National Electrical Manufacturers Association

*A NEMA Lighting Systems Division Document*
*LSD 55-2017*

# Outdoor Lighting and Human/Animal Factors: An Industry Evaluation

*Prepared by:*

NEMA Lighting Systems Division
**National Electrical Manufacturers Association**
1300 North 17th Street, Suite 900
Rosslyn, Virginia 22209



The opinions expressed in this statement represent the consensus views of the member companies of the Lighting Systems Division of the National Electrical Manufacturers Association. The members of the Lighting Systems Division manufacture indoor and outdoor lamps, which include incandescent, fluorescent, light-emitting diode, and solid-state lamps, lighting fixtures, and lamp ballasts.

## Introduction

Outdoor lighting at night provides many obvious and accepted benefits to society, including the ability to safely travel on roadways, facilitate commerce, enable outdoor activities such as recreation, provide for the lighting of architecture and landmarks, and provide for social and personal security.

NEMA Lighting Systems Division members have significant concerns with published materials that portray any type of outdoor lighting as contributing to a negative nighttime environment without giving due consideration to all the factors involved and the existing body of research. The views of the Lighting Systems Division members are shaped by the principle that, regardless of the issue, public policy that relates to technical issues should always be based on sound scientific evidence and not built on speculation or conjecture.

## Factors Influencing NEMA's Point of View

NEMA Lighting Systems Division members share the same fundamental concerns as many do regarding the need for energy conservation, dark sky preservation, mitigation of potential ecological impacts of outdoor lighting, and the growing body of research that seeks to understand and explain the effect of the circadian cycle on human and animal health.

NEMA Lighting Systems Division members support ongoing efforts by various agencies and organizations, such as the Illuminating Engineering Society (IES), International Dark-Sky Association (IDA), and the United States Department of Energy. Members also support initiatives that will minimize the amount of outdoor electric lighting needed to achieve functionality that reduces unnecessary stray light. This includes the likelihood of light trespass, nighttime sky glow, and excess energy consumption associated with inefficient lighting. NEMA lighting member companies are committed to providing improved lighting solutions that help achieve these objectives. For instance, members of NEMA's Lighting Systems Division were actively involved in the development of the IDA's Model Lighting Ordinance that promotes quality lighting standards for municipalities. NEMA members also continue to work in collaboration with the IES's Roadway Lighting Committee regarding this general topic. Many NEMA members have been aggressive in developing and promoting the types of outdoor lighting products and practices that are endorsed or recommended by IDA, including sharp cutoff luminaires and lighting controls. NEMA members also support the adoption of sensible generic outdoor lighting ordinances and specific requirements that are sometimes tailored to localities that have particular concerns, such as disruption of sea turtle habitats.

Collaborative activity among interested parties based on sound scientific evidence and best practice is the best way to achieve outdoor lighting that will benefit global climate, ecology, astronomy, and, potentially, human health. Many of the subjects pertinent to the issue of light exposure and its effects on the day/night cycle in humans and animals are scientifically complex, and are not yet fully understood, even by the scientific community—such that specific technical recommendations, particularly regarding outdoor light source spectral content, cannot yet be developed, much less propounded. There are many current efforts to establish a technical requirement regarding spectral content address scientific questions that are not yet completely understood. NEMA Lighting Systems Division members contend that technical recommendations that have the potential to impact lighting products, emerging technologies, outdoor lighting design and architectural practices, lighting codes, and legislation must be based on expert consensus after full scientific discourse and peer review. By definition, sound science must include adequate replication of results and validation of theories and hypotheses in the form of supporting measurements and data—not simply in a laboratory environment, but also under real world field conditions. Only in this manner can sufficiently detailed technical and mathematical relationships be

developed that can form the basis of actionable practices and standards. Any guidance should be based on scientific studies.

Some proposals oversimplify the ecological tradeoffs that are inherent with any proposal to limit outdoor lighting to a certain correlated color temperature (CCT). Such recommendations do not recognize the inconsistencies of such a spectrum choice, for instance, that long wavelength “red” light purportedly may disturb certain bird migrations while short wavelength (i.e., blue) light distracts sea turtles. How is such a trade-off to be reconciled between species? The topic of lighting color is complex and involves many factors beyond CCT. Thus, promoting specific CCTs to advance a particular outdoor lighting policy may have unintended consequences on overall lighting quality and other concerns of public policy such as safety and security.

Outdoor lighting products, technologies, and practices have been strongly grounded in sound engineering practices driven by the careful measurement and analysis of data. This focus on data-driven methods must continue, especially if future technical recommendations are expected to drive change in how outdoor lighting is practiced credibly, how emerging technologies such as solid state lighting are treated, and how future product offerings are configured.

Communities today are focused on promoting quality outdoor lighting, but the issues are not simple. A careful balance of controlling light pollution, excessive lighting infringing on residential property, and energy use while addressing issues of visual acuity and safety/security requires consideration of not only the lighting equipment installed but also the design and layout of the lighting equipment on a site. These issues are typically best addressed by local community ordinances rather than regional or national regulations. NEMA LSD 11-2010 *Outdoor Lighting Issues and Quality Lighting Applications* identifies specific lighting issues, defines correct lighting terminology, and provides straightforward technical guidance applicable to outdoor lighting installations in the U.S. The publication is intended to be used by anyone dealing with the selection, installation, or management of outdoor lighting systems. The key recommendations are:



NEMA Lighting Systems Division members fully support many outdoor lighting recommendations currently being advocated such as:

a. use of light control options such as motion sensing, time-of-night dimming, and stepped power switching (including an appropriate use of complete shutoff for some applications) to conserve energy;

b. luminaire shielding to curtail excessive uplight, glare, and light trespass;

c. limiting illumination to the specific task or targeted area; and

d. designing for the minimum light levels and connected power load necessary for the task.

## The Color of Light

NEMA Lighting Systems Division members do not believe there is sufficient data to recommend that outdoor lighting systems be limited to any CCT.

Outdoor lighting products typically emit a broad spectrum from violet to red that is combined to make white light. The spectral distribution can be more heavily weighted toward the blue or red, or it can be more heavily weighted to the middle of the spectrum to produce yellow or green light. While the

technology producing the light can change from fluorescent to high-pressure sodium, to metal halide, or to LED, the light energy is all the same, regardless of the source. There is no difference between the short wavelength blue light energy produced by a fluorescent lamp, or a metal halide lamp or an LED source; it is all radiated short wavelength blue light.

The lighting industry characterizes the color of white light using the term CCT. Color temperatures of common light sources used outdoors can range from approximately 2000K to 7000K. Lamps that have a 2000K color temperature, such as high-pressure sodium, look very yellow. Lamps that have color temperature of 7000K look very blue. Lamps that have CCT between 3000K and 4000K have a balanced color spectrum and tend to look white. 3000K lamps have a slightly warmer (yellow) appearance than 4000K lamps.

A single color temperature is not appropriate for all applications. Each application must be evaluated on a case by case basis to select the most appropriate color temperature for that application. Proposals for outdoor lighting that suggest that limiting the CCT to a maximum of 3000K in all cases are not supportable and are focused on resolving issues for specific applications to the detriment of other applications.

## The Case for Only Using Higher Color Temperature Lamps

Some groups have made the case to only use higher color temperature sources when outside, e.g., 4000K, 5000K, or higher. Their point is that light sources with higher CCT have more energy in the short wavelength (i.e., blue) part of the spectrum which is better seen by the human eye at the very low light levels typical of outdoor applications. The argument is that use of high color temperature sources, therefore, can improve human reaction time, and improve energy efficiency, safety and security. Following this logic, they argue that using such sources may also allow designers to reduce light levels, rather than using lower color temperature sources to achieve the same visual lighting effect.

## The Case for only using Lower Color Temperature Lamps

The American Medical Association Community Guidance issued on June 14, 2016, suggested only using lower color temperature sources of 3000K or less over concerns about circadian rhythm effects. They argue that the short wavelength radiation, (i.e., blue light) found in higher color temperature sources can potentially suppress melatonin and negatively affect sleep cycles. However, it has been documented in several studies that such effects can only occur with a high exposure level and a long exposure time to blue light. The required exposure to blue light for the retina is extremely unlikely to be achieved under outdoor lighting conditions where outdoor light levels are very low, and users are generally exposed to outdoor lighting for a very short period. In contrast, people with seasonal affective disorders (SAD) who try to suppress melatonin levels in the morning are often told to sit next to a lighting fixture containing high-intensity, high CCT light sources for 30 to 60 minutes.

The Lighting Research Center (LRC) has indicated that CCT is not the correct metric to predict blue light content. Rather, it is recommended that the appropriate metric must consider spectral power distribution (SPD) along with light level expressed in photopic lux.[1]

[1] LRC Response to the 2016 AMA Report on LED Lighting,
http://www.lrc.rpi.edu/resources/newsroom/AMA.pdf
LRC Webinar on Blue Light - Response to AMA,
https://www.youtube.com/watch?v=2BcfcONrm58&feature=youtu.be
LRC Releases Free, Open Access Circadian Stimulus Calculator,

## Color Summary

When selecting an outdoor lighting source, there are many factors to consider beyond the narrow recommendations of one particular group. Factors such as the overall lighting quality, light distribution, glare control, lighting trespass, public safety concerns, unique application requirements, operating costs, and maintenance costs with respect to each outdoor application. After all of these critical aspects are considered, color temperature options are reviewed.

There is no one right answer for color temperature for all applications; this is why manufacturers offer products with a wide range of color temperatures options so users can select the product that best meets their needs. Unlike traditional outdoor lighting sources such as high-pressure sodium lamps that are only available at lower color temperatures, or metal halide lamps that are mainly available at high color temperatures, new LED technology provides a wide range of color temperature choices.

## American Medical Association Guidance

The American Medical Association issued **a report** for Community Guidance Regarding Street Lighting on June 14, 2016. In this report, the AMA Council on Science and Public Health expressed concern regarding the impact of LED street lighting on glare, disruption of nocturnal species and disruption to the human circadian system.

Many media outlets reported on this AMA guidance and presented conclusions that were either inconsistent with the guidance or extended beyond the body of scientific research. Various lighting authorities have provided public statements to clarify the use of LED lighting and result from lighting research. (See Appendix A)

The AMA guidance when taken into consideration with the responses from various lighting authorities, clearly articulates that LEDs offer by far the most energy efficient method for street lighting. There is also consensus that when properly designed and applied, LED lighting provides many advantages. These benefits, which are true for street lighting as well as all outdoor site and area applications, go beyond energy savings and can enhance people's experience.

## Health Impact Considerations of AMA Guidance—Disruptions to Circadian Rhythm and Melatonin Production

Several responses to the AMA guidance are critical of the AMA's assertion that LEDs present a health risk, particularly as it pertains to blue light levels. For example, the LRC indicates that the CCT metric ignores nearly all of the important factors associated with light exposure (amount, duration, timing) and is only relevant to a single biological response (perceived tint of illumination). The LRC further indicates that CCT should never be used to characterize light as a stimulus for blue light hazard. An important point omitted from the AMA's guidance is that blue light is not restricted to LEDs. Many HID sources emit as much as or more blue light (short wavelength radiation). In addition, a number of electronic devices produce blue light, such as cell phones, tablets, laptops, television, and e-readers. When using these devices, the typical user experiences more intense light for longer exposure times than received from any outdoor lighting system.

---

http://www.lrc.rpi.edu/resources/newsroom/pr_story.asp?id=338#.WSWNC6DfO00

Scientific research has validated that disruption occurs only when there is a short wavelength blue light exposure exceeding a specific intensity aimed at the retina for an extended period during normal sleep hours. Research utilizing field measurements has shown that the light exposure, both intensity, and duration, from typical street or outdoor lighting is insufficient to cause disruption associated with melatonin suppression.

Much of the research related to health impacts has been based on intensity and duration of light exposure at night associated with shift work such as with third shift hospital workers. The levels of exposure in these applications are significantly higher than common outdoor lighting applications, and therefore cannot be extrapolated to the reduced light level and shorter duration activities associated with street lighting.

Shift workers may be at greater risk of circadian disruption; however, exposure to short wavelength blue light for working people at night is likely to improve their reaction time. This can be a critical factor for people working at night in interior applications. In this sense, as with other applications where visual performance and task accuracy are important, a relatively higher level of blue light may be desirable.

Much of the research studying melatonin suppression associated with outdoor lighting used technology comparisons that do not represent the most popular LED technology being considered today. These comparisons often represent drastic differences in colors (such as a 6000K LED to a 2000K High Pressure Sodium). The current LED designs focus on 3000K CCT for “warmer” color appearance or 4000K CCT for “cooler” color appearance. Both are in between the two research extremes and spectral variations between the two most popular LED sources are not that significant. Therefore, the research conclusions of previous studies are not applicable to today’s technology decisions.

## Quality Design Requirements for each Unique Outdoor Application



Design requirements to promote quality lighting include a variety of considerations such as: visibility, reaction time, safety, security, optical and glare control, color discrimination, lighting zones and impacts on neighboring properties. Special requirements may also be considered for areas near observatories, “dark sky” preserves such as national parks, or concerns with protecting the local habitat.

LED lighting is widely available with various values of CCT, which is important depending on the application. Research has also confirmed that visual acuity and reaction time is improved with sources that have relatively higher ‘blue’ (short wavelength) content. For many outdoor applications, protecting the public with lighting that promotes a safe and secure environment may be the highest priority to the community. It is clear that there is no single color temperature of light that will optimize the design criteria for all applications.

While some research has confirmed that sources with more blue spectral content can result in increased atmospheric scatter causing glare, luminaire optics have a far greater impact on reducing high angle brightness to effectively control scatter and glare.

Responsive lighting includes systems that dim when occupancy in an area is low or is scheduled to dim or turn off late at night. These systems not only reduce energy consumption but also reduce the potential for negative environmental impacts. HID lighting such as metal halide or high-pressure sodium is difficult and costly to dim. In addition, the slow startup time of these technologies limits the option to turn the lights off for short periods of time.

An LED lighting system has the capability to link all street lighting assets, remotely control luminaires and communicate over the network in real-time that enables on-demand dimming and expand control capabilities. It is one of the most efficient options compared to traditional lighting technologies.

In summary, there are several well-respected organizations (see Appendix A) attempting to address the above issues. Much of the current research compares 2000K to 6000K and does not represent the 3000K or 4000K that is being installed in the outdoor space today. Also lacking is definitive research on exposure time. Research thus far has been largely focused on shift workers and their exposure to artificial light in the interior space. This in no way represents the possible exposure that individuals typically experience under street lighting. The IES has organized numerous forums for the presentation and discussion of information and collected data from a wide range of researchers and laboratories. There is still not consensus within IES on these matters. This demonstrates the need for additional research and more scientific study. More studies must be conducted, and scientific data must be collected for the industry to establish agreed upon corresponding actions. NEMA welcomes the opportunity to work with various organizations to prioritize and drive projects to research this area further. We are committed to improving outdoor lighting based on factual data and scientific conclusions.

# APPENDIX A

**NEMA encourages a thorough review of statements issued by government and academic experts on this topic:**

**U.S. Department of Energy Posting, June 21, 2016**
Jim Brodrick, Solid-State Lighting Technology Manager at the U.S. Department of Energy (DOE), explains that there is nothing different about the blue light emitted by LEDs as compared to other sources with blue, rich content. He also indicates that there is nothing inherently dangerous about LED lighting and that it should be used with the same prudence with which we use any other technology. It is commonly agreed that light should be directed only where it is needed at the minimal levels required to support visibility, safety, and security, and to use a spectral content that supports the needs of the application. DOE also indicates that lighting products with low CCTs may result in light that no longer appears white and colors can be substantially distorted, reducing visibility. In this case, higher lighting levels may be required, which may completely negate the effects of reducing the relative amount of short wavelength 'blue' emission.

DOE related documents include:

*True Colors, LEDs and the relationship between CCT, CRI, optical safety, material degradation, and photobiological stimulation, October 2014, https://www.osti.gov/scitech/biblio/1165332*

*Street Lighting and Blue Light Frequently Asked Questions, February 2017, https://energy.gov/sites/prod/files/2017/03/f34/Street%20Lighting%20and%20Blue%20Light%20FAQs.pdf*

*View all DOE documents and presentations relating to Street Lighting and Blue Light at https://energy.gov/eere/ssl/street-lighting-and-blue-light*

**Illuminating Engineering Society Updates, June 2016**
IES expresses concern with the varying degrees of information and misinformation about claims and recommendations in the AMA report specific to the use of blue-rich lighting. IES also questions if the references in the 2016 AMA are sufficient to justify the expanded recommendations from the 2012 AMA report. IES continues to work with researchers and experts on this subject.

**Lighting Research Center Response, June 30, 2016**
The LRC suggests that CCT ignores nearly all important factors associated with light exposure and is only relevant to the perceived color of illumination. The LRC concludes that CCT should never be used to characterize light as a stimulus for blue light hazard. The LRC also provides an example illustrating that, given equal illuminance; a 3500K source may produce greater melatonin suppression than a 5000K source. The LRC believes that there is not enough research available yet to reach firm conclusions about blue light and circadian disruption.

**Lam Partners Statement: Is LED Street Lighting Bad For Your Health?**
**Glenn Heinmiller, June 29, 2016**
Glenn Heinmiller, a lighting designer in Boston, indicates that the AMA report cites no evidence that the intensity and duration of exposure typically experienced from street lighting are sufficient to have any

melatonin-suppressing effect. He also cites a report from the Northwest Energy Efficiency Alliance concluding that 4100K LED street lighting resulted in significantly better ability of drivers to detect pedestrians at greater distances, compared to the other higher and lower color temperatures tested. Mr. Heinmiller suggests that this might make 4100K the best choice from a safety standpoint on streets with pedestrians and cyclists.

**U.S. Department of Energy Municipal Solid State Street Lighting Consortium**
**The Light Post, July 2016**
The Municipal Solid State Street Lighting Consortium states that new LED luminaires with improved optical distribution emit only half (or less) of the light output of luminaires using conventional light sources. Therefore, the reduction in light levels may reduce the overall melanopic output for the application even if there is an increase in blue spectral content of the source compared to traditional technologies. This report furthermore lists the melanopic content of several different light sources, with the conclusion that LED lighting with a CCT as high as 4500K can have the same melanopic content as an incandescent lamp at 2700K. It is important to note that two highly regarded researchers in this specific field of light and health, Bud Brainard, Ph.D. and Robert Lucas, Ph.D., provided a review of this report for accuracy and that Bud Brainard was also listed as a contributor to the AMA report.

**U.S. Department of Energy "Get the Facts on LED Streetlighting" Solid State Lighting webcast, October 2016**
**A presentation** on key issues underlying concerns raised by the American Medical Association community guidance on street lighting, and their applicability to LED street lighting. This presentation highlights the facts as we know them today and points out that there is no single solution for all applications. Users need to understand all key factors prior to making a decision on their lighting solution. The DOE discusses their investigations into items such as sky glow, light source comparisons, proper measurement of total blue light exposure, and research on how much light is actually coming into homes. DOE highlights the fact that by using LED luminaires with lower lumens, and the ability to dim for a portion of the night, the experience may be less blue light exposure compared to traditional light sources.
https://energy.gov/eere/ssl/downloads/webinar-get-facts-led-street-lighting

**National Institute of Health (NIH) "Lighting and its Impact on Circadian Disruption and Health: What We Know, What We Don't Know and What We Need to Know" webcast, Dr. Mariana G. Figueiro, February 2017**

**Webcast** provides an overview of light as it affects the circadian system, discusses tools to measure and specifies circadian effective light. It also proposes gaps in besides no underscore, what is Webcast? Is that the name of something? our knowledge of the health effects of light. Also discussed are potential research studies to minimize these gaps.

# APPENDIX B
# Industry References

1. Lockley SW, Evans EE, Scheer AJL, Brainard GC, Czeisler CA, Aeschbach D. Short-Wavelength Sensitivity for the Direct Effects of Light on Alertness, Vigilance, and the Waking Electroencephalogram in Humans. *Sleep Physiology.* 2006;29(2):161–168.

2. Rea M, Figueiro M, Bullough J, Bierman A. A model of phototransduction by the human circadian system. *Brain Research Review.* 2005;(50):213–228.

3. Rea M, Figueiro M, Bierman A, Hamner R. Modelling the spectral sensitivity of the human circadian system. *Lighting Research & Technology.* 2012 Dec;44(4):386–396.

4. Gooley J, Rajaratnam S, Brainard G, Kronauer R, Czeisler C, Lockley S. Spectral responses of the human circadian system depend on the irradiance and duration of exposure to light. *Science Translational Medicine.* 2010;2:31ra33.

5. Wirz-Justice A, Fournier C. Light, health, and Wellbeing: Implications from chronobiology for architectural design. *World Health Design.* 2010 Jan;3(1):44–49.

6. Brainard GC, Coyle W, Ayers M, Kemp J, Warfield B, Maida J, et al. Solid-state lighting for the International Space Station: Tests of visual performance and melatonin regulation. *Acta Astronautica.* 2013;92(1):21–28.

7. Santhi N, Thorne HC, van der Veen DR, Johnsen S, Mills SL, Hommes V, et al. The spectral composition of evening light and individual differences in the suppression of melatonin and delay of sleep in humans. *Journal of Pineal Research.* 2012;53:47–59.

§