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CONTINUING EDUCATION

Overexposed

A newfound appreciation for dark skies, a model lighting ordinance, and LEDs may help maintain night vision by reducing outdoor illumination levels.

In cities around the world, telling a child, "I used to see stars from my backyard," may soon sound as credible as, "I used to walk 10 miles to school in 6-foot-high snowdrifts uphill in both directions." Sky glow, light pollution, and light trespass are the consequences of development and outgrowth in urban and rural landscapes. The damage isn't merely aesthetic. Research suggests that excess night light can harm nearly everything living under the sun. The offender may be as simple as stadium lights fatally mistaken by fledgling birds for the moon, or the neighbor's porch light that beams into your bedroom, resulting in fatigue and diminished productivity.

The amount of energy and money expended to illuminate what is essentially water vapor and floating particulates in our atmosphere is not trivial. According a 2009 document published by the nonprofit International Dark-Sky Association (IDA), the U.S. expends 22,000 gigawatt-hours of electricity—the equivalent of 3.6 million tons of coal—each year in light pollution. At the rate of 10 cents per kilowatt-hour, this energy translates to $2.2 billion annually.

Past Practices: The Bad and the Ugly

For decades, charts in outdoor-luminaire catalogs and standards such as ANSI/IESNA RP-8: Roadway Lighting dictated exterior lighting design. It seemed like nearly anyone could be a lighting designer—no calculations required. Manufacturers sold a bunch of luminaires and everything was overlit. Energy was cheap and sky glow was mostly ignored outside the astronomer community, which watched its observatories become decreasingly effective.

In the past half-century, the light source of choice for streets and parking lots was high-intensity discharge (HID) lamps, which included mercury vapor and low-pressure sodium lamps, but mostly the ubiquitous yellow-orange high-pressure sodium (HPS). The prevalence of HPS, possibly the greatest source of light pollution in the U.S., is evident in NASA's aerial photographs, which are both beautiful and lamentable.

It is difficult to design optics that can control stray uplight and glare without significant tradeoffs in luminaire efficiency. Despite their notoriously poor color rendering, HPS lamps are inexpensive, can last up to 24,000 hours, and output a lot of light initially; the output declines as they age. In the last 30 years, the use of metal halide, an HID source that produces whiter light than HPS, has increased, but HPS still dominates.

Millions of HPS drop-lens or "cobra head" streetlight luminaires remain in use today. Because they produce large amounts of high-angle light, they can create a lot of glare. With routine maintenance such as lamp and ballast replacement, they can last for 30 or more years. Because they are still being installed, it will be decades before some are ready for replacement. In the U.S., most roadway lighting, which is owned by municipalities or utility companies, is not subject to energy codes.

Zoned In: New Codes and Standards

The California Energy Commission's Title 24: Building Energy Efficiency Standards contains the most stringent lighting requirements in the nation. Though Title 24 first issued regulations regarding lighting for interior spaces in the early 1990s, it wasn't until the 2005 edition that maximum exterior-lighting power densities were included. It also recognized that overlighting one area makes it difficult to see into surrounding areas, which, as a result, are also overilluminated

Title 24 introduced the concept of lighting zones to regulate the power density of the exterior lighting allowed in each zone. U.S. Census Bureau maps determined the boundaries for three of the four zones: Zone 1 applies to parks, recreation areas, and wildlife preserves; Zone 2 encompasses rural areas, where low levels of ambient lighting are allowed; and Zone 3 is set aside for urban areas. Zone 4 is reserved for special-use districts, such as a sports complex, which is determined and adopted by local jurisdictions.

But Title 24 "is an energy standard," says Nancy Clanton, president of Clanton & Associates, a lighting-design firm based in Boulder, Colo. "It can't address issues like light pollution and glare."

In 2004, Clanton co-chaired a task force to take on the problem of expanding the lighting zones Title 24 established into the Model Lighting Ordinance (MLO) that would address the issue of light pollution. The joint International Dark-Sky Association/Illuminating Engineering Society (IDA/IES) task force included dark-sky advocates, lighting manufacturers, lighting designers, and a city planner.

After years of research, intense negotiations among parties, and public reviews, the IDA and IES boards approved the MLO in June 2011. The writers intended it for use as a zoning overlay ordinance, meaning that its lighting zones could closely follow a municipality's land-use maps. The MLO has five lighting zones: Lighting Zone 0 (LZ-0) is for environmentally sensitive areas that should have no light at all; LZ-1 is for one- and two-family residential neighborhoods and small rural communities where low ambient light is suitable; LZ-2 applies to areas for multifamily and institutional use where moderate ambient light is acceptable; LZ-3 is for commercial areas, where moderately high ambient light levels would be allowed; and LZ-4 is for special culture and entertainment districts, such as New York's Times Square where extensive light is unavoidable.

In municipalities that choose to adopt the MLO, individuals seeking building permits or approvals from the local planning department would have to comply with its guidelines, subject to consequences determined by the particular city. By adopting the MLO, communities that want to be night-sky friendly do not need to hire engineers, planners, and lighting designers to develop regulations for them. The MLO provides regulatory consistency from town to town.

The MLO recommendations are similar to ANSI/ASHRAE/USGBC/IES 189.1P: Standard for the Design of High Performance Buildings, but they also cover residential lighting. However, they only cover lighting on private property; the MLO's roadway-lighting section is optional.

The MLO uses "BUG ratings" developed by the IES in TM-15-07: Luminaire Classification System for Outdoor Luminaires. Manufacturers derive the Backlight-Uplight-Glare (BUG) ratings for luminaires from their photometric data. Backlight references the light that emanates from the back of the luminaire and often causes light trespass. Uplight—light 90 degrees or above nadir—is generally responsible for sky glow. Glare—visually disabling light that can cause discomfort or be a nuisance—originates from any part of the luminaire, though BUG ratings are primarily concerned with high-angle light projected from the luminaire's front and back.

Luminaire designers use lenses and reflectors to control how the light produced by a fixture is distributed; this distribution, along with the amount of light output, also factors into its BUG rating. The highest number in its BUG rating determines the minimum lighting zone in which the fixture may be used. For example, you can use a fixture with a BUG rating of B2-U2-G4, which puts out low levels of backlight and uplight but the highest level of glare, only in Lighting Zone 4 because of its G4 rating. If its rating had been B1-U1-G2, then the fixture could be used in LZ-2, LZ-3, and LZ-4. Manufacturers are beginning to assign BUG ratings to specification-grade exterior luminaires as a standard practice.

"One of the problems is that, on paper, the low-glare luminaires are less efficient than the glare bombs," Clanton says. "So the worst fixtures tend to be very popular." Because glare bombs will likely have poor BUG ratings, their use will be limited in environmentally sensitive areas.

The MLO also distinguishes itself by restricting the total allowable lumens in a given area rather than specifying allowable watts-per-square-foot power densities. Though power densities are generally easier to calculate than lumens, Clanton says, the task force concluded that relying on the use of power densities instead of lumen levels would make it too easy for people to game the system: "Some people would just choose the most efficient source possible, and then we still would not be decreasing the amount of stray light being produced."

The MLO also has a provision for a curfew. Municipalities that adopt the ordinance can require that lighting be dimmed or turned off after a certain hour.

Jim Benya, principal of Portland, Ore.–based Benya Lighting and co-chair of the IDA/IES task force that authored the MLO, points out another reason the document is significant: "The whole premise is to reduce light pollution, by preventing bad practices—and not by encouraging good practices," he says. "Good practices are hard to define and encourage. But by preventing bad practices, we can get our arms around the issue."

Less Bright, Better Sight

Reducing allowable lumens and power densities gives lighting designers the chance to reacquaint people with the ambience and calming effects of lower light levels.

The lighting design for the Ellen S. Clark Hope Plaza at the BJC Institute of Health at Washington University School of Medicine in St. Louis, exemplifies the idea. Linnaea Tillett, principal at Tillett Lighting Design in Brooklyn, N.Y., collaborated with artist Maya Lin and landscape architect Michael Van Valkenburgh Associates to design the plaza's centerpiece: an 80-foot-diameter fountain dotted with fiber optics to form a visual representation of a constellation, which is viewable from an adjacent 38-foot platform.

The client's desire to earn LEED credit for light-pollution reduction gave Tillett the freedom to keep lighting levels extremely low. She used 14 34-watt, warm-white metal halide lamps mounted in downward-aimed, sharp-cutoff floodlight fixtures to light just the paths around the fountain. Seven 18-foot-high poles are topped with two floods each. Less than 0.2 footcandles can be measured at the edge of the plaza—a very low level for a public space.

Tillett's observations about the finished project reinforce the idea that overilluminating one area leads to overlighting other areas. The brightly lit Central West End Station of the St. Louis Metrolink adjacent to the space led to designers to question whether their plaza lighting was bright enough. "When the project was finished," Tillett says, "we saw that the boundary that separates lighting that is restorative and a little bit mysterious, from too little lighting—which creates anxiety and fear—is very narrow. If you go on the wrong side of that, you are actually creating a psychological environment in which people are not comfortable."

Still the power of low-light levels should never be underestimated, in the proper setting. A private garden lit on Long Island, N.Y., by Janet Lennox Moyer, founder of the Landscape Lighting Resource in Troy, N.Y., shows the tremendous effect that a few very low-wattage incandescent lights and LEDs can have when used in lieu of bright ambient light, which would overwhelm it.

"I never use more than a 37-watt halogen light in my work," Moyer says. "The amount of light we're dealing with is a quarter of a footcandle and if we really go nuts, 5 footcandles." For adjustable fixtures, she eliminates light trespass through shielding and by choosing the appropriate location and aiming angle. Decorative fixtures, meanwhile, should be low-brightness luminaires with concealed lamps.

Rethinking the Whole Package

No discussion of outdoor lighting today would be complete without mention of solid-state lighting technology. LEDs will lessen our effect on the night sky and energy use. The light-emitting surface of solid-state lighting chips is much smaller than the arc tube of an HID lamp. It is easier to design fixtures with BUG ratings—which manufacturers are beginning to include on spec-grade LEDs—that direct light where it needs to be, which is not in the sky. Because LEDs don't work with existing HID light fixture lens and reflector designs, luminaire designers are returning to the drawing boards with the MLO's and Standard 189.1P's restrictions in mind.

LEDs are much easier to dim than HID lamps. Today, most exterior luminaires are controlled by individual photocells. It is also much easier to put solid-state light fixtures on motion sensors. HID lamps take several minutes to warm up, making motion sensors ineffectual. A control system for a single building—or an energy-management system for an entire city—could quickly dim or turn off a few or even thousands LED fixtures to comply with lighting curfew rules.

A growing body of research supports the notion that less light is needed to see an object clearly when white light is used instead of HPS. Not only does solid-state lighting require less electricity to do the same job as HPS, but the quantity of white light it produces will also be less. “The lower the lighting level, the greater the white-light effect is,” Clanton says. “It is a whole new way of thinking. Wattage will decrease, lighting levels will be less, and fewer fixtures will be needed. I think that’s the reason cities will start replacing their HPS street lighting very soon.”

IDA public affairs director Scott Kardel sums up the potential of the MLO and the switch to LEDs: “Nothing can be done to have a more significant impact to the environment more easily than making these changes.” So while 6-foot-high snowdrifts may not be in the offing, the ability for future generations to glimpse the Milky Way from their own backyards may live on.

Note: This story has been updated since first publication to clarify that decorative fixtures should be low-brightness luminaires in outdoor environments.