The Value of Dark Skies - About Environmentally Friendly Lighting

For many years no one worried about light pollution: on the contrary, the brighter the better. Then it became evident that darkness also has its value. J. Scott Feierabend, executive director of the International Dark-Sky Association (IDA), presents and explains in detail, the latest findings and suggestions published in the “New IDA LED Lighting Practical Guide” and “New IDA Standards on Blue Light at Night”. He also discusses how to illuminate public areas while avoiding excess light pollution.

LED technology is transforming the way we light our cities and towns, offering a once-in-a-lifetime chance to radically improve how we use both energy and our outdoor spaces at night. With this opportunity comes an obligation to manage these changes responsibly and sustainably. The stakes are high and the potential rewards great, but outcomes depend critically on policymakers, professional lighting designers, and the public having access to reliable information.

Unfortunately, municipalities enticed by substantial cost savings - and reduction in greenhouse gas emissions - continue to rush into LED lighting conversions without doing their homework to ensure the conversion has the best possible outcomes for municipalities, the public, and the nocturnal environment. Too often, misinformation leads to the installation of overly-bright, potentially harmful street lighting.

It is increasingly common to read news reports that claim LEDs reduce light pollution, improve safety and security, and save money while lowering carbon emissions. While these positive outcomes are certainly possible when switching to LEDs from older lighting technologies, they are not inevitable. This is why it is essential to be armed with information that is both timely and accurate.

Color Matters

New technical capabilities often come with unanticipated consequences. Most white LED lighting on the market emits significant amounts of potentially hazardous blue light. In 2010, the International Dark-Sky Association (IDA) released a comprehensive review paper, "Visibility, Environmental, and Astronomical Issues Associated with Blue-Rich White Outdoor Lighting", detailing the hazards of blue-rich white light sources. In the years since, scientific evidence has solidified around its conclusions.

In natural settings, exposure to artificial blue light at night has been shown to adversely affect the nocturnal habitat. Every year new research is published expanding the breadth of species known to be negatively impacted by artificial light at night, and often the higher the lighting temperature, the greater the impact. For example, a 2015 study in eLife found that corals exposed to artificial light at night in the green and blue part of the spectrum delayed their spawning times by six hours to two days compared to corals exposed to ambient light or artificial light with a strong red

Figure 1:
The Berlin Wall has been down for decades, but the divide between East and West is still visible at night from space. This image, taken by astronaut Chris Hadfield in 2012, shows the gas lamps of the West and the orange high-pressure sodium lamps of the East, with a stark contrast between them. The image is a powerful reminder that lighting choices made by city planners are long lasting indeed. Given that many cities are now rushing to change to more energy efficient LED streetlights, this image demonstrates that smart lighting decisions is very important, as their consequences last a long, long time

component. This is significant because delayed spawning can negatively affect the reproduction of an already threatened species.

City dwelling and migratory species that often stop over in cities, are not immune to the threats posed by artificial light at night. Recent research has shown that that everything from the feeding strategies to reproductive timing of urban wildlife is altered, delayed or inhibited in the presence of artificial light at night. Millions of birds die each year in nighttime collisions with lighted radio transmission towers and skyscraper windows. Exposure to short-wavelength artificial light at night has also been been implicated in the onset of various chronic human diseases, although intensity and exposure duration thresholds are not yet well established. In 2012, the American Medical Association concluded, “Pervasive use of nighttime lighting … creates potentially harmful health effects and/or hazardous situations with varying degrees of harm,” and recommended “further multidisciplinary research on occupational and environmental exposure to light-at-night, the risk of cancer, and effects on various chronic diseases.”

Outdoor lighting with significant blue light content not only presents known threats to ecology and human health, but is also more likely to contribute to light pollution. Because blue light scatters more efficiently through our atmosphere than light of other colors, it has a much greater geographic reach. As a result, even if cities that convert their old municipal lighting systems to white LED at a fixed amount of light, the shift to a bluer spectrum is expected to yield increased skyglow visible at large distances from cities.

For these and related reasons, IDA issued new standards in 2014 for its Fixture Seal of Approval program, which provides objective, third-party certification for lighting that minimizes glare, reduces light trespass, and light pollution. The new requirements limit certification to lighting that has a Correlated Color Temperature (CCT) of no more than 3000 K. But, it is important to note that 3000 K still includes a good amount of blue light and may not be appropriate for ecologically sensitive places in cities such as greenbelts and riparian areas. For these fragile sites, the use of amber LEDs is most appropriate, which has a very narrow bandwidth, similar to low-pressure sodium lighting.

It is still widely believed that using low-color temperature white lighting for outdoor applications is cost prohibitive due to significant losses from low luminous efficacy. The fact is, that is simply no longer the case. While it was once true that the efficacy difference between low- and high-CCT white LED systems presented a significant financial dilemma to municipalities planning white LED conversion projects, technological advances have enabled cost-competitive solutions that minimize blue light emissions.

Road Safety

LED lighting can both help and harm motorists, pedestrians, and bicyclists who all share the road at night simultaneously. The key to public safety on streets and highways is visibility, which is enhanced by high contrast between objects and the background. Uniformity of lighting, on the other hand, reduces contrast and lowers the odds that motorists will be able to see moving objects in the road.

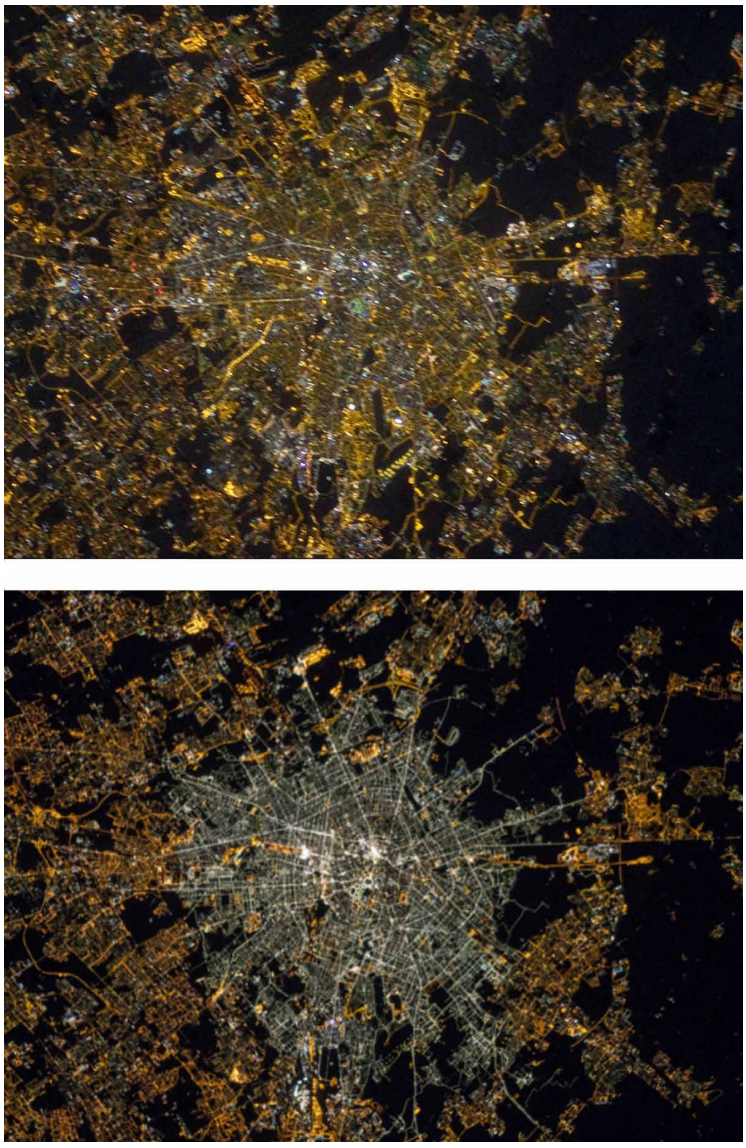

Figure 2:
Changes to cities that have adopted LED for municipal street lighting are literally visible from space. The city of Milan, Italy is shown here at night in images taken from the International Space Station before (2012, top) and after (2015, bottom) the conversion of the city center's lighting from an existing high-pressure sodium system to white LED. The new lighting system makes central Milan noticeably more blue at night

The strong directionality of LED sources enables precise control of illuminated regions. Early LED products attempted to conserve the precious lumens, due to low luminous efficacy, by controlling light distribution very strictly. As light has become cheaper to produce with LEDs, manufacturers have taken a relaxed attitude toward distribution. This makes proper luminaire design that aims to achieve good contrast more challenging.

Along with low contrast, glare presents a significant threat to visibility for all users of roads at night. Glare is a reduction in visual acuity caused by the presence of intense light sources in the field of view, and is a symptom of wasted light that illuminates the eye itself rather than a scene. Glare is never a good thing and only serves to reduce visibility. In response to glare, the pupil of the eye narrows, reducing the eye's ability to quickly react to changing illumination levels. In fact, a 2012 report of the American Medical Association Council on Science and Public Health stated: "Glare from nighttime lighting can create hazards ranging from discomfort to frank disability." The problem is more acute in older eyes whose ability to adapt pupil size is diminished.

While LED roadway luminaires are effective at controlling glare at large distances, the glare they produce at short distances can be crippling. Better luminaire design, including optics to reflect or diffuse light, particularly toward the center of the light distribution, can help reduce the negative impacts of glare.

The Crime and Safety Quagmire

Under the guidance of law enforcement, city officials and planners often elect to install bright white lighting systems under the assumption that they will increase traffic safety and deter crime. However, these claims are not backed by clear scientific evidence.

Some believe that the more vivid colors provided by white LEDs increase traffic safety, but there's no research support for this argument, either. An unpublished study by the lighting design firm Clanton and Associates showed that the color of lighting may be a factor in the ability to see moving objects at night. But no one knows yet how color influences actual traffic safety. For now, there simply is no conclusive evidence that LED lighting enhances traffic safety.

Regarding crime, research to date has mostly focused on the brightness of light and ignored its other characteristics. LED lighting has the potential to decrease safety because it is a highly directional source that can yield scene illumination with large contrast and harsh shadows. While uniformity of illumination is thought to be detrimental to traffic safety, it is of paramount importance in pedestrian situations such as parking areas. In these places, uniformity is desirable because too much contrast can lead to deep shadows in which criminals may hide. Exquisite cutoff can be achieved with LEDs like no other source, but when coupled with the great potential for glare, LED lighting may well be detrimental to our security regardless of its color. Done right, where the feathering from light to darkness is gradual, outdoor lighting creates a much safer environment and a feeling of true security.

White LED lighting need not emit large amounts of blue light in order to accurately render colors in outdoor spaces at night. Low-CCT white LED systems now achieve color rendering index values comparable to those of higher-CCT lights, further lowering barriers to their adoption. This quality addresses concerns frequently addressed by law enforcement agencies about the color of lighting and its perceived effect on public safety.

Figure 3: **Filtered LED (left) and phosphor-converted amber LED (right) are shown here in a test installation at an intersection in Flagstaff, Arizona. The City of Flagstaff is currently testing these and other low-blue-light LED technologies for the replacement of its existing low-pressure sodium municipal lighting system** (credit: IDA / John Barentine)

Listening to the Community

From Seattle, Washington to West London in the United Kingdom, news stories recount complaints from city dwellers living under new LED lighting. The recent lighting debacle in Davis, California, makes a good case in point.

In 2014, the City of Davis contracted to replace 2,600 high-pressure sodium 'cobrahead'-style lights with new white LED fixtures. A hail of complaints followed the installation of half of these new streetlights, culminating in a line of angry residents running out the door at a city council meeting. Protestors characterized the new system as "zombie lights" and "prison lighting."

Jim Benya, a lighting engineer and former member of the International Dark-Sky Association Board of Directors, wrote about the episode for LD+A. According to Benya, the city failed to consider relevant specifications including glare, light trespass, and color temperature when designing its new street lighting system. Poorly-installed, high-CCT lighting utilizing ineffective shielding resulted in bright white light shining into peoples' homes and the degradation of the nighttime ambience in a "cozy college town." In the end, Davis listened to its citizens and replaced the lighting with a 2700 K white LED system at a cost of $350,000 to local taxpayers.

The cautionary tale of Davis makes it clear: local governments that fail to adequately consider popular opinion on the specifications of proposed municipal lighting changes risk public rejection of new lighting systems. In order to avoid costly replacements, city staff should engage residents with test installations before committing to the purchase of new LED lights. Test sites must include a meaningful number and variety of LED options - including several CCT values - if they are to properly serve the public interest, and residents should be given a sufficient amount of time to evaluate the options and provide their feedback.

Lastly, cities should take care so as not to fall victim to the Jevons Paradox, a concept from economics in which the progress of technology increases the efficiency of resource use, but the rate of its consumption fails to decline because a lower cost of providing the resource spurs further demand from consumers. The Paradox is itself a form of the more familiar Rebound Effect. According to researcher Blake Alcott, who coined the term, "Governments and environmentalists generally assume that efficiency gains will lower resource consumption and are an effective

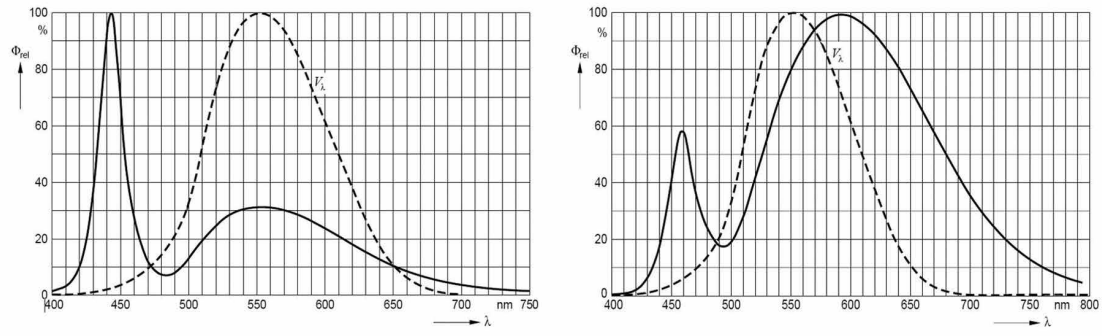

Figure 4: **A comparison of the spectrum of white LEDs (solid lines) with the response of the human visual system in the photopic regime (dashed lines) for two LED correlated color temperatures: 5500 K (left) and 3000 K (right). The curves match well for 3000 K, indicating that much of the light generated by LEDs at this color temperature is efficiently perceived by the eye, while the strong blue emission component of the 5500 K LED goes largely undetected**

policy for sustainability, ignoring the possibility of the paradox arising." The LED revolution is particularly susceptible to the Jevons Paradox because the cost reduction resulting from improved energy efficiency makes routing the savings into the purchase and installation of more (and unnecessary) lighting an attractive option.

Solution and Considerations

There are already many white LED options now available on the outdoor lighting market and that number will only rise in the future. IDA has developed a set of recommendations to help guide those choosing among them. These suggestions will aid in selecting lighting that is energy and cost efficient, yet ensures safety and security, protects wildlife and promotes the protection of dark night skies.

IDA recommendations include:

- Always choose full-cutoff fixtures that emit no light above a horizontal plane passing through the light-emitting element of the fixture nearest to the ground
- Use "warm-white" or filtered LEDs (CCT ≤ 3000 K) to minimize blue emission
- Look for products with adaptive controls like dimmers, timers, and motion sensors
- Consider dimming or curfew requirements during overnight hours
- Avoid the temptation to overlight because of the increased efficacy of LEDs
- Only light the exact space and in the amount required for particular tasks

LED technology is here to stay. It leads the lighting industry and dominates streetlight sales, and will continue to do so for the next decade or more. Cities that have yet to convert to LED certainly will in the next five years. By educating the public, professional lighting designers, and city officials and planners, money is saved, our carbon footprint is reduced, and a healthy, safe outdoor environment is ensured for humans and wildlife. ■