ANSI/IES TM-37-21

Illuminating Engineering Society

# TECHNICAL MEMORANDUM: DESCRIPTION, MEASUREMENT, AND ESTIMATION OF SKY GLOW

## AN AMERICAN NATIONAL STANDARD

Approved American National Standard

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# TECHNICAL MEMORANDUM: DESCRIPTION, MEASUREMENT, AND ESTIMATION OF SKY GLOW

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Publication of this Technical Memorandum
has been approved by IES.
Suggestions for revisions
should be directed to IES.

**Prepared by**
**The IES Sky Glow Calculations Committee**




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**Prepared by the IES Sky Glow Calculations Committee.**

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## Preface

Numerous human benefits derive from the use of light at night. Unfortunately, increased brightness of the night sky, or *sky glow,* also directly accompanies the alteration of natural lighting levels by human-based light sources. The first, most easily observed effect of sky glow is decreased visibility of the night sky (see **Figure P-1**). Associated expressions of concern began almost simultaneously with the widespread deployment of electric lighting, and are now common around the globe.

**Figure P-1. Effects of sky glow from Las Vegas are very evident from Lake Mead, about 76 kilometers distant.** (Image courtesy of Dan Duriscoe)

More recently, apprehension has expanded to include the potential adverse influences on animals and plants from light at night occurring at "unnatural" periods during the normal diurnal cycle. The ongoing large-scale conversion of outdoor lighting sources from low- and high-pressure sodium to white light-emitting diodes (LED) has been especially criticized for LEDs' greater content of wavelengths in the portion of the visible range between 380 and 550 nm. Because the natural night sky has relatively low levels of wavelengths within this range (see **Section 2.2.2**), any such addition from human-based sources does in fact represent a significant departure from natural conditions.* While some amount of detrimental effect more or less accompanies all anthropogenic light at night, a mounting body of evidence indicates that these shorter wavelengths can be particularly disruptive, affecting natural ecosystems in addition to imposing outsized interference on the work of the astronomical community. In all cases, human-based sky glow can be considered an environmental pollutant akin to other acknowledged pollutants that engineers and designers strive to minimize while still meeting the wide-ranging needs of modern society. Global calls for action can be expected to continue and grow as documented impacts of anthropogenic light at night become better measured and understood.

It is important to recognize that all white light sources emit wavelengths within the noted range. Any white light visible from any source in any outdoor location (e.g., light emitted from building interiors) contributes to the issue, and thus multiple approaches are available (and will be necessary) to effectively address it. It is also important to recognize that lighting is intrinsically linked to a broad host of other concerns, among them safety, security, and energy use and its attendant effects.

This Technical Memorandum represents the beginning steps of a proactive response from the lighting community toward addressing the panoply of concerns in the most well-rounded and practical manner possible. While more work is needed, it is clear that improved understanding and estimation of the associated sources, quantities, characteristics, and resulting behaviors of light entering the night sky will be essential components of a comprehensive remediation strategy.

This document provides guidance on means of reducing human contributions to light in the night sky and information on estimating the relative effectiveness of the different options available.

A glossary of relevant terms is included in **Section 8.**

* Although the moon introduces these wavelengths to varying degrees and intensities over the course of a lunar cycle, moonlight's cyclical nature, vulnerability to weather conditions (e.g., cloud cover), and inseparable role in the evolutionary development of life on Earth render it distinctly different from continuous ground-based electric lighting.

# 1.0 Introduction and Scope

## 1.1 Introduction

Human-based light in the night sky mainly originates from outdoor sources intended to enable or enhance use of exterior spaces when natural light levels are insufficient for the intended purpose. To a lesser extent, light at night also comes from building interior lighting that escapes via windows or other means. Sky glow resulting from light reaching the night sky is a distinct phenomenon from other potential undesirable effects of the use of light, such as light trespass or exposure to the direct or reflected glare from an outdoor luminaire (sometimes included under the broader term "light pollution"), or light at night to which an individual may be exposed from interior sources (e.g., televisions, smart phones or tablets, clocks, nightlights). The various effects experienced by an individual would often involve a combination of such sources; this Technical Memorandum (TM) focuses exclusively on the brightness and related characteristics of the night sky and how these are influenced by the human-based light reaching it.

All light released to the external environment propagates through Earth's atmosphere to at least a limited extent. The atmosphere is a complex and dynamic combination of elements that influence the amount and characteristics of light beams traveling through it. As in other forecasts involving the atmosphere (e.g., weather), such complexity ensures that no estimation procedure or model can ever achieve perfect accuracy. The precision of the results varies from that ideal in proportion to: 1) the degree of inaccuracy introduced by any simplifying assumptions required; 2) the level of computing power necessary and available to conduct the estimation; and 3) the impacts of variable inputs. This last group includes, for example, real-time localized atmospheric conditions and particulate loading (including quantities, sizes, and shapes); presence of other lighting sources not considered in the estimate*; growth of vegetation and local geographical conditions that are difficult to precisely represent throughout a widespread scenario; blocking by buildings; and varying reflectivity of nearby surfaces.

Despite the associated challenges, such complexity does not preclude the potentially valuable insight to be gained from carrying out an "imperfect" estimation. At the community or regional level, however, knowledge of the absolute amount of sky glow present before and after planned installations is required in order to keep track of cumulative impacts. At present, this is assessed most quickly and accurately through pre- and post-installation measurement because accurate methodologies for prediction are still very much under development. This TM proposes a workable future methodology, although multiple components of it remain to be developed (see **Section 4.0**). In the interim, locations undergoing large-scale changes (e.g., a street lighting conversion) should consider conducting pre- and post-measurement of night sky brightness levels, not only for their own immediate purposes, but also to provide useful documented data to help with future methodologies. **Section 6.0** introduces measurement of night sky brightness.

Careful selection and implementation of lighting equipment does, in fact, directly influence the amount and properties (see **Sidebar – Properties and Characteristics**) of light that ultimately winds up in the night sky, as well as how far that influence extends away from the illuminated area. Such attention also helps address other important light pollution issues, such as light trespass and nuisance glare, while reducing costs of operation. Identifying when lighting is needed and when and where it is not, and then

**SIDEBAR – Properties and Characteristics**

This document refers to both "properties" and "characteristics" of light. These terms are often elsewhere used interchangeably, but a distinction is made here. "Properties" refers to qualities inherent in a given light beam, such as its spectral content and intensity, whereas "characteristics" is used as a broader term that includes additional influences from attributes of the lighting application, such as hours of use, initial directions of emission (which may differ from the portion of that light reaching the sky), and reflectances of surfaces being illuminated.

* Including natural sources such as airglow caused by cosmic rays, chemiluminescence, and other atmospheric effects. Other than moonlight, natural sources are typically low in magnitude relative to human-based sources.