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Report to: Outdoor Advertising Association of America

A Preliminary Estimation of the Impact of Billboard Lighting on Sky Glow

Executive Summary

Sky glow is caused by lighting at night entering the atmosphere and being scattered by airborne particulates. Sky glow may result from the use of lighting fixtures that emit light above a horizontal plane so that it enters the atmosphere directly. The effect also is caused by light reflecting from lighted objects, such as a road surface or a billboard.

This study has evaluated the amount of light entering the atmosphere from a variety of lighting installations. Measured in "sky lumens," the results allow a comparison to be made of different lighting systems relative to sky glow. Specifically calculations have been made to compare the sky lumens produced by a typical billboard lighting system to the sky lumens caused by roadway and parking lot lighting.

Various scenarios have been used for the roadway lighting, combining residential and major highway lighting in a typical neighborhood. Areas have been considered that consist only of roadway lighting, as well as areas that contain both roadway and parking lot lighting.

The results of the study support a conclusion that the vast majority of sky glow is a product of urban development. Even where full cut-off fixtures are used on all roadway and parking lot lighting fixtures, and if there is an average of one billboard per square mile, over 96% of the sky glow produced per urban square mile is from those sources and not billboard lighting, for the conditions examined. For the examples considered, a single three fixture billboard lighting systems produces approximately 2 to 3% of the sky lumens caused by roadway/parking area lighting in a typical one square mile area. For a four fixture billboard lighting system, the range becomes roughly 2.5 to 4%. These figures can be prorated. For example, if there are two such billboards per square mile, the percentages are doubled; if there is on such billboard per two square miles, the percentages will be halved.

The exact percentages of sky glow are affected by the density of roadways/parking areas, the type of lighting fixtures used and the lighting level provided, among other factors. However, it is apparent that for the scenarios considered, the contribution of billboard lighting to sky glow is small in comparison to that from other sources of lighting. The other sources produce 96 to 98% of sky glow, compared to the 2 to 4% produced per billboard in the example urban square mile.

Introduction

Lighting Sciences Inc. has completed phase I of the study based on LSI's proposal of January 28, 2004 and authorized in David Jones' letter of February 6, 2004.

The findings reported are preliminary and incorporate certain assumptions. However, these assumptions are believed to be realistic such that results give a reasonable estimate of the effects involved. The analysis is likely conservative, in that lighting from major freeways and sources such as soccer and baseball fields have not been factored into the lumen counts.

The output of light from lamps and lighting fixtures is measured in lumens. For example, the light produced by a typical 100 watt household incandescent bulb is 1710 lumens. The values given in this report are in the terms of "sky lumens." This quantity gives the amount of light entering the atmosphere from a given lighting system. It is therefore a good measure for comparing the effects of different lighting systems on the basis of sky glow.

Billboard Lighting Analysis

Diagrams have been supplied by Mr. Jones that show standard mounting arrangements for the bottom lighting of a 14 x 48 ft. billboard, using both 3 and 4 lighting fixtures.

Light output data have been obtained for a widely used sign lighting fixture. Calculations are based on use of a 400 watt clear metal halide lamp producing 40,000 initial lumens, which is typical for billboard lighting. All calculations have been based on a 0.70 Light Loss Factor, or Maintenance Factor, to account for the reduction of light output as the lamp ages and as the fixture collects dirt.

For each of the two lighting systems, the following quantities have been calculated, both for the initial condition of new lamps and clean fixtures, and the maintained condition of old lamps and dirty fixtures:

- Total upright lumens emitted by the group of fixtures
- Total lumens intercepted by billboard
- Total lumens intercepted by underboard
- Total lumens emitted upwards by fixture that do not strike the billboard or underboard.
(Direct sky lumens)
- Total lumens reflected upwards by billboard
- Total lumens reflected upwards by underboard
- Total lumens reflected upwards. (Indirect sky lumens)

It is to be noted that no additional shielding was assumed for the lighting fixtures.

Results obtained for the 3 and 4 fixture systems in terms of total sky lumens are as follows:

- 3 fixture system: 23,415 lms
- 4 fixture system: 31,535 lms

These values will be affected by the reflectance of the billboard face material, which is dependent on the lightness/darkness of the material. An average value has been used, derived from laboratory measurements.

No account is taken in these calculations of the direction of the uplight lumens as they enter the atmosphere, which is likely to have some influence on the degree of sky glow that is produced.

Roadway Lighting

For this preliminary study, billboard lighting will be compared to roadway lighting. While it is recognized that there are many sources of nighttime light other than roadway lighting, this form of lighting usually constitutes a major source of uplight lumens.

Published work has been reviewed that illustrates a relationship between the form of lighting design and the sky glow produced by roadway lighting. There are conflicting results in the published data regarding the type of lighting fixture that is best at controlling sky glow, and the extent of the sky glow produced. For this reason, LSI has not relied on these data but has produced roadway lighting designs of different types, and has computed resultant sky glow.

Three different roadway types have been analyzed, all using the "medium pedestrian conflict" criterion:

Local roadway. Illuminating Engineering Society of North America (IESNA) specification is 0.7 footcandles average maintained lighting level, with a 6:1 average to minimum uniformity. (i.e. The minimum footcandles at any point will not be less than one sixth of the average.)

Collector roadway. IESNA specification is 0.9 fc maintained, 4:1 uniformity.

Major roadway. IESNA specification is 1.3 fc maintained, 3:1 uniformity.

For each roadway, lighting system design has been conducted using a flat glass "full cut off" fixture, and the older style "cobra-head semicutoff" fixture with glass bowl lens. The full cut off fixture allows no light to escape above the horizontal, while the semicutoff fixture emits a few percent of its total lumens above the horizontal.

Most existing roadways, particularly where the lighting was installed 10 or more years ago, will use the glass bowl lens. Because of a desire to control sky glow, many agencies have now switched to full cut-off optics. In any urban area, both types of fixtures are likely to be present. By analyzing roadway lighting with each of these fixture types, a realistic range of possibilities is examined.

For all designs, various pole heights were investigated. Each design was optimized to acquire the maximum pole spacing that can be used while meeting the IESNA lighting specifications. Thus the design procedures were similar to those used by typical roadway lighting designers.

For each lighting system, the following were calculated, all on the basis of a single mile of roadway:

- Total lumens falling on the roadway
- Total lumens falling on the ground outside of the roadway
- Total lumens reflected upwards from the roadway
- Total lumens reflected upwards from the ground outside the roadway
- Total lumens emitted upwards directly from the fixtures. (This quantity is zero for the cutoff fixture.)

Typical known reflectance values were used for the road surface and areas outside the roadway. (Reflectance is a measure of the proportion of light falling on a surface that is reflected by the surface.)

Results of the computation, given in sky lumens per mile are as follows:

Local roadway, full cutoff fixture:	25,837 sky lumens per mile
Local roadway, semicutoff fixture:	38,079 sky lumens per mile
Collector roadway, full cutoff fixture:	47,652 sky lumens per mile
Collector roadway, semicutoff fixture:	64,071 sky lumens per mile
Major roadway, full cutoff fixture:	153,355 sky lumens per mile
Major roadway, semicutoff fixture:	259,910 sky lumens per mile

Comparison of Billboard and Roadway Lighting Results

The sky lumens produced by one billboard 3 fixture lighting system are approximately equal to the sky lumens produced by:

- 0.91 miles of local roadway with full cutoff fixtures
- or 0.49 miles of collector roadway with full cutoff fixtures
- or 0.15 miles of major roadway with full cutoff fixtures
- or 0.61 miles of local roadway with semicutoff fixtures
- or 0.37 miles of collector roadway with semicutoff fixtures.
- or 0.09 miles of major roadway with semicutoff fixtures

The sky lumens produced by a 4 fixture billboard lighting system are roughly equal to the sky lumens produced by:

- 1.22 miles of local roadway with full cutoff fixtures
- or 0.66 miles of collector roadway with full cutoff fixtures
- or 0.21 miles of major roadway with full cutoff fixtures
- or 0.83 miles of local roadway with semicutoff fixtures
- or 0.49 miles of collector roadway with semicutoff fixtures.
- or 0.12 miles of major roadway with semicutoff fixtures

As another way of comparing the data, the total roadway lighting per square mile of an urban area can be computed and compared to billboard lighting. An example city square mile has been checked (in Denver, CO). For a typical built-up area, the following roadway lengths were present in the selected 1 sq. mile:

Total length of local roadways: 21 miles
Total length of collector roadways: 1 mile
Total length of major roadways: 1 mile

The total sky lumens, assuming all roadways are lighted, for this square mile have been calculated and are:

For all roadways lighted by full cutoff fixtures: 743,584 lumens
For all roadways lighted by semicutoff fixtures: 1,123,640 lumens

If a single billboard is situated in this example square mile, the percentage of total sky lumens created by the billboard lighting is as follows:

Billboard sky lumens as % of total, for 3 fixture system, when roadways are lighted with full cutoff fixtures: 3.1%
Billboard sky lumens as % of total, for 4 fixture system, when roadways are lighted with full cutoff fixtures: 4.2%
Billboard sky lumens as % of total, for 3 fixture system, when roadways are lighting with semicutoff fixtures: 2.1%
Billboard sky lumens as % of total, for 4 fixture system, when roadways are lighting with semicutoff fixtures: 2.8%

Other assumptions for the density of roadway lighting and number of billboards can be similarly determined. For example, if the roadway lighting is as above, but the density of billboards is halved, the percentage sky glow from the billboards with be halved.

In certain urban areas, the roadway lighting usage may be greater than in the selected example area. There may be other sources of sky glow such as floodlighting for buildings and sports facilities. In such conditions, the percentage contribution of a given amount of billboard lighting to the overall sky glow will be reduced. Further efforts under an extended research program could analyze large urban areas and survey lighting usage by types.

Parking and Roadway Lighting

As another example scenario, calculations have been made for a 1 square mile area consisting of both roadway lighting and parking lot lighting. In this example, a parking lot size of one quarter mile square has been selected. The total length of local roadways has been reduced to 16 miles. The parking lot is assumed to be lighted to an average level of 1.5 footcandles.

Because the parking lot is lighted to a higher level than the roadway it replaces, and because a larger area is being lighting, the total sky lumens are increased versus the earlier example that assumes the presence of roadways only.

The modified values of total sky lumens are:

For all roadways and parking areas lighted by full cutoff fixtures: 836,687 lumens

For all roadways and parking area lighted by semicutoff fixtures: 1,273,028 lumens

If a single billboard situated in this example square mile, the percentage of total sky lumens created by the billboard lighting is as follows:

Billboard sky lumens as % of total, for 3 fixture system, when roadways and parking areas are lighted with full cutoff fixtures: 2.8%

Billboard sky lumens as % of total, for 4 fixture system, when roadways and parking areas are lighted with full cutoff fixtures: 3.8%

Billboard sky lumens as % of total, for 3 fixture system, when roadways and parking areas are lighting with semicutoff fixtures: 1.8%

Billboard sky lumens as % of total, for 4 fixture system, when roadways and parking areas are lighting with semicutoff fixtures: 2.5%

Assumptions

It should be noted that in this analysis, all lumens reflected from surfaces or emitted upwards directly from the fixtures are assumed to enter the sky. This is probably true for most billboard lighting systems. For roadway and parking lot lighting, however, reflected light may be blocked by objects such as buildings or trees. If this blockage is 50%, for example, the above % contribution of billboard lighting to sky lumens will be doubled. Nonetheless, even assuming a scenario where all roadway and parking lot lighting sources are fully-shielded fixtures, the sky glow caused by billboards is a small percentage of the overall sky glow, under the conditions evaluated.

The preliminary nature of this analysis is emphasized. It should further be noted that the % contribution figures for billboards can be significantly reduced if shielded fixtures are employed.

Complete details of all calculations are available upon request.

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