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Understanding Four Fundamentals Can Make All the Difference

Some people install new lighting and derive a very small portion of the overall bottom-line benefits available. Others derive far more. Those who derive far more understand four fundamentals. If you understand them, you may be able to derive amazing dollar benefits, too.

Light is for people

“Why did we put lighting in here in the first place?”
That’s an important question to address whenever you plan to modify a lighting system. The answer is, “So people can see better and therefore get their work done better.” That work may involve factory operations, office tasks, shopping, or providing security. Nonetheless, the way some people approach lighting modifications, you’d think lighting is installed so they can pay the electric utility each month. And the less that’s paid, of course, the better. Or is it?
The amount of money it costs to operate a lighting system has very little to do with the value of the system. Do not believe that the less you pay the better. Paying less is worthwhile only when the system delivers everything you want. For example, it costs far less to operate a small car than a large truck, but that doesn’t matter very much when you need to move household furniture. You benefit when you have the right equipment for the job. When the job involves visual tasks performed by people, lighting is part of the equipment you need. The quality of light you provide can make all the difference. Better light means getting the job done faster, with fewer errors. The value of benefits like these can often exceed the utility’s lighting bill for a year.

All light is not the same

Many people assume that “light is light”; i.e., if two systems provide about the same amount of light, they’re about the same. But nothing could be further from the truth, because the quality of light is what really counts. You’ve probably noticed this yourself while reading a magazine at home. Frequently, the relationship between the source of the light, your eyes, and the page is such that you experience glare, making the words you’re reading just about illegible. You can improve the quality of your lighting by changing visual relationships, e.g., by moving the light, changing your position, or moving the magazine. In most offices, factories, and other work areas, however, people cannot alter visual relationships. The light source is in a fixed position and its light output cannot be adjusted. The task surface also is fixed, and workers cannot easily change their position to make things better. Under these circumstances, people do the best they can, often unaware of the significant difference better-quality lighting can have; lighting that is designed specifically for the tasks involved and those performing them; lighting that is adjustable, so it can be used to provide the optimal seeing conditions essential for optimal working conditions. In short, all light is not the same, and thinking otherwise can be costly, in terms of lost productivity, high error or reject rates, or compromises to safety or security.

Most lighting is not optimal

Much of the electric illumination currently in place is not as effective as it could be. For example, in many offices and other work areas where people use computers, the existing lighting was designed to support tasks that are as opposite from computer work as could possibly be imagined. The result can be screen glare, slowed operations, errors, eye strain, and headaches, all of which can sap productivity and worker morale. Likewise, the lighting installed in many factories is antiquated in comparison to what’s currently available. And much the same can be said about the lighting used in schools, gymnasiums, and medical facilities, as well
as that installed along highways and roadways. While much of this existing lighting consumes far more energy than necessary, the real loss occurs because it does not do its job well. Better lighting could contribute to fewer highway accidents, longer student attention spans, fewer product rejects, and much, much more.

**Being exact about savings potential is difficult**

People in the energy savings business have grown accustomed to using exact numbers. For example, they can calculate exactly how many kilowatt-hours a building consumes for air conditioning. If a new, more efficient cooling system is installed, consumption will drop to a lesser number that also can be calculated. Since they know how much the new installation will cost and how much energy will be saved, they can provide precise data about any number of dollar concerns.

This same approach can be used with lighting, of course, but you do not get the most from your lighting dollar by saving energy, because energy-efficiency is only one component of a high-benefit lighting system. What are the big-dollar elements of high-benefit lighting? Productivity is often number one. Also consider error reduction, improved safety, better security, and enhanced retail sales, to name just a few. While analysis can identify where improvements are likely to occur, being exact about predictions is difficult. The inability to be precise is no reason to exclude the value of lighting benefits from calculations, however. At the very least, conservative estimates of the value of lighting benefits should be factored into the overall analysis, to help assure effective decision-making. As an example, consider a hypothetical office space occupied daily by 50 computer operators. The cost of operating and maintaining the lighting system these people would need would ordinarily be less than $4,000 per year. However, the salary and fringe benefits of the workers probably would amount to more than $1.5 million annually. If better lighting were able to result in a productivity improvement of just 3 percent, its value would be $45,000 per year — ten times the cost of operating and maintaining the lighting system.

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**CASE IN POINT**

**NEW LIGHTING REVIVES SHOPPING MALL**

Inadequate lighting in the parking lot was creating a serious problem for the owners of Fairmount Fair Mall, a major retail facility located in Camillus, NY, 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 and 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, it would have taken more than 100 years for the system to have paid for itself. Payback was achieved in months, however, because of the other contributions of high-benefit lighting.

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, management was able to cut back on security patrols, saving $5,000 per year. The new lighting also permitted faster snow removal in the parking lot, saving another $7,300 annually. Because the lighting also called shoppers' and prospective shoppers' attention to the next store, sales increased, generating $90,000 annually in additional rent for the mall's owners and about $2.5 million in increased sales for retailers.
High-Benefit Lighting Pays off on the Bottom Line

In order to create a high-benefit lighting system, you need to evaluate the tasks that will be performed in the lighted environment. The more lighting can be used to help attain the purpose for which it is needed, the more valuable it becomes. In this respect, be aware of lighting's many “ripple” effects. For example, better lighting that improves safety and reduces accidents can also help you reduce your exposure to government penalties and fines, reduce the cost of personnel turnover and reliance on temporary services, lower the cost of insurance, and help keep staff morale high. The following list highlights just a few of the many bottom-line impacts of high-benefit lighting:

Improved productivity
It doesn’t take much to have a productivity improvement pay big dividends. For example, suppose better lighting were to help a group of ten warehouse workers identify material more quickly, so that what used to take them 60 minutes now takes them 59 minutes and 24 seconds. Assuming that these workers are paid $20,000 per year and that taxes and benefits amount to another $6,000 annually, that relatively tiny time savings would be worth more than $2,500 per year. Chances are that’s more than what it costs to provide 100 percent of the warehouse’s lighting!

Fewer errors and rejects
How much is an error worth? Even when the error is somewhat simple, it can have major repercussions. In the case of customer invoices, errors will create inconvenience and, in some cases, they will lead to loss of customers. In the industrial sector, errors mean rejects, resulting in both time and material waste. And, when the error goes undetected, it can mean a product that fails to do what it should, or which somehow causes injury and damage. When errors show up in government reports, it may take days or even weeks to straighten things out. Better lighting helps people perform their work with fewer errors, just as it helps those in quality control whose job it is to detect errors before they go “out the door.”

Increased customer satisfaction
Customers want good quality service and products and they want them at competitive rates. Lighting helps. It helps those who do the work do it right the first time; it helps those who check the work find errors before they reach the customer. Good lighting can also help keep costs in line, and not just by lowering the cost of energy. Fewer errors lower cost; so do increased productivity, lower labor replacement costs (due to fewer accidents), and so on.

Enhanced image
Lighting contributes to your improved image by helping to enhance overall product quality. The lighting used in your facility can also have an image impact, however, especially in lobby areas where you have a chance to make an important first impression. Consider, too, what lighting can do to highlight graphics on a wall (including awards won), and what it can do at night, when outdoor lighting serves to enhance the appearance of your property and attract attention to it.

Increased retail sales
To increase retail sales, select lighting that is well suited for the merchandise being displayed, the image the store wants to create, and other factors unique to a given setting. Lighting can make a bottom-line difference by creating an effective “mini-environment” for a given display, highlighting a carousel of impulse-purchase merchandise, bringing out the color and texture of fabrics, or lending sparkle to crystal and jewelry. Outdoor lighting helps, too. For example, when a store wants to encourage nighttime shopping, illumination in parking lots and along walkways creates conspicuous security, helping people overcome a fear of crime that could otherwise keep them away.

Enhanced curb appeal
Particularly when building space is available for lease, effective lighting can help create curb appeal at night and thus can have a vital impact on overall space marketing activities.

Improved safety
The darkness caused by insufficient outdoor lighting at night, and the shadows created by lighting that is improperly positioned, can mask hazards that otherwise...
would be self-evident: steps along a walkway, fallen branches, or pavement cracks. In parking lots, along access roads, and at entrances and exits, effective lighting can help reduce the likelihood of accidents. Indoors, especially in industrial settings, lighting can be used to highlight potential hazards, such as moving machinery or areas that are particularly susceptible to liquid spills. Improved safety translates into less time lost in accident response, less time required for finding and training temporary, time saved thanks to fewer accident reports, less exposure to OSHA fines and workers’ compensation claims, and the opportunity to purchase insurance at a lower cost.

**Heightened security**

Security problems can create litigation exposures as well as negative publicity. Even such relatively minor problems as vandalism can have serious repercussions, however, because of the image of vulnerability it creates. Note that the lighting used to improve security can perform additional functions. For example, facade lighting can be as effective for beautification as it is for detecting the presence of unauthorized personnel. Use lighting to maintain indoor security, too; e.g., by integrating certain lighting and security controls, all lighting in a given area can be illuminated when a security breach is detected.

**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 security lighting can help assure that people do not leave a multifamily residential or commercial building because it lacks 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.

**Less absenteeism**

Employee absenteeism is a major management concern; National Lighting Bureau cases suggest that improper lighting may be a significant cause. Improper lighting often is characterized by glare, typically caused by poorly shielded lighting fixtures (luminaries) or a bright light source surrounded by a dark background. Muscles cause our eyes to adapt to such conditions and, over time, these muscles may become strained, leading to visual fatigue, headaches, and eye strain. Effective lighting can help eliminate such problems and the absenteeism they cause.

**Liability loss prevention**

Effective lighting can help prevent lawsuits by reducing opportunities for the incidents that can be grounds for claims; e.g., employee accidents or parking lot purse-snatchings. Installation and proper operation and maintenance of effective lighting also provide tangible evidence of a building owner’s foresight and concern, something that could at least help moderate an otherwise substantial damage award.

**Lower insurance costs**

The rate paid for insurance is affected by risk; lighting that lowers risk can help reduce the cost of coverage. Effective outdoor lighting makes accidents, vandalism, break-ins, and assaults less likely, just as effective indoor lighting can reduce the frequency and severity of work-related accidents. By emphasizing to insurers the quality of a lighting system and its effectiveness, lower premiums may be offered.

**Effective mood-setting**

Lighting’s ability to affect mood is an important consideration in restaurants, conference rooms, and other spaces and facilities. By selecting the level of

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**CASE IN POINT**

**FEDERAL BUILDING AND COURTHOUSE SAVES TAXPAYERS MILLIONS**

A $1.3 million investment in lighting improvements at the San Diego Federal Building and Courthouse paid for itself in less than eight years due to significant improvements in productivity, safety, security, and energy efficiency. The project created a 147 percent simple return on investment and realized an overall savings of $1.4 million.

- The Federal Building and Courthouse were originally built in 1976. The project used the most energy-efficient lighting equipment on the market to enhance the work environment, increase employee productivity, improve security, and facilitate maintenance.

- Costs were recognized immediately. Productivity improved 2 percent in office areas and 1.5 percent in the courthouse, prison, and Post Office spaces. With a total of 1,200 employees at an average wage (including benefits) of $32,400 per year, the 2 percent productivity improvement saves the federal government $1,285,000 per year in the Federal Building alone.

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6 Getting the most from your lighting dollar
light suitable for the mood, and by choosing lamps that will produce desired color effects, you are much more likely to attain the desired ambience. Flexibility is often an important concern in this regard, as in conference rooms where controls can be used to adjust lighting to complement the nature of discussion.

**Low-cost space differentiation**

In open landscaped offices, department stores, and similar facilities, electric illumination can be used to differentiate one space from another without erecting partitions or walls, by using different luminaires, different lighting levels, and/or different colors of light. Compared to alternatives, the savings can be substantial.

**Accommodation of frequent spatial changes**

Most office areas are rearranged once every two years; larger retail stores and many other display-oriented facilities are rearranged even more frequently. If their lighting systems cannot be easily and inexpensively adjusted to accommodate spatial changes, inferior — and thus costly — illumination may result, making flexibility of illumination a key concern. Numerous techniques are now available to achieve this flexibility, including luminaires that are easily repositioned or reaimed, and controls that change luminaire light output. Although a modest premium may be necessary to achieve flexibility, long-term benefits generally make it an extremely wise investment, for both leased and owner-occupied space.

**Enhanced building value**

Shopping centers that do more business usually have higher occupancy rates, derive higher rents, are more valuable, and are 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. 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.

**Improved employee morale**

Improved morale is a frequent result of better lighting, in that many employees view improved illumination as a demonstration of management’s concern. Better morale also can result because of lighting’s ability to promote more satisfying work performance, safer conditions, and more attractive space appearance.

**Less downtime**

Industrial downtime often occurs because operational mistakes cause a piece of machinery to break down. To the extent that these mistakes are caused by a visual error, better lighting can help solve the problem. Downtime is also occasioned by equipment that breaks down soon after being repaired. Better lighting helps make this less likely, since it permits those working on equipment to identify and replace parts that are near failure, so equipment can stay operating longer. In one case history, performance in a hosiery mill’s knitting machine repair shop was improved 10 percent due to better electric illumination.

**Tax and other benefits**

Certain types of flexible lighting systems can be easily removed and relocated. As a result, they reportedly do not have to be classified as improvements to real property and, as such, may be subject to faster depreciation. It may also be possible to lease such lighting or elements of it, thereby writing off the system as an ongoing expense while also preserving credit lines.

**Lower utility costs**

Both energy and electric demand costs can be trimmed when more efficient lighting is installed. But consider,
too, how lighting’s impact on other functions may be able to lower utility costs. For example, when productivity is improved or errors are reduced, fewer overtime hours are necessary to get a job done. When people work overtime, a building’s energy systems must work overtime, too. As such, less overtime means less energy consumption. Recognize, too, that the heat generated by a building’s lighting systems often can be used to reduce the amount of space heating otherwise required to maintain comfort. The captured “heat of light” can also be employed for other energy-saving purposes, such as preheating domestic hot water.

More profit
Not many organizations regard their electric illumination as a profit center, but better lighting can contribute significantly to more profit, due to benefits such as less labor per unit, less energy per unit, more units per hour or worker, more sales, and fewer rejects. The key to achieving these benefits is proper attitude. If one approaches lighting as an expense that should be reduced, chances are the focus will be cutting expenses without regard to other factors. By contrast, when you approach lighting as a means to derive benefits whose value greatly exceeds whatever the cost of lighting may be, significant profit can be realized.

Improved civic pride
Many cities boost civic pride through lighting. They illuminate important monuments and public buildings, as well as structures such as bridges. Lighting is also used to help deter crime and create a strong sense of well-being, so more people are encouraged to use a city or spaces in it after dark.

Pollution prevention
Energy-efficient lighting offers the potential for saving electricity which, in turn, prevents air pollution caused by electricity generation. If energy-efficient lighting were used everywhere it were profitable, the Environmental Protection Agency estimates, electric use for lighting would be cut by 50 percent and aggregate national electricity demand would be reduced by 10 percent. This reduction would free $18.6 billion from ratepayer bills for useful investment and reduce annual carbon dioxide emissions by 232 million tons (4 percent of the national total); sulfur dioxide emissions by 1.7 million tons (7 percent of the national total); and nitrogen oxide emissions by 900,000 tons (4 percent of the national total). Other forms of pollution — boiler ash, scrubber waste, acidic drainage and waste from coal mining, radioactive waste, and natural gas leakage — also would be reduced.
Begin Your Journey to the Bottom Line With Understanding and Analysis

The amount of money associated with a lighting retrofit goes far beyond the value of the energy consumed or even the costs associated with replacing an entire system. Productivity, quality control, sales, image, and a wide array of other concerns — each with a price tag of its own — also are involved. You cannot afford to gloss over the issue, nor should you allow it to proceed as a simple “energy project.”

Given the stakes, having expert assistance is essential. High-quality assistance can sometimes be obtained without any expense. But, even when a fee is required, it is worthwhile. Recognize, however, that whoever you rely on may not share your understanding and objectives. Lighting professionals sometimes focus on certain aspects of lighting and may thus stress initial cost more than other factors, or might equate long-term considerations almost exclusively with long-term energy costs. You need to stress that your objective is, first and foremost, providing maximum support of human activities by providing lighting that is optimally suited for the tasks, workers, and spaces involved. By providing high-quality seeing conditions through use of energy-efficient components and systems, energy efficiency will also be optimized. Determining what optimal conditions are requires that you understand the three basic elements of all lighting systems: human elements, nonenergized elements, and energized elements.

Human elements

The human elements of an electric illumination system include, in particular, those who operate and maintain lighting systems and those who rely on lighting to get their work done.

A lighting professional can estimate the ability of a lighting system to support human activity by determining the extent to which the quantity and quality of illumination provided meet recommended values.

More information will be obtained during a walk-through, by observing existing conditions, and discussing lighting issues with users.

Analysis also should address lighting maintenance. The physical review of energized systems will indicate the quality of maintenance being provided. Discussions with maintenance personnel should help determine what their instructions have been and the training they have received.

Nonenergized elements

Nonenergized elements include sources of daylight and principal reflective surfaces in a space. To what extent can or does daylighting contribute to overall illumination? What is the quality of daylighting given the manner in which windows and skylights are located and maintained, the nature of the tasks being performed, and the orientation of workstations to daylight sources? With respect to the surfaces in a space, to what extent do they reflect light and what occurs with respect to the quality of light? In some instances, light-colored walls can be a tremendous benefit by contributing to energy efficiency without any negative impacts. In other cases, light-colored walls might be a source of glare that leads to a degradation of lighting quality and, in turn, productivity losses.

The lighting professional should be able to develop an overall assessment that identifies existing equipment and conditions and the impacts that would occur due to modification of existing conditions as part of the general routine, e.g., cleaning and painting.

Energized elements

Energized elements include lamps, luminaires, and controls. Once components of the existing energized system have been identified, they can be depicted graphically to indicate where they are located with respect to other elements of a space. One approach to doing this is indicated in Figure 1.

![FIGURE 1: Room Sketch Showing Locations of workstations and Luminaires](image)
Based on the tasks being performed in a space, a lighting professional will be able to indicate the quantity and quality of lighting needed to optimize task performance. Quantity needs can be determined easily, through simple reference to data developed by the Illuminating Engineering Society of North America (IESNA). Quantity actually being delivered can be determined with a lightmeter. Quality factors are not so easily determined, however, and often they can be crucial. In fact, lighting quality usually is more important than lighting quantity, and — unlike quantity — you don’t need to consume energy in order to have it.

Based on review of the existing system, one of the first orders of business often is analysis of maintenance being provided. If maintenance is not effective, the quantity and quality of light the system delivers will be far less than that which the system is capable of delivering simply as a consequence of more frequent cleaning and lamp replacement. All too often a maintenance analysis is not performed and, as a consequence, managers authorize system changes that are not needed or which are of little help.

**Report and recommendations**

The result of the examination should be a report of existing conditions and recommendations for change. These recommendations should be accompanied by estimates of investment requirements and likely savings to be achieved, including recognition of savings likely to be derived from enhanced productivity and other lighting benefits.

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**CASE IN POINT**

**LIGHTEST ON ACCIDENT-RECORD STUDY SHOWS**

In an effort to cut costs and energy consumption, the Wisconsin Department of Transportation deactivated 35 miles of Milwaukee area freeway lighting. The public was alerted by the measure, and after 20 days, full lighting was restored. But the elimination of lighting had a significant impact on accident rates. The issue was to examine which the state’s transportation department decided to study. Their study showed conclusively that streets and highway lighting saves lives.

One of the studies compared nighttime accident data for the 20-day period with average data for the same period in three prior years. When the lights were out, it was shown, the number of reportable nighttime accidents rose by 14 percent, interchange ramp accidents increased by 17 percent, and the number of persons injured was up by 30 percent.

Another study compared nighttime accident data for the 20-day lights-off period with that from the prior 20 days. When the lights were on, the overall number of reportable nighttime accidents rose by 12 percent; the number of accidents with injuries rose by 23 percent; and the number of persons injured increased by 17 percent.

Life-saving accident prevention is not the only public benefit to be derived from effective street and highway lighting. Comments on the situation, a Milwaukee area public works director noted that inadequate lighting would jeopardize snow-removing and salting operations, leading to massive delays despite the estimated $60,000 extra per season that these operations would cost due to slower performance. A law enforcement official said that, without adequate street and highway lighting, spotlights would have to be installed on all squad cars and security patrol would take longer and require additional personnel to achieve comparable levels of safety.

10  Getting the most from your lighting dollar
You Need Help in Selecting Energized Elements

The lighting industry’s response to America’s need for energy efficiency has been amazing. The array of new products and technologies is so large that it can be bewildering to those who are not involved with lighting on a full-time basis. Bear in mind, also, that you should be concerned not only with the individual elements, but also with their interrelationships. Everything needs to work together to produce a high-benefit system that is reliable, easy to maintain, and energy-efficient. Note, too, the need for flexibility. The layout of work stations in an area seldom stays unchanged for long; the work performed in an area is subject to change as well. A lighting system that can be adapted to support changed conditions is far more valuable than one which cannot. Some of the key concerns associated with lamps, luminaires, and controls are covered quickly below. More detailed discussion is found in other National Lighting Bureau publications.

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. Incandescent lamps convert utility-provided power to light directly, by heating a tungsten filament to the point of incandescence (glowing with white heat). Generating light in this way results in low efficiency (only 10 percent of the energy consumed results in light) as well as short life (750 to 3,500 hours). All the other lamp types operate on a gas-discharge principle, whereby light is produced by the passage of an electric current through a gaseous vapor.

Efficacy

Efficacy is the technical term used to indicate a lamp’s efficiency. It is expressed in terms of lumens (a measure of light output) per watt (of power required to operate the lamp). The efficacies of lamps vary considerably, as shown in Table 1.

The lumens-per-watt rating used to indicate lamp efficacy is somewhat similar to the miles-per-gallon rating used to indicate an automobile’s efficiency, with one major difference: The miles-per-gallon rating is determined as a result of all automobile components working together. By contrast, a lamp is only one component of an overall system. Specifying high-efficacy lamps is no guarantee the system will be efficient.

<table>
<thead>
<tr>
<th>Table 1: General Lighting Lamp/Ballast Characteristics¹</th>
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<tbody>
<tr>
<td>Type of Lamp</td>
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<tr>
<td>Low-Pressure Sodium</td>
</tr>
<tr>
<td>High-Pressure Sodium</td>
</tr>
<tr>
<td>Metal Halide</td>
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<tr>
<td>Mercury Vapor</td>
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<tr>
<td>Standard</td>
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<tr>
<td>Self-Ballasted</td>
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<tr>
<td>Fluorescent</td>
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<tr>
<td>Incandescent</td>
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</tbody>
</table>

NOTES:
1. Data are based on the more commonly used lamps and are provided for comparison purposes only. Actual results to be derived depend on factors unique to the specific products and installation involved. Consult manufacturers for guidance.
2. Lumens (of light output) per watt (of power input) is a common measure of lamp efficiency (efficacy). Initial lumens-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 an installation. The actual efficiency of a lighting system depends on far more than the efficiency of lamps or lamps/ballasts alone. More than efficiency should be considered when evaluating a lighting system.

Getting the most from your lighting dollar 11
**Rated life**

Rated life is determined by manufacturers as that point in time when half the lamps of a large group of test lamps fail. Rated life is an important economic criterion, given the cost of replacement lamps as well as the cost of labor (and sometimes rented equipment) needed to replace them. Rated life data is published in lamp manufacturers’ catalogs.

**Lamp lumen depreciation (LLD)**

The light output of most lamps diminishes through a process called lamp lumen depreciation (LLD). Because energy consumption remains constant, however, the lamps become steadily less efficient. In fact, the cost per lumen of light ultimately becomes so high it usually is economical to replace lamps before they burn out. Figure 2 illustrates typical LLD curves for commonly used lamps.

**Color temperature and color rendition**

Color temperature and color rendition are two interrelated concerns. Color temperature refers to the whiteness of light, for example, 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.

Each type of lamp has a different spectral distribution and thus tends to emphasize or deemphasize some colors more than others. Incandescent and some types of daylight are often considered “standards” of color rendition. Due to new phosphors used to coat tube walls, and new techniques for applying these coatings, some fluorescent and metal-halide lamps provide excellent color rendition without sacrificing efficacy.

High-pressure sodium (HPS) lamps, which are used extensively for outdoor lighting, produce what is called a “golden white” color. Although they cause some “color shifting” (e.g., reds take on a brownish hue), all colors they illuminate remain recognizable.

Low-pressure sodium lamps — the most efficient of all — produce all their light in the yellow portion of the visible spectrum. As a result, colors they illuminate appear as shades of yellow or grey. Low-pressure sodium lighting is suited for applications where color recognition is of no importance (e.g., in a warehouse where “picking” is not color-dependent) or where it can be mixed with other types to enhance overall system efficiency while minimizing color impacts.

**Luminaire compatibility**

A given lamp’s compatibility with a luminaire is an important factor only when there is some type of restriction on luminaire selection. This sometimes occurs in modernization projects when it is decided to reuse the existing fixtures for purposes of economy or authenticity.

In some cases it may be possible to reuse a luminaire “as is” and install a lamp which is far more energy-efficient or which provides far more light than the lamp for which the luminaire originally was designed (Table 2). A knowledgeable person should always be relied
Table 2: Interchangeability of several selected lamps

<table>
<thead>
<tr>
<th>STANDARD LAMP</th>
<th>REPLACEMENT LAMP</th>
<th>WATTAGE SAVINGS$</th>
<th>COMPARATIVE LIGHT OUTPUT OF REPLACEMENT LAMP$</th>
<th>VALUE OF ENERGY SAVINGS OVER LIFE OF REPLACEMENT LAMP AT 0.08/KWH</th>
</tr>
</thead>
<tbody>
<tr>
<td>60W Incandescent</td>
<td>55W Reduced-Wattage Incandescent</td>
<td>5</td>
<td>-</td>
<td>$0.40</td>
</tr>
<tr>
<td></td>
<td>13WTT Compact Fluorescent with Ballast Adapter</td>
<td>44.5</td>
<td>+</td>
<td>$35.60</td>
</tr>
<tr>
<td>75W Incandescent</td>
<td>70W Reduced-Wattage Incandescent</td>
<td>5</td>
<td>-</td>
<td>$0.40</td>
</tr>
<tr>
<td></td>
<td>22W Circine Fluorescent</td>
<td>45</td>
<td>-</td>
<td>$43.20</td>
</tr>
<tr>
<td></td>
<td>18W Compact Fluorescent</td>
<td>57</td>
<td>-</td>
<td>$34.20</td>
</tr>
<tr>
<td>100W Incandescent</td>
<td>95W Reduced-Wattage Incandescent</td>
<td>5</td>
<td>-</td>
<td>$0.40</td>
</tr>
<tr>
<td></td>
<td>44W Circine Fluorescent</td>
<td>56</td>
<td>-</td>
<td>$33.60</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>
</tr>
<tr>
<td></td>
<td>45W Incandescent (Halogen)</td>
<td>30</td>
<td>-</td>
<td>$4.80</td>
</tr>
<tr>
<td>150W R-40 Flood Incandescent</td>
<td>75W ER-30 Incandescent$^4</td>
<td>75</td>
<td>-</td>
<td>$12.00</td>
</tr>
<tr>
<td></td>
<td>120W ER-40 Incandescent$^4</td>
<td>30</td>
<td>+</td>
<td>$4.80</td>
</tr>
<tr>
<td>150W PAR-38 Spot or Flood Incandescent</td>
<td>90W PAR-38 Spot or Flood Incandescent</td>
<td>60</td>
<td>-</td>
<td>$9.60</td>
</tr>
<tr>
<td></td>
<td>120W PAR-38 Incandescent</td>
<td>30</td>
<td>-</td>
<td>$4.80</td>
</tr>
<tr>
<td>300W R-40 Flood Incandescent</td>
<td>120W ER-40 Incandescent$^6</td>
<td>180</td>
<td>-</td>
<td>$28.80</td>
</tr>
<tr>
<td>500W Incandescent</td>
<td>450W Self-Ballasted Mercury Vapor$^6</td>
<td>50</td>
<td>*</td>
<td>$64.00</td>
</tr>
<tr>
<td>1,000W Incandescent</td>
<td>750W Self-Ballasted Mercury Vapor$^6</td>
<td>250</td>
<td>-</td>
<td>$320.00</td>
</tr>
<tr>
<td>F-40 Fluorescent</td>
<td>F-40 Reduced-Wattage, High-Efficiency Fluorescent</td>
<td>7</td>
<td>-</td>
<td>$11.20</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>
</tr>
<tr>
<td></td>
<td>F-40 Reduced-Wattage, High-Efficiency, Color-Improved Fluorescent</td>
<td>7</td>
<td>*</td>
<td>$11.20</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>
</tr>
<tr>
<td></td>
<td>F-40 High-Brightness Fluorescent</td>
<td>0</td>
<td>+</td>
<td>$0.00</td>
</tr>
<tr>
<td>F-40 Fluorescent (Ushape)</td>
<td>F-40 Reduced-Wattage, High-Efficiency Fluorescent (Ushape)</td>
<td>7</td>
<td>-</td>
<td>$11.20</td>
</tr>
<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>
</tr>
<tr>
<td>F-96 HO Fluorescent</td>
<td>F-96 HO Reduced Wattage, High-Efficiency Fluorescent</td>
<td>21</td>
<td>*</td>
<td>$20.20</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>
</tr>
<tr>
<td>175W Mercury Vapor</td>
<td>15W Retrofit High-Pressure Sodium</td>
<td>40</td>
<td>++</td>
<td>$38.40</td>
</tr>
<tr>
<td>250W Mercury Vapor</td>
<td>215W Retrofit High-Pressure Sodium</td>
<td>65</td>
<td>++</td>
<td>$62.40</td>
</tr>
<tr>
<td>400W Mercury Vapor</td>
<td>325W Retrofit Metal Halide</td>
<td>70</td>
<td>++</td>
<td>$112.00</td>
</tr>
<tr>
<td></td>
<td>400W Retrofit Metal Halide</td>
<td>0</td>
<td>++</td>
<td>$6.00</td>
</tr>
<tr>
<td></td>
<td>360W Retrofit High-Pressure Sodium</td>
<td>60</td>
<td>++</td>
<td>$76.80</td>
</tr>
<tr>
<td>1,000W Mercury Vapor</td>
<td>880W Retrofit High-Pressure Sodium</td>
<td>160</td>
<td>++</td>
<td>$204.80</td>
</tr>
<tr>
<td></td>
<td>950W Retrofit Metal Halide</td>
<td>50</td>
<td>++</td>
<td>$48.00</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), and - (substantially less). Consult manufacturers for accurate information relative to conditions unique to the lamps and installations involved.
4. When installed in a stack-baffled downlight.
5. For high voltages only.

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upon to evaluate any such plan. Although its implementation is simple, inferior lighting could result; safety hazards may be created as well.

Another alternative is converting an existing luminaire so it can accept a new kind of lamp. In some instances the savings can be remarkable. For example, many existing luminaires designed to house four 40W fluorescent tubes and two standard electromagnetic ballasts can be fitted with four T8 fluorescent lamps and just one electronic ballast. Although the refitted fixture will produce virtually the same amount of light as before, its energy consumption will have been reduced by almost 40 percent. Note, however, that a close cost analysis should be performed before modifying a luminaire, because — in some cases — the cost of the modification may be close to or even exceed the cost of replacement. The luminaire’s condition also is an important factor. If interior surfaces have become dulled and a new lens or louver is required, luminaire replacement almost always will be more cost-effective than modification.

**Luminaires**

Technically speaking, a luminaire is a complete lighting unit, including lamps, ballast(s), lamp holders, reflectors, and shielding/diffusing media.

**Coefficient of utilization (cu) rating**

A luminaire’s efficiency is determined as the ratio between its light output and the light output of the lamp or lamps it houses. For example, a luminaire that produces 20,000 lumens using a lamp that produces 25,000 lumens is 80 percent efficient, meaning it absorbs or traps 20 percent of the lamp’s light. The amount of light a luminaire produces generally is not as important a concern as the manner in which it directs the light. For this reason, most lighting professionals evaluate luminaire performance in terms of coefficient of utilization or CU, a factor that describes the proportion of light generated by the lamps that ultimately reaches the work plane, i.e.:

\[
\text{Lumens Reaching the Work Plane} \quad \text{CU} = \frac{\text{Lumens Generated by the Lamps}}{\text{Lumens Reaching the Work Plane}}
\]

As a consequence of this relationship, a luminaire would have a CU of 0.70 when it delivers 14,000 lumens to the work plane using a lamp or lamps that produce 20,000 lumens.

Evaluating the CU of luminaires is important because it has such a pronounced effect on a system’s initial and life-cycle costs.

Luminaire manufacturers publish the CUs of their products based on standardized calculation procedures. Note, however, that a luminaire’s CU rating is application-dependent. The size and shape of a specific space affect luminaire CU. The reflectances of a room’s surfaces also affect CU. For example, a room with high-reflectance (white) surfaces creates higher CUs and thus

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**CASE IN POINT**

**KARL KOVACS SAVES THOUSANDS THANKS TO LIGHTING INVESTMENT**

“We had been planning to improve lighting for the past five years or so, but the dollars required for remodeling could not be justified based on O&M [operation and maintenance] savings,” that’s the way John Kaufman summarized the situation at the American Hardware Supply Company’s 318,000-square-foot distribution center that he managed at the company’s national headquarters in Butler, PA. Nonetheless, he decided to test a high-benefit lighting decision that he proposed be tested at a successful company. Saving on many of the existing fixtures (cleaned and reinstalled), plus new metal halide units, his plan achieved the following objectives:

1. Personnel were able to work faster than before. Mr. Kaufman estimated that a 1 percent productivity improvement was achieved, worth a minimum of $35,000 per year.
2. Workers made fewer errors. The savings, estimated at $1,800 annually, were comparatively small, because there was no room for improvement.
3. Because of the company’s excellent record, it was assumed that little could be done to improve safety. Nonetheless, the company estimated that better lighting’s safety benefits had a value of $1,000 per year, due to time savings and lower insurance premiums. But as Mr. Kaufman noted, “The principal benefit involved is one that cannot be calculated: sparing loyal employees the pain (or worse) that can result from an injury.”
4. Increased sales worth $50,000 annually were attributed to better lighting. In large part because of the much improved image created when customers visited the facility. According to Mr. Kaufman, “The one word most commonly heard when we talk to a store owner or prospective owner through the warehouse is, ‘View.’ The lighting is the first thing they see when they enter. It makes the warehouse look much larger than before; much cleaner, and more contemporary. It instantly conveys the impression that we are a large, modern organization.”
5. Employee morale improved because employees were able to perform their work faster and better, and the improved appearance of the space and appreciated management’s investment in their comfort and safety.

Overall, lighting benefits carried a value of just under $88,000 per year. O&M cost saving added another $4,776 to the total, bringing it to $102,786 annually. Given the company’s investment of $176,888, simple payback was achieved in 1.7 years. Simple return on investment (ROI) came to 36 percent per year.

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requires fewer luminaires to achieve design conditions than a room with dark, low-reflectance surfaces. Accordingly, room surface reflectances can dramatically affect overall lighting efficiency, as well as initial and life-cycle lighting costs. Note, however, that high-reflectance surfaces can in some situations create problematic viewing conditions, necessitating close consideration of quality factors before a decision is made.

**Visual comfort probability (VCP) rating**

Visual comfort probability, or VCP, is a rating used to indicate how much glare an indoor luminaire is likely to produce. A VCP of 70 indicates that 70 percent of the people seated in the least desirable location of a space would not consider the system “glary” or visually uncomfortable. Historically, VCPs of 70 or higher have been considered good for most offices. Offices that rely heavily on video display terminals (VDTs) require luminaires with a minimum VCP of 80.

As with CU, VCP ratings are application-dependent; a luminaire that provides adequate visual comfort in a small space may be completely inappropriate for a larger one.

**Luminaire dirt depreciation**

Luminaire dirt depreciation or LDD indicates a fixture’s ability to resist dirt build-up on light-reflecting and transmitting surfaces, as well as lamps. The better a luminaire resists dirt build-up, the fewer luminaires are required to maintain a given amount of illumination averaged over time, and the less frequently the fixtures need to be cleaned.

**Maintainability**

Luminaires should be cleaned on a regular basis; at least annually. Some are far easier to maintain than others by virtue of their design. If a luminaire is particularly difficult to clean, chances are it will not be cleaned as well as it should be and the efficiency of the system will suffer.

**Shielding and diffusing media**

Shielding and diffusing media — lenses and louvers — shield bare lamps from view and distribute their light. As such, different shielding and diffusing media result in different CUs and VCPs. The light distribution properties of shielding and diffusing media are particularly important in situations where VDT screen reflections may be a problem.

**Ballasts**

Gas-discharge lamps require a ballast for starting and proper operation. Ballasts are designed to meet the specific needs of the lamps they operate in order to assure optimum light output and lamp life.

Developments in the area of fluorescent ballast manufacture have been particularly pronounced, epitomized by electronic or high-frequency ballasts. They are more efficient than energy-saving electromagnetic ballasts, last as long, are silent, and can be more versatile, due to their compatibility with dimming controls. Although they cost more than electromagnetic ballasts, their energy savings potential makes them more cost-effective. And in some cases, fewer of them may be required. For example, four- and three-lamp fluorescent luminaires formerly requiring two electromagnetic ballasts, each operating one or two lamps, can now operate with just a single electronic ballast designed for four- or three-lamp operation.

**Reflectors**

Reflectors are installed inside a luminaire to reflect lamp light. Luminaire manufacturers design their reflectors to work with other fixture components, such as the lens or louver, to achieve specific distributions of

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**CASE IN POINT**

**METAL PLANT ACHIEVES 29-WEEK PAYBACK**

Superior Pipe Specialties Company (Cicero, IL) knew it could reduce energy consumption by rewiring new lighting but obtaining information on alternatives was not always easy.

- Workers at the $5,000,000-a-year plant engaged in basic heavy metal operations, welding, forming and surface-treatment for major utility pressure vessels. After evaluating several alternatives, the company invested in a new high-benefit lighting system that relied on high-pressure sodium (HPS) lamps and luminaires. According to records of the employees’ performance:
  - Productivity increased significantly throughout the plant in the first year more than others. Savings amounted to $15,000 per year.
  - The number of rework was greatly reduced; saving $48,000 per year.

Superior also reduced oil-firing-system operation and maintenance (O&M) costs by $6,000 per year. A total of $135,561 annually saved was paid back in 29 weeks and the simple annual investment (SRI) was 112 percent per year.

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light. To obtain optimal efficiency, quality, and useful life, reflectors — as other luminaire components, including lamps — should be cleaned on a regular basis.

Highly polished retrofit reflectors are marketed for installation in existing fluorescent luminaires. Optimal performance requires custom design and fitting. Overall, the expense required may be close to that associated with other, potentially more effective modification options, such as lamp and ballast replacement, or with installing brand-new luminaires.

**Controls**

No matter how efficient a lighting system may be, it will waste energy whenever it is used unnecessarily or when it provides more light than needed. Automatic controls now are being applied extensively in and around buildings to provide light when and where it is needed while helping to assure savings are attained without having to rely on human memory. Nonetheless, manual controls still can be effective when they are properly applied.

**“Intelligent building” controls**

Lighting control can be integrated with other “intelligent building” automation systems, including HVAC and security networks that rely on a central computer which handles a wide variety of other functions. These functions include system data processing, HVAC monitoring and control, energy logging and control, and security — even fire safety (code permitting).

To keep a building competitive for years to come, those directing modernization projects should consider including lighting control as part of their automation systems. In such highly sophisticated systems, individuals are sometimes able to control the lighting for their space either through their computer or telephone keypad.

Another control scheme, somewhat less sophisticated than fully integrated systems, are stand-alone automated building control systems, used principally for energy monitoring, logging, and control. They, too, are fully capable of handling lighting from a central control module, with most on-off and dimming functions being performed on an automated, programmed basis, usually aided by sensors of different types.

Multifunction programmable controllers are another option, used principally for handling local on-off and dimming functions. Designed particularly for lighting, they can handle other building systems as well, such as motorized window shades.

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 sensors and controls can be integrated into a centralized control system to provide automatic functions, often in conjunction with manual controls.

**Other automatic controls**

The timeswitch is one of the most established automatic controls. Applied originally for outdoor purposes, it is now used extensively indoors, too, to activate and deactivate lighting at predetermined times, to help minimize energy waste. Some of these devices are electro-mechanical; others are electronic.

Photosensor controls also were developed principally for outdoor lighting. When ambient light falls below a predetermined level, the lighting is activated. Most have a delay feature that prevents rapid cycling during partly cloudy periods.

Photosensor-timeswitch controls represent a refinement of the prior two. They usually are applied to turn lighting on in response to signals from the photosensor, and then turn lighting off at a predetermined time, via the timeswitch.

Photosensor-dimmer controls are used principally for indoor applications, for luminaires near windows or skylights. They rely on daylighting to help maintain a given lighting level. The photosensor monitors the
**Federal legislation bans certain lamps**

In order to help the nation reduce energy waste, the federal government enacted the Energy Policy Act of 1992 (EPACT), a statute that now bans the manufacture and import of certain fluorescent and incandescent lamps. Some of the lamps affected include:

**Incandescent**
- R30 (75)
- R40 (75, 100, 150)
- PAR38 (75, 100, 150, 200)
- 75/120 (100/60, 150/120)

**Fluorescent**
- F40 CW
- F40 WW
- F84T12/CW
- F84T12/WW
- F84T12/CW/HO
- F84T12/WW/HO

Once existing stocks are depleted, these lamps will no longer be available. In most cases, replacement lamps have been on the market for a number of years and can easily be obtained. In the case of F40 shop lights and F84T12 service lights, however, replacement lamps and fixtures should be used, due to the potential for overheating as a consequence of lamp/ballast incompatibility.

In most instances, relying on different lamps will pose no problem, in fact, depending on the choice made, the new lamps will provide not only energy efficiency, but also better quality light and longer lumien maintenance.

In the case of particularly old fluorescent luminaires that still have their original ballasts installed, reliance on a new lamp may cause some ballasts to simply fail. In these instances, new ballasts can be installed. Given the expense involved, however, owners would be well advised to consider installation of new fixtures. New lamp/luminaire options can result in significant energy savings, as well as the provision of lighting that is specifically designed for the space, workers, and tasks involved. Obtain more information from a lighting professional.

daylight and, as the amount available diminishishes, the luminaire’s light output is automatically increased. These controls can be applied on an individual luminaire or a centrally located sensor can be used to control a group of luminaires. Care should be used in determining which luminaires to control and in locating the sensor.

**Timeswitch-dimmer controls** are useful when space usage patterns are known. For example, a study may reveal that only 15 percent of a store’s sales occur during the hours of noon to 4:00PM, and that the additional attention given to customers by salespeople during that time would compensate for the negative sales impact caused by dimming the lights 20 percent. Accordingly, it may be appropriate to install a timeswitch-dimmer control that would automatically effect a 20 percent light reduction from noon to 4:00PM.

Simple mechanical *occupant sensors* have been available for many years, in the form of spring-loaded doormframe buttons. Today’s occupancy sensors use ultrasonic sensing and other means to control lighting in large areas. They automatically activate lighting when people are detected, then deactivate it within a certain predetermined period during which no one’s presence is sensed. These devices can be used in conjunction with dimmers, an application that can be particularly appropriate in certain retail operations: As people approach a display, lights are brought up to full output. When they leave, lighting levels are automatically reduced to the preset low level.

More than just good energy-saving devices, these controls are now required by a number of building codes.

**Manual controls**

Some older buildings still rely on the most basic of all manual controls: A *circuit breaker at a central panelboard*. This is the least effective control, because it offers little if any selectivity, requires manual operation, and is remote from users. Frequently, lighting is turned on early and left on late, or not turned off at all, for the convenience of those with lighting control responsibility. Building codes now forbid this approach as the sole means of lighting control in new buildings.

*Wall switches (AC snap switches)* located within the illuminated space at least give users the ability to turn off lighting that is not needed.

*Low-voltage switching systems* can be used much as conventional line-voltage switches. A low-voltage switch operates a relay that performs the actual switching function. These systems enhance convenience and flexibility, because switches can operate any number of relays.

**CASE IN POINT**

**NEW LIGHTING WORTH $1 MILLION TO PAY FOR**

When the Pillowtex Corporation decided to move its showroom to Dallas’ World Trade Center, it also decided to invest in the services of a consulting illumination engineer. The high-benefit design developed employed museum-type lighting using fixtures with low-voltage halogen lamps, mounted beneath glass sleeves. According to the company’s director of product development, numerous buyers commented on the lighting system, and he estimated about $1 million per year in increased sales due to high-quality illumination. The lighting itself was no more expensive than a conventional system, and actually saved $3 per year to operate and maintain. The $2,000 premium paid for a better design was recovered during the system’s first 12 hours of use.
CASE IN POINT
NEW LIGHTING RETURN PAIN TO THE PEOPLE

Located on 6.7 acres in Spring Valley, a suburb of San Diego, Spring Valley Park was known for its handsome grounds and a 133,000-square-foot community center. For a while it was also known for problems brought about by inadequate lighting: several serious incidents of assaults with injury each year; automobile break-ins; almost one vehicle-pedestrian accident each week; with older people often the victims; about 40 vehicle-vehicle accidents annually; almost daily spray painting of the community center (costing $7,000 per year to correct); and $25,000 worth of theft and damage caused by break-ins at the community center.

Determined to do something about these problems, the County of San Diego Department of Parks and Recreation invested $17,230 in a new, high-benefit lighting system. Assaults and robberies were virtually eliminated; vehicle-pedestrian accidents were cut by 75 percent; while vehicle-vehicle accidents were reduced by almost 90 percent. Vandalism was virtually eliminated, saving $10,000 per year, and community center break-ins were stopped, saving another $35,000 each year. As a result of these latter two benefits alone, simple payback for the new lighting occurred in slightly more than six months. Perhaps more important, the Park has once again become a community resource.

Key-activated switches are used as conventional line- or low-voltage switches. They are applied for security purposes; only authorized personnel with a key may use them.

Dimmers can be integrated into automatic control systems and can be used manually as well. They are available for most types of lighting. Some permit reductions to any point between 100 and 1 percent light output; others allow limited reductions (e.g., 100 to 20 percent of full light output). Fluorescent lighting requires use of electronic dimming ballasts. Dimming can provide a high degree of flexibility. Even a space illuminated by a uniform lighting system can be given the effectiveness of nonuniform lighting through dimming. Some of the newer systems permit workers to control the light output of individual luminaires in their workplace by means of a hand-held remote control.
Maintenance: A Path to Guaranteed Savings

In many settings, lighting is not maintained, except to replace lamps once they burn out. This allows dust and dirt to build up on lamps and luminaires, eroding not only the amount of light distributed, but its quality as well. Significant savings can result from cleaning such a system on a regular basis. The cost? Very little. Given the impact maintenance can have, you probably should not modify your existing system until it has been cleaned or even cleaned and relamped. And once you do make modifications, plan to provide regular maintenance to help assure you keep the benefits you get originally.

Planned lighting maintenance

Knowing that many systems will not be well maintained, lighting designers often include compensatory lighting — additional lamps and luminaires — in their designs to help assure adequate lighting despite poor maintenance; e.g., lamps left in place long after their diminished light output warrants replacement, and luminaires that are not cleaned often enough.

If those responsible for a lighting system can assure that planned lighting maintenance (PLM) will be performed, compensatory lighting can be eliminated.

Regular cleaning and timed group relamping are two key elements of PLM. Regular cleaning helps assure dust and dirt do not build up to such a degree that they absorb excessive quantities of light. It may increase average light output over time by 50 percent or more. For purposes of economy, all luminaires in a system or large area should be cleaned at the same time (group cleaning), usually during nonoccupied hours. (Lighting management companies can be hired to perform this function.)

Group relamping

Group relamping is almost always a major money-saver. It involves replacing all lamps in a system at the same time. Typically, all lamps, lamp-changing equipment, and personnel are assembled at a preplanned time when lamp-changing operations will not affect others’ activities. This greatly expedites the lamp-changing process, typically reducing time requirements to three minutes (0.05 hr) per lamp. Assuming a labor rate of $15 per hour (inclusive), the cost of replacing 720 lamps would amount to $540 (assuming no additional costs for proper lamp and ballast disposal). Since this would be done once every five years, the annualized cost would be $108 per year.

If lamps are left in place until they burn out, they must be changed on an individual basis. The time required to do this, all things considered, generally averages about 30 minutes (0.50 hr) per lamp or longer, considering the need to select the proper lamp, obtain a ladder, move furniture or interrupt others’ work, discard the old lamp, etc. The cost of relamping labor on this basis would be $6,000. Since, on average, a complete changeover would become effective every 6.67 years, the annualized cost would be $900. As such, the premium that would have to be paid for discarding lamps only after they burn out would amount to $1,530.

Although group relamping does not eliminate the need for some spot relamping, it does require maintenance of a far smaller inventory of lamps. This means fewer dollars tied up on material sitting on a shelf, less space required for lamp inventory, less breakage, and less “inventory shrinkage.” In addition, substantial discounts may be attainable when lamps are purchased on a bulk basis. Group relamping also makes contract lighting maintenance practical (in the private sector, the cost is amortized monthly over the length of the contract) and that can lead to reduced demand for staff time. Note, however, that federal law and some state laws affect the manner in which many types of lamps and certain ballasts are disposed of. These laws and their attendant regulations must be followed and doing so may elevate lighting maintenance costs. Nonetheless, group relamping should still remain a cost-effective option.

Timed group relamping

With timed group relamping (TGR), group relamping is performed at an optimal time, based on the lamps’ lumen depreciation characteristics. As a result of replacing lamps on this basis, the average amount of light they produce while in place is higher than it otherwise would be. Accordingly, the average light output of the entire system is higher than it otherwise
would be. In many instances, maintenance of higher system light output through TGR permits a designer to use up to 25 percent fewer fixtures and lamps in the initial installation, depending on lamp type.

Although TGR is a proven money-saver, misdirected "common sense" can sometimes be an obstacle. This occurs when some individuals find it unacceptable to discard lamps that are still serviceable. That can be an expensive attitude. Consider the hypothetical installation shown in Table 3. It comprises 200 four-lamp fluorescent luminaires operated 3,000 hours per year, each lamp having a rated life of 20,000 hours. At an assumed cost of $3 per lamp, the annualized cost of replacement lamps is $360.

With TGR, the number of fixtures is reduced by a conservative 10 percent to 180, but lamps are replaced at 75 percent of rated life or every 15,000 hours instead of every 20,000 hours. As such, the cost of replacement lamps increases by $72, from $360 per year to $432 per year. However, this premium is offset by an energy cost savings of $720 per year, assuming a connected load of 150W/luminaire and an energy rate of $0.08/kWh (averaged to include demand). The annualized cost of cleaning and rebalancing also would be reduced by 10 percent, and the benefits of group relamping also would be attained.

Table 3: PLM comparison

<table>
<thead>
<tr>
<th></th>
<th>WITHOUT PLM</th>
<th>WITH PLM</th>
<th>SAVINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminaires</td>
<td>200</td>
<td>180</td>
<td>20 luminaries</td>
</tr>
<tr>
<td>Lamps/Luminaire</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Load/Luminaire</td>
<td>275W</td>
<td>275W</td>
<td></td>
</tr>
<tr>
<td>System Load</td>
<td>55kW</td>
<td>49.5kW</td>
<td>5.5kW</td>
</tr>
<tr>
<td>Hours of Use</td>
<td>4,000 hrs/yr</td>
<td>4,000 hrs/yr</td>
<td></td>
</tr>
<tr>
<td>kWh/Year</td>
<td>220,000kWh/yr</td>
<td>198,000kWh/yr</td>
<td>22,000kWh/yr</td>
</tr>
<tr>
<td>Avg. $/kWh</td>
<td>$0.10/kWh</td>
<td>$0.10/kWh</td>
<td></td>
</tr>
<tr>
<td>(incl. demand)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Cost</td>
<td>$22,000/yr</td>
<td>$19,800/yr</td>
<td>$2,200/yr</td>
</tr>
<tr>
<td>Useful Lamp Life</td>
<td>24,000 hrs</td>
<td>18,000 hrs</td>
<td>(6,000 hrs)</td>
</tr>
<tr>
<td>Lamps Replaced</td>
<td>33.3 lamps/yr</td>
<td>40.0 lamps/yr</td>
<td>(6.7 lamps/yr)</td>
</tr>
<tr>
<td>Cost/Lamp</td>
<td>$40</td>
<td>$40</td>
<td></td>
</tr>
<tr>
<td>Replacement Lamp Cost</td>
<td>$1,332/yr</td>
<td>$1,600/yr</td>
<td>($268/yr)</td>
</tr>
<tr>
<td>Time to Replace One Lamp</td>
<td>0.67hrs/lamp</td>
<td>0.17hrs/lamp</td>
<td>0.50hrs/lamp</td>
</tr>
<tr>
<td>Relamping Labor Time</td>
<td>22.3hrs/yr</td>
<td>6.8hrs/yr</td>
<td>15.5hrs/yr</td>
</tr>
<tr>
<td>Labor Cost</td>
<td>$10/hr</td>
<td>$10/hr</td>
<td></td>
</tr>
<tr>
<td>Relamping Labor Cost</td>
<td>$223/yr</td>
<td>$68/yr</td>
<td>$155/yr</td>
</tr>
<tr>
<td>Cleaning Time</td>
<td>0.1hr/lum</td>
<td>0.1hr/lum</td>
<td></td>
</tr>
<tr>
<td>Cleaning Time/Year</td>
<td>20hrs/yr</td>
<td>18hrs/yr</td>
<td>2hr/yr</td>
</tr>
<tr>
<td>Cleaning Cost/Year</td>
<td>$200/yr</td>
<td>$180/yr</td>
<td>$20/yr</td>
</tr>
<tr>
<td>Total O&amp;M Costs</td>
<td>$23,755/yr</td>
<td>$21,648/yr</td>
<td>$2,107/yr</td>
</tr>
</tbody>
</table>
Making Cost-Effective Lighting Decisions

A lighting professional should present a report that includes an array of options for your consideration. Some of the options will represent different approaches to illuminating the same area; others will be options among areas, in other words, relight Area A, Area B, or both. At one time decisions would be based strictly on a basic investment analysis of some type, such as simple payback. Today, more alternatives exist, making it possible to do more with less, depending on programs available from local utilities and others. Chances are the organization you work for already has established investment analysis methods. For example, federal government life-cycle costing methods are described in Life-Cycle Cost Manual for the Federal Energy Management Program (order No. PB881 138227) available from the U.S. Department of Energy (DOE), Washington, DC. Building Life-Cycle Cost (BLCC) Software also is available from DOE.

Economic factors

Economic evaluations should consider a variety of factors. Some of the most common are indicated below.

Initial costs

Initial costs include the cost of design, system components, and installation. Initial costs will be reduced by any incentives or rebates offered by the local utility. Purchase is only one of several options for hardware acquisition. Under a lease agreement, an investor (lessor) finances the purchase and installation of lighting equipment and the building owner (lessee) makes monthly payments for its use. The building owner also is responsible for maintaining the equipment. At the end of the lease agreement, the building owner can purchase the equipment at a predetermined residual value, extend the lease, or have the equipment removed.

Through shared energy savings (SES) contracts, a third party — usually an energy service company (ESCO) — designs, installs, and owns the lighting equipment at the owner’s facility, with the ESCO receiving a share of the energy savings that result.

Financing by banks or other third parties also is an option, with initial costs being split into equal monthly payments and paid over a period of years. In many cases, the value of energy savings exceeds the monthly time payment, resulting in a positive cash flow.

Operating costs

Operating costs are related principally to energy and demand. Although these can be calculated manually, computer programs give better results. Many utilities and manufacturers provide computer analyses for their customers without charge. The federal government also has developed computer programs, such as ASEAM, developed by the U.S. Department of Energy.

Economic life

The economic life of a lighting system can be determined in a variety of ways. One is to base it on the anticipated life of the system itself. Another is to base it on the anticipated life or remaining life of the building involved. Still another approach is to use the amount of time during which the owner anticipates staying in the building, or — when a tenant is involved — to base it on the length of the lease.

Maintenance costs

Most maintenance costs can be projected on an annualized basis. They include the cost of replacement lamps, lamp replacement labor, lamp and fixture cleaning labor, ballast replacement, and lamp and ballast disposal. One would also consider the cost of maintaining control systems, including those used in conjunction with daylighting.

Value of benefits

Assigning precise dollar values to lighting benefits is difficult, but conservative approximations should be applied whenever they are warranted. For example, if the existing system is plagued by quality problems and the work involved is highly dependent on effective lighting, some conservative assumptions about productivity enhancement should be included. This
Evaluating economic factors

Simple payback is the most common economic analysis method used and also is the easiest to compute. It is expressed as:

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

If a system that costs $2,000 to install saves $1,200 per year, its simple payback is 1.7 years. If it saves $1,500 per year, payback occurs in 1.3 years or (1.3 yrs. x 12 mos./yr =) 16 months. When life-cycle costing is applied, internal rate of return (IRR) and savings-to-investment ratio (SIR) often are used, among many other techniques. These are discussed in various engineering economics handbooks.

CASE IN POINT

Sometimes these things just happen. That, in essence, was management's conclusion after a janitor in the circulation department of a daily newspaper in Bellevue, WA, was assaulted in the newspaper's parking lot when returning to work at 5:30 AM. The conclusion was not unusual. After all, the parking lot was well illuminated, relying on a system consisting mostly of mercury vapor lighting. When a similar assault occurred a year later, however, the newspaper decided something had to be done.

A local electrical contractor was contacted and asked to evaluate the parking lot lighting. His conclusion: Not bad, but better illumination could be provided by converting existing units to high-pressure sodium (HPS) operation to deliver more light and more efficiently. In fact, according to the electrical contractor's calculations, the new high-benefit system would be significantly less expensive to operate and the local electrical utility — Puget Sound Power & Light Company — might even pay for a portion of the retrofit.

The convention was highly successful. The new system produced 21 percent more light than the old one yet cost 74 percent less to operate and maintain. Most importantly, no further assaults occurred in the parking lot. While achieving their objective, the contractors also demonstrated management's concern for employees, improving employee attitudes and morale. In addition, people commented that the new lighting, with its distinctive golden white color characteristics, made the buildings and grounds more attractive, linking them into a unified whole at night. The total cost of conversion was $1,200 and the utility paid more than half.
To the Rescue!
Sources of Assistance

Electric illumination is a long-term investment. Even when a building is slated for sale, long-term considerations are important because most prospective purchasers will want to “see the numbers.” You need professional help and sources of it are indicated below. When it comes to obtaining design input, however, select individuals and organizations with care.

National Lighting Bureau

The NLB has for many years worked to alert decision-makers to the value of high-benefit lighting and some of the many options available to derive these benefits at minimal expense. The Bureau has many other publications available (see page 27) and will provide a directory of its publications without charge. (National Lighting Bureau, 1300 North 17th Street, Suite 1847, Rosslyn, VA 22209)

Illuminating Engineering Society of North America

The IESNA is a national membership organization with chapters (sections) throughout North America. Many of its members are independent illuminating engineers. Others are affiliated with utilities, manufacturers, and other organizations. The IESNA publishes the IES Lighting Handbook, a work that most lighting professionals consider the “Bible of the industry.” IESNA also publishes some less technical materials which can be of substantial help. (Illuminating Engineering Society of North America, 120 Wall Street, 17th Floor, New York, NY 10005)

National Electrical Contractors Association

NECA is a national association of electrical contractors. The organization has chapters throughout the United States. Many electrical contractors, in addition to installing lighting systems, have complete design departments. Some also are active in the area of equipment leasing and contract maintenance. NECA offers a computerized service that can match specific lighting needs with qualified contractors in all areas of the country. To access this service, call 1-800-888-NECA (6322). (National Electrical Contractors Association, 3 Bethesda Metro Center, Suite 1100, 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 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, 45 Danbury Road, Wilton, CT 06897)

International Association of Lighting Management Companies

NALMCO comprises lighting management and related companies. The organization promotes professional lighting management techniques and the benefits of quality lighting. NALMCO sponsors seminars and other training activities and offers three certification programs: Certified Apprentice Lighting Technician (CALT); Certified Senior Lighting Technician (CSLT); and Certified Lighting Management Consultant (CLMC). (International Association of Lighting Management Companies, 10201 Lee Highway, Suite 580, Gatewood Plaza Fairfax, VA 22030)

Department of Energy

The U.S. Department of Energy (DOE) sponsors a variety of ongoing research studies in the area of lighting energy conservation, and it has developed or sponsored development of many instructional materials, as well as computer software, training materials, etc. DOE’s Office of Federal Energy Management Programs (Forrestal Building, 1000 Independence Avenue, CE44, Washington, DC 20585; 202/856-5772) also is responsible for coordinating the Federal Relighting Initiative.
Environmental Protection Agency

The Environmental Protection Agency (EPA) has initiated an innovative, voluntary, nonregulatory program called Green Lights which encourages major U.S. corporations to install energy-efficient lighting technologies. Under this program, EPA commits to help Green Lights participants with technical support projects (e.g., computerized decision support system, national lighting product information program, and guide to financing sources for energy-efficient lighting), help strengthen the infrastructure of the energy-efficient lighting industry, and lower the barriers to energy-efficient lighting. (Green Lights Program, Environmental Protection Agency, 401 M Street, SW (ANR-445), Washington, DC 20460)

Manufacturers

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

Others

Other sources of assistance include your local electric utility. 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. Many electric utility companies offer rebates and other financial incentives for lighting modernization projects that can result in substantial cost savings. These usually are conducted under demand-side management programs. For a detailed listing of the electric utilities providing incentives for retrofit, contact the Association of Demand-Side Management Professionals (P.O. Box 4658 Berkeley, CA 94704; 415/528-5566).

A state’s 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 likely will be a number of chapters of national groups that can be of help, at least by providing referrals to its members. Many of these are listed in the local telephone company’s yellow pages directory.

CASE IN POINT

NEW LIGHTING CREATES MILLION DOLLAR BENEFIT AT COLONIAL PARK PLAZA

Prior to initiating a lighting management program, owners of the 500,000-square-foot, 72-store Colonial Park Plaza in Harrisburg, PA, were spending $12,745 annually to operate and maintain the mall’s common area incandescent lighting. They scrapped the existing system and replaced it with a high-benefit fluorescent lighting system that cut common area lighting operating and maintenance (O&M) costs by 66 percent, to $4,349 per year. As substantial as the $8,397 annual savings were, they were dwarfed by the value of other benefits created by the new system:

Because it provided far more light, the high-benefit system gave what some patrons called “sparkle” to the promenade area, lending more depth and brilliance to surface colors, and generally making the mall a much more pleasant place for shopping. Word spread, and within two years the average traffic count moved from 60,000 persons per week to 80,000. Store owners who were surveyed indicated their sales rose by 38 percent, worth $10 million per year.

Because sales increased, more retailers became interested in locating in the mall and the vacancy rate fell from almost 19 percent to just 8 percent, increasing the owners’ rental income by $1.76 million annually. In addition, slipping/dropping accidents — something that had affected older shoppers in particular — were significantly reduced, saving the general public what an independent underwriter estimated to be $10,000 per year.

Altogether, these benefits created yet another benefit — increased resale value of the mall — worth an estimated $12.6 million.

24 Getting the most from your lighting dollar
Glossary

Some of the more common words and phrases used in discussions of indoor and outdoor lighting are defined below.

**Ballast:** A device that modulates incoming voltage and current to provide the circuit conditions necessary to start and operate gas-discharge lamps.

**Brightness:** As commonly applied, brightness (or luminance) is the intensity of the sensation that results from viewing a surface or space that directs light into the eyes. The candela/meter\(^2\) is a measure of brightness.

**Coefficient of Utilization:** A measure commonly applied to indicate the efficiency of a specific luminaire in a given space. Coefficient of utilization (CU) comprises a ratio of the light delivered to the work surface by a luminaire compared to the total light output of the lamp(s) alone. This ratio changes with room size, shape, and surface reflectances.

**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 NCR copy of a purchase order.

**Diffuser:** A device commonly put on the bottom or sides of 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. The metric equivalent to footcandle is lux, where one lux (lx) is equal to one lumen per square meter.

**Glare:** A discomforting or disabling condition that 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 to control the direction and brightness of the light as it comes out of the luminaire.

**Light Loss Factor:** A multiplier applied to account for temperature and voltage variations, lamp aging, and dirt build-up on lamp, luminaire, and room.

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**CASE IN POINT**

**LIGHTING REPLACES LABOR AT CMU**

Determined to provide the best possible security for students and faculty, Central Michigan University (Mount Pleasant, MI) was spending about $150,000 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 high-benefit strategy more than doubled light output, but it also resulted in higher O&M costs. 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 comprising safety or security. The labor savings created a benefit worth $10,500 in the first year alone.
surfaces, factors that reduce light output over time. In common practice, light loss factors are applied to initial footcandles to determine the light level that will be maintained in a given area.

**Light Trespass:** A situation that occurs when, due to lack of adequate beam control, light from a source (usually an outdoor source) is distributed onto areas where the illumination is not wanted.

**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.

**Lux:** Unit of illuminance equal to one lumen per square meter.

**Nonuniform Illumination:** This is the illumination that results when a system’s light sources are located with respect to the tasks, including displays, so more lighting falls on those tasks than on surrounding areas.

**Reflector:** A device inside a luminaire used to redirect light from a lamp by the process of reflection.

**Task Lighting:** The lighting, or amount of light, that falls on a given visual task.

**Veiling Reflection:** Also known as reflected glare, a reflection of a light source that partially or totally obscures details by reducing the contrast between task details and their background.
Also available from the National Lighting Bureau

Performing a Lighting System Audit .................................................. $10 per copy
NLB Guide to Industrial Lighting .................................................. $10 per copy
NLB Guide to Retail Lighting Management ................................. $10 per copy
Profiting from Lighting Modernization ....................................... $10 per copy
Solving the Puzzle of VDT Viewing Problems .............................. $10 per copy
The NLB Guide to Office Lighting and Productivity ....................... $10 per copy
Lighting for Safety and Security ................................................... $10 per copy
Lighting and Human Performance: A Review ............................... $75 per copy
Lighting and Human Performance: A Summary Report ................. Free
NLB Guide to Energy-Efficient Lighting Systems ......................... $10 per copy
NEMA Guide to Lighting Controls ................................................. $10 per copy
NEMA Guide to Emergency Lighting ............................................. $10 per copy
Lighting and Industrial Productivity ............................................. Free
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For more information about these publications, postage and handling charges, and bulk purchase discounts, contact the National Lighting Bureau at 1300 North 17th Street, Suite 1847, Rosslyn, VA 22209; tel. 301/587-9572; fax 301/589-2017.