they are implemented. Otherwise the result could be inferior lighting, safety hazards, or other problems, such as those associated with lamp-ballast incompatibility.

Another option is to convert an existing luminaire so it can accept a new kind of lamp. This procedure usually involves installation of a new ballast and, in some instances, the savings can be remarkable. Nonetheless, a close cost analysis should be performed first. The cost of modification can at times approach or even exceed the cost of replacement. The luminaire's condition is an important factor in this respect. If its interior surfaces have dulled and a new lens is required, luminaire replacement will probably be more cost-effective.
**Cut-Off Type**
The predominant characteristic of this luminaire is its ability to reduce direct glare. It is used for lighting medium to large areas where control of spill light and direct glare is important, as examples, in commercial parking areas or for security lighting adjacent to residential neighborhoods. A low profile, horizontal lamp unit is used for street lighting where glare control and aesthetic appearance are concerns.

**Refractor Type**
This type of luminaire provides wide beam distribution, but produces high brightness and visible glare outside the lighted area. (The low-pressure sodium and fluorescent types produce lower source brightness, but they permit less control.) Refractor-type luminaires are used for highway, street and general area lighting where glare and spill light control are less important than wide pole spacing.

**Low-Mounted Site Lighting**
This is a low-wattage luminaire which has optical systems below eye level for glare-free lighting of small areas. Variants include “bollard” types which hide the light source as well as “downlight” models. Low-mount luminaires are used around architectural building complexes where aesthetic appeal, control of brightness and low-level lighting are desired.

**Post-Top (Uncontrolled)**
This is a low-wattage, decorative luminaire which provides uniform 360° light distribution. A considerable amount of light may be wasted above horizontal.

**Post-Top (Controlled)**
This is a low- to medium-wattage luminaire which also has decorative appeal. It is a more efficient area illuminator because it directs the majority of lamp light onto the desired area. It is used for site lighting, medium and small area lighting, and pedestrian walkways.
Cost

Lamp costs can be categorized in a variety of ways. For purposes of cost realism, however, one should consider the annual cost of replacement lamps based on the lamp’s useful life, that is, the amount of time the lamp will be left in place. (If the lamp will be left in place until it burns out, which seldom is desirable, useful life would equal rated life.) Given this approach a $25 lamp which has a useful life of 12,000 hours could have an annual cost of $8.33 when used 4,000 hours per year.

\[
\frac{4,000 \text{ hrs/yr}}{1,500 \text{ hrs/lamp}} \times \frac{12,000 \text{ hrs/lamp}}{267\% \text{ lamp life/yr}} \times $25\text{lamp} = $8.33/\text{yr}
\]

Given the same annual usage, a $5 lamp with a useful life of 1,500 hours would cost $13.33 per year.

\[
\frac{4,000 \text{ hrs/yr}}{1,500 \text{ hrs/lamp}} \times \frac{1500 \text{ hrs/lamp}}{267\% \text{ lamp life/yr}} \times $5\text{lamp} = $13.33
\]

Also consider the lumen output of various lamps, since this factor helps determine how many lamps and luminaires will be required to attain a given lighting level while maintaining quality illumination.

Luminaires

Technically speaking, a luminaire is a complete lighting unit, including lamps, ballast(s), and lens, among other components. Luminaires come in virtually all sizes and shapes and many reproductions are available for purposes of historical renovation. As with lamps, a number of factors should be considered in making selections.

Coefficient of Utilization (CU) Rating

Luminaire efficiency is determined as the ratio between a fixture’s light output and the light output of the lamps alone. For example, a luminaire that produces 40,000 lumens using lamps that produce 60,000 lumens is 67 percent efficient. (The remaining 33 percent is trapped within a luminaire or absorbed by its surfaces.) But the amount of light produced by a luminaire is not as crucial a factor as the manner in which it directs light. Particularly with respect to indoor lighting, luminaire efficiency often is referred to as coefficient of utilization or CU, a factor that considers the amount of a luminaire’s light that reaches the area to be illuminated. Given this relationship, a luminaire housing lamps that produce 60,000 lumens would have a CU of 33 percent if only 20,000 lumens are directed to the area to be illuminated. The CUs of various luminaires should be evaluated closely because they can have such a pronounced effect on both initial and life-cycle costs. Luminaire manufacturers identify the CUs of their products by using standardized procedures.

Light Distribution Patterns

Luminaires are available to produce virtually any light distribution pattern. Maximum efficiency will be achieved when the target area is illuminated with little or no “spill” by a luminaire with a high CU. Figure 4 indicates the wide variety of luminaire types available and the light distribution pattern commonly associated with each.
**Depreciation Factors**

Two luminaire depreciation factors need to be considered: *luminaire dirt depreciation (LDD)* and *luminaire surface depreciation*. LDD indicates a luminaire's ability to resist dirt build-up on light-reflecting and transmitting surfaces, as well as lamps. By relying on luminaires that resist dirt build-up well, fewer are needed to maintain a given amount of illumination averaged over time. Luminaires that resist dirt build-up also need less cleaning.

The *luminaire surface depreciation* rating indicates how effectively a fixture resists deterioration of exterior and interior surfaces. The reflective surfaces inside a luminaire are particularly important. If they become dull, more light is absorbed and efficiency falls. More importantly, less light can be provided where it is needed.

**Maintainability**

Luminaires should be cleaned per manufacturer's recommendations, given the specific fixtures involved and the environment in which they are located. Some are far easier to clean than others. If a luminaire is particularly difficult to maintain, chances are its appearance will be degraded. Alternatively, it will not be cleaned as often as it should, and that can result in premature aging.

**Aesthetics**

Aesthetics are a concern in many instances because the outdoor lighting installation will be seen during the day. In some cases inconspicuous equipment is desired. In others, it is necessary for the lighting — usually the luminaire and pole — to complement or contribute to the overall image, be it antique, traditional, or contemporary. As indicated in Figure 5, a wide variety of styles and materials is available. Some of the contemporary installations take on a sculptural appearance during the day and, in and of themselves, are triumphs of design.

**Cost**

As with lamps, life-cycle cost factors tend to be the most important. They also consider many other factors such as the ease of maintenance. Durability is another important factor, given the lighting's continual exposure to the elements.

**BALLASTS**

Ballasts are transformer-like devices used to modify voltage and current to establish conditions compatible with the gas-discharge lamps used inside a luminaire. As with other lighting system components, ballasts have been the subject of many new developments in recent years. Many of the most substantial developments affect fluorescent lighting. Fluorescent lighting is not used extensively outdoors, except for signage.

As a general rule, whenever ballast options exist, each should be studied. Energy performance is a key concern in this respect, because high-efficiency ballasts can produce the same amount of light while consuming much less energy than others designed for the same purpose. Ballast life may be an issue, too. Most manufacturers provide a ballast warranty period of two years from the date of manufacture. Nonetheless, most properly applied outdoor ballasts last an average of 10 years or so.

Cost factors are important, but usually more in evaluating competing technologies than competing equipment. In other words, you may wish to consider ballast replacement costs when comparing an HPS system to a metal halide alternative, or when comparing HPS systems of different wattages.
LENSES

The lens options available with respect to outdoor lighting are far fewer than those associated with indoor luminaires. Indoors there are far more constraints on the shape of a luminaire and, thus, the lens must play a significant role in light distribution. Outdoors such restrictions do not exist, so luminaire shape is a key determinant in where light will be placed.

One of the major choices will relate to the toughness of the material used. Particularly in areas which may be subject to vandalism, it often is wise to invest in a polycarbonate plastic lens material designed to resist pellets, stones, and — in some cases — small-caliber bullets.

Most manufacturers can provide performance information about lens material, including its resistance to coloring or clouding and its ability to withstand temperature extremes, among other factors.

POLES AND MOUNTS

Some outdoor lighting fixtures are mounted directly into the ground or may be somewhat decorative in nature and be strung through a tree or shrubbery. For purposes of area lighting, however, height is usually essential and it can have an impact on lighting system design and specification.

Increased height permits use of higher-wattage (and usually more efficient) lamps and luminaires without causing glare. Since more than one luminaire can be mounted on taller poles, increased height can also result in fewer poles being needed. The fundamentals of good design must be observed, of course. The decisions made should complement the overall architectural and environmental concerns.

Pole height is not the only issue. The materials of which poles are constructed and their overall mechanical design also are factors. Wood, steel, aluminum, concrete, and fiberglass are among the most common pole materials. Selection factors include initial cost, maintenance requirements, durability, and aesthetics over time. Consider, too, the degree to which pole design supports or impedes maintenance. Some poles make lamp changing and luminaire cleaning easy because the luminaires can be easily lowered and raised, or because the pole is hinged to permit access to the lighting fixtures. In other cases it will be necessary to rent equipment such as a “cherry picker” if maintenance is to be performed on an in-house basis. That situation is becoming more the exception than the rule, however, as lighting maintenance is commonly performed by lighting maintenance specialists on a contract basis. This approach helps assure that work is done on a regular schedule and whenever an emergency occurs, by individuals who have been trained specifically for the function, using materials and equipment ideally suited for the specific installation. The cost of this type of maintenance should be a consideration in determining what type of poles to obtain. It may not be worthwhile to invest in articulated poles if a maintenance contractor would use a “cherry picker” in any event.

In many instances poles will not be needed at all, simply because a fixture can be mounted on the side or roof of a building. Is that the option to use when it is available? Not necessarily. The goal in all cases should be quality lighting. If a less expensive option will yield quality, then, obviously, it is the option to select. If it will compromise quality, however, initial cost savings pose the danger of creating a substantial long-term expense.

Figure 6 indicates different design approaches. The top illustration (6a) shows the area to be illuminated. The dotted line indicates the level of illumination desired. In Figure 6b, the illumination level needed is achieved through use of one pole fitted with a high-wattage luminaire. This approach affords good utilization of lamp lumens, control of spill light, and acceptable uniformity. The design shown in Figure 6c also achieves good utilization, using a lower-wattage cut-off type luminaire mounted at a lower height. The cut-off type is supplemented by directional luminaires mounted on the building and on poles located along the property line.
FIGURE 6: The area needing illumination (a) receives it through any one of the four methods shown, but two are effective (b and c) while two are not (d and e).

Figures 6d and 6e illustrate lighting system configurations which achieve the desired footcandle level on an average basis only. Because proper beam control is not provided, a large percentage of light and energy is wasted. The system also causes glare and light trespass.

CONTROLS

Even the most efficient lighting system wastes energy when it is used unnecessarily. Automatic controls are being applied to help assure waste is minimized, because they do not rely on human memory. Several types are available.
Automatic Controls

Timeclocks are the most established automatic control, used to activate and deactivate lighting (or other "loads") at predetermined times. Some timeclocks are electro-mechanical; others are electronic. An "astronomic feature" is one of the most popular timeclock options, causing the device to adjust for changing hours of darkness. A battery or spring-wound back-up mechanism can be obtained to assure regulation despite a power outage. Most timeclocks can be programmed a week at a time.

Photocell controls activate electric illumination when ambient light falls below a predetermined level. The lighting is turned off when ambient light levels rise. Most photocell controls include a delay feature to prevent rapid cycling during partly cloudy periods.

Photocell timeclock controls are applied to keep lighting off during a predetermined period, via the timeclock, and at other times to vest control in the photocell. These are commonly used to control parking area lighting such that the illumination system is controlled by the photocell until, say, 1:00 a.m. At that time the timeclock turns the lighting off and keeps it off until 5:00 a.m. or 6:00 a.m. or so, whenever the first arrivals are expected.

These and other types of automatic controls can be integrated into "intelligent building" controls. Intelligent buildings are those that employ local area networks (LANs) served by a central computer which also functions as a private branch exchange (PBX), handling telephone communications, intercom, paging, message center support, word and data processing, facsimile transmission, HVAC monitoring, energy logging and control, security — even fire safety (code permitting). Lighting control can easily be integrated into these systems as well as the automated building control systems used principally for energy monitoring, logging, and control. Automated building control systems have been available for more than a decade and, over that time, have been continually refined. They permit lighting control from a central control module, with most on-off functions being performed on a programmed basis, usually aided by sensors of different types.

Multifunction programmable controllers also can be applied, principally for on-off functions. Some of these have been designed particularly for lighting but can handle other systems also. Others have been developed for general purposes.

Most programmable control systems require dedicated hard wiring. Others use existing power wiring to transmit and receive signals (line-carrier control systems) or transmit signals without wiring, via radio frequencies. A number of other automatic controls can be integrated into a centralized control system to act as automatic overrides, and manual controls can be used in much the same manner.

Manual Controls

Some buildings still use central circuit breakers to control lighting. Because of the remote location of the control, operators may activate lighting early and leave it on later for their own convenience. Some building codes forbid this approach as the sole means of lighting control in new buildings.

Wall switches (AC snap switches) located near exits leading to illuminated outdoor areas can be of some value. To prevent accidental activation or deactivation, key-activated switches are recommended. They function the same as other switches but can be activated only by personnel with a key.

A manual line-carrier ballast load switching system permits manual off-on operation of connected luminaires. Switches are arranged on a central console which then sends signals over existing AC power wiring to receivers mounted in controlled fixtures' ballast housings. These controls can be easily automated through integration of timeclocks, photocells, and computers.

CASE IN POINT

Improved Lighting Cuts College Parking Lot Crime, Accidents

Smithfield, RI — Bryant College was facing a problem in its 1,557-space commuter parking lot: serious vehicular accidents, vandalism, and theft. After evening students expressed their concern, the school's physical plant director took action, directing a conversion of the existing mercury vapor security lighting to high-pressure sodium (HPS). Effects of the retrofit were immediate and far-reaching. The number of auto accidents was cut by 80 percent and their severity was sharply decreased. Vandalism and theft were cut by more than half and, for the most part, the character of incidents changed from major to petty. Many students and faculty members commented that the new lighting enhanced aesthetics at night in addition to creating an improved sense of safety. The physical plant department was pleased because the new lighting that created these benefits cost 45 percent less to operate and maintain, combining with other savings to create a simple payback of 1.3 years.
Lighting is designed and installed to perform a variety of important functions. Its ability to perform those functions can be seriously impaired when the equipment is not adequately maintained. Dirt that builds up on luminaire and lamp surfaces restricts light distribution and can affect distribution patterns. The interior surfaces of luminaires can be eroded. Dirt build-up on integral photocells can impair their operation. As significant as these problems can be, the worst is what they lead to — the inability of lighting to do its job. When this job is providing security — protecting employees or patrons, for example — inadequate performance of the illumination system can have grave consequences.

**EFFECTIVE MAINTENANCE SAVES**

Effective lighting maintenance can save far more than it costs. And effective maintenance need not be complex. In essence, it amounts to regular cleaning of lamps and fixtures and replacement of all lamps at the same time, before they actually burn out.

The most difficult aspect of the concept is early replacement of lamps. Called *timely lamp replacement*, or TLR, its justification rests on the fact that the efficiency of all lamps declines with usage. In most instances this occurs because light output recedes while energy consumption stays the same. In some cases it occurs because light output stays the same while energy consumption increases. In the latter instance, the basic loss is money, a situation that does not necessarily jeopardize the safety of anything except one's pocketbook. When the loss is in the form of lumens, however, safety and security can be at risk. Thus, while the lamps still work, they do not work as well because they cannot provide as much light. This can lead to the creation of dark areas, shadows, and other "safe harbors" for those up to no good. By replacing these lamps before they burn out, then, quality lighting can be maintained.

As essential as TLR may be, some maintenance personnel simply cannot appreciate its importance nor can they fathom why lamps which still work should be discarded. Table 4 has been prepared to provide a graphic explanation of why TLR should be used.

**Minimization of Compensatory Lighting:** Lighting designers must deal with realities. Their experience indicates that lighting maintenance will not be performed as well as it should. Therefore, they will routinely specify *compensatory lighting* in a system, that is, additional lighting used to help assure adequate illumination is provided despite poor maintenance. The data shown in Table 4 relates to two hypothetical systems, A and B. It is assumed A will not be well-maintained and that B will be. As shown, System A comprises 100 luminaires and lamps and ten of these are for compensatory purposes. As such, B comprises 90 and thus costs $3,000 less to install, assuming an average cost of $300 per luminaire.

Assuming a 25-year life for the system, this initial savings of $3,000 results in an annualized ownership cost savings of $125/year.

**Energy Savings:** Because System B needs fewer lamps and luminaires to provide equivalent illumination over time, its connected load is smaller (43.2kW vs. 48kW) and it consumes less energy each year. The value of the energy savings, at an assumed 80 cents/kWh, is $1,536 annually.
<table>
<thead>
<tr>
<th></th>
<th>SYSTEM A</th>
<th>SYSTEM B</th>
<th>NET ANNUAL SAVINGS (A-B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminaires installed</td>
<td>100</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Lamps installed</td>
<td>/luminaire</td>
<td>/luminaire</td>
<td></td>
</tr>
<tr>
<td>Installation cost</td>
<td>$30,000</td>
<td>$27,000</td>
<td></td>
</tr>
<tr>
<td>Annualized value of</td>
<td></td>
<td></td>
<td>$125/year</td>
</tr>
<tr>
<td>initial savings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamp wattage</td>
<td>400W</td>
<td>400W</td>
<td></td>
</tr>
<tr>
<td>System load</td>
<td>48kW</td>
<td>43.2kW</td>
<td></td>
</tr>
<tr>
<td>Annual use</td>
<td>4,000 hrs/yr</td>
<td>4,000 hrs/yr</td>
<td></td>
</tr>
<tr>
<td>Energy consumption</td>
<td>192,000kWh/yr</td>
<td>172,800kWh/yr</td>
<td></td>
</tr>
<tr>
<td>Energy cost/unit</td>
<td>$0.08/kWh</td>
<td>$0.08/kWh</td>
<td></td>
</tr>
<tr>
<td>Energy usage cost</td>
<td>$15,360/yr</td>
<td>$13,824/yr</td>
<td>$1,536/yr</td>
</tr>
<tr>
<td>Replacement lamp use</td>
<td>16.67/yr</td>
<td>18/yr</td>
<td></td>
</tr>
<tr>
<td>Lamp cost</td>
<td>$50</td>
<td>$45</td>
<td></td>
</tr>
<tr>
<td>Replacement lamp cost</td>
<td>$834/yr</td>
<td>$810/yr</td>
<td>$24/yr</td>
</tr>
<tr>
<td>Labor</td>
<td>$15/yr</td>
<td>$15/yr</td>
<td></td>
</tr>
<tr>
<td>Lamp replacement labor</td>
<td>$375/yr</td>
<td>$315/yr</td>
<td>$240/yr</td>
</tr>
<tr>
<td>Lamp cleaning labor</td>
<td>-0-</td>
<td>$540/yr</td>
<td>($540/yr)</td>
</tr>
<tr>
<td>Ballast replacement</td>
<td>$1,000/yr</td>
<td>$900/yr</td>
<td>$100/yr</td>
</tr>
<tr>
<td><strong>TOTAL BENEFIT</strong></td>
<td></td>
<td></td>
<td>$1,485/yr</td>
</tr>
</tbody>
</table>

**Maintenance Cost Savings:** The lamps being used in both systems have a rated life of approximately 24,000 hours. Given annual usage of 4,000 hours, it can be anticipated that the lamps will average 6 years of life each. They will not all fail at the same time, of course, but for planning purposes it is appropriate to state that System A will go through 16.67 lamps per year, derived as:

\[
100 \text{ lamps} + 6 \text{ yrs/lamp} = 16.67 \text{ lamps/yr}
\]

The lamps are purchased one or two at a time, as they burn out, and cost $50 each. Therefore, the annual expenditure for lamps is $834.

Although System B has fewer lamps, they are replaced earlier — once every five years, before they burn out. And they are all replaced at the same time. Because of the group replacement aspect, the owner is able to make one large purchase and obtain a 10 percent discount. As a result, although more lamps are used on average per year, the total amount spent for lamps is slightly less: $810 vs. $834.

System A is not cleaned except when lamps are replaced. It is assumed that each replacement takes about 90 minutes, considering the time required to obtain a ladder, move to the affected area, and so on. The labor rate of $15 per hour includes an allowance for a helper. Since an average of 16.67 lamps are installed each year, the annual labor cost amounts to $375.
Insofar as System B is concerned, all lamps and luminaires are cleaned annually on a group basis. However, because all materials and equipment are assembled for the purpose, the work can be done much faster—at the assumed rate of 30 minutes per luminaire. In the fifth year, new lamps are installed. As a result, the annual expense for cleaning and lamp replacement comes to $675.

The projected ballast savings of $100/year accrues because fewer ballasts are installed. It is assumed they will last for 15 years and will cost $150 each to replace.

Although the “numbers” shown are purely hypothetical, it is important to review several of the basic issues. First, it is doubtful that having just ten more luminaires installed would actually provide the additional light needed for effective performance over a five-year period. In addition, cleaning luminaires and installing new lamps on a sporadic basis could seriously impair the geometry of the lighting and its appearance. There would be a serious lack of uniformity. Stated another way, it would have been acceptable to make the “luminaires installed” difference larger, so that the operation and maintenance costs of System A would be even more substantial. Yet despite the added cost, and despite the additional initial cost, System A will provide inferior lighting.

Why do you use your lighting? To provide safety and security? To also attract customers and enhance sales and profits? It’s foolish to jeopardize lighting’s ability to fulfill these important roles when, in fact, the maintenance required may actually save money in other ways, too!

Be aware that a number of firms throughout the nation provide contract lighting maintenance. They will clean lamps and luminaires on a regular basis and also install new lamps. Many can perform additional services as well, both for indoor and outdoor lighting. Very often the cost of relying on these firms is not substantially more—and often can be less—than the cost of relying on in-house personnel who may not be as well-equipped (physically and in terms of training) to do the work.
Sources of Assistance

Lighting is important. System design makes the difference between achieving and not achieving goals. Some sources of assistance are indicated below. When it comes to obtaining design input, select individuals and organizations with care. A great deal is at stake. Be sure to determine the names of others whom a given source has served and contact those clients to assess their satisfaction. Consider visiting their facilities to see their systems in action.

National Electrical Contractors Association

NECA is the national association of electrical contractors with chapters throughout the United States. In addition to installing lighting systems, many electrical contractors have complete design departments. Some also are active in the area of equipment leasing and contract maintenance. To locate a NECA-member contractor, contact the NECA chapter closest to you or write the national office for a chapter directory. (National Electrical Contractors Association, 735 Wisconsin Avenue, Bethesda, MD 20814)

National Association of Electrical Distributors

NAED is a national association of electrical distributors, those who stock and sell lighting system components, among other electrical apparatus. NAED sponsors comprehensive lighting seminars and is otherwise active in increasing its members' knowledge of lighting. Many electrical distributors can provide effective guidance on options available and their costs. (National Association of Electrical Distributors, 28 Cross Street, Norwalk, CT 06851)

International Association of Lighting Management Companies

NALMCO is an international association of lighting maintenance contractors. In addition to providing contract lighting maintenance (e.g., scheduled lamp replacement and luminaire cleaning), many NALMCO members also perform rebalasting and luminaire modernization, among other services. NALMCO conducts seminars and other training for its members and offers two certification programs, for Certified Lighting Management Contractors and Certified Lighting Management Consultants. (International Association of Lighting Management Companies, 379 Princeton-Hightstown Road, Cranberry, NJ 08512)

Manufacturers

Manufacturers can provide catalogs and other materials which provide information on their products. Manufacturers also have a number of guides available which provide some general information on lighting, specific types of components, and so on. In addition, manufacturers' sales representatives and application engineers can provide valuable assistance in the design and specification process. Most use sophisticated computer programs for these purposes. Some have computer programs which also provide data about life-cycle costs.

Others

Other sources of assistance include local electric utilities. Many have energy conservation or energy management departments, some staffed by specialists in lighting. The degree of assistance they can provide varies from utility to utility. Note also, that some utilities offer incentive programs which can result in substantial cost savings. Speak with your local electrical utility representative to determine what help is available.

A state energy office may be of value. Some also have incentive programs they can make available. Most have publications that can be of assistance.

Especially in major metropolitan areas, there will likely be chapters of national groups which can be of help, at least by providing referrals to their members. Many of these are listed in the local telephone company's yellow pages directory, under the heading associated with membership, e.g. "engineers, consulting," "engineers, illuminating," "contractors, electrical," and so on. Many also will be listed under "associations."
GLOSSARY OF TERMS

Many different terms are used in discussions of electric illumination. Some of the more commonly used words and phrases are defined below.

**Ballast:** A device that modifies incoming voltage and controls current to provide the electrical conditions necessary to start and operate electric discharge lamps.

**Beam Spread:** The vertical and horizontal displacement of the beam in degrees, bounded by the angle at which 10% of maximum candlepower occurs. (Maximum candlepower is the highest intensity in the beam.)

**Brightness:** As commonly applied, brightness is the intensity of the sensation which results from viewing a surface or space which directs light into the eyes.

**Coefficient of Utilization:** A measure commonly applied to indicate the efficiency of a luminaire. Coefficient of utilization (CU) comprises a ratio of the light delivered to the area to be illuminated compared to the total light output of the lamp(s) alone.

**Contrast:** The relationship between the brightness of an object and its immediate background. An example of this would be the relationship between the letters printed on this page and the paper itself. An example of poor contrast would be a third or fourth carbon copy of a purchase order or computer printout.

**Diffuser:** A device commonly put on the bottom or sides of a luminaire to redirect or spread the light from a source. It is used to reduce brightness from the source.

**Footcandle:** The basic measure used to indicate illuminance (level of illumination). One footcandle is equal to one unit of light flux (one lumen) distributed evenly over a one-square-foot surface area.

**Footcandle (or Uniformity) Ratio:** The relationship between average footcandles and minimum footcandles (such as 3:1) or maximum footcandles and minimum footcandles (such as 6:1). The maximum:minimum ratio generally is preferred because average footcandles cannot be seen.

**Footcandles, Average:** The theoretical average amount of light falling on a surface, as derived by averaging the illumination falling on all points of the surface. Two systems may produce identical average footcandles while providing highly dissimilar illumination.

**Footcandles, Horizontal:** Footcandles perpendicular to a horizontal surface, such as a street. All horizontal footcandles are in the same plane for the same surface. They can be added together arithmetically when more than one source provides light to the same surface.

**Footcandles, Initial:** Footcandles (minimum, maximum, or average) produced when lamps and luminaires are new.

**Footcandles, Maintained:** Footcandles (minimum, maximum, or average) calculated through application of a light loss factor.

**Footcandles, Maximum:** The amount of light falling on that point of a surface with the most illumination.

**Footcandles, Minimum:** The amount of light falling on that point of a surface with the least illumination.

**Glare:** A discomforting or disabling condition which occurs when a high-brightness source contrasts with a low-brightness background, making it difficult for eyes to adjust. High brightness alone does not cause glare.

**HID:** High-intensity discharge lighting, including mercury vapor, metal halide, and high-pressure sodium light sources. Although low-pressure sodium lamps are sometimes included in the HID category, they are not HID sources.

**Lamp:** A light source, commonly called a bulb or tube.

**Lens:** A glass or plastic shield that covers the bottom, and sometimes sides, of a luminaire. Lenses can also be designed to control the direction and brightness of the light as it comes out of the luminaire.

**Light Loss Factor:** A multiplier which is applied to account for conditions which reduce light output over time. These include temperature and voltage variations, lamp aging and dirt build-up on lamp, luminaire and room surfaces. In common practice, light loss factors are applied to initial footcandles to determine the light level that will be maintained in a given area.

**Louver:** A series of baffles arranged in a geometric pattern used to shield a lamp from view at certain angles, to avoid glare from the bare lamp.

**Luminaire:** A complete lighting fixture including one or more lamps and a means for connection to a power source. Many luminaires also include one or more ballasts and elements to position and protect lamps and distribute their light.

**Spill Light:** Lumens distributed by the luminaire which are outside the beam spread.