

REPORT OF THE COUNCIL ON SCIENCE AND PUBLIC HEALTH

CSAPH Report 2-A-16

Subject: Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting

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Referred to: Reference Committee E
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1 INTRODUCTION

2
3 With the advent of highly efficient and bright light emitting diode (LED) lighting, strong economic
4 arguments exist to overhaul the street lighting of U.S. roadways.¹⁻³ Valid and compelling reasons
5 driving the conversion from conventional lighting include the inherent energy efficiency and longer
6 lamp life of LED lighting, leading to savings in energy use and reduced operating costs, including
7 taxes and maintenance, as well as lower air pollution burden from reduced reliance on fossil-based
8 carbon fuels.

9
10 Not all LED light is optimal, however, when used as street lighting. Improper design of the lighting
11 fixture can result in glare, creating a road hazard condition.^{4,5} LED lighting also is available in
12 various color correlated temperatures. Many early designs of white LED lighting generated a color
13 spectrum with excessive blue wavelength. This feature further contributes to disability glare, i.e.,
14 visual impairment due to stray light, as blue wavelengths are associated with more scattering in the
15 human eye, and sufficiently intense blue spectrum damages retinas.^{6,7} The excessive blue spectrum
16 also is environmentally disruptive for many nocturnal species. Accordingly, significant human and
17 environmental concerns are associated with short wavelength (blue) LED emission. Currently,
18 approximately 10% of existing U.S. street lighting has been converted to solid state LED
19 technology, with efforts underway to accelerate this conversion. The Council is undertaking this
20 report to assist in advising communities on selecting among LED lighting options in order to
21 minimize potentially harmful human health and environmental effects.

22 23 METHODS

24
25 English language reports published between 2005 and 2016 were selected from a search of the
26 PubMed and Google Scholar databases using the MeSH terms “light,” “lighting methods,”
27 “color,” “photoc stimulation,” and “adverse effects,” in combination with “circadian
28 rhythm/physiology/radiation effects,” “radiation dosage/effects,” “sleep/physiology,” “ecosystem,”
29 “environment,” and “environmental monitoring.” Additional searches using the text terms “LED”
30 and “community,” “street,” and “roadway lighting” were conducted. Additional information and
31 perspective were supplied by recognized experts in the field.

32 33 ADVANTAGES AND DISADVANTAGES OF LED STREET LIGHTS

34
35 The main reason for converting to LED street lighting is energy efficiency; LED lighting can
36 reduce energy consumption by up to 50% compared with conventional high pressure sodium (HPS)

1 lighting. LED lighting has no warm up requirement with a rapid “turn on and off” at full intensity.
2 In the event of a power outage, LED lights can turn on instantly when power is restored, as
3 opposed to sodium-based lighting requiring prolonged warm up periods. LED lighting also has the
4 inherent capability to be dimmed or tuned, so that during off peak usage times (e.g., 1 to 5 AM),
5 further energy savings can be achieved by reducing illumination levels. LED lighting also has a
6 much longer lifetime (15 to 20 years, or 50,000 hours), reducing maintenance costs by decreasing
7 the frequency of fixture or bulb replacement. That lifespan exceeds that of conventional HPS
8 lighting by 2-4 times. Also, LED lighting has no mercury or lead, and does not release any toxic
9 substances if damaged, unlike mercury or HPS lighting. The light output is very consistent across
10 cold or warm temperature gradients. LED lights also do not require any internal reflectors or glass
11 covers, allowing higher efficiency as well, if designed properly.^{8,9}
12

13 Despite the benefits of LED lighting, some potential disadvantages are apparent. The initial cost is
14 higher than conventional lighting; several years of energy savings may be required to recoup that
15 initial expense.¹⁰ The spectral characteristics of LED lighting also can be problematic. LED
16 lighting is inherently narrow bandwidth, with “white” being obtained by adding phosphor coating
17 layers to a high energy (such as blue) LED. These phosphor layers can wear with time leading to a
18 higher spectral response than was designed or intended. Manufacturers address this problem with
19 more resistant coatings, blocking filters, or use of lower color temperature LEDs. With proper
20 design, higher spectral responses can be minimized. LED lighting does not tend to abruptly “burn
21 out,” rather it dims slowly over many years. An LED fixture generally needs to be replaced after it
22 has dimmed by 30% from initial specifications, usually after about 15 to 20 years.^{1,11}
23

24 Depending on the design, a large amount blue light is emitted from some LEDs that appear white
25 to the naked eye. The excess blue and green emissions from some LEDs lead to increased light
26 pollution, as these wavelengths scatter more within the eye and have detrimental environmental
27 and glare effects. LED’s light emissions are characterized by their correlated color temperature
28 (CCT) index.^{12,13} The first generation of LED outdoor lighting and units that are still widely being
29 installed are “4000K” LED units. This nomenclature (Kelvin scale) reflects the equivalent color of
30 a heated metal object to that temperature. The LEDs are cool to the touch and the nomenclature has
31 nothing to do with the operating temperature of the LED itself. By comparison, the CCT associated
32 with daylight light levels is equivalent to 6500K, and high pressure sodium lighting (the current
33 standard) has a CCT of 2100K. Twenty-nine percent of the spectrum of 4000K LED lighting is
34 emitted as blue light, which the human eye perceives as a harsh white color. Due to the point-
35 source nature of LED lighting, studies have shown that this intense blue point source leads to
36 discomfort and disability glare.¹⁴
37

38 More recently engineered LED lighting is now available at 3000K or lower. At 3000K, the human
39 eye still perceives the light as “white,” but it is slightly warmer in tone, and has about 21% of its
40 emission in the blue-appearing part of the spectrum. This emission is still very blue for the
41 nighttime environment, but is a significant improvement over the 4000K lighting because it
42 reduces discomfort and disability glare. Because of different coatings, the energy efficiency of
43 3000K lighting is only 3% less than 4000K, but the light is more pleasing to humans and has less
44 of an impact on wildlife.
45

46 *Glare*

47

48 Disability glare is defined by the Department of Transportation (DOT) as the following:
49

50 “Disability glare occurs when the introduction of stray light into the eye reduces the ability to
51 resolve spatial detail. It is an objective impairment in visual performance.”

1 Classic models of this type of glare attribute the deleterious effects to intraocular light scatter in the
2 eye. Scattering produces a veiling luminance over the retina, which effectively reduces the contrast
3 of stimulus images formed on the retina. The disabling effect of the veiling luminance has serious
4 implications for nighttime driving visibility.¹⁵

5
6 Although LED lighting is cost efficient and inherently directional, it paradoxically can lead to
7 worse glare than conventional lighting. This glare can be greatly minimized by proper lighting
8 design and engineering. Glare can be magnified by improper color temperature of the LED, such as
9 blue-rich LED lighting. LEDs are very intense point sources that cause vision discomfort when
10 viewed by the human eye, especially by older drivers. This effect is magnified by higher color
11 temperature LEDs, because blue light scatters more within the human eye, leading to increased
12 disability glare.¹⁶

13
14 In addition to disability glare and its impact on drivers, many residents are unhappy with bright
15 LED lights. In many localities where 4000K and higher lighting has been installed, community
16 complaints of glare and a “prison atmosphere” by the high intensity blue-rich lighting are common.
17 Residents in Seattle, WA have demanded shielding, complaining they need heavy drapes to be
18 comfortable in their own homes at night.¹⁷ Residents in Davis, CA demanded and succeeded in
19 getting a complete replacement of the originally installed 4000K LED lights with the 3000K
20 version throughout the town at great expense.¹⁸ In Cambridge, MA, 4000K lighting with dimming
21 controls was installed to mitigate the harsh blue-rich lighting late at night. Even in places with a
22 high level of ambient nighttime lighting, such as Queens in New York City, many complaints were
23 made about the harshness and glare from 4000K lighting.¹⁹ In contrast, 3000K lighting has been
24 much better received by citizens in general.

25 26 *Unshielded LED Lighting*

27
28 Unshielded LED lighting causes significant discomfort from glare. A French government report
29 published in 2013 stated that due to the point source nature of LED lighting, the luminance level of
30 unshielded LED lighting is sufficiently high to cause visual discomfort regardless of the position,
31 as long as it is in the field of vision. As the emission surfaces of LEDs are highly concentrated
32 point sources, the luminance of each individual source easily exceeds the level of visual
33 discomfort, in some cases by a factor of 1000.¹⁷

34
35 Discomfort and disability glare can decrease visual acuity, decreasing safety and creating a road
36 hazard. Various testing measures have been devised to determine and quantify the level of glare
37 and vision impairment by poorly designed LED lighting.²⁰ Lighting installations are typically
38 tested by measuring foot-candles per square meter on the ground. This is useful for determining the
39 efficiency and evenness of lighting installations. This method, however, does not take into account
40 the human biological response to the point source. It is well known that unshielded light sources
41 cause pupillary constriction, leading to worse nighttime vision between lighting fixtures and
42 causing a “veil of illuminance” beyond the lighting fixture. This leads to worse vision than if the
43 light never existed at all, defeating the purpose of the lighting fixture. Ideally LED lighting
44 installations should be tested in real life scenarios with effects on visual acuity evaluated in order to
45 ascertain the best designs for public safety.

46 47 *Proper Shielding*

48
49 With any LED lighting, proper attention should be paid to the design and engineering features.
50 LED lighting is inherently a bright point source and can cause eye fatigue and disability glare if it
51 is allowed to directly shine into human eyes from roadway lighting. This is mitigated by proper

1 design, shielding and installation ensuring that no light shines above 80 degrees from the
 2 horizontal. Proper shielding also should be used to prevent light trespass into homes alongside the
 3 road, a common cause of citizen complaints. Unlike current HPS street lighting, LEDs have the
 4 ability to be controlled electronically and dimmed from a central location. Providing this additional
 5 control increases the installation cost, but may be worthwhile because it increases long term energy
 6 savings and minimizes detrimental human and environmental lighting effects. In environmentally
 7 sensitive or rural areas where wildlife can be especially affected (e.g., near national parks or bio-
 8 rich zones where nocturnal animals need such protection), strong consideration should be made for
 9 lower emission LEDs (e.g., 3000K or lower lighting with effective shielding). Strong consideration
 10 also should be given to the use of filters to block blue wavelengths (as used in Hawaii), or to the
 11 use of inherent amber LEDs, such as those deployed in Quebec. Blue light scatters more widely
 12 (the reason the daytime sky is “blue”), and unshielded blue-rich lighting that travels along the
 13 horizontal plane increases glare and dramatically increases the nighttime sky glow caused by
 14 excessive light pollution.

15

16 POTENTIAL HEALTH EFFECTS OF “WHITE” LED STREET LIGHTING

17

18 Much has been learned over the past decade about the potential adverse health effects of electric
 19 light exposure, particularly at night.²¹⁻²⁵ The core concern is disruption of circadian rhythmicity.
 20 With waning ambient light, and in the absence of electric lighting, humans begin the transition to
 21 nighttime physiology at about dusk; melatonin blood concentrations rise, body temperature drops,
 22 sleepiness grows, and hunger abates, along with several other responses.

23

24 A number of controlled laboratory studies have shown delays in the normal transition to nighttime
 25 physiology from evening exposure to tablet computer screens, backlit e-readers, and room light
 26 typical of residential settings.²⁶⁻²⁸ These effects are wavelength and intensity dependent,
 27 implicating bright, short wavelength (blue) electric light sources as disrupting transition. These
 28 effects are not seen with dimmer, longer wavelength light (as from wood fires or low wattage
 29 incandescent bulbs). In human studies, a short-term detriment in sleep quality has been observed
 30 after exposure to short wavelength light before bedtime. Although data are still emerging, some
 31 evidence supports a long-term increase in the risk for cancer, diabetes, cardiovascular disease and
 32 obesity from chronic sleep disruption or shiftwork and associated with exposure to brighter light
 33 sources in the evening or night.^{25,29}

34

35 Electric lights differ in terms of their circadian impact.³⁰ Understanding the neuroscience of
 36 circadian light perception can help optimize the design of electric lighting to minimize circadian
 37 disruption and improve visual effectiveness. White LED streetlights are currently being marketed
 38 to cities and towns throughout the country in the name of energy efficiency and long term cost
 39 savings, but such lights have a spectrum containing a strong spike at the wavelength that most
 40 effectively suppresses melatonin during the night. It is estimated that a “white” LED lamp is at
 41 least 5 times more powerful in influencing circadian physiology than a high pressure sodium light
 42 based on melatonin suppression.³¹ Recent large surveys found that brighter residential nighttime
 43 lighting is associated with reduced sleep time, dissatisfaction with sleep quality, nighttime
 44 awakenings, excessive sleepiness, impaired daytime functioning, and obesity.^{29,32} Thus, white LED
 45 street lighting patterns also could contribute to the risk of chronic disease in the populations of
 46 cities in which they have been installed. Measurements at street level from white LED street lamps
 47 are needed to more accurately assess the potential circadian impact of evening/nighttime exposure
 48 to these lights.

1 ENVIRONMENTAL EFFECTS OF LED LIGHTING

2
3 The detrimental effects of inefficient lighting are not limited to humans; 60% of animals are
4 nocturnal and are potentially adversely affected by exposure to nighttime electrical lighting. Many
5 birds navigate by the moon and star reflections at night; excessive nighttime lighting can lead to
6 reflections on glass high rise towers and other objects, leading to confusion, collisions and
7 death.³³ Many insects need a dark environment to procreate, the most obvious example being
8 lightning bugs that cannot “see” each other when light pollution is pronounced. Other
9 environmentally beneficial insects are attracted to blue-rich lighting, circling under them until they
10 are exhausted and die.^{34,35} Unshielded lighting on beach areas has led to a massive drop in turtle
11 populations as hatchlings are disoriented by electrical light and sky glow, preventing them from
12 reaching the water safely.³⁵⁻³⁷ Excessive outdoor lighting diverts the hatchlings inland to their
13 demise. Even bridge lighting that is “too blue” has been shown to inhibit upstream migration of
14 certain fish species such as salmon returning to spawn. One such overly lit bridge in Washington
15 State now is shut off during salmon spawning season.

16
17 Recognizing the detrimental effects of light pollution on nocturnal species, U.S. national parks
18 have adopted best lighting practices and now require minimal and shielded lighting. Light pollution
19 along the borders of national parks leads to detrimental effects on the local bio-environment. For
20 example, the glow of Miami, FL extends throughout the Everglades National Park. Proper
21 shielding and proper color temperature of the lighting installations can greatly minimize these types
22 of harmful effects on our environment.

23
24 CONCLUSION

25
26 Current AMA Policy supports efforts to reduce light pollution. Specific to street lighting, Policy H-
27 135.932 supports the implementation of technologies to reduce glare from roadway lighting. Thus,
28 the Council recommends that communities considering conversion to energy efficient LED street
29 lighting use lower CCT lights that will minimize potential health and environmental effects. The
30 Council previously reviewed the adverse health effects of nighttime lighting, and concluded that
31 pervasive use of nighttime lighting disrupts various biological processes, creating potentially
32 harmful health effects related to disability glare and sleep disturbance.²⁵

33
34 RECOMMENDATIONS

35
36 The Council on Science and Public Health recommends that the following statements be adopted,
37 and the remainder of the report filed.

- 38
39 1. That our American Medical Association (AMA) support the proper conversion to community-
40 based Light Emitting Diode (LED) lighting, which reduces energy consumption and decreases
41 the use of fossil fuels. (New HOD Policy)
42
43 2. That our AMA encourage minimizing and controlling blue-rich environmental lighting by
44 using the lowest emission of blue light possible to reduce glare. (New HOD Policy)
45
46 3. That our AMA encourage the use of 3000K or lower lighting for outdoor installations such as
47 roadways. All LED lighting should be properly shielded to minimize glare and detrimental
48 human and environmental effects, and consideration should be given to utilize the ability of
49 LED lighting to be dimmed for off-peak time periods. (New HOD Policy)

Fiscal Note: Less than \$500

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