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The Future of Outdoor Lighting

By Bob Parks

For centuries outdoor lighting has helped mankind shape the environment. By pushing back the night, lighting has allowed us to extend the day, enhance commerce, and feel safer. But over the last few decades, the world has seen an explosion of poorly designed outdoor lighting that has degraded the nighttime environment, wasted resources, fueled climate change, and impacted the health of both humans and wildlife.

Recent technological advances are causing seismic shifts in the outdoor lighting industry. With the advent of light-emitting diode (LED) technology, the industry has introduced a host of new lighting fixtures, as well as new devices such as computerized controls that maximize efficiency and reduce maintenance costs. For decades energy efficiency has been slow to improve, but current improvements dwarf those of the past, with continued improvement expected for decades to come. City officials everywhere are asking, "What should we do about LED lighting?"

During the next decade cities will retrofit much of their existing outdoor lighting. These changes have already begun. Los Angeles installed 140,000 LED streetlights over a period of four years, ending in 2013. New York City has announced plans to replace 250,000 fixtures with LED. Millions of dollars will be spent in this decade to improve outdoor lighting, and the new technologies now emerging offer an important opportunity to do it well.

Planning professionals can have a profound impact on the future of public lighting. From a planning perspective, there has never been a better time to develop standards that will guide this transition. However, outdoor lighting standards have been somewhat of an outlier in the planning community. Lighting design is not in most planners' skill sets, and the topic is easy to ignore — until citizen complaints about excessive lighting demand action.

The new outdoor lighting technology can save 50 percent or more on current energy use, reducing energy bills and carbon footprints. However, with this new technology we need to develop new standards that eliminate glare and light trespass, improve visibility and safety, and protect the night sky and the environment. This *PAS Memo* provides planners with guidance in navigating this brave new world of outdoor lighting technology. It provides a brief history of outdoor lighting and delves into the technical aspects of traditional and new technologies. It then makes the case for revamping local outdoor lighting standards as well as lighting beliefs, and concludes with information on important resources and next steps planners can take to address outdoor lighting standards in their communities.

A Brief History of Outdoor Lighting

To understand the future, it is important to understand the history of outdoor lighting. Few technologies have been so inextricably linked to our development from prehistoric times to today. Fire not only helped us to cook, its light helped us combat our primal fear of darkness, and we became less likely to become a predator's dinner.

Street lighting has been documented as far back as the 4th century, but it didn't really take off until the invention of the gas light in 1792. By the early 19th century cities across the globe embraced the new technology to extend the day. The world at night changed in 1880 when Wabash, Indiana, became the first city to install streetlights using Thomas Edison's electric incandescent light bulb. Cities everywhere

began to light their streets in order to attract customers to businesses. As roads were built to accommodate the new automobile, street lighting was installed to improve safety and mobility.

Outdoor lighting is a ubiquitous part of the nighttime urban landscape. Photo Jim Richardson.

Incandescent lighting technology ruled outdoor lighting until the 1950s when new high-intensity discharge (HID) lighting became commonplace. Mercury vapor (MV) HID streetlights were twice as efficient as incandescent streetlights and the lamps lasted 10 to 20 times longer. High-pressure sodium (HPS) HID lighting was introduced in the 1970s and doubled the efficiency of MV. While there have been other lighting technologies over the last century, these have dominated streetlighting.

Not until the turn of the 21st century did another technology challenge HID. Solid-state lighting (SSL) using light-emitting diode (LED) technology has been in the labs since the 1960s, but its efficiency was no match for HID until about five years ago. LED streetlights began to be installed in cities around 2005. While the efficiency of LED now exceeds HID, it's LED's long life that now makes it a compelling replacement for other technologies. LED manufacturers claim fixture lives of more 100,000 hours or more, which means less maintenance. By comparison, HPS lamps are rated at around 20,000 hours and need to be replaced every five to six years. The continued improvement of efficiency and life expectancy and reduced operating costs and maintenance will propel a tsunami of LED retrofits over the next decade.

Why is efficiency such an important consideration in outdoor lighting? There are approximately 160 million outdoor commercial and public exterior lighting fixtures in U.S., illuminating roads, streets, parking lots, and buildings. These fixtures use two percent of the total energy used in the U.S. Eighty percent of that energy is used for commercial and public exterior lighting. The approximate amount of energy wasted annually by our outdoor lights through unnecessary lighting, over-lighting, light trespass, glare, and uplight is 1.1 petawatt hours (PWH), the equivalent annual output of approximately 500 power plants. This wasted energy could power approximately 7.75 million homes, produces 750 million tons of CO2, and costs local governments and citizens approximately $110 billion annually (IDA 2013).

The promise of dramatic efficiency improvement has encouraged the federal government to promote SSL as part of the U.S. Department of Energy (DOE) energy conservation goals. DOE has allocated funds to support the research and development of new technologies and processes to improve the energy efficiency of SSL. It has also established a program to actively promote the accelerated adoption of SSL in the U.S.

While not completely unprecedented, the involvement of DOE has had the effect of expediting the commercial development of SSL technology. Although the federal government's support of this immature technology is a boon to the industry, it has created new problems as well. The most apparent side effect is that manufacturers have created and promoted lighting that potentially increases glare and is potentially harmful to human health and wildlife.

A Primer on LED

What we call "white" light comes in a wide range of colors. These are usually described on a scale of "warm" to "cool." Warm white light is on the red/yellow side of the spectrum, while cool white is on the blue side. Technically, this scale is also described as Correlated color temperature (CCT) and measured in Kelvin (K). Most consumers prefer warm white light, which is produced by incandescent lamps. A typical incandescent lamp is around 2700 K CCT. Commercial interior lighting is often cooler, with a typical range of 3500 K to 5000 K. High-pressure sodium (HPS) lighting, which currently accounts for 70-80 percent of all exterior lighting, is approximately 2000 K CCT.

What makes LED different is that it has a large portion of its spectral energy concentrated in the blue side of the visible light spectrum, thus making it a "cool" white light. With early LED technology, only cool white light could complete with the energy efficiency of the HID lighting it was replacing. Cool white light greater than 5000 K CCT was seldom used in interior or exterior lighting prior to LED. While the differences between high CCT (>5000K) LED white light and HPS lighting is often considered purely an aesthetic issue, it has profound impacts on both visibility and ecology.

New light-emitting diode (LED) technology creates a "cool" white light. Photo Bob Parks.

Higher CCT LEDs are perceived by the human eye as more glaring than other light sources, reducing visibility and thus safety unless the fixture is fully shielded so that the source isn't easily visible. A growing body of scientific evidence also indicates that exposure to light at night, particularly blue-rich white light, disrupts our circadian rhythm — the sleep-wake pattern governed by Earth's 24-hour cycle of light and dark. All species have evolved under a cycle of roughly 12 hours of day and 12 hours of night. When this period is disrupted, the negative impacts can be significant on a wide range of activities and biological functions, and can lead to increased risk of obesity, depression, sleep disorders, diabetes, breast cancer, and other health issues. Studies also have shown numerous negative repercussions for wildlife as well.

Blue-rich white light also contributes to light pollution. In 2009, a research study showed that this type of light source scatters light into the atmosphere at a rate two to five times greater than that of currently-used HPS lamps (IDA 2010). The scatter results in increased sky glow, which is the most easily recognized component of light pollution. An important consequence of this is that if current HPS

fixtures are replaced with high-CCT white LED fixtures at the same illumination levels, the result will be a substantial increase in light pollution.

Additional research indicates that humans perceive the "brightness" of white light at the same illumination level to be greater than that of the HPS that it is often replacing. Although conclusions have varied somewhat, high-CCT white light may appear to be 25 to 50 percent brighter than HPS. This happens because the human eye sees better in broad-spectrum white light, so much so that reductions in illumination levels of up to 75 percent may still result in equivalent visibility compared to HPS. This means that using recommended illumination levels from current Illumination Engineering Society (IES) standards for outdoor lighting results in retrofits that appear far brighter than the lighting that was replaced. Unless the fixtures are well designed, a proportional increase in glare may result.

These results of the new LED technology — greater light scatter and glare potential — are often met with complaints from residents. Because of these different characteristics of LED lighting, new illumination standards are required to account for these differences and prevent overlighting with cool white LEDs.

Lighting Standards

In most cases, communities rely on national standards to inform their outdoor lighting regulations. The Illumination Engineering Society produces recommended practices (RPs) for almost every type of lighting application that provides illumination guidelines. The RPs specify the amount of illumination for various tasks and other qualities like uniformity. Many cities use the RP as their standards for lighting practices for outdoor and indoor lighting. The IES RP is designed to help design lighting that will improve visibility.

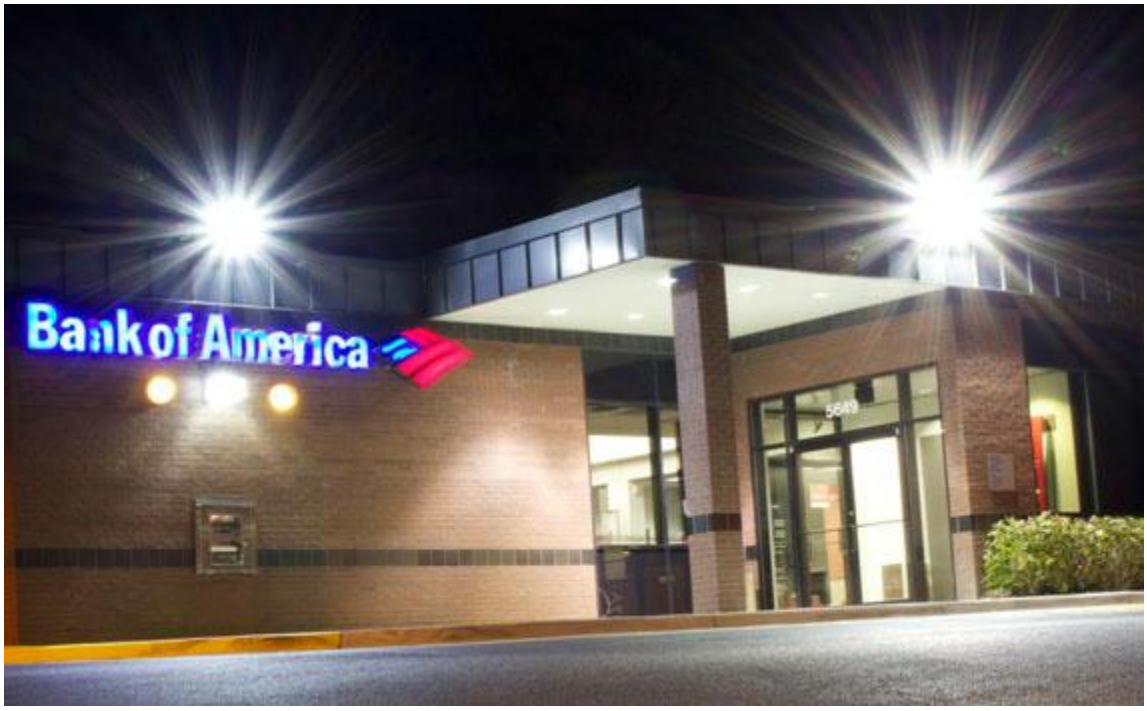
Based on recent research, however, a new understanding of visibility has emerged. Most current lighting standards tend to focus only on illumination levels and uniformity with little concern for the actual impact on visibility. The results of the new research show that the future of lighting standards should be based on visual contrast: both luminance and color. This new metric for visibility will allow for dramatically reduced light levels using broad spectrum light sources like SSL.

Until national standards are updated to reflect new research on visibility, many communities will not consider reducing illumination levels. Though results from studies clearly show a consumer preference for warmer CCT and lower illumination levels, cost considerations lead cities to install higher-CCT LED sources based on the 10–15 percent increase in energy efficiency over warmer LED options. This creates the situation described above: lighting that provides 25–75 percent more illumination than necessary because communities are following long-established standards. Most communities lack the expertise to translate new research into reduced lighting levels. Cities will be reluctant to use lower illumination levels until the IES revises the appropriate RP documents. Unfortunately it takes time for new research to become incorporated in RPs, and revisions can lag years behind the science.

New standards could allow communities to dramatically reduce illumination levels and carbon footprints while saving large amounts of energy and money at the same time. Effective lighting standards need to control the quality and quantity of lighting. Fully shielding light fixtures eliminates uplight, controls glare, and improves visibility. To control the quantity of light used it is important to limit the illumination levels. Communities need to reassess the amount of lighting required to appropriately illuminate communities. One major component of this is rethinking the connections between outdoor lighting and crime.

Lighting and Crime

Crime and lighting have an interesting history. Thomas Edison and other early proponents of electric light played the safety "card" as a principal sales tool. It has been used for over a hundred years as the primary reason to install lights. However, there has been little independent research on the effects of outdoor lighting on crime levels.



Illuminating the nighttime environment makes people feel safer. Photo Bob Parks.

One reason for the assumed correlation between outdoor lighting and a decrease in crime is that the introduction of outdoor lighting satisfies the "feeling of safety." When there is no outdoor lighting, pedestrians may genuinely feel fear. Simply being able to see makes us feel safer. However, feeling safe and actually being safe are not the same. Adding light to the environment may not reduce the incidence of robbery or injury, but might make pedestrians feel safe right up until the moment they become a crime statistic.

The most surprising study that shows the futility of using lighting to deter criminal behavior comes from Chicago. In 1998, after the city experienced very high levels of violent crime, it decided to increase street lighting illumination levels and add lighting to alleys. Not only did the city install lighting where previously there was none, it did so at illumination levels three to five times higher than normal. The conventional wisdom was that increased lighting would deter crime.

Feedback from residents was mostly positive and the perception that the city had taken proactive steps to reduce crime was politically popular as well. The only problem was that the program did not reduce crime. To the contrary, in the areas where "enhanced lighting" was installed, incidence of crime increased. In similar communities where no additional lighting was installed, crime actually decreased during the same period (Morrow and Hutton 2000). Studies in the United Kingdom comparing communities with similar demographics in which the only difference was the introduction of street lighting have found no significant variation in the rates of crime.

Most studies indicate that reducing crime requires multiple strategies. Community policing, coupled with employment and educational opportunity, seem to work very well, but implementing those tactics requires far more resources than installing lighting. Lighting has become a quick and easy action creating the perception that elected officials are responsive to the needs of the community. Often, that is more than enough justification. Whether allocating these limited resources to the policies that have proved more effective in reducing crime will never be known. Using an economics term, it can be said that the true cost of some outdoor lighting policies may bear the "opportunity cost" of *not* reducing crime.

Better Outdoor Lighting Standards

So what is the solution to the problem of overlighting? The intelligent use of outdoor lighting. Smart lighting policy can be summed up in one sentence: Light only what is needed, when needed, and only at

illumination levels necessary to get the job done. This policy will eliminate the three main components of light pollution: skyglow, glare, and light trespass.

Skyglow is the brightness of the night sky in a built-up area as a result of outdoor lighting. Glare is the uncomfortable or disabling visual sensation caused by excessive and uncontrolled brightness. Light trespass occurs when light from fixtures illuminates more area than intended, falling where it is not needed — or where it can cause a nuisance. For example, light trespass is occurring if the careless installation of "security" lights end up shining light into a neighbor's bedroom window. This is the most common complaint a planning authority is likely to receive. This type of social irritation can result in ill feelings, legal action, and even violence. The desire for the "feeling of safety" can often clash with the wish for "peaceful enjoyment" and it becomes an issue that planners are forced to manage.

Skyglow (left), glare (center), and light trespass (right) are the three main components of light pollution. Photos Bob Parks.

The best way to make sure that cities are using outdoor lighting intelligently is to adopt community outdoor lighting standards. This is a complex issue, however, and few planning departments have the in-house expertise to draft lighting guidelines. The technical details associated with outdoor lighting can be intimidating, and incorrect or inaccurate terminology can reduce the effectiveness or enforceability of a lighting ordinance. Even when the resources are available, developing a comprehensive outdoor lighting ordinance can take months or years and hundreds of staff hours. For these reasons, communities may want to use guidance to help them draft their lighting ordinances.

The International Dark-Sky Association (IDA), a nonprofit organization founded to raise awareness of light pollution and promote solutions to it, has been working with planners for 25 years to develop effective outdoor lighting ordinances. In 2005, the IDA joined with the IES to develop a **Model Lighting Ordinance (MLO) template** (IDA IES 2011). The MLO uses IES recommendations to create a template that can save planners most of the time needed to create ordinances customized to the needs of their communities. The primary value of the MLO, a framework developed and endorsed by the leading outdoor lighting standards groups, is that it includes all the information needed to create a successful ordinance.

The IDA/IES Model Lighting Ordinance (MLO)

The MLO takes an approach to regulation that encourages energy savings while reducing light pollution. It provides a lumen allowance for outdoor lighting based on the area of developed "hardscape" for the parcel. Developers are free to use the allowance where it is needed. In addition, fixtures must meet the requirements of the Backlight/Uplight/Glare (BUG) classification system, which replaced the previous IES "cutoff" classification in 2011. It rates each component of a fixture — backlight (the light directed in back of the mounting pole, which creates light trespass), uplight (the light directed above the horizontal plane of the fixture which contributes to skyglow), and glare — on a scale ranging from 0 to 4 (IDA 2009). A "0" indicates the least amount and "4" the most; therefore, a "B0-U0-G0" rating has the least amount of backlight, uplight, and glare.

Good lighting fixtures are designed to reduce or eliminate backlight, uplight, and glare. Photo Bob Parks.

The MLO acknowledges that more light may be needed in highly developed urban areas than in pristine natural parks. To quantify this, it incorporates an environmental zone system of five zones. For example, EV0 would indicate a natural park area and EV4 would mean Times Square or the Las Vegas Strip. EV1 is a rural area, EV2 is a suburban area, and EV3 is an urban area. These are the three zones used by most cities. The BUG classification system requirements limit the types of fixtures used to those appropriate in each zone. For example, in the EV0 zone, fixtures rated "B0-U0-G0" must be used.

Using the MLO replaces after-the-fact lighting enforcement in the field at night to up-front compliance at the planning office. Developers submit lighting plans to the authority for review and approval. The planning staff must verify the calculations for allowable lumens, the choice of BUG ratings for the fixtures, and their locations. Once approved, the developer must have a professional engineer certify that the installation was installed as approved.

When adopted, the MLO ensures that property owners can use the appropriate amount of illumination to meet industry standards while reducing light pollution, carbon footprint, and energy waste. Enforcement is usually limited to a review of plans, but staff may need additional training to do this effectively.

IDA and IES are currently revising and improving the original MLO. The new MLO will be joined by an "MLO Lite" designed for smaller communities that may not need the full MLO. In addition, the updated MLO will include new sections for situations that typically need a special permit. These include sports lighting, lighted and electronic signs, and protected areas like optical astronomy observatories and ecologically sensitive areas. Each of these sections can be included in the full or lite version of the MLO as required.

Action Steps for Planners

Developing a comprehensive lighting ordinance can be daunting unless there is a staff member that has some experience with outdoor lighting. This doesn't mean that the planner has to be a lighting engineer, but without a basic understanding of the concepts and terminology it may be hard to properly assess what will be needed to complete the process. In most cases it will be helpful to contact a lighting consultant that has had experience writing a lighting ordinance.

Before getting started, however, planners should determine that there is sufficient support of the planning commission or other elected officials that will ultimately need to approve the ordinance. Lighting ordinances are more complex than most other standards that these officials deal with regularly. It is essential to have someone on staff or as a consultant that can present the proposed regulation in layman's terms and can explain the details in an easily understandable manner.

Be prepared for opposition from some citizens, developers, and businesses. In many cases lighting standards will be considered as unnecessary regulation. It is important to include public education and meetings in the process to explain the value of the regulation. Focus on the reductions in glare, light trespass, and improved visibility. Emphasize that the ordinance will meet national lighting standards and will not impact safety. This public education program should continue after the ordinance is approved to educate developers and the general public.

Allocate enough staff time and budget to implement the ordinance, train staff, and enforce the ordinance after it is approved. Too often this is the area that is most neglected. Without adequate training of the staff that will approve lighting plans and field inspectors that will verify compliance, lighting ordinances will seldom be effective.

Finally, be prepared to revise the ordinance within three to five years to incorporate lessons learned and new lighting standards and technology. Often after an ordinance has been in place for several years and concerns over it have abated, it is possible to include elements that may have been omitted during the original development.

The Future of Outdoor Lighting

From the discussion above, it should be clear to planners that outdoor lighting has a multitude of often detrimental effects on the built and natural environments as well as on our health. New lighting technologies offer exciting advances in energy efficiency and cost savings, but also come with potential costs. If existing standards are not adjusted to account for the spectral characteristics of the LED lighting being created and promoted by the lighting industry today, we could, ironically, be faced with higher levels of light pollution, glare, and overlighting.

Outdoor lighting should be installed to minimize its effect on the environment. Good, ecologically responsible outdoor lighting will employ color temperatures that are as "warm" as feasible, while also eliminating glare and light trespass. While consumer preference may favor "white" light over HPS and low pressure sodium (LPS) light sources, evidence also clearly shows that the public dislikes blue-rich white light. Fortunately, LED technology is capable of providing all of these requirements efficiently.

Good LED lighting design illuminates the nighttime environment while reducing light pollution and energy waste. Photo Bob Parks.

LED technology allows us to dynamically "tune" the spectrum of the fixture to minimize its impact on the environment, including human health.

Therefore, a reasonable balance between maximum energy efficiency and adverse ecological impact can be achieved. Being "green" is not just a question of energy savings. New ecologically responsible developments in LED include amber LED and filtered LED that removes blue light by eliminating wavelengths below 500 nanometers. These technologies, along with the use of fully shielded LPS, should be used in and around ecologically sensitive areas, optical astronomy facilities, and in communities with a high degree of awareness and concern for the environment.

The choice is clear: we can use responsible standards to guide lighting design, or we can continue to allow uncontrolled lighting to degrade our quality of life and negatively impact human health and ecology. Planners have important roles to play in making the former scenario a reality in their communities.

About the Author

Bob Parks is the owner of Smart Lighting Associates. He is a Lighting Certified (LC) lighting designer and consultant specializing in ecologically responsible outdoor lighting. He is the former executive director of the International Dark-Sky Association and is a member of the IES. He worked on the original IDA/IES Model Lighting Ordinance Task Force that developed the MLO and is part of the current IDA MLO committee that is currently revising it.

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