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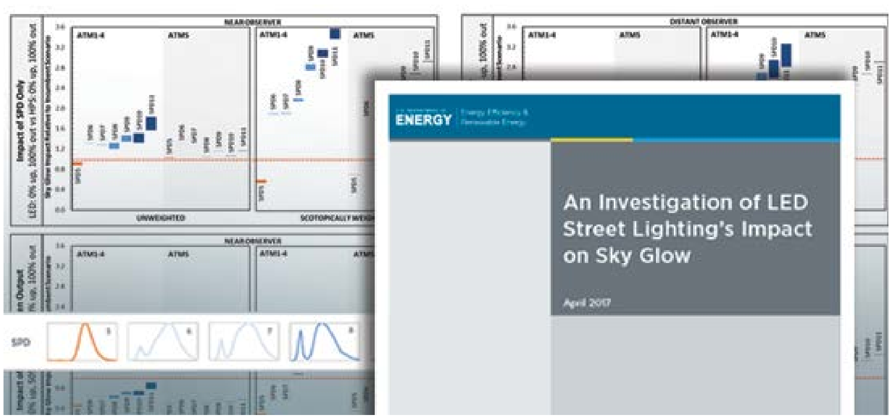
A New Study on LED Street Lighting's Impact on Sky Glow

Like all white-light sources, LEDs produce a significant portion of their output in shorter wavelengths that may include components of violet, indigo, blue, cyan, and other colors. Because shorter wavelengths scatter more readily in the Earth's atmosphere than do longer wavelengths, concerns have been raised regarding the potential reduction of night-sky visibility from converting exterior lighting sources with low short-wavelength content – primarily high-pressure sodium (HPS) – to broad-spectrum LEDs. Street lighting is often a focus of these concerns, which center on an increase in the amount of scattered light – a phenomenon commonly referred to as sky glow.

DOE, together with experts in atmospheric scattering and astronomy, has conducted a study of the expected contributions to sky glow from converting HPS street lighting to broader-spectrum (i.e., white light) sources, with specific focus on LEDs. The just-released report, [*An Investigation of LED Street Lighting's Impact on Sky Glow*], presents the contributions relative to HPS baseline conditions.



Street lighting is only one of many sources of light at night in urban areas. Other sources include interior light escaping through exterior windows, architectural and landscape lighting, signage, parking lots and garages, recreational lighting, and vehicular lighting. The new study only considered contributions to sky glow from street lighting.

While increasing the short-wavelength content of exterior lighting sources increases the corresponding potential for sky glow when spectral content is considered in isolation of other variables, other common characteristics of LED street-lighting conversions reduce these effects, due to reductions in both total luminous output and percent uplight compared to the system that was replaced. External factors also influence the amount of sky glow for an observer, such as distance from the source of light, the size of the source (in this case, city area), and the atmospheric conditions at the time of observation. The study estimated the influence of each of these factors using a computer model called *SkyGlow Simulator*, developed by Dr. Miroslav Kocifaj at the Slovak Academy of Sciences.

As in any modeling effort, the results are only as valid as the underlying assumptions, so care was taken to select values for variables that are reasonable and representative of typical conditions and scenarios in the United States. In terms of luminaire characteristics, four levels of uplight (0%, 2%, 5%, and 10%) were compared, along with two levels of lumen output (100% and 50%). Ten different spectral power distributions (SPDs) from actual products of different light-source types were modeled. Two observer positions were modeled: one at the perimeter of the city (the "near" observer) and one at 40 km (25 mi) from the city center (the "distant" observer).

The computer runs allowed for looking at the effect of each factor individually with other factors held constant, to isolate influences of important variables such as light distribution and SPD. This also enabled more-comprehensive comparisons of sky glow resulting from representative streetlight conversions in the U.S. today, such as replacing a typical HPS glass refractor cobra-head streetlight (2% uplight) with an LED streetlight (0% uplight) emitting half the lumens. The latter characteristic is commonly enabled, in the U.S. at least, by the elimination of hot spots at nadir and most of the stray light that characterizes earlier lamp-based technologies.

Focusing on the typical U.S. street lighting conversion, a key finding is that, for both the near and distant observers, all of the modeled LED product conversions reduce sky glow relative to an HPS baseline, when the results are expressed as unweighted radiant power. Unweighted results are most useful for astronomical observation instruments and the evaluation of impacts not specifically related to human vision. When the results are instead scotopically weighted to evaluate the effects on human vision (e.g., on visibility of the night sky), some LED products reduce sky glow for the near observer compared to the baseline, and others increase it, depending on their relative content of shorter wavelengths. However, an important related finding is that CCT is not a very reliable predictor of sky glow impacts, especially when scotopic weighting is not applied. Overall, the results for LED conversions in the study ranged from a low of 0.2 to a high of 1.6 times the baseline HPS sky glow, depending on the particular combination of the variables and factors studied.

Another key finding pertains to uplight. For the distant observer, even at only 40 km from the city center, the elimination of uplight that occurs in typical conversions nearly removes (by 95% or greater) the contribution to sky glow from the street lighting system, for both the unweighted and scotopically weighted results, for all LED SPDs and all atmospheric conditions. (This effect may be reduced in locations where tall buildings or terrain features independently remove some portion of low-angle uplight.) For residents living near the city, results indicate that the visible contribution to sky glow from a typical streetlight conversion is likely to be no worse than with the previous incumbent system, and may even have improved.

It's also important to remember that all light added to a nighttime environment has the potential to contribute to sky glow. For electric sources that offer wide flexibility in terms of spectral content, such as LED streetlights, reducing the content of short wavelengths reduces this corresponding potential but may also degrade visual performance and perception of brightness. The spectral content of sources affects both the luminance contrast and the color contrast of objects, and facilitates the ability to see and recognize the task and situation.

Ultimately, cities undertaking a street lighting conversion should proceed through their design and selection process with as much knowledge of the various benefits and tradeoffs as possible, to enable a comprehensive and optimal balance among the results.

For complete details, see the full report.

Best regards,
Jim Brodrick

As always, if you have questions or comments, you can reach us at postings@akoyaonline.com.