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2022 REPORT ON LEDS

By Soft Lights Foundation

Introduction

On June 6, 2018, the Scientific Committee on Health, Environment, and Emerging Risks (SCHEER) published an analysis of the risks of Light Emitting Diodes. The purpose of this document is to draw attention to the latest research and data showing that LED visible electromagnetic radiation emits non-uniform luminance, that the radiation does not disperse following an inverse square law, that LED visible radiation is harmful to human and ecosystem health, and to call for a new report from SCHEER using the latest research and data.

Health Data and Documentation

Reports of significant health risks and impacts have emerged in the population as a result of exposure to LED light sources in their multitude of forms. The Soft Lights Foundation has accumulated data from approximately 2,000 people who have reported their adverse health experiences from LED light. Many people have reported eye strain/pain, headache, while a substantial number of people have also reported profound illness including seizure, migraine, exacerbation of auto-immune disease such as lupus, and other neurological reaction.

The SCHEER report divides people into separate groups, including “general healthy population”, “children”, and “elderly”. Yet, the SCHEER does not define “general healthy population”, so we do not know the criteria for who falls into this category. The SCHEER report does not explain why it is useful or valid to divide people into these categories for their analysis of the impacts of LED light on humans. The use of these categories causes the SCHEER report to misleadingly imply that LED light is safe because it is safe for the undefined “general healthy population.”

Many people have been diagnosed with a medical condition which impacts their lives but does not exclude them for society. For example, an adult with epilepsy is able to maintain a job just as well as a person in the “generally healthy” category, so long as the seizure triggers are avoided. Many people who have autism make excellent computer programmers. A person who has severe migraines can be a librarian or perform mathematical calculus as part of his job evaluating water quality. So, other than the diagnoses of epilepsy, autism, and migraine, these people are “generally healthy”. However, the SCHEER does not explain which of these people are in the “generally healthy” population and which are not. The SCHEER also does not explain why an elderly person, or a child is not a member of the “general healthy population.” The updated SCHEER report must define the criteria for inclusion into each category and must justify the use of such categories in the analysis of the impacts of LED light.

Diagnosed Medical Conditions

The gravity of the impacts of LED light on people with a diagnosed medical condition is documented as follows, listing a selection of cases which depict the health consequences that have emerged due to exposure to LED sources. When possible, medical letters from the treating clinicians are included.

Personal Statement	Medical Reports
Epilepsy	
MarieAnn I live in a small, appealing village of about twelve hundred residents, surrounded by farms and forests. My family has been very content living here for many years. I have life-long epilepsy and migralepsy. Medications don't control my condition, so I learned to manage my epilepsy by adapting my life habits and adjusting to carefully avoid anything known to cause my seizures. Over time it became second nature, and I was healthy, happy, employed, independent, and nearly seizure-free for decades. Seven or so years ago, however, I had my first encounter with an LED light. It triggered one of the worst, most violent seizures I'd ever experienced. I didn't even know what LEDs were back then. Since then, I've found that almost every version of LEDs provokes that kind of instantaneous reflex seizure, and other LEDs cause migraines which lead to seizures. It's a matter of minutes or of a split second, but one or the other happens every time I can't avoid LED lights. In the brief moment I have to see before my brain reacts, the worst LEDs look like a spray of strobing needles. Full text here:[1]	October 28, 2020 To Whom it May Concern: [Patient] is a patient who I have seen in her consultation for her stated diagnosis of photosensitive epilepsy. She reports, as do several members of her family that have witnessed her seizures that they were triggered by LED lights. Specifically, her seizures seemed under control prior to January when LED lights were installed in her village. Since that time, the frequency of her seizures has increased. Her daughter and her husband state that they have witnessed her having seizures in response to these LED lights. She reports that she has had to move from her village in order to avoid having seizures triggered by the LED lights installed there. Please consider making adjustments to the LED lights in order to accommodate this patient's ability to live in her village. Emma Weiskopf, MD
Heidi March 17, 2022 – Yesterday at around 5:20pm, I was driving home from work and I encountered an RRFB (Rectangular Rapid Flashing Beacon). A pedestrian pushed the button on the RRFB and the	

[1] http://www.softlights.org/wp-content/uploads/2021/09/modified-for-Softlights-.pdf

strobing RRFB was so distracting and blinding that I almost drove into the pedestrian. I have photosensitive epilepsy and my epileptic auras began. I was immediately nauseous, my left leg started to twitch, and I felt pain in my eyes. My legs were wobbly, and I felt physically unstable. I drove to my apartment, stepped inside, and then felt like I was losing control of my bladder. Instead, I vomited. I then did almost nothing but sleeping for the next two days and missed work.	
Toxic Encephalopathy	
Kristina	July 19, 2022 To Whom it May Concern: I have been providing psychotherapy, stress management, and cognitive rehabilitation to Patient for several years. She has also undergone neuropsychological testing and functional brain imaging. Her care is coordinated with her primary treating physician. Patient suffers from toxic encephalopathy (ICD-10, G92.8) and hyper-photosensitivity to light, other than the sun (ICD-10, L59.8), specifically light from LEDs. Patient should not be considered or labeled as psychosomatic or hysterical but taken seriously regarding her underlying medical condition. In fact, in many ways she is the "Miners Canary." That is chemical and light pollution affects all of us adversely. Currently, Patient is suffering significant health problems from photo toxicity due to excessive exposure to high-intensity, artificial light, often produce by light emitting diodes in the blue spectrum. Recently, there have been several published studies providing increasing evidence of health problems related to exposure to these kinds of lights. Health problems include disruption of circadian rhythms and thus sleep,

	metabolic dysregulation, cancer risk, damage to the eyes, and behavioral and cognitive dysfunction. Attached to this letter is a list of references to recent research documents on the problem of photo toxicity. Patient tells me that bright lights have been put up near her home causing her to experience a number of health problems. She has experienced eye pain, swelling around her eye, blurred vision, nausea and vomiting, and anxiety. The effects of these bright lights on her brain are demonstrated by changes in her brain electrical functioning as measured by a quantitative EEG with neurometric analysis. After exposure, health problems can exist for days. I am strongly recommending that these bright lights around Patient's house be removed. This accommodation should meet ADA guidelines for the disabled. If you have any other questions, please feel free to contact me. B. Robert Crago, Ph.D. Licensed Psychologist, State of Arizona, Certificate #866 National Registry of Health Care Service, Providers in Psychology, Certificate #30209 ASPPB Certificate of Professional Qualification Psychology, CPQ #2058 American Board of Disability Analysts, Senior Disability Analyst/Diplomate #2478-96 Biofeedback Institute of America – EEG, Fellow: Certificate #1022 Board Certified Diplomate Fellow in Geriatric Psychology (GCICPP)
ADHD	
<u>Stacie</u>	August 27, 2022 To Whom it May Concern:

	I have been seeing and treating Patient in clinic since 4/9/2022 for ADHD. She has been reporting heightened light sensitivity and pain related to exposure to LED lights are her work since her work scheduled shifted to evenings in mid-July where LED exposure is greater than normal levels of daily living. While Patient reports her eye doctor finds no functional problem with her eyes, in a study published in Frontiers of Neurology and available online via National Library of Medicine, 69% of people with ADHD have light sensitivity issues. As a result, I think this is likely the cause of Patient's light sensitivity issues which is exacerbated by the intensity of exposure she is currently experiencing. If there could be accommodations made that allow her to work in a safe and pain free environment, this would be optimal for her mental health. Thank you for your consideration. Sincerely, Dr. [Name]
Autism / Anxiety	
Mark The use of high-powered LED lights has dramatically changed my life. I have no difficulty using low-intensity LED computer screens and cell phones, but I cannot neurologically tolerate LED car headlights because they capture and steal my attention. LED Daytime Running Lights make me feel high levels of anxiety, to the point of fear. When the ambient lighting is darker, LED headlights are unbearable and painful. If I drive at night, I am forced to close one eye or hold my hand over my eyes. One time I was caught behind a firetruck that turned on LED flashing lights. It was	April 4, 2019 Narrative Mark is a 54 year old Male BIB PD from middle school after welfare check due to erratic bx. PT is a 7th grade math teacher and the dept chair of the math dept. PT was hitting self in head and fled school on foot. PT told PD he wanted to die. PT reports he is having problems with the LED lights and the unshielded 5000 Kelvin temp for 2 years. Reports he is getting progressively worse, and the 2 floodlights recently installed at the school torture him mentally. He wanted the lights turned off and when only some could be turned off, he became upset and cried to the principal's office who took him to the park with

torture for me. Because we were stuck behind the truck with nowhere to go, I jumped out of the car and ran over to the crew in the firetruck and began screaming at them to stop torturing me. When the laughed at me, I fell to the ground screaming and rolling around. I never had these problems with incandescent or halogen or fluorescent or CFL or sodium lighting.	the RN where he rolled on the ground until PD arrived. Kaiser Permanente
Migraines	
<u>Janine</u> A translator / interpreter by profession, now requiring total digital assistance, this woman experiences severe migraine with unilateral numbness to the face, nausea and faintness upon exposure to LED illumination and screens. She has had several episodes of syncope secondary to exposure to larger quantities of unexpected LED illumination. She had been informed by a neurologist in her early twenties to avoid flickering light including strobe and fluorescent, and the like as it could pose a risk of seizure. She is excluded from al public buildings and recurrently exposed to LED lighting due to residing in a densely populated city of close urban infill.	
<u>John</u> I've been thinking about all the dysfunction in lighting and have concluded that there are two types of people when it comes to lighting - those who are sensitive and those who are not. I have to look away from LED lights when I walk past. This is a nightmare policy scenario because it means that when limits are set based on sensitive groups, the others are going to be complaining. This binary issue needs to be addressed somehow.	

As for me, I will be on the floor in seconds exposed to indoor florescent or LED light without sunglasses, and even with sunglasses and a ball cap, the eye migraine starts to trigger and will take hold if I am exposed more than say half an hour at Home Depot or Costco. Brighter stores like Walmart or Walgreens even less time to get out. I will only get nausea as a result of acute exposure, which will be a function of brightness, color temperature and degree of shielding. Think of shielding as sunglasses and ball cap. In other words, I am out of the store or on the floor in ripping eye pain before getting nausea. When I was a child, I would get the nausea and vomit, but in those days did not realize I had a light problem and was not wearing any shielding and filters. In terms of color temperature, without shielding I would say the number would be very low, maybe even less than 2000K, because LED is a flat source which creates a laser-beam type of light. With proper shielding, 2700K may work, but my city didn't consider sensitive receptors, so the only shielding the Cobra street lights have here is on top for dark skies.	
<u>Elaine</u> - Testimony to Irish Parliament, Joint Committee on Disability Matters, February 3, 2022 “I thank the committee very much for this opportunity. I also hope that this can help, in many ways, the others who are suffering around the world from light emitting diode, LED, sensitivity and artificial light sensitivity. I have been made ill from LEDs since 2007. It is more than a sensitivity; it is a disability. I am disabled by my environment, like so many others,	

and excluded from society. This is also an accessibility issue." Full text here[2]	
Electromagnetic Hypersensitivity Syndrome	
<u>Dave</u> - I have been diagnosed with Electromagnetic Hypersensitivity Syndrome ICD-9 code 995.3 also called electromagnetic radiation sickness, caused, or aggravated by exposure to LED lighting and other fluorescent lighting. Other codes that apply, 368.13 visual discomfort, 780.4 dizziness/vertigo, 438.7 disturbance of vision.	
Lupus	
<u>Kristen</u> – From the time the car dealership installed LED parking lot lights across the street from me, I have had horrible sleep. On the first night after installing the LEDs, I had a bloody nose, which I haven't had since I was little. I have since installed black out curtains, but I still cannot sleep properly. I just feel more defeated every day and thinking of all the natural life in my yard that won't survive because of the LED lights.	
Additional Cases	
<u>New Zealand Case 1</u> A man approximately 30 years old experiencing difficulty carrying out his profession, requiring frequent use of his mobile phone in the real estate business. He describes eye discomfort, augmenting to a sensation of 'crawling' into the eyes and associated frontal headache, not	

[2] https://www.oireachtas.ie/en/debates/debate/joint_committee_on_disability_matters/2022-02-03/2/

diminished despite dimming or decreased blue spectrum on the phone.	
<u>New Zealand Case 2</u> A man approximately 50 years old, builder by trade, experiencing eye pain, strain, and irritation upon viewing LED screen television. Also associated with delayed sleep latency, lighter nature of sleep and fatigue on rising. The eye pain and irritation could persist for several days.	

General Healthy Population

The statements that the Soft Lights Foundation has collected proves that LED light has adverse impacts on people in the "general healthy population" ranging from loss of comfort to pain, eye injury, and emotional trauma. When we understand the impacts of visible electromagnetic radiation (a.k.a. "light") on biological systems, including humans, it becomes clear that the introduction of LED light should be expected to have significant impacts on people in all categories. Below are quotes and personal stories from people who we believe to be in the "general healthy population."

Case 1 - "*Then a couple of cyclists approach along the riverside path and the profound peace is shattered by intense jolts of shuddering [LED] light that come searing through the space between us. I flinch as they pass, shielding my eyes with my hand. They're chatting to each other, oblivious, a cheery couple enjoying a beautiful evening cycle. I feel like they've punched me in the stomach and screamed in my face.*"[3]

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[3] https://lightaware.org/2022/09/what-has-happened-to-light/

Case 2 - *I think for every one of us [LED lights are] taking a tremendous amount of emotional and physical energy to try to implement and maintain coping strategies so we can engage in even the most basic daily activities. The extra work it is taking to try and get our bodies and brains to listen when we know these lights are dangerous and know we cannot avoid them is more than superhuman (if and when we can just for a moment/second) We should not have to be superhuman just to live on this planet.*

Case 3 – *"Prior to the NHTSA and the DOT allowing LED headlights to be legal, I never have had any light sensitivity. If I was outdoors and forgot my sunglasses it was no big deal. Halogen headlights never bothered my eyes, not even on high beam (though annoying). This all changed when LED headlights started appearing in this area in early 2019. Every exposure would hurt my eyes and make them go blurry or "white out" and cause ocular pain. This was a cumulative effect with every exposure causing my eyes to take longer to recover, from at first seconds, to minutes, to hours, then days. To protect half of my vision, I started closing my left eye when meeting LED headlights, leaving the right eye open. This continued until October 31, 2019, when I met a semi-truck with LED headlights so blinding that after meeting it, my right eye (the one I kept open) never recovered. None of the ophthalmologists I have gone to have been able to come up with a diagnosis with the equipment they have, though they recognize there is damage."*[4]

Case 4 - *Up the road there's a new business in town where 100s of ppl are walking down the street..you used to be able to see and avoid the ppl until they put up megabright LEDs and*

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[4] http://www.softlights.org/wp-content/uploads/2021/05/Damage-to-Eye-Story.pdf

now you cannot see a thing- you cannot see where to drive- you cannot see the ppl-How's that for energy efficient? Efficient at killing ppl would have to be the only outcome-and I guess that'll sustain the planet for..

Case 5 - *"Then the parking lots, street lights, outdoor lighting at customers and in the railroad yard, the number board lights, gauge lights.. EVERYTHING went to LEDs and my migraine headaches became constant.. I was taking multiple doses of Excedrin, Tylenol, Anacin and other medications to try to combat the headaches, rage, nausea and other symptoms that the LEDs were causing.. until I finally had to quit."*

Case 6 – *"I can't be out after dark.. more than 20 minutes of all the LED streetlights, security lights, stoplights, billboards… that flicker result in a massive headache. So when I travel I go with my mom. I drive during the day and she drives after dark. This past fall we went down to Joplin MO to visit family and after the sun went down I put on dark sunglasses while we are in the county with less lights. as we get to the town/city areas with more lights on, I switch to a sleep mask to block all light, as i haven't found any other way to block the flicker. There was one corner as we turned I heard my mom (who was driving) gasp as I SAW light through my sleep mask! and she said that it was a billboard. that is outrageous!"*

Case 7 – *"I was just mentioning that to someone I know today. I knew people who had fluorescent and strobe lighting headaches and seizures. The LEDs are so much worse than anything I've seen before."*

Case 8 – *"I get headaches all the time now from delivery driving, now the job that I've done for 20 years has turned into a mess"*

Case 9 – "*Thank goodness i don't get migraines but tonight every oncoming car blinded me and it was horrible."*

Here are some statistics of classes of people in the world whose health may be harmed by LED light.

50,000,000 people with epilepsy.[5]

75,000,000 people with autism.[6]

620,000,000 people with blue eyes.[7]

709,000,000 elderlies.[8]

1,000,000,000 people with migraines.[9]

2,200,000,000 children.[10]

Physics

Flat Surface vs. Curved Emitters

In nature, all emitters of light, such as the sun, a candle, and a tungsten filament light bulb emit light essentially uniformly in all directions in 3D space. The formulas and measurement techniques and previous understanding of light assumes spatial uniformity.

LEDs, on the other hand, emit light from a flat surface, which causes the light to be focused in a very tight beam of non-uniform energy. Since the light from an LED has a different energy at every point in space, simple formulas can no longer be used. Each photon will now

[5] https://www.who.int/news-room/fact-sheets/detail/epilepsy
[6] https://www.tpathways.org/faqs/how-many-people-have-autism/
[7] https://www.aucklandeye.co.nz/about/blog/7-interesting-facts-about-blue-eyes
[8] https://www.un.org/en/development/desa/population/publications/pdf/ageing/WorldPopulationAgeing2019-Highlights.pdf
[9] https://migraine.com/migraine-statistics
[10] https://www.humanium.org/en/children-world/

have a different impact on the recipient because each photon will have a different energy, and because of this, the spectral and temporal characteristics of LED light must be considered separately for each point in space.

Figure 1 shows the spatial differences between a curved source and a flat source. Notice in the 2D cross-section that the light from a curved surface creates a uniform pattern, while the flat surface creates a non-uniform pattern.

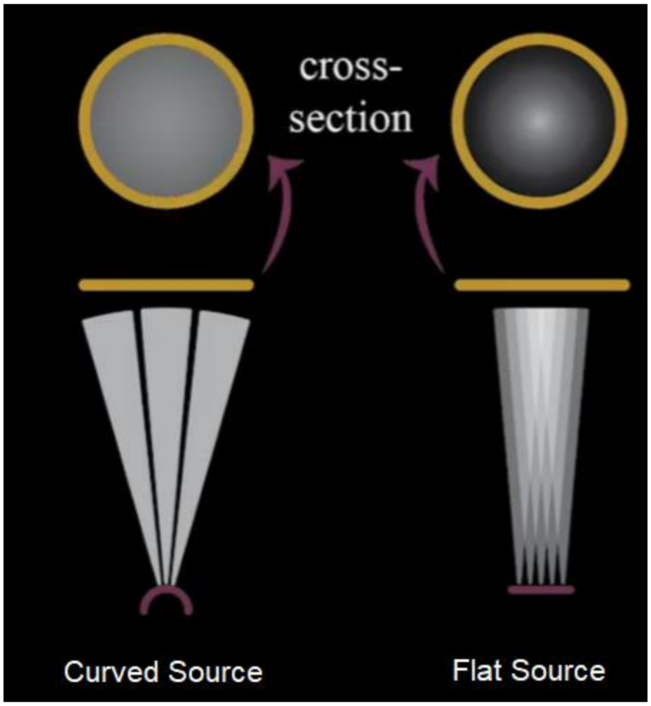

Figure 1 - Curved vs. Flat Source[11]

The SCHEER did not recognize the drastic differences in characteristic between flat surface emitters and curved surface emitters in their 2018 LED report. Because of this, the

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[11] https://youtu.be/fkb1zeoXIug?list=PL5A3ppJRK9Eo49g5fWbG_9pUcY50NsmUG

SCHEER report on LEDs must be updated to reflect the effects of flat surface spatially non-uniform light on humans and the ecosystem.

Radiance vs. Irradiance

The correct metric for measuring intensity of a light from a flat surface emitter is the peak radiance, which is the density of the electromagnetic radiation emitted at the middle of the chip. Throughout their report, the SCHEER incorrectly uses irradiance as the metric for LED power. Yet, in Section 6.8.3.1, the report states, "*Spectral measurements were performed showing that the radiance between 400 nm and 480 nm of the LED screen was higher (0.241 W/(sr.m2))"*. This reference to radiance occurs because the LED display industry correctly measures LED intensity in radiance (Watts / steradian-m^2) and luminance (candela / m^2 also known as nits). The LED lighting industry and SCHEER incorrectly use illuminance and irradiance when measuring intensity for LED devices.

In Section 6.10, the SCHEER report states, "*Since the assessment was carried out in terms of source radiance, the assessment conclusion was made independent of viewing distance."* Here we see another instance where SCHEER reports on the correct metric of radiance, which again is because the LED display industry uses the correct metric of radiance. SCHEER correctly notes that radiance is independent of distance. The SCHEER must update the LED report using only the correct metrics of peak radiance and peak luminance, and not the incorrect metrics of illuminance and irradiance.

Spectral Power Distribution

Figure 3 shows the Spectral Power Distribution for an incandescent lamp. Note that the graph shows continuously increasing power from low violet and low blue up through high power in red and infrared. This is the graph of a spherical emitter with uniform energy

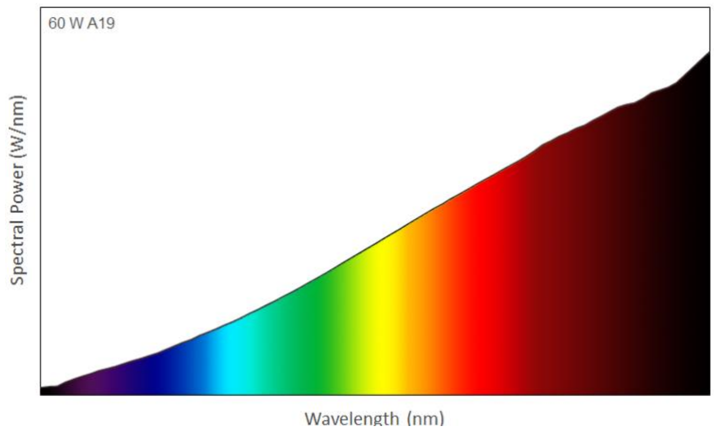

Figure 2 - Incandescent Spectral Power Distribution[12]

Figure 3 shows the Spectral Power Distribution for a 4000 Kelvin and 6500 Kelvin LED ceiling panel. The spectral distribution from LEDs is vastly different than the SPD of incandescent. The spectral quality of an LED is significantly lower than the spectral quality of incandescent.

[12] https://www.energy.gov/sites/prod/files/2016/11/f34/royer_spectral-power-dist_denver2016.pdf

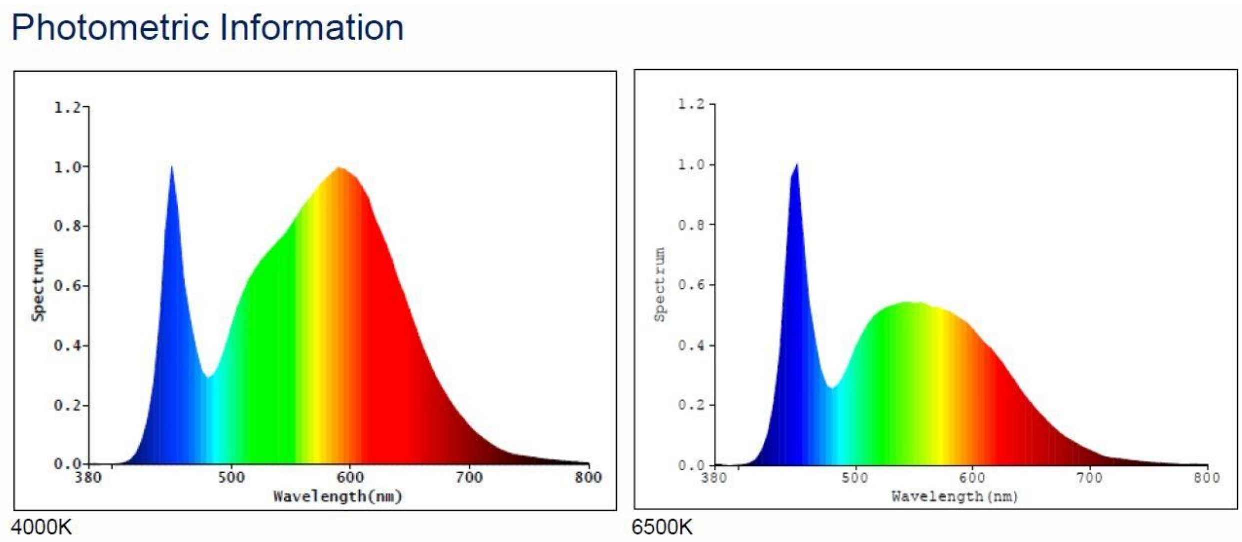

Figure 3 - LED Spectral Power Distribution[13]

These graphs show only relative power, and not absolute power. It is necessary to review and evaluate the adverse effects of this peak of blue wavelength light using the radiance metric. In addition, the piecewise spectral distribution also has an adverse effect on human health. The spike of blue, the lack of cyan, and the lack of red and infrared have neurological impacts that must be assessed. Numerous research studies show definitely that blue wavelength light is a dangerous toxin that must be avoided.

It is critical to note that since flat surface light is spatially non-uniform, a single SPD graph for an LED light source is not valid. Since each point in space has a different energy, the absolute power will be different at each point in space. This fact greatly complicates the ability to convey the impacts of LED light to the reader.

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[13] https://www.novelenergylighting.com/kosnic-led-recess-ceiling-panel-60w-80w-switchable-1200x600-kled6080pnl-w65-6500k.html

Square Wave Flicker

Dr. Softky's video: https://youtu.be/9IOSwlQxDxE

The article 1789-2015 - IEEE Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers shows the difference between the analog sine wave flicker from an incandescent, and the digital square wave flicker of an LED.[14] As noted by IEEE, "*Presently, there are no standards on safe modulating frequencies for high-brightness LEDs*." This lack of safety standards for LEDs makes LEDs very dangerous because chip makers and lamp manufacturers have no restrictions on the flicker emitted by the LED.

Figure 4 shows the flicker characteristics of an incandescent. The sine wave is continuous and smooth and the light output changes by 6.6% as the alternating current cycles.

[14] https://ieeexplore.ieee.org/document/7118618

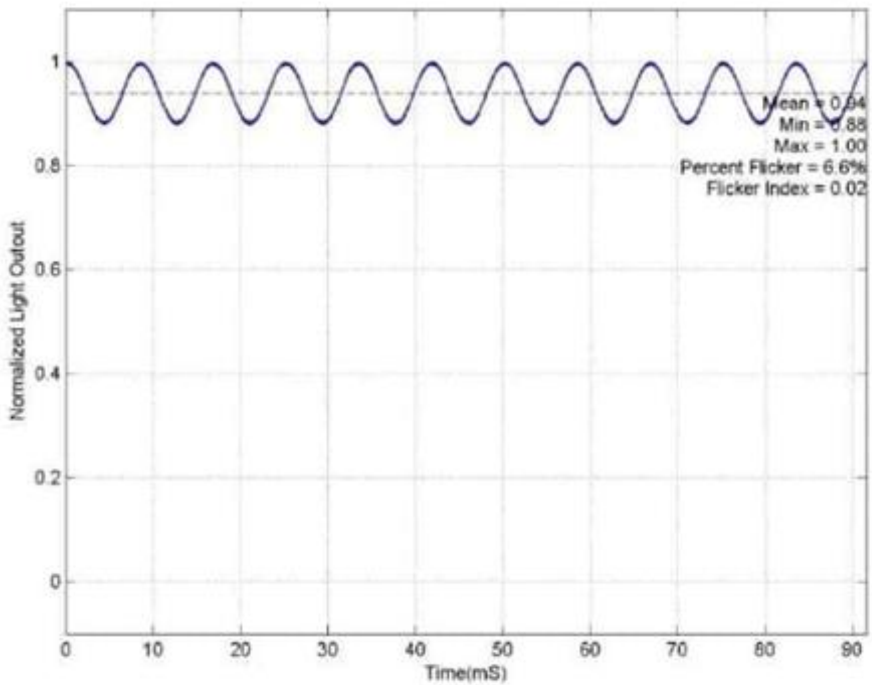

Figure 4 - Incandescent Flicker – 6.6%

On the other hand, Figure 5 shows the essentially discontinuous function of the square wave flicker of an LED. The light output drops from 100% to 0% and then back to 100% as the alternating current cycles. The discontinuous function and the extreme change between states produces flicker that is incompatible with the human nervous system.

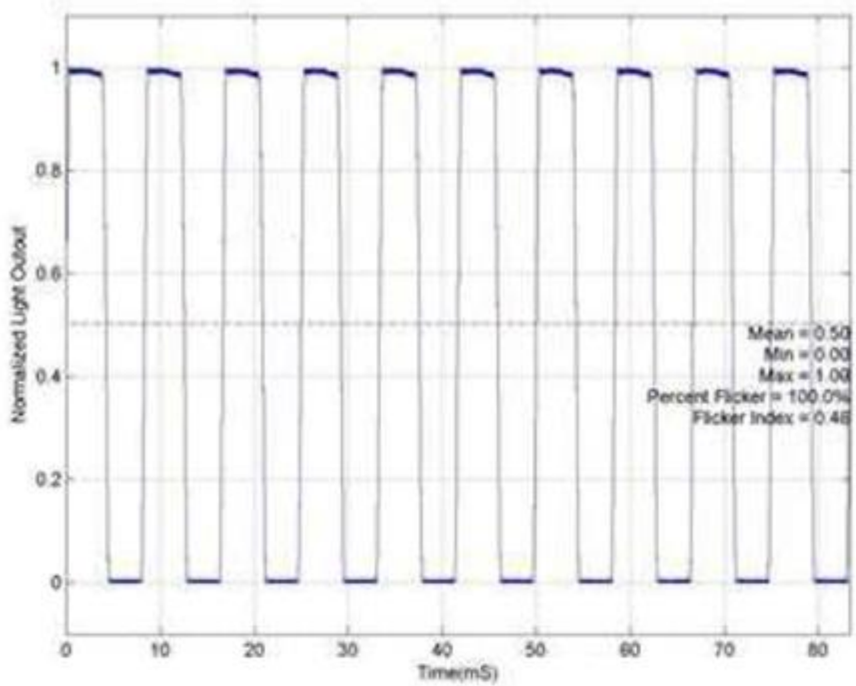

Figure 5 - Solid State Flicker - 100%

The square wave flicker is neurologically dangerous for many people and this makes LED light a low-quality light. For some people, this flicker is not consciously noticeable, but for others the flicker is consciously noticeable. However, even if the square wave flicker is not consciously noticeable, it is still having a negative effect on human health and is to be avoided.

Blue Light Hazard

An April, 2019 study states, "*This review concludes that blue light poses **maximum risk** to cause retinal degeneration based on the evaluated studies*."[15] This study uses the incorrect

[15] https://www.sciencedirect.com/science/article/pii/S1013905218306187

metric of irradiance; however, the conclusion that blue light poses maximum risk is still valid. If blue wavelength light poses maximum risk, then the questions become why do government regulators allow high levels of blue wavelength light in LED streetlights, LED vehicle headlights, and LED lamps for home use and why are there not strict comfort, health, and safety restrictions for devices that emit blue wavelength light?

The LED lighting industry sells LED lights with excessive blue wavelength light because it is the cheapest to manufacture and produces the highest luminous efficacy. Because of the lack government regulations, the LED lighting industry has been free to sell products that emit the most dangerous blue light, and which poses the maximum risk of retinal degeneration. Without government action to eliminate those LED devices that have already been installed or sold, these products will continue to cause eye damage possibly for decades to come.

Blue wavelength light causes cumulative and permanent eye damage.

Glare

Glare is the unwanted light that enters the eye. Light from the sun reflects from objects, providing visual information that allows us to identify these objects and make sense of the world. Light aimed directly into the eye does not provide the desired outcome and only causes a reduction in vision. There is no situation where glare is beneficial for the person being subjected to the glare, and thus all efforts must be made to reduce this unwanted light called glare.

Because of their small size and high luminance, LEDs emit the opposite of quality lighting. LEDs produce much higher amounts of glare as compared to spherical/point source emitters such as incandescent and sodium. LED vehicle lights produce more dangerous glare than tungsten or tungsten/halogen. LED streetlights are typically not diffused, and thus the barediode light enters the eye directly, greatly increasing painful glare. LED strip lights such as on the edges of vending machines create undesirable and harmful glare.

The first LED lighting company to admit that the industry has failed to accurately account for glare from flat surface LED lights sources is Cree Lighting International. In their report published in December, 2021, Cree explains that all current glare formulas cannot be used for LED light sources and that the application of existing glare formulas to LEDs is wrong.[16] Cree states, "*Without a speedy agreement on metrics for measuring LED intensity, spectrum, photometry, and LED spacing, we will be installing millions of LED luminaires for street lighting purposes that are not suitable for use, could even be described as dangerous, and that will be costly to replace.*" In other words, all LED streetlights that have already been installed could be described as dangerous and that the wrong metrics were used for their installation. Cree implies that all of these LED streetlights will likely need to be replaced due to the dangers of blue light hazard, excessive glare, and peak luminance/radiance that exceeds human tolerances.

Aesthetics and Quality

Light is fundamentally important to our psychological mood. Poor quality LED light has a direct impact on mood. The SCHEER failed to address the psychological toll of LED light that is described as "harsh", "blinding", "nasty" and many other adjectives. The goal of artificial lighting is not to punish people or to subject humans to the power of the technology. The goal of artificial lighting is to improve the human experience, and yet LED light does the opposite.

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[16] https://online.flippingbook.com/view/702884488/

LED Products

LEDs have theoretically unlimited luminance. Figure 6 shows LED peak luminance ranging from 100,000 nits (candela per square meter) to 100,000,00 nits as of 2018. This extreme brightness and power are in conflict with maximum human comfort level of 300 nits and maximum human tolerance of 50,000 nits.

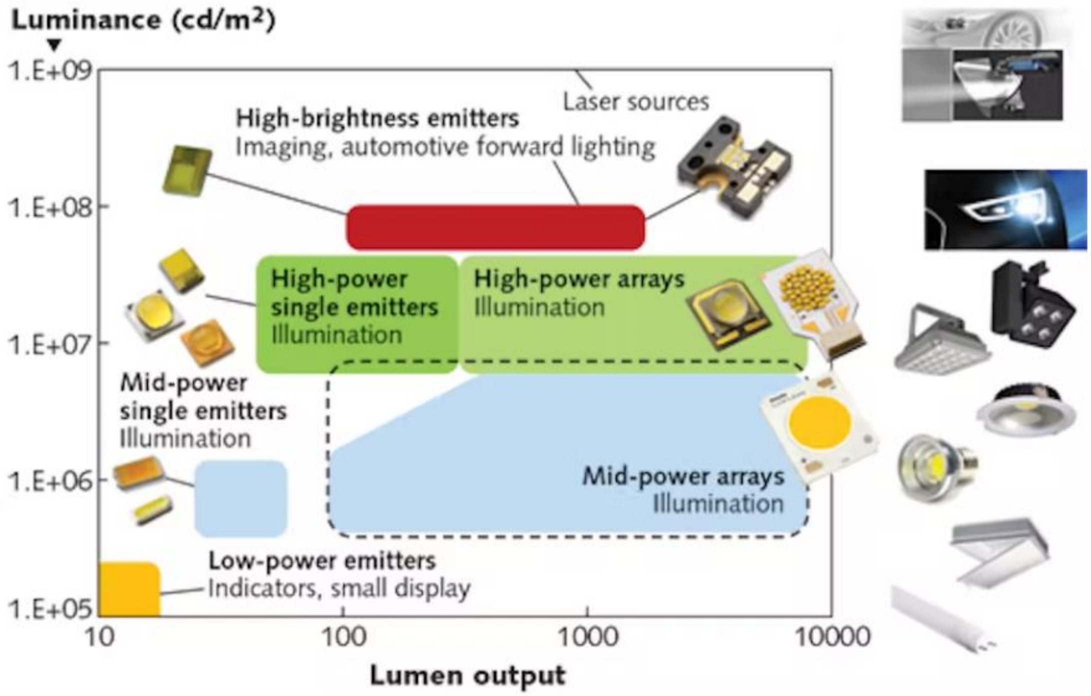

Figure 6 - LED Luminance[17]

Vehicle Headlights

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[17] https://www.laserfocusworld.com/test-measurement/research/article/16555223/nonlaser-light-sources-highluminance-leds-target-emerging-automotive-lighting-applications

Figure 7 shows the blinding glare and blue wavelength light emitted by LED vehicle headlights. The switch to LEDs has greatly increased discomfort and disability glare to the detriment of public safety.

Figure 7 - LED Headlight Glare

Figure 8 shows a photo taken by the Insurance Institute for Highway Safety showing five vehicles with LED headlights. Notice that this photo is taken at dusk, and yet the headlight glare is already difficult to see through, nearly covering the entire front of the vehicle with a curtain of glare. As of this writing, the IIHS has not acknowledged that LED headlights emit non-uniform luminance. The IIHS uses the wrong meausuring devices and metrics for LED light, leading to invalid conclusions about the safety of LED headlights.

Figure 8 - IIHS Headlights

Figure 9 shows the LED Daytime Running Lights on an electric Rivian R1T. The lack of regulations for flat surface LED light sources and the failure of government regulators to enforce existing regulations has led to this situation where LED vehicle lights are a major distraction and source of physical pain.

Figure 9 - Rivian R1T

Compare the excessive glare and excessive blue wavelength light from the LED headlights in the previous images to the soft, uniform glow and low blue of spherical/point source tungsten headlights shown in Figure 10.

Figure 10 - Tungsten Headlights

The Soft Lights Foundation manages an online petition to ban blinding LED headlights through Change.org. (https://www.change.org/p/u-s-dot-ban-blinding-headlights-and-save-lives) It is important to note that this petition was started by a private citizen unassociated with the Soft Lights Foundation for the first several years of the petition's existence. As of this writing, the petition has over 30,000 signatures and comments which describe the dangers and suffering caused by LED headlights.

Figure 11 is a meme from the Internet. These types of social media postings must be acknowledged as evidentiary data that is just as significant as the data from controlled laboratory experiments.

Figure 11 - LED Internet Meme

In the USA, the federal National Highway Traffic Safety Administration is tasked with regulating vehicle headlights. The Federal Motor Vehicle Safety Standard Section 108 regulates vehicle headlights, taillights, daytime running lights, and brake lights. FMVSS-108 was written for spherical/point source emitters such as tungsten and tungsten/halogen and does not contain the necessary metrics for regulating surface source LED vehicle lights. Thus, the reason that there are over 30,000 signatures on the petition and Internet memes about blinding LED headlights is that the restrictions for spatial non-uniformity, peak luminance/radiance, spectral power distribution, and square wave flicker have not been published by NHTSA.

Researcher Peter Veto, Ph.D. has made several videos that explain why LED headlights create excessive glare.

1 – Why Are LED Headlights so Glaring? Part 1: Luminance

https://youtu.be/fkb1zeoXIug?list=PL5A3ppJRK9Eo49g5fWbG_9pUcY50NsmUG

2 – Why Are LED Headlights so Glaring? Part 2: Color (Spectral Power Distribution)

https://youtu.be/YINHa_zwFQs?list=PL5A3ppJRK9Eo49g5fWbG_9pUcY50NsmUG

3 – Demo: LED vs. Halogen Apparent Luminance Distribution

https://youtu.be/9TZG49xoClo?list=PL5A3ppJRK9Eo49g5fWbG_9pUcY50NsmUG

LED headlights, daytime running lights, brake lights, taillights and turn signals are dangerous and do not comply with existing government safety regulations which were designed for spherical/point source emitters.

Streetlights

Figure 12 shows a comparison of the light from LED streetlights on the left and High-Pressure Sodium on the right.

Figure 12 - Streetlight Comparison

The LED streetlights on the left show a white ball of glare in the middle plus the blue and violet wavelengths around the edges. The streetlights create a zebra pattern of light and dark on the pavement. The unwanted and dangerous glare is excessive. Trees and bushes along the road are being harmed by the artificial light. There are no vehicles or pedestrians on the road, and yet the lights are using energy and damaging the natural night resource.

The HPS lights on the emit a safer amber color and spatially uniform light that is safer for the eyes, creates less glare, and is less damaging to the natural night resource.

A study published in Science Advances on September 14, 2022, uses photographs from the International Space Station to prove that the switch to LED streetlights has increased light pollution and is wrecking human health and the entire ecosystem.[18] LED streetlights are not energy efficient as claimed by the industry. The reason that LED streets can be operated at a reduced financial cost is because of the switch to toxic blue wavelength light. The switch to LED street lights was not a switch from one technology to a different technology of the same quality, but rather a downgrade in quality which has now been proven to be causing serious harm to human and ecosystem health.

Figure 13 shows a purple LED streetlight. This occurs when the chemical phosphor rubs off or wears out. LED streetlights are not "white", but rather violet or blue, and the LED industry uses a magic trick to create the illusion of white light. In fact, this so-called white light is simply undesirable glare with no true color. The main wavelength is blue or violet which has been shown to be very toxic and unacceptable for use in the night time environment.

[18] https://www.science.org/doi/10.1126/sciadv.abl6891

Figure 13 - Purple LED Streetlight

Figure 14 compares the illumination pattern from a sodium streetlight on the left and an LED streetlight on the right. Notice that the LED streetlight produces non-uniform coverage which impairs vision and is psychologically disturbing. At the time of this writing, no government agencies or lighting organizations have published photometric standards for spatially non-uniform LED street lights. Cree Lighting International has described LED streetlights as "dangerous."

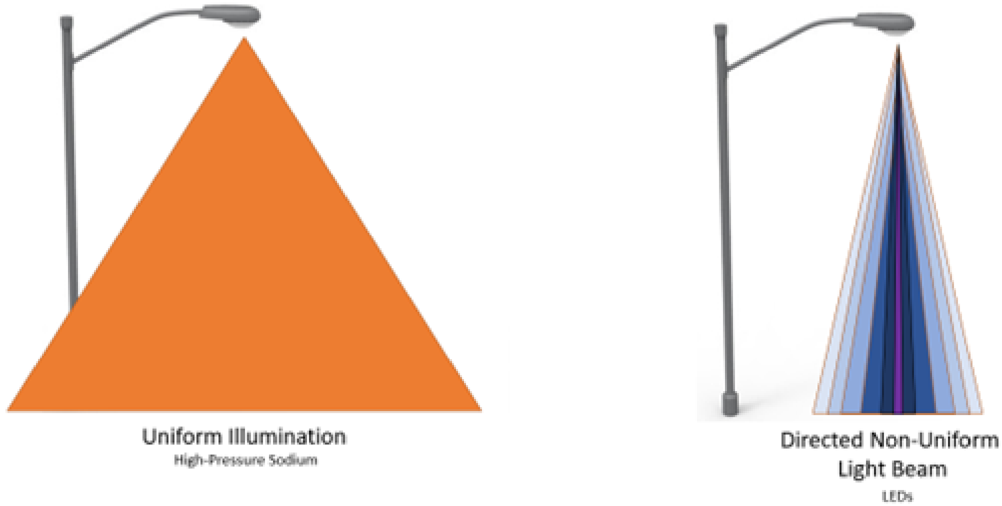

Figure 14 - Streetlight Beam Comparison

Flood Lights

Figure 15 shows the disabling glare from LED floodlights at a business. The light is directed directly into the eyes of the public, increasing the risk of harm to the eye, increasing anxiety, and decreasing visibility.

Figure 15 - LED Flood Lights

Figure 16 shows two LED wall pack floodlights. The excessive glare creates a harsh, unwelcoming, and unsafe environment with sharp edges and shadows.

Figure 16 - LED Wall Pack Flood Lights

Multiple studies have shown that this type of lighting does not improve safety and does not reduce crime. In fact, this type of lighting is likely increasing property crimes and anti-social behavior. Figure 17 shows heavy use of LED floodlights which likely contributed to a homicide via a combination of the increased amount of light and increased agitation triggered by the flood lights. The use of the LED flood lights certainly did not make the neighborhood safer, as is often claimed by officials.

Figure 17 - Floodlights and Crime

Figure 18 shows an LED floodlight that is advertised as “30% brighter” with a luminous flux of 6000 lumens and a 5000 Kelvin color temperature. This is a dangerous light. There are no regulations to protect the public from this intense light. Since LED light can travel great distances with little dissipation, this LED light can adversely affect people up to several miles away. A product this powerful and dangerous must be regulated.

Figure 18 - LED Floodlight

Compare the previous images with the shielded and diffused amber wall light in Figure 19 which allows a person to safely navigate the environment without enduring the harsh and dangerous glare of high-glare LED floodlights aimed directed into the eyes.

Figure 19 - Amber Wall Light

Indoor Lamps

Figure 20 is a marketing image, showing the different in Color Temperature. We know that blue wavelength light is dangerous, and yet the marketing image encourages the use of 3000K LED lights in the bedroom. The use of the term “daylight” for the 5000K LED light is false advertising, as the spectral power and spatial distributions of natural daylight are nothing like the characteristics of the LED product. A 5000K LED light can trigger powerful negative emotions.

Figure 20 - LED Indoor Lamps

Strip Lights

LED strip lights are dangerous, shining high intensity, undiffused blue-rich light with no limits on peak radiance directly into the eyes of the public, including children, putting the eyes at risk of injury. Examples are shown in Figure 21.

Figure 21 - LED Strip Lights

Lights on Towers

The use of LED lights on towers, bridges, and other tall structures has damaged the natural night resource and has adverse effects at great distances. LED flashing lights on towers are a violation of basic civil rights because they interfere with cognitive functioning and pulse dangers visible electromagnetic radiation into the eyes of the public without their permission.

Figure 22 - LED Lights on Towers

Figure 23 shows a product called an inflatable tower light. There are little or no regulations to protect the eyes or nervous system or the natural night resource from this type of LED light.

Figure 23 - Inflatable Tower Light

Flashing Lights on Vehicles

LED flashing/strobing lights are so powerful and intense that they will cause seizures, migraines, panic attacks, and likely eye injury. The rapid digital on/off strobing, the unregulated peak radiance, and the large quantity of emitters puts dangerous glare directly into the eyes of the viewer, reducing their ability to see, think and concentrate.

Figure 24 - Police LED Flashing Lights

Handheld Flashlights

The operator's manual for the Ryobi P705 Flashlight includes the following: "WARNING: Do not direct the light beam at persons or animals and do not stare into the beam yourself (not even from a distance) Staring into the light beam may result in serious injury or vision loss." The parenthetical "(not even from a distance)" indicates a high level of danger.

> ⚠ **WARNING:**
> Do not direct the light beam at persons or animals and do not stare into the light beam yourself (not even from a distance). Staring into the light beam may result in serious injury or vision loss.

Bicycle Lights

An LED bicycle light can trigger feelings of agitation, anger, rage, and fear because of the drastic contrast between the dark and the light, because we are not psychologically prepared to be receiving this much intense blue wavelength light at night, and because the glare hides the bicycle rider, leaving us to guess whether the rider is a threat or not.

Figure 25 - LED Bicycle Headlight

Summary

Figure 26 shows the dystopian world we now live in due to the ubiquity of LED lights. Humans are not evolutionarily equipped to tolerate this artificial non-uniform luminance light that shines directly into our eyes. Strict regulation of LED visible electromagnetic radiation is needed to match human biology and to ensure psychological well-being.

Figure 26 - LED Lights Everywhere

Ecology

The Australia National Light Pollution Guidelines provide us with a fundamental guiding principle: "*Start with natural darkness and only add light for specific purposes*."[19] The introduction of LED lighting has obliterated that concept, and instead of adding light only as absolutely necessary, we have powerful and toxic LED light everywhere. The Environmental risks from artificial nighttime lighting widespread and increasing across Europe study states that LED lighting has increased light pollution and is having severe impacts on the ecosystem.[20]

The photo in Figure 27 was taken at Observatory Park in Northeast Ohio, USA and shows a perfect example of what responsible outdoor lighting can look like.[21]

Figure 27 - Responsible Outdoor Lighting

[19] https://www.environment.gov.au/biodiversity/publications/national-light-pollution-guidelines-wildlife
[20] https://www.science.org/doi/10.1126/sciadv.abl6891
[21] https://archive.wksu.org/news/story/31524

Below is a list of some of the research studies showing the impacts of light pollution and LED light on the natural night resource and the ecosystem.

September 14, 2022 – Environmental risks from artificial nighttime lighting widespread and increasing across Europe – LEDs have increased light pollution and have increased the emissions of toxic blue wavelength light.

September 9, 2022 – The Dark Side of LEDs: Suppression of Melatonin by Blue Light – An article about the studies of researcher

May 20, 2022 – Light pollution can disorient monarch butterflies – Even a single light can interfere with a butterfly's navigation system.

March 29, 2022 – Broad spectrum artificial light at night increases the conspicuousness of camouflaged prey – LED light leads to predator advantage.

April 27, 2022 – Oriented Migratory Flight at Night: Consequences of nighttime light pollution for monarch butterflies – ALAN interferes with monarch butterfly migration.

2022 – Artificial Light at Night: State of the Science 2022 – IDA report. Discusses how LED light is increasing light pollution. Falsely claims that LEDs are energy efficient.

August, 2021 – Street lighting has detrimental impacts on local insect populations – This study shows that LEDs are killing insects even faster than High Pressure Sodium.

August, 2021 – First Estimation of Global Trends in Nocturnal Power Emissions Reveals Acceleration of Light Pollution – Light pollution continues to grow and LED blue wavelength light is making it worse.

April, 2021 – Narrow Spectrum Artificial Light Silences Fireflies – Artificial light, especially bright amber, suppresses courtship. "we should focus on minimizing the time that lights are on and how bright they are." – News Story

March, 2021 – Light Pollution Drives Increased Risk of West Nile Virus – Even low levels of artificial light at night increase the risk of transmission of the virus.

March, 2021 – Superoxide is Promoted by Sucrose and Affects Amplitude of Circadian Rhythms in the Evening – Both light and sugars affect the biological clock of plants. – News Story

March 10, 2020 – Artificial Lighting Impacts to Salmon in WRIA 8 Briefing Memo – Artificial light is impacting the survival of juvenile salmon.

January, 2020 – Australian Light Pollution Guidelines for Wildlife This detailed document describes best lighting practices.

2020 – “use lamps with the lowest CCT, melanopic response, or M/P value possible to achieve the goals of the lighting project.” – Illuminating Engineering Society – On the Use of Summary Metrics of Light Spectral Characteristics to Assess Effects of Artificial Light at Night on Wildlife

2020 – “ALAN reduces habitat suitability” – El Sevier – Effects of artificial light at night on the foraging behavior of an endangered nocturnal mammal

July 30, 2018 – Waters under Artificial Lights: Does Light Pollution Matter for Aquatic Primary Producers? – ALAN and LED light negatively impacts periphyton.

July 30, 2018 – Waters under Artificial Lights: Does Light Pollution Matter for Aquatic Primary Producers? – ALAN negatively impacts periphyton.

2018 – “Anthropogenic lighting drastically alters nocturnal environments, threatening a wide range of species” – Colorado State University – Anthropogenic light disrupts natural light cycles in critical conservation areas

2018 – “we advocate warm color temperature white light as nighttime illumination” – Health and Human Services USA – Light at night disrupts nocturnal rest and elevates glucocorticoids at cool color temperatures

2018 – “bombarded with numerous novel stimuli in their environment that could lead to grave consequences.” – Journal of Ecology – Connecting spectral radiometry of anthropogenic light sources to the visual ecology of organisms

2018 – “if the tendency to light more when light is cheaper can be overcome” – Luger Research – Hazard or Hope? LEDs and Wildlife

2017 – “When the installation was illuminated, birds aggregated in high densities, decreased flight speeds, followed circular flight paths, and vocalized frequently” – Proceedings of the National Academy of Sciences – High-intensity urban light installation dramatically alters nocturnal bird migration

2013 – “alters detection of day and night” – Exeter University – Measuring biological light pollution and uncovering its ecological effects

2013 – “the significant impact that even low levels of nighttime light pollution can have” – Cambridge University – The ecological impacts of nighttime light pollution: a mechanistic appraisal

November, 2017 – Artificially lit surface of Earth at night increasing in radiance and extent – This study uses satellite data to show that light pollution has increased due to the use of LED lights.

2017 – “Managers should avoid lights that have ultraviolet or blue light (shorter wavelengths)” – National Park Service – Artificial Night Lighting and Protected Lands

April, 2015 – Artificial Light at Night and the Predator-Prey Dynamics of Juvenile Atlantic Salmon – Even tiny amounts of artificial light affect salmon.

2015 – “The most immediate threat from anthropogenic noise and light is the loss of species” – Trends in Ecology & Evolution – A framework to assess evolutionary responses to anthropogenic light and sound

May 29, 2014 – Potential Biological and Ecological Effects of Flickering Artificial Light – Explains how the visual system of different creatures have a rate at which they capture images. Electric light interferes with this system, causing perceived flicker.

2014 – “exacerbate existing domestic, e.g., midge swarms and industrial infestations of sanitary and phytosanitary pests” – Ecological Society of America – LED lighting increases the ecological impact of light pollution irrespective of color temperature

2012 – “Technological innovations and changes in lighting strategies should consider benefits for reductions in greenhouse gases and energy consumption in parallel with their potential ecological impacts” – Global Change Biology – Conserving energy at a cost to biodiversity? Impacts of LED lighting on bats

2009 – “Light pollution can have significant conservation consequences for a threatened bat species” – Current Biology – Street Lighting Disturbs Commuting Bats

Energy Efficiency

Below are five definitions of energy efficiency. Each definition is slightly different, but all five are similar.

United States Department of Energy – “Simply put, energy efficiency means using less energy to get the same job done.”

- West Virginia Department of Environmental Protection – "Energy efficiency means using less energy to accomplish the same task"
- Environmental and Energy Study Institute – USA – "Energy efficiency simply means using less energy to perform the same task."
- United Kingdom Department of Energy and Climate Change – "*On a technical level, energy efficiency is the relationship between the energy consumed and the output produced by that energy, often called 'energy services', for example the number of miles travelled for a gallon of fuel. Increasing energy efficiency means using either less energy to provide the same level of energy services, or using same level of energy to provide a higher level of energy services.*"
- Law Insider – Energy Efficiency means a decrease in customer consumption of electricity or natural gas achieved through measures or programs that target customer behavior, equipment, devices, or materials without reducing the quality of energy services.

A simple definition of **energy efficiency is providing the same quality of service using less energy.** This means that when LED light is compared against incandescent light, the light quality must be equivalent in order to state whether LED is more energy efficient than incandescent. Since LED light is spatially non-uniform, has a piecewise spectral power distribution shape, often with excessive blue wavelength light, and has square wave flicker, the light quality of LED is much lower than the light quality of incandescent. Therefore, the claim that LEDs are more energy efficient than incandescent cannot be made because the two sources are not providing the same quality of service. LED light is simply a low-quality light, not an energy-efficient light.

Action: **Juror Status Change**
Action Date/Time: **06/28/2021 11:11 AM**
User: [redacted]
Status: **Excused**
Status Date:
Response Method: **Manual**
Source Page:
Comments: [redacted] **can not be in the vicinity of any LED lights. Contact with LED lights cause her to have seizures. Since I can not guarantee she will be able to avoid LED lights, I am excusing her from any jury duty in the future.**
Prev Elig Date: **6/5/2021**
Prev Perm Inelig Flag: **true**

Dockets and Legal Cases

As could be expected when dangerous products are sold without proper regulation, legal action follows. Below are some of the known dockets and legal cases involving LED products.

US Food and Drug Administration

The US Congress directed the FDA to regulate electromagnetic radiation, including visible light, from electronic products in 1968, but the FDA never published the regulations for LEDs. The Soft Lights Foundation has submitted a citizen petition to the FDA to regulate LED products. Docket FDA-2022-P-1151[22]

US Department of Energy

The DOE claims that incandescent light and LED light have the same characteristics and that there are no known health effects from LED light. This claim has been proven false in this document. The Soft Lights Foundation has submitted a request to the DOE to renounce their false claims.[23] As of this writing, the DOE has not responded.

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[22] https://www.regulations.gov/docket/FDA-2022-P-1151
[23] http://www.softlights.org/wp-content/uploads/2022/07/DOE-Final-Rule-Appeal.pdf

US Federal Highway Administration

The FHWA published an interim approval of a device called a Rectangular Rapid Flashing Beacon which shines high intensity strobing light into the eyes of drivers at a pedestrian crossing. The RRFBs have been documented to trigger epileptic seizures, migraines, panic attacks and likely eye injury. A discrimination case with the FHWA, Case Number 2022-0375, has been initiated.

US National Highway Traffic Safety Administration

NHTSA is responsible for the safety of motor vehicles in the USA. The Federal Motor Vehicle Safety Act Section 108 regulates vehicle lighting. FMVSS-108 is only applicable to spherical/point source emitters and does not contain the necessary language to regulate surface source LED light. Thus, all vehicles using LED headlights do not comply with federal safety standards. The Soft Lights Foundation has submitted citizen petitions to NHTSA to issue orders of non-compliance to the auto makers. As of this writing, NHTSA has not responded.

New York State Public Service Commission

A discrimination case has been filed with the NYSPSC due to LED street lights triggering epileptic seizures. Case 21-02623[24]

California Energy Commission

California Public Utilities Commission

Minnesota Department of Human Rights

Irish Parliament

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[24] https://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=21-02623&CaseSearch=Search

Regulatory Agencies and Standards Bodies

Europe

European Commission

United Nations

SCHEER

ICNIRP

USA

Congress

FDA

NHTSA

DOE

IES

AASHTO

UL

PUCs

Australia

ARPANSA

Review of 2018 LED Report

In this section, we provide comments and feedback on each paragraph of the 2018 SCHEER LED report. There are numerous instances in the 2018 report where the SCHEER noted that they were unsure of the negative impacts of LED light or stated that the impacts needed further study. This document is being written in 2022, which means that four years of additional time has passed for which to receive and analyze data. This latest data confirms that LED light is highly toxic, dangerous, and discriminatory.

1.SUMMARY

The eye and skin are the most susceptible target organs for effects due to optical radiation, and action spectra also exist for effects on skin and eye (ICNIRP, 2013). – The non-uniform luminance of LED light also impacts the nerves and the brain.

The type of effect, injury thresholds and damage mechanisms vary significantly with wavelength. – The adverse effects of LED light also vary with spatial non-uniformity, piecewise spectral power distribution, square wave flicker, and flash patterns.

There are several variables to be taken into account when referring to effects of optical radiation from LEDs on human health: spectrum of an LED light source; intensity of the lighting, especially in the blue/violet part of the spectrum; duration of exposure; exposure level of the eye or skin; health of the eye or skin; direct staring without deviation versus active eye movement. – Additional variables that must be taken into account are spatial non-uniformity, peak radiance/luminance, square wave flicker, square wave flash rates and patterns, sensitivity of the individual, medical conditions such as epilepsy, autism, PTSD, and migraines, multiple devices operating simultaneously, angle of the source, and contrast with ambient lighting conditions.

In order to assess the potential health risks associated with LEDs, it is necessary to take into account all exposure parameters - the irradiance (the flux of optical radiation that reaches a target, distance dependent), the radiance (radiation flux leaving the source depending on emission angle, independent of distance to target), LED spectrum, and the exposure duration. – We agree that the radiance must be taken into account, but there is not just one radiance measurement. There is a peak radiance measured at the chip in near field, and there is a different radiance at all points in space that creates a spatial energy profile that must be evaluated against human health. In addition, the square wave flicker, measured to at least 10,000 Hz must be accounted for. Flashing LEDs pose yet another, even more significant hazard. As well, the effects of multiple simultaneous LED sources from different angles and different distances and intensities must be evaluated to simulate real world conditions.

For many people, exposure to natural optical radiation will predominate, i.e. exposure to optical radiation from LEDs is likely to be insignificant compared with the

exposure to natural light outdoors. – Flat surface light is an entirely different class of light, separate from any natural or spherical/point source artificial light. It cannot be stated that LED optical radiation is insignificant, especially considering that the documented evidence shows that LED light causes severe adverse neurological reactions and eye injury.

Potential health effects of LEDs in the general population

Published studies show that the blue light-weighted (for eyes) radiance from screens (for example computer/tablet/mobile phone/TV) is less than 10% of the ICNIRP blue light photochemical retinal exposure limit, assuming viewing greater than about 3 hours (acute exposure). See Annex IV on dosimetry. – ICNIRP data is unreliable since it does not consider the spatial non-uniformity of LED light. ICNIRP is also industry biased. Numerous research studies have shown that blue wavelength light is very toxic, even in tiny amounts.

The search of the literature for the long-term impact of LED emissions on human health did not identify any studies since the technology has been recently distributed on the market for the general population. Because the technology is still evolving, it is important to continue monitoring the scientific literature. – The SCHEER LED report was published in 2018. It is now 4 years later, 2022, and the epidemiological data definitively shows that LED emissions are extremely harmful to human health. As the SCHEER report notes, "it is important to continue monitoring." Four years after publication of that statement, the results show conclusively that LED visible electromagnetic radiation is unsafe and there is no known safe level for this radiation.

The SCHEER concludes that the available scientific research does not provide evidence for health risks to the eye or skin associated with LEDs when the total exposure is below the international agreed exposure limits (ICNIRP). –ICNIRP exposure limits are scientifically invalid because they do not account for the spatial non-uniformity of LED light. The SCHEER is missing an analysis of the evidence that shows that the spatially non-uniform energy of LED light causes adverse neurological reactions.

It is expected that the risk of adverse effects will increase if these limits are exceeded. However, there is insufficient information in the scientific literature on the dose-response relationship for adverse health effects for optical radiation exposure of the healthy general public. – This report does not define who "healthy general public" is. It is necessary for the SCHEER to identify who constitutes the healthy general public and why it is necessary or valuable to isolate the public into categories such as "children", "healthy general public", "the elderly", and "those with light sensitivities". Most people will travel through each of these categories over time, which means that the majority of people will be outside of the "healthy general public" category at some stage in their lives.

The “insufficient information” has now been replaced by “substantial information” via epidemiological data and research that confirms that unregulated LED light sources can cause adverse reactions in the healthy general public, as well as in other categories of the population.

In addition, no evidence was found for increased risk of skin photosensitivity from LED lamps when compared with other lighting technologies. Indeed, the absence of ultraviolet radiation from general LED lamps may reduce the risk of skin photosensitivity for a number of these conditions. - Nothing is stated here about the lack of red and infrared light from LEDs which is known to be beneficial. The measurement techniques used to arrive at this conclusion are invalid, since the chip-level peak radiance and angle were not accounted for in the experiments.

Although not completely understood, experiments have shown that, overall, circadian rhythms are mostly affected by short-wavelength light (peak around 480 nm). It has been shown that normal use of LEDs or screens illuminated by LEDs during the evening can perturb the circadian system, as do other types of artificial lights. Light sources with a higher component of short-wavelength light, such as some LEDs, have increased impact on the circadian system, perhaps influencing sleep quality. At the moment, it is not yet clear if this disturbance of the circadian system leads to adverse health effects. Although there is some evidence that use of screens technology into the evening may impact sleep quality, it is not clear whether this is due to the optical radiation or the activity being carried out. – The use of the word “normal use of LEDs” is not defined which then leads to unusable conclusions. The use of the phrases “although not completely understood” and “perhaps influencing” and “it is not yet clear” can now be replaced with definitive language such as, “Short-wavelength light has severe impacts on circadian rhythms, even in tiny amounts.” LED streetlights, for example, have been shown via research to increase the risk of premature births, autism, prostate and breast cancer, and mood disorders.

In addition, some LEDs raise concerns in terms of temporal light modulation (flicker). Observers of some point-like LED sources may experience dazzle, distraction and glare. This was also reported to be a concern with some LED street lights. – The phrase “point-like” is undefined and a source of confusion within the industry. LEDs do not emit uniform energy, and therefore cannot be treated as mathematical point sources. In this paragraph, if SCHEER uses “point-like” to mean highly focused, with the light beam having a high peak radiance, then we agree that these high-peak-radiance LEDs increase dazzle, distraction, and glare. In addition, the square wave flicker is a serious health threat. It has been documented that many people can see the subsensory flicker and that many people can feel the effects of the flicker, even if not consciously visible. The use of the phrases “some LEDs” and some LED street lights” does not convey useful information. The LED characteristics that are causing discomfort, pain and trauma must be quantified.

Temporal light modulation from some LED lamps can cause stroboscopic effects. There are claims by a small number of people of adverse health effects such as migraines or headaches. There appear to be no technical reasons why LED lamps need to produce a time-modulated emission, since many models do not. – The words "small number of people" can now be replaced with "many people". The statement that there are no technical reasons why LEDs produce flicker is unjustified. LEDs produce square wave flicker because LEDs are digital devices and yet the current driving them is analog. The conversion process from A/C to D/C creates both flicker and radio frequency radiation, none of which is regulated. Manufacturers will create the cheapest possible drivers to maximize profit since no government agency is protecting the public from this square wave flicker.

Potential health effects of particular LED sources (toys, car lights)

The European standard EN 62115 for electronic toys limits the emission of optical radiation from toys. This is because some LED emission spectra may induce photochemical retinopathy, which is a concern, especially for young children. LEDs are used in virtual reality headsets where the screen is very close to eyes. However, the luminance of the source is very low and the exposure limits are not likely to be exceeded. The reported disorientation and nausea after extended use of these headsets is likely to be due to effects such as motion sickness rather than the optical radiation emitted by the screen. – This paragraph fails to mention the spatial non-uniformity of LEDs and the impacts that this non-uniformity has on the nervous system. Standard EN 62115 likely does not specify the maximum allowed peak radiance for LED products.

The SCHEER is concerned about the high-luminance exterior sources used on some vehicles. Current examples appear to be blue-rich, which increases glare and scattering, particularly for older observers. The internal car lighting with LEDs that has replaced standard incandescent bulbs has emission levels that will result in exposures significantly below internationally agreed exposure limits. However, some exhibit pulsed emission modes that can result in phantom arrays when the head or eye is moved quickly. Such effects can be distracting. Distraction, dazzle and glare effects do not result in direct harm to the eye, but there could be consequences if the person exposed is carrying out a safety-critical task, such as driving. – This underwhelming paragraph language can now be replaced with definitive, strong language. Over 30,000 people have signed a petition demanding that LED headlights be banned due to dangerous glare. There are no comfort, health, or safety regulations for peak radiance, spectral power distribution, or square wave pulsing. In the USA, LED headlights do not comply with federal regulations and no vehicle manufacturer has applied for or received approval to use a flat surface light source as a headlight. Since LEDs do not emit uniform luminance and do not provide uniform illumination, and since LED headlights are in the 5000K to 6500K color temperature range, the glare and impacts on the nerves is extremely dangerous. A main component in a glare formula is luminance and since LEDs are a small size, the luminance has greatly increased, thus increasing dangerous glare while providing no improved performance for visual acuity. LEDs are not fit for the purpose of headlights. LED dashboards push visible electromagnetic energy into the drivers and passengers, causing the body system to suffer. Many people cannot neurologically tolerate LED dashboards which creates a discrimination problem.

Susceptible groups

People who suffer from photosensitive conditions have been considered. As the eye ages scattering may increase. This is a particular problem for blue light. Therefore, older people may experience discomfort problems with exposure to LED systems with a high blue content, not clearly seeing the blue LED displays (such as destination displays on the front of buses). – This paragraph does not mention people with autism, epilepsy, PTSD, migraines, lupus, and hundreds of other groups who are susceptible to LED light. This paragraph does not discuss the neurological impacts of spatially non-uniform visible electromagnetic energy on those who are susceptible. The statement, “older people may experience discomfort” means that older people’s lives have been made worse by the introduction of LEDs, since before they may have had a comfortable life, but now with LEDs everywhere, their lives have become uncomfortable. This paragraph leads to the conclusion that nearly all members of society will eventually suffer eye discomfort problems as they age into the category of “older people”.

People with degenerative and vascular disease of the retina may be more susceptible to harm from LEDs than the general population, but the risk is considered similar to that from other lighting sources with similar emission characteristics. – It is impossible to consider that harm from a spherical/point source would be similar to that of a surface source emitter. The two types of light are entirely different. The impacts of LED light on those with degenerative and vascular diseases must be considered separately from the impacts of natural light.

Additional aspects to consider

The worst-case viewing condition is generally on axis viewing of an LED source, for example staring at a screen or an LED lamp. If a source is safe for viewing on axis it will be safe under all other viewing conditions at the same distance. Flashing LED sources in the peripheral vision are more likely to cause distraction than those on axis. – We agree that the on-axis viewing angle will be the most intense and most dangerous. What is missing from this statement is how there are no comfort, health, or safety regulations for this peak luminance and no discussions of how the spatial non-uniformity impacts the nervous system. Flashing LEDs exacerbate the problem of spatial non-uniformity and have been documented to cause seizures, migraines, panic attacks, and emotional trauma.

LED lamps used for area illumination are usually more energy efficient than many other sources. For the same colour temperature, the blue light component of the optical

emission can be similar to that of an incandescent lamp. However, the infrared (and possible ultraviolet emission) may be greatly reduced or absent (in comparison with other types of lamps), which might influence (positively or negatively) the normal human physiology. This aspect needs further research. – LEDs are not more energy efficient than other sources because LEDs emit non-uniform luminance, piecewise spectral power distribution with high blue content, and square wave flicker, all of which are toxic for humans. An energy efficiency comparison can only be made when the two light sources emit the same quality of light. Since LEDs and incandescent emit entirely different classes of light, an energy efficiency comparison cannot be made. The lack of red and infrared light could be a significant health risk, while the increase in blue wavelength light is a known health risk. The blue component of an LED device is not similar to the blue component from an incandescent lamp.

2. MANDATE FROM THE EU COMMISSION SERVICES

2.1 Background

The LEDs are energy efficient and last much longer than the conventional light sources, which make them widely used by the general population. Hence it is important to know the implications of LED radiation on the human health. – LEDs are not energy efficient because the definition of energy efficiency is providing the same quality of service using less energy. A surface light source such as LED does not provide the same quality of service as a curved surface light source such as incandescent.

Recently, researchers have analysed potential risks of white LEDs [1], issuing recommendations to avoid the hazards. Another group of researcher has speculated about the effects of LED radiation on retinal epithelium cells (RPE) [2], - The analysis of LED risks has been performed incorrectly, thus producing invalid results by failing to address spatial non-uniformity. The word "speculation" about effects of LED radiation on retinal epithelium cells can now be replaced with "has confirmed". The risk of LED light has been firmly established.

Directive 2006/25/EC of the European Parliament and of the Council of 5 April 2006 on the minimum health and safety requirements regarding the exposure of workers to risks arising from physical agents (artificial optical radiation) (19th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC), JO L 114 of 27.04.2006 Regarding the protection of the occupational population, the ELVs of Directive 2006/25/EC2, which set the minimum safety requirements regarding the exposure of Potential risks to human health of workers to risks arising from artificial optical radiation, are based on the ICNIRP recommendations applicable at the time of publication. – ICNIRP has failed to acknowledge that LEDs emit spatially non-uniform visible electromagnetic radiation which then disqualifies ICNIRP's exposure limits from consideration.

EN 62471 on the "Photobiological safety of lamps and lamp systems" sets a risk group structure and methods to assess the photo-biological risks of lamps including LEDs. The specific safety requirements regarding photobiological hazards are contained within

the LED modules and luminaire safety standards (EN 62031 and EN 60598-series) and in other lamp safety standards: EN 62560 and EN 62776. – EN 62471 fails to account for the spatial non-uniform luminance of LEDs and thus invalidates the conclusions.

2.2 Terms of Reference (ToR)

1. What are the potential health hazards associated with LEDs emission in the general population with regard to wavelength, intensity, duration and viewing position? – The SCHEER must define "general population" and justify separating out the "general population" from the rest of the population. People who are the most sensitive to LED emissions is the category of people who must be used to drive all comfort, health, and safety regulations for LED light.

2. If possible, identify dose response relationship associated with LEDs emission in the general population with regard to wavelength, intensity, duration and viewing position? The phrase "if possible" does not explain whether this describes a situation where the data is not yet available, or whether there are technical difficulties with drawing conclusions from measurements.

3. What are the potential health risks associated with LED displays (e.g., TV sets, laptops, phones, toys and car lighting) in the general population and in vulnerable and susceptible populations (e.g., children and elderly people)? - The criteria for a person being in the "general population" is undefined. In addition to children and the elderly, there are people with autism, PTSD, lupus, migraines, and epilepsy who are affected by LED light.

4. What are the potential health risks associated with LED lamps (e.g., toys and car lighting) in the general population and in vulnerable and susceptible populations (e.g., children and elderly people)? – The criteria for a person being in the "general population" is undefined. In addition to children and the elderly, there are people with autism, PTSD, lupus, migraines, and epilepsy who are affected by LED light.

3. OPINION

LEDs are optical radiation emitters. Optical radiation does not penetrate deeply into the body; the eye and skin are the organs that are most susceptible to damage. – The definition of "deeply" is not provided. According to one study, laser light from 630nm to 1000nm can penetrate 50mm.[25] Higher energy light, such as at 450nm, would likely penetrate further. LED light is a directed beam of highly focused energy. The SCHEER must quantify the

[25] https://pubmed.ncbi.nlm.nih.gov/18077939/

peak radiance and wavelength and provide the depths of penetration as a chart. Pulsing light can likely penetrate deeper and cause more damage.

The risks following exposure to optical radiation hazards are a complex function of wavelength and exposure conditions. International organisations, such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP), have produced weighting functions for different hazards associated with optical radiation. ICNIRP guidelines for optical radiation in general do not differentiate between exposure to workers and exposure to the general public. ICNIRP has no radiation hazard guidelines for flat surface visible electromagnetic radiation sources and thus ICNIRP's existing guidelines cannot be used for LEDs.

Most current white-light LED lighting devices (blue LED and yellow phosphor) emit blue light combined with green/yellow light without significant red or any near infrared wavelengths. Whether or not the absence of ultraviolet or near infrared wavelengths has any health implications is now under investigation. – The effects of the absence of ultraviolet and near infrared must now be reported.

Published studies show that the blue light-weighted (for eyes) radiance from screens is less than 10% of the blue light photochemical retinal hazard limit, assuming viewing greater than about 3 hours (acute exposure). See Annex IV on dosimetry. For a comparison, 14% of that limit corresponds to a mid-range incandescent lamp. The ICNIRP guidelines are based on observed eye or skin injury after experimental exposure of primates and rodents, and on information from human accidents. Reduction factors are used in setting the exposure limits for humans when animal studies are used. – It has now been shown via hundreds of studies that blue wavelength light is a significant toxin and that exposure to blue wavelength light at night is a significant health hazard, even in tiny amounts.[26] This research confirms that LED streetlights and LED headlights with blue wavelength light are a comfort, health, and safety hazard.

It has been shown that normal use of LEDs or screens illuminated by LEDs during the evening can perturb the circadian system influencing sleep quality because of the high component of the short-wavelength light. However, the full action spectrum for the influence of light on the circadian system requires further research as other wavelengths have an influence as well. At the moment, it is not clear if this evening disturbance of the circadian system leads to long-term adverse health effects. – We now can state unequivocally that short-wavelength light exposure can lead to significant increases in prostate and breast cancer, premature births, mood disorders, and autism. The use of blue wavelength light in public spaces is an unacceptable health hazard.

Intensity

[26] http://www.softlights.org/human-health/

Radiant intensity (W/sr) is a parameter characterising the emission of the source, while luminous intensity (lm/sr) is important in terms of visual perception including distraction, glare and after-images. The optical radiation incident on a target tissue is expressed in terms of irradiance (W/m^2) or illuminance (lm/m^2 or lux). For photochemical processes, the effect is a function of not only the irradiance (or radiance) but also of the exposure duration. The product of these two factors gives the dose (the radiant exposure (J/m^2) or radiance dose (J/m^2sr)). The irradiance (or radiance) used in this calculation of effects is weighted by the appropriate action spectrum. – Only radiance can be used as the basis for research on the effects of flat surface LED light. This radiance must be measured at the chip in near field. The radiance from a flat surface source is essentially unchanged over distance, even at distances greater than 1 mile.

Most people receive exposure to optical radiation from a range of sources including different LEDs in any given 24-hour period. In order to assess the potential health hazards associated with LEDs, it is necessary to take into account all of these exposures. For many people, exposure to natural optical radiation will predominate, i.e. exposure to optical radiation from LEDs is likely to be insignificant compared with the exposure to natural light outdoors. The SCHEER concludes that the available scientific research does not provide evidence for health hazards associated with LEDs when the total exposure is below the ICNIRP exposure limits. However, reversible biological effects in terms of flicker, dazzle, distraction and glare may occur. –Flat surface light is entirely different than curved surface light and it cannot be stated that natural light is the dominate exposure because the two light classifications are entirely different. Exposure to short-wavelength light is not reversible. The research proves that the damage caused by blue light exposure is irreversible. LEDs pose significant and serious health hazards.

Animal experiments and in vitro studies suggest that cumulative blue light exposure below the levels causing acute effects can also induce photochemical retinal damage. The search of the literature for long-term impact of LED emission on human health did not identify studies investigating the healthy general population. However, technology is still evolving and it is important to continue to monitor the literature. – Studies have now clearly shown that retinal damage occurs due to LED exposure, thus requiring the removal of LED sources, especially LED streetlights, LED floodlights and LED vehicle headlights. Long term eye damage is highly likely. The long-lasting harmful psychological effects of LED light has been well documented.

Due to the point-source nature of some LED lighting, studies have shown that these emitters can cause discomfort and glare. – Mathematically, LEDs are not a point-source. LEDs emit a directed beam of non-uniform energy that far exceed comfort, health and safety limits for humans. Discomfort and glare only begin to hint at the harm caused by LED light. As of 2018, LED chip makers had reached 100,000,000 nits of peak luminance, far beyond the maximum human tolerance of 50,000 nits, and greatly exceeding human comfort level of 300 nits. Due to the ubiquity of LEDs and their tiny size, the entire population is frequently experiencing discomfort and glare. The use of LEDs has reduced the quality of life for most people.

Duration

The time spent in school, work and/or leisure activities with the use of LED screens should not exceed the recommended exposure limits of ICNIRP. In addition, the cumulative effect of light on the skin and eyes should be considered. – ICNIRP's exposure limits are invalid for LEDs and the cumulative damage is significant. LED vehicle headlights expose the public the short-wavelength light without their consent, dooming all members of the public to high levels of dangerous glare and likely macular degeneration as they age.

Viewing position

The worst-case viewing condition is generally on axis viewing of an LED source, for example staring at a screen or an LED lamp. If a source is safe for viewing on axis it will be safe in all other viewing conditions at the same distance. However, flashing LED sources in the peripheral vision are more likely to cause distraction than those on axis. – This statement does not account for motion, where a person may be directly in front of the source at one point in time, and slightly off-axis at another moment in time. The change on position will dramatically affect the location of the energy landing on the viewer, which in turn will cause significant interference with the nervous system. Flashing LED sources are dangerous and trigger seizures, migraines, and panic attacks. The intensity of LED flashing sources feels like assault and torture to many people.

Q2.If possible, identify dose response relationship associated with LEDs emission in the general population with regard to wavelength, intensity, duration and viewing position.

If the exposure is below ICNIRP exposure limits, the SCHEER is not aware of any risk of damage to the eye and skin. The risk of damage to the eye or skin will increase if ICNIRP exposure limits are exceeded. Although a general threshold has been identified for optical radiation based on experimental data, the profile of the dose-response relationship is not well known. – It has been well documented that LED light can damage the eye and skin. The ICNIRP exposure limits are not valid for flat surface light. Medical reports prove that LED light is dangerous.

Since LED emission characteristics like exposure patterns and spectra (wavelength-dependent intensity) vary from one emitter to another, it is not possible to predict the profile of the dose-response function for a general LED emitter. –Computer modeling is extremely sophisticated and there is no doubt that computer algorithms, when provided valid information, can model the effects of LED light. In addition, even if computer modeling were not used, the effects of a single LED emitter can be quantified. LED products should not be allowed into the public space without understanding their toxicity which has been shown to be significant.

Q3.What are the potential health risks associated with LED displays (e.g., TV sets ,laptops, phones, toys and car lighting) in the general population and in vulnerable and susceptible populations (e.g., children and elderly people)?

Evaluating the retinal blue light hazard effectively requires taking account of the irradiance of the retinal image of the source viewed. For momentary viewing, the retinal image subtends the same angle as does the source. With increasing exposure time, the retinal image is spread over an increasingly large area of the retina due to eye movement (saccades) and task-determined movement, resulting in a corresponding reduction in retinal radiant exposure at any given point on the retina. A time-dependent function of the angular subtense of the retinal image for exposures from 0.25 sec (aversion response time) to 10,000 sec is defined, ranging from 1.7 mrad (taken as the smallest image formed on the retina) to 100 mrad. – Irradiance is not a valid measurement unit for flat surface sources. The only correct measurement LEDs is radiance, which must be measured at chip-level in near field. There is no reduction in exposure the peak radiance as the eye moves, only a change of location on the eye where the most damage is occurring. Because LED light is so intense, a person will feel significant pain during the 0.25 seconds before the aversion response occurs. Due to the billions of emitters already in the environment, people are now frequently experiencing pain from LED light throughout their daily routines.

Light from screens has been shown to influence the circadian system. There is some evidence that use of screen technology into the evening may impact sleep quality. However, it is not clear whether this is due to the optical radiation or the activity being carried out. – It is now clear from numerous research studies that blue light is a hazard.

There is a European standard for electronic toys that limits the emission of optical radiation from toys. However, children have a higher sensitivity to blue light and although emissions may not be harmful, blue LEDs may be very dazzling for young children. Some LED emission spectra may induce photochemical retinopathy, which is especially a concern for children below about three years of age. The standard does not take into account a product that is not a toy, which may be given to a child to use (for example smartphones or tablets). – An example is LED strip lights in a vending machine that is set at the level of a child. Children will stare at the bright LED lights, not knowing that their eyes are being damaged. Comfort and safety standards must be set for products such as LED strip lights that set limits on peak luminance/radiance.

Internal car lighting with LEDs has replaced standard incandescent bulbs in new vehicles. Emission levels are significantly below ICNIRP exposure limits for blue light to eyes. Since many such LED sources are operated in pulsed emission modes this can result in phantom arrays when the head or eye is moved quickly. Such effects can be distracting. – The act of pushing spatially non-uniform visible electromagnetic radiation into the eyes of drivers and passengers is mentally exhausting and certainly less desirable than passive controls and backlit displays. LED displays are distracting and, at night, create an extreme contrast differential between the outside night and the cockpit. The use of LED displays must be limited by regulation.

As the eye ages, scattering may increase. This is a particular problem for blue light. Therefore, older people may experience discomfort with exposure to LED systems, including blue LED displays (for example destination displays on the front of buses will be blurred). – This statement asserts that each person who ages into the category of an older person will then find the quality of their life reduced. It is the responsibility of government to ensure that a person in the category of "older person" does not have a reduced quality of life.

People with degenerative and vascular disease of the retina may be more susceptible to harm from LEDs than the general population, but the risk is considered similar to that from other lighting sources with similar spectral characteristics and under similar human exposure conditions. – The risks of harm from flat surface sources such as LED is far greater than the risks from spherical/point sources such as incandescent.

LEDs are used in virtual reality headsets where the screen is very close to eyes. However, the luminance of the source is very low and the exposure limits are not likely to be exceeded. Manufacturers give guidance on maximum duration of use for such headsets. Some people report disorientation and nausea after extended use of these headsets. This is likely to be due to the motion sickness rather than the optical radiation emitted by the screen. – We note here that the SCHEER correctly uses the metric "luminance" to describe the intensity of LED light. SCHEER must recognize that the physics is the same, whether the product is an LED virtual reality headset or LED vehicle headlight or LED streetlight. Luminance or radiance must be used in all situations involving LEDs, not just displays. The phrase "very low" must be quantified and the phrase "likely" must be justified with factual evidence.

Q4.What are the potential health risks associated with LED lamps (e.g., toys and car lighting) in the general population and invulnerable and susceptible populations (e.g., children and elderly people)?

LED lamps used for area illumination are usually more energy efficient than other sources and therefore consumers have been encouraged to use them instead of, for example, incandescent lamps. Most domestic applications are likely to use retrofit lamps. For the same colour temperature, the blue light component of the optical emission is similar to an incandescent lamp. However, the infrared (and possible ultraviolet emission) may be greatly reduced or absent (in comparison with other types of lamps), which might influence (positively or negatively) the normal human physiology. – LEDs are not energy efficient. The LED industry encouraged consumers to adopt LEDs through false claims of energy efficiency, when in fact LED light is simply a lower-quality, highly toxic light. LED light does not have a similar spectral distribution for the same color temperature as incandescent.

It is good practice in lighting design to ensure that lamps for illumination are either positioned outside of the usual field of view or are of such low luminance that the source does not produce significant glare. Some sources available on the market incorporate "point" LED sources without diffusers, which can cause glare if viewed. This was also reported to be a concern with some LED street lights. – There are now millions of emitters that have been installed in public spaces that are directly in the field of view or have a high luminance that produces significant glare. Government must regulate LED lamps to ensure that none cause comfort, health, or safety issues. Voluntary measures are not effective.

Temporal light modulation (TLM) has been measured at 100 Hz from some LED lamps. It is not possible for consumers to identify which LED lamps exhibit TLM and which do not at the point of purchase. Since some LED lamps have TLM of almost 100%, this can result in stroboscopic effects (for example a waved hand appears as a series of stationary images). A small number of people report adverse health effects such as migraine or headaches. Although not a direct adverse health effect, it is foreseeable that any moving machinery (including food mixers) may appear stationary at particular speeds under flickering LED lamps. There appear to be no technical reasons why LED lamps need to produce time-modulate emissions, since many models do not. However, the use of a dimmer switch may introduce temporal modulations in LED lamps that do not flicker on full power. – This paragraph clearly identifies a major problem, and yet LEDs have been allowed to be sold over with little or no government regulation to protect people from dangerous square wave flicker. The adverse impacts on this unquantified "small number of people" must be eliminated through government regulation. LED flicker is consciously noticeable at rates far higher than 100Hz, and the negative effects of flicker as high as 10,000 Hz have been documented. Packaging must be updated to include the square wave flicker characteristics and government regulations must prohibit flicker from light that is placed in a public place.

The SCHEER is concerned about the high luminance sources used on some vehicles, particularly daylight running LED lights that remain on without dimming at night. Current examples appear to be blue-rich, which increases glare and scattering, particularly for older observers. These running lights are a greater glare source in fog than more traditional vehicle lighting. However, the SCHEER is not aware of any risk of direct harm to the eyes from the blue light component of external vehicle LED lighting at normal viewing distances, although if a driver's vision is impaired this could result in accidents. – This is a serious issue and over 30,000 people have signed a petition demanding that LED headlights be banned.[27] The small size and flat surface of LEDs create excessive luminance without increasing visual acuity and thus LEDs are not an appropriate choice for vehicle headlights or daytime running lights because they produce more glare than tungsten or tungsten/halogen. The excessive blue wavelength in LED headlights and DRLs is likely to cause cumulative damaging effects such as irreversible macular degeneration. Government must regulate peak luminance, spectral power distribution, or square wave flicker.

Apart from the concern over TLM, no evidence was found for increased photosensitivity risk from LED lamps when compared with other lighting technologies. Indeed, the absence of ultraviolet radiation from general LED lamps may reduce the risk of photosensitivity for a number of these conditions. –The flicker from LEDs is a major hazard and must not be dismissed. In addition, the documented cases of epileptic seizures,

[27] https://www.change.org/p/u-s-dot-ban-blinding-headlights-and-save-lives

migraines, panic attacks, anxiety, nausea and other negative nervous system reactions to spatially non-uniform LED light must be addressed to ensure the protection of those who cannot neurologically tolerate the non-uniform luminance and other characteristics of LED light. The use of excessively powerful blue wavelength light is causing eye injury and likely long-term eye damage, where this type of damage did not occur with incandescent or sodium lights.

There is a European standard for electronic toys that limits the emission of optical radiation from toys. However, children have a higher sensitivity to blue light and although emissions may not be directly harmful, blue LEDs may be very dazzling for young children. – This paragraph makes clear that LED light is dangerous for young children. Government regulations must be adopted to ensure the comfort, health, and safety, both in acute situations and for a 100-year lifespan.

Additional information

Many LEDs contain toxic substances and in order to assess their potential health impact/effect there is a need for further research on waste management. – LEDs are electronic devices, not light bulbs. LEDs must be regulated in the same way that televisions, radios, and x-ray machines are regulated

4.MINORITY OPINIONS

No minority Opinion. – The SCHEER must recognize that nobody recommended following the precautionary principle and demanded that LEDs must not be allowed into the public space until all safety precautions had been put in place. Policies must be put in place by the SCHEER to ensure that reviews of technology address and heed the Precautionary Principle.

5.DATA AND METHODOLOGY

The general approach by the Scientific Committee to health risk assessment is to evaluate all available evidence from human, animal and mechanistic studies regarding effects to exposure to the agent of concern and then to weigh this evidence together across the relevant areas to generate a combined assessment. – SCHEER must recognize that LEDs emit non-uniform luminance and recognize the impacts of LED light on people with epilepsy, migraines, autism, lupus, and others, recognize the drastic negative impacts of LED light on viruses, wildlife, and the environment.

5.1 Data/Evidence

Evidence

The health risk assessment evaluates the evidence within each of the identified areas and then weighs the evidence together across the areas to generate a combined assessment. This combined assessment addresses the question of whether or not a hazard exists, i.e. if there is a causal relationship between exposure and some adverse health effect. In the present Opinion, the potential risks to human health of LEDs have been assessed by reviewing the literature on epidemiological studies, experimental studies in humans, experimental studies in animals and mechanistic in vitro studies. – The SCHEER must recognize the real-world experiences of people who are adversely impacted by LED light and ensure the comfort, health, and safety of all.

The potential health risks to human health of LEDs have been studied via different approaches as controlled studies, case reports, and experimental studies in animals. Also keeping the benefits from the LED lighting in mind, the risk from the LED optical radiation hazard may be managed by exposure optimisation. This is shown in Figure 2, below. – The SCHEER does not justify Figure 2 from the report. Since LED light is a toxin at all levels, increasing does does not lead towards increased benefit. There is no known safe level of LED light. SCHEER must abandon this graph.

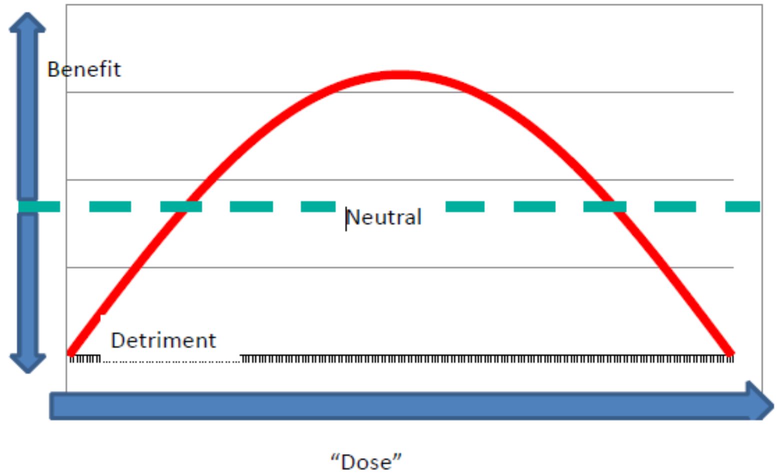

Figure 28 - SCHEER Fig. 2

The shape of the curve in Figure 2 depends on a number of factors, such as the part of the optical spectrum under consideration, time of exposure, prior exposure, possibly age and individual differences (such as photosensitivity, eye pathologies, etc.). For example, too little ultraviolet radiation exposure may result in vitamin D deficiency and associated health effects. High levels of ultraviolet radiation may result in sunburn and an increased risk of skin cancer. Therefore, an exposure between the two is optimum. For light, if the task is reading, there is an optimum illuminance of the page: too little and we cannot see, too much and we are dazzled or in extreme cases risk eye injury. Therefore, reducing the exposure level to as low as achievable may have adverse consequences, some of which will be health related. – Since LEDs do not provide uniform illumination, there is no known good level of LED light. Increasing the does not increase the quality of the light from non-uniform to uniform luminance. Similarly, increasing the does increases the effects of temporal modulation and the effects of high-energy blue wavelength light. The best level of LED light is zero does and continuously increasing towards more and more dangerous as exposure increases.

The risk assessment approach used in this Opinion is based on that promoted by the European Commission for workplaces (EC 1996) and for products used by consumers (EC 2015). This Opinion is primarily concerned with the risk arising following exposure of the

eyes or skin to optical radiation from LEDs. Therefore, this will be considered the hazard. It may be necessary to quantify the hazard using an appropriate metric, but usually quantification is only relevant if the optical radiation exposure geometry and distance substantiate the risk of exposure of people. If exposure is possible then the exposure scenario needs to be considered. For example, if the source of exposure is an indicator LED, or if it forms part of a display screen, then it is very likely that people will view the source. However, for many illumination sources, the LED should be shielded from direct viewing and such direct viewing will be likely only under accidental or improper use conditions. Once an exposure scenario has been identified, the optical radiation exposure conditions, for example of the eye or skin, will need to be quantified and compared with relevant limits. These limits may be instantaneous limits or time-averaged limits. In the latter case, exposure from a number of different sources throughout a day will need to be considered. If the exposure is less than the relevant limit, then the risk of adverse health effects is considered low. This assessment needs to be carried out under normal use of the LED and under reasonably foreseeable conditions of misuse. – In addition to risk to the eyes, LED light exposure is highly risky for the human nervous system. This paragraph says, "should be shielded" and yet in the real world, due to lack of government regulations, this is rarely the case. The claim "direct viewing will be likely only under accidental or improper use conditions" is unsubstantiated. What is missing from this paragraph is the real-world epidemiological data that proves that LED light is too dangerous to be allowed in public spaces because real people are suffering real adverse reactions to LED light. LEDs must be strictly regulated, at least as tightly as laser light.

In addition to consideration of direct harm, the risk assessment also needed to consider issues that may arise from direct viewing of some LED sources where the risk arises due to temporary visual impairement, such as distraction, glare and after-images. These effects depend not only on the optical radiation incident on the eye, but also the ambient light level and the task being carried out at the time of exposure. – LED headlights have been shown to impair driver vision and the small source, flat surface creates higher luminance and thus higher glare. There is no justification for using LEDs in vehicle headlights, as the light quality is far more dangerous than tungsten filament with no improvement in visual acuity or safety. LED flashing lights such as used in Rectangular Rapid Flashing Beacons and on police vehicles, ambulances, and fire trucks aim the light directly into the eyes of the viewer, creating the distraction, glare, and after-images specified in this paragraph. The SCHEER must call for government regulations to protect people from the harm of direct viewing of LED emitters.

A third category of risk is potentially due to the temporal characteristics of the optical radiation emitted by the LED. The potential effects may be due to the actual emission of the source as directly viewed, or due to head or eye movement, or to the impact on moving equipment. – Square wave flicker is dangerous. Humans and other biological creatures are analog systems and the use of digital light is dangerous. The SCHEER must call for strict government regulation and package labelling of square wave flicker to at least 10,000 Hz.

A fourth category is where exposure to optical radiation from an LED may impact the circadian rhythm or other aspects of wellbeing. – The research has now established conclusively that LED light is toxic. The SCHEER must call for strict government regulation of spectral power distribution characteristics.

The SCHEER LED report ignores a fifth category of exposure to spatially non-uniform luminance from a flat surface source. The SCHEER must call for strict government regulation of spatial non-uniformity and peak luminance/radiance from flat surface LED emitters.

6.ASSESSMENT

6.1.Photometry and radiometry

LED characteristics including physical size, flux levels, spectrum and spatial distribution, separate them from typical element sources, which are generally employed and measured for photometric and radiometric quantities. For every radiometric quantity there is a photometric analogue. – In this paragraph SCHEER admits that spatial distribution is a characteristic of LED light. The SCHEER must address the spatial non-uniformity of LED light and its impact on the human nervous system.

Photometry is the science of the measurement of light, in terms of its perceived brightness to the human eye. It is distinct from radiometry, which is the science of measurement of radiant energy (including light) in terms of absolute power. Concepts such as radiance, irradiance, radiant power and radiant intensity used in radiometry can easily be defined via simple geometric relationships. While sharing these identical relationships, photometry also introduces detector response modelled after human visual characteristics. – We can note here that brightness for curved surface sources is measured with luminous intensity in candela and radiant intensity. On the other hand, brightness for flat surface sources such as LEDs is measured with luminance in nits (candela per square meter) and radiance. The spatial geometry of flat surface light is not easily defined via geometric relationships since every point in space has a different energy. Simple formulas cannot be used for flat surface light and data must be presented in tables and with formulas involving calculus. Detectors of LED light must be extremely precise, to the femtometer or picometer scale to capture the changes in luminance/radiance from the small surface of an LED chip.

Radiometry deals with the measurement of electromagnetic radiation across the total spectrum (infrared, visible, ultraviolet and beyond). Photometry is concerned only with the visible portion of the spectrum, from about 380 nm to 780 nm and measures luminous flux, luminous intensity, illuminance and luminance. – Luminous Intensity and Illuminance are not appropriate measurement units for flat surface sources. Organizations such as ICNIRP and IES have incorrectly used illuminance for LED light. Luminance is the correct measurement quantity for LEDs and nits (candela per square meter) is the correct unit and must be measured at the chip in near field due to the precision required to measure such spatially non-uniform light from a small source.

6.2 Physical characteristics of LEDs sources

The basic technology of an LED is that of a conventional diode, i.e., the creation of a positive-negative or p-n junction by doping (impregnating) semiconductor materials with impurities. In a p-n junction, current can flow from the p-side of the material to the n-side, but not in reverse. As electrons move and meet holes, they fall into a lower energy level by the emission of photons. The wavelength (colour) of the light thus emitted depends on the band gap energy of the semiconductors that form the p-n junction. It should be noted, however, that there are situations (e.g., silicon or germanium diodes) where the recombination of electrons and holes does not lead to an optical emission. – We can also note that LEDs emit photons within an escape angle that is defined by the physical characteristics of the chip. Photons that overlap reinforce the waves, creating a peak luminance in the center of the chip and a Lambertian spatial shape of non-uniform luminance due to the flat surface geometry of the LED chip.

The spectral irradiance for a domestic retrofit LED lamp is shown in the Figure 3, with the spectrum from an incandescent lamp for comparison. However, the emission spectrum depends on the type of LED. In particular, for white light LED lamps, the emission may be produced by a blue LED accompanied by a broad emission phosphor (as shown in the Figure 3) or by multiple LEDs emitting different colours that can be mixed in various proportions to produce "white" at different colour temperatures. – It is imperative to note here how dramatically different the LED spectral distribution is compared to incandescent. The quality of the LED spectra is vastly lower than that of LED because instead a continually increasing graph from low blue to high read, the LED spectra is piecewise, with a spike of dangerous blue wavelength light and almost no red. In addition, this graph does not at accurately show how a high color temperature LED has a larger spike of blue wavelength than shown in this graph. The updated SCHEER report must include multiple graphs with different color temperatures from 1000K to 7000K.

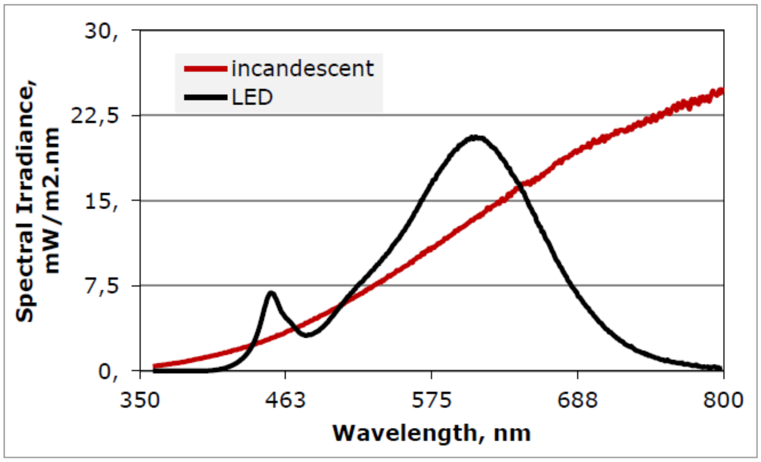

Figure 29 - SCHEER Figure 3

It is important to put exposure to optical radiation from LEDs into context with natural optical radiation sources. The data above is shown in Figure 4 on a log/linear scale for the spectral irradiance for comparison with a blue sky (minus any direct contribution from the sun). It can be seen that the spectral irradiance from the sky is about two orders of magnitude greater than from the LED or incandescent lamp over a considerable part of the spectrum shown. – An LED source is very close to the observer and irradiance is not the correct metric to use. Only radiance can be used form a flat surface source when gathering data for the impacts on human health. In addition, when LEDs are used at night, blue wavelength light is completely unsafe. The graph associated with this paragraph cannot be used in the updated SCHEER report.

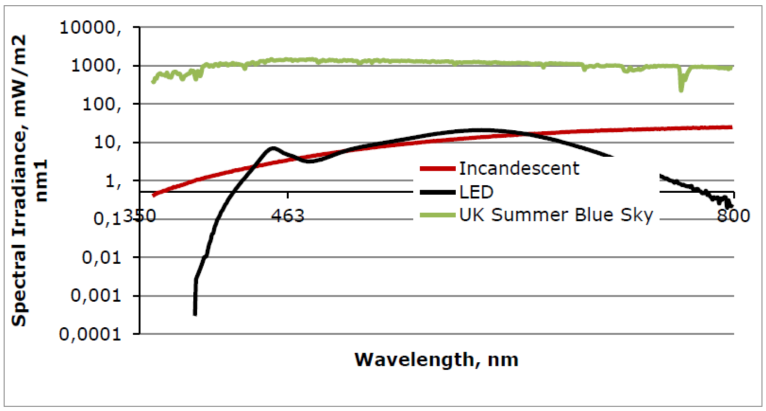

Figure 30 - SCHEER Figure 4

6.3 Point source vs diffuse source

In this report it is necessary to differentiate not only between point source light (light emitted from an LED chip) and diffused light LED sources, but also between diffused light that illuminates the environment and diffused light emitted by (for example) an LED screen that is directly viewed by users. In this sense, the exposure conditions (irradiance, distance from source and exposure duration) are totally variable and should be considered independently. For example, screens are mostly tactile and the distances of use are dependent on the user's length of the arms and the quality of their eyesight. However, at any given time, a person is likely to be exposed to optical radiation from a range of different optical radiation sources, including optical radiation from the sun. Any exposure to optical radiation from LEDs needs to put into context. – The statement that LEDs are a point source of light is mathematically incorrect. While LEDs do emit a narrowly focused beam, the light source is not a point. An LED light source is a flat surface which creates non-uniform luminance in a Lambertian shape. Irradiance is not a valid metric for a flat surface source. The correct metric is radiance. Whether the distance is arms-length or 1 mile, the radiance will be nearly identical which is just one of the reasons why LEDs are so dangerous.

To save energy, the European directives from the Eco-design of Energy Using Products (2005/32/CE) have recommended the replacement of incandescent lamps by more economic devices such as LEDs. However, the emission spectra from earlier types of white-light LEDs were rich in blue radiation, known to be potentially dangerous to the retina for high radiant exposures (Krigel et al., 2016). Therefore, it is important to consider actual source characteristics and exposure conditions. – LEDs do not "save" energy. The switch to LEDs may theoretically reduce the cost of operation, but it does so by reducing light quality. There is no "savings" only a reduction in quality. It is true that spectral power distribution must also be considered, as well as flicker and spatial characteristics.

There are several variables to be taken into account when referring to effects of optical radiation from LEDs on human health: 1) spectrum of an LED light source, 2) intensity of the lighting, especially in the blue part of the spectrum, 3) duration of exposure, 4) exposure level of the eye or skin, 5) health of the eye or skin, 6) direct staring without deviation versus active eye movement. – In addition, the impacts of spatial non-uniformity must be considered, as well as square wave flicker considerations and impacts on the nerves and brain. The overlapping impacts of multiple sources in a given environment and the contrast must also be considered.

6.4. The interaction between light and matter

Light (or more generally optical radiation) reacts with matter in various ways. These interactions are based on the absorption of the optical radiation by matter. When the energy of a photon is taken up by matter, reflection (the optical radiation is returned either at the boundary between two media or at the interior of a medium), refraction (change in direction of wave propagation due to a change in its transmission medium), scattering (the process of deflecting a unidirectional beam into one or many directions), or absorption (Das, 1991; Elliott, 1995; Hillenkamp, 1989) may occur.

There are four basic mechanisms that can occur following absorption of optical radiation: photothermal, photochemical, photomechanical and photoelectric interactions (see Annex II for details). However, only the first two are relevant to the optical radiation from current LEDs. – Photomechanical and photelectric interactions must also be considered to either show the effects or lack of effects on biological systems.

6.5. Eye optics fundamentals

The visual sensitivity of the eye to optical radiation varies with wavelength between about 380 and 780 nm. The wavelength range varies between individuals and the absolute response also has a distribution. However, the International Commission on Illumination (CIE from the French, Commission Internationale de l'Eclairage) have published response curves for so-called standard observers, based on experimental studies, taking account of whether the light levels are high (day time), low (night time) or in between. These are termed photopic, scotopic and mesopic curves, respectively. The photopic and scotopic curves are shown in Figure 6. – It is critical for the SCHEER to understand that these curves were generated using isotropic light. With anisotropic light from LEDs, everything has changed and these previous studies cannot be used for surface source light. For LED emissions, each point in space will have a different energy, which means that the response curve will be different at every point in space.

6.5.1 Thermal and photochemical aspects

The risk of thermal effects is related to burns to the retina, generally resulting from short-term exposure to very intense visible and IR-A radiation. Lesions occur on the outer retina (photoreceptors and cells of the pigment epithelium) and appear after some time has passed (usually about 24 hours). With photochemical interactions, first, reactive oxygen species may be generated, second, the presence and action of these represent oxidative stress, and unless repair mechanisms and detoxification processes or adaptive processes alleviate the impact, cell death (any type) may occur (Serezhnikova et al., 2017). Photoreactive pigments (lipofuscin) in the epithelium accumulate with age, increasing the risk of oxidative stress. The photopigment fragments thus created act as free radicals, which may lead to the death of the photoreceptor cells (Kuse et al, 2014; Chamorro et al., 2013). The radiation absorbed, which depends on the radiance of the light source and the duration of exposure, causes photochemical decomposition of the pigments present in the photoreceptor cells. – This paragraph confirms that damage to the eye is cumulative. Also, note that the paragraph states that the radiation is dependent on the radiance of the source. For a flat chip emitter such as LED, this peak radiance can be extremely high, and yet there are no comfort, health, or safety regulations for peak radiance from an LED chip. LED light is at least as dangerous as laser light, and yet LED light is unregulated.

The retina is exposed to all of the visible wavelength range, the most severe retinal damage is likely to result from the effects of the shorter wavelengths (400-600 nm); this is commonly known as the "blue-light-hazard" (see action spectrum below, ICNIRP 2013). However, the retina contains a number of endogenous photosensitisers (such as vitamin A derivatives, lipofuscin, melanin, flavins, porphyrins and rhodopsin) which can be excited by visible/infrared radiation reaching the retina (Rozanowska et al., 1995). In addition, exogenous photosensitisers, such as certain drugs, can induce ocular phototoxicity (Roberts, 2002). The retina contains many chromophores that can lead to photochemical damage when excited at each wavelength of light. Optical radiation emitted by LEDs may induce cell damage depending on the wavelength and therefore some wavelengths may produce more severe retinal photoreceptor cell damage than other wavelengths (Chamorro et al., 2013). Short wavelength light can penetrate through tissues to the cells and their organelles, inducing the generation of reactive oxygen species (ROS) in RPE mitochondria and even apoptosis (Roehlecke et al., 2009). Also, optical radiation emitted by LEDs can cause a phototoxic effect, especially from the most energetic radiations: the violet and blue (400 – 500 nm) (Godley et al., 2005). The higher toxicity of the blue part of the spectrum is recognised in the ICNIRP action spectrum for the blue light hazard shown in Figure 7. Also shown in Figure 7 is the aphakic action spectrum, intended for people without a lens, but which can also be applied for very young children. – This paragraph, along with hundreds of supporting research studies, makes clear that blue wavelength light is a hazard. Yet, there are no comfort, health, or safety standards for such blue wavelength light. LED vehicle headlights are typically 6500K and aimed directly into the eyes which will result in cumulative, irreversible damage to the eyes. LED streetlights are 5000K, 4000K and 3000K in the public outdoor spaces without no diffusion and high amounts of blue wavelength light that should not exist in a night time environment.

6.5.2.The effects on the healthy eyes

6.5.2.1.Computer Vision Syndrome

Computer vision syndrome (CVS) is the combination of eye and vision problems associated with the use of computers and was a concern before the introduction of LED screens. In modern society the use of computers for both vocational and recreational activities is almost universal. However, CVS may have a significant impact not only on visual comfort but also occupational productivity since between 64% and 90% of computer users experience visual symptoms which may include eyestrain, headaches, ocular discomfort, dry eye, diplopia and blurred vision either at near or far distance after prolonged computer use. Rosenfield (2011) reviewed the principal ocular causes for this condition, namely oculomotor anomalies and dry eye. Accommodation and vergence responses to electronic screens appear to be similar to those found when viewing printed materials, whereas the prevalence of dry eye symptoms is greater during computer operation. The latter is probably due to a decrease in blink rate and blink amplitude, as well as increased corneal exposure resulting from the monitor frequently being positioned in primary gaze.

The aim of another study (Argiles et al., 2015) was to evaluate spontaneous eye blink rate (SEBR) and percentage of incomplete blinks in different hard-copy and visual display terminal (VDT) reading conditions, compared with baseline conditions. Its conclusions are that the high cognitive demands associated with a reading task led to a reduction in SEBR, irrespective of type of reading platform. However, only electronic reading resulted in an increase in the percentage of incomplete blinks, which may account for the symptoms experienced by VDT users. –The SCHEER must address the needs of those who cannot neurologically tolerate LED screen.

6.5.2.2Anterior Segment of the Eye

To date there is no evidence that commercially available LED light sources have a deleterious effect on the anterior segment (conjunctiva, cornea and lens) of the human eye.

It has been reported that the severity of damage induced by light depends on radiation intensity, radiation wavelength and time of exposure (Lee et al., 2016). To date there are scientific reports showing that blue LED light at high doses (i.e. in excess of exposure limits) is toxic for the ocular surface. The excess of blue light LED radiation stimulates the production of pro-inflammatory cytokines (e.g., IL-1, IL-6, and IL-8, through the c-jun amino-terminal kinase [JNK] pathway, p38 pathway, and nuclear factor– kB [NF-kB] pathway) and enzymes (e.g. MMP-1) that mediate prostaglandin and leukotriene biosynthesis, as well as antioxidant enzymes in corneal epithelial cells (Lee et al., 2016).

The overexposure to emitting violet radiation (410 nm) at 50 J/cm2 can induce oxidative damage and apoptosis to the cornea, which may manifest as increased ocular surface inflammation and resultant dry eye compared to an LED emitting red and green irradiation (Lee et al., 2016).

Regarding the lens, cataract is the major cause for legal blindness in the world (Ide et al., 2015). Oxidative stress on the lens epithelial cells is the most important factor in cataract formation. Cumulative light-exposure from widely used LEDs may pose a potential oxidative threat to the lens epithelium. However, blue light exposure from the sky dominates and exposure to blue light from current LEDs is a small additional contribution to the natural exposure. – The claim that blue light exposure from the sky dominates is unsubstantiated. Night shift workers may never see the sky and thus LED light would be their only exposure to blue light. In addition, the intensity of LED light and its close proximity to the viewer make LED blue light an entirely different issue from blue light from the sky. The blue wavelength light from vehicle headlights is aimed directly at the eye. Professional truck drivers will be exposed to excessive amounts of blue wavelength lights from LEDs in vehicle headlights, LED floodlights, LED lights at filling stations, LED streetlights and LED street signals, resulting in dangers to the eye that they were not exposed to from tungsten headlights and sodium streetlights.

Xie et al., (2014) analysed the photobiological effect of white LED light exposure with multichromatic correlated colour temperatures (CCTs) of 2954, 5624 and 7378K on human lens epithelial cells (hLECs). In vitro experiments showed that compared with 2954 and 5624 K LED light, LED light having a CCT of 7378 K caused overproduction of intracellular reactive oxygen species (ROS) and severe DNA damage, which triggered cell cycle arrest and apoptosis. These results indicate that white LEDs with a high CCT could cause significant photobiological damage to hLECs. – Thus, it has been shown that higher blue content causes SIGNIFICANT PHOTOBIOLOGICAL DAMAGE.

Caution should be exercised regarding the effect of LED light on the human lens as this study was conducted using human lens epithelial cells in cultures. Responses to blue light irradiation might be variable in clinical situations involving human subjects. Humans are not ordinarily exposed to blue light with high radiant exposure, as they were in experimental studies. It is possible that under specific occupational circumstances, humans may be exposed to high radiant exposure blue light. However, existing European legislation for the exposure of workers to artificial optical radiation would apply. –The Precautionary Principle states that all efforts must be made to ensure eye safety prior to allowing such dangerous technology. Many workers experience very little blue light from the sun, but significant blue light from artificial LED sources. Hundreds of research studies confirm the dangers of blue wavelength light, and these studies justify and demand the removal of artificial blue wavelength light from the night time environment.

Some concern should be raised for medical professionals working under intensive shadowless lamps in the operating room. The incandescent or halogen light sources for surgical lamps are being replaced by more energy-efficient light emitting diodes (LEDs). However, occupational exposure legislation will apply. – LEDs are not energy-efficient as claimed in this paragraph. Occupational legislation has not been approved to protect workers from LED light and thus workers are right now being subjected to dangerous LED light.

6.5.2.3 Posterior Segment of the Eye

The present review did not identify any peer-reviewed literature demonstrating damage of the posterior segment of the human eye following exposure to optical radiation from commercially available white LED lamps in everyday life. Data are available only concerning the effect of LED light exposure or overexposure for in vitro or in vivo animal model studies. – The Precautionary Principle dictates that we avoid the use of LEDs until the studies have been performed to confirm or deny any adverse reactions from LED light.

Some concerns regarding possible hazard of LED light exposure comes from the fact that white light from LEDs appears normal to human vision, however a strong peak of blue light ranging from 460 to 500 nm may also be emitted within the white light spectrum; this blue light corresponds to a potential retinal hazard, but only at levels significantly in excess of the exposure limits recommended by ICNIRP (Behar-Cohen et al., 2011, Bullough et al., 2017). See also Figure 3 for a comparison with the exposure to optical radiation from a blue sky. – Figure 31 shows the blue light emitted by LED parking lot lights, trespassing from one person's property onto another person's property. The owner of this property has suffered a bloody nose, vomiting, and loss of sleep due to the blue wavelength LED light. A comparison between the blue light from daytime sky and blue light from an LED in the night time environment cannot be made.

Figure 31 - Floodlights with Blue Wavelength

The composition of the white-light spectrum differs among LED products and their light qualities may change over time. Although it is robust in the beginning, a white light LED may progressively release more short-wavelengths (blue light) when LED lumen depreciation occurs because of phosphor degradation. The quality of the light deteriorates after the lights pass below the 70% lumen maintenance level (U.S. Department of Energy 2009). These characteristics suggest that a white LED might cause more blue light exposure than other domestic lighting sources at the end of their life. Cumulative exposure to blue light has been argued to accelerate ageing of the retina and possibly play an etiological role

in age-related macular degeneration (e.g. Behar-Cohen et al., 2011). – This paragraph makes clear that the high blue content of LEDs is unacceptably dangerous and must be prohibited.

Irradiating human RPE cells in vitro with three different LED light sources - blue (468 nm), green light (525 nm), red light (616 nm) or white light at an irradiance of 5 mW/cm2 induce a significant reduction of the viability of the cells for all four LED sources (Chamorro et al., 2013). However, ROS levels increased only after the exposure with blue, green or red light but not after the exposure to white light compared to non-irradiated cells, although there was an increased degradation of nucleic acids in all irradiated cells in comparison with control cells. Notwithstanding, apoptosis (cell death) also increases significantly following white light exposure (blue 86%, green 84%, red 66%, white 89%) compared to only 3,7% of apoptosis of the non-irradiated RPE cells. Summing up, three light–darkness cycles (12 h/12 h) exposure to LED lighting, including white LED, affect the growth of RPE cells and produce cellular stress, increasing ROS levels as well as increasing DNA damage and the number of apoptotic cells. – The death of eye cells and DNA damage demands that the SCHEER Committee recommend the elimination of LED products in public spaces in its updated report.

LED light at domestic lighting levels induced retinal injury in a Sprague-Dawley (albino) rat model after chronic exposure (Shang et al., 2014; Shang et al., 2017). Retinal cell function loss was demonstrated in vivo by electrofunctional test showing a significant decrease of bwave amplitude after 9 and 28 days of blue or white LED, or compact fluorescent lamp (CFL), light exposure. The findings were confirmed ex vivo by a significant thinning of the outer nuclear layer where the nuclei of photoreceptor cells are located and more apoptosis after blue and white LED light exposure, compared with the exposure to the light from the CFL. The retina has one of the highest oxygen consumption levels of tissues in the body and it is sensitive to oxidative stress (Yu and Cringle, 2005). Oxidative stress is the crucial risk factor for photoreceptor degeneration, which is caused by the generation of toxic ROS within retinal tissue. The retina contains enzymes involved in detoxification or synthesis, particularly in the outer segment or retinal pigment epithelium (Shang et al., 2014; Shang et al., 2017). The spectrum emitted by white LED lights contains photons with energies that exceed the threshold for damage of the enzymes serving as a stress-induced protection mechanism (Behar-Cohen et al., 2011); thus, exposure to optical radiation from white LEDs may result in severe damage to the outer retina at high levels of exposure. Wavelengths at the higher energy end of the spectrum , as well as retinal irradiance, are risk factors that contribute to the risk of photochemical retinal injury. To prevent or decrease this potential retinal damage, some companies are increasing the market segments of lower colour temperature (i.e. lower blue component) LEDs for domestic lighting (U.S. Department of Energy 2012). – This paragraph clearly confirms that LED light is dangerous. In the updated report, the SCHEER must make clear to government officials that LED light is dangerous and that protection of citizens cannot be left to market forces.

Recently the potential for retinal damage from optical radiation emitted by 10 commercially available LED light sources and an LED lantern for home use was evaluated

(James et al., 2017). Each lamp was tested by measuring the spectral irradiance and spectral radiance. The authors concluded that all light sources tested are in the exempt group according to the ANSI/IESNA Recommended Practice RP-27 series of documents (ANSI/IESNA 2005, 2007) which is the equivalent of the European Standard EN 62471 and therefore they do not pose an ocular hazard. – The conclusion of this study must be re-evaluated in the updated SCHEER report. We do not believe that ANSI RP-27 is valid for flat surface light sources such as LEDs.

6.5.3 Potential effects on the non-healthy eyes

Age-related macular degeneration (AMD) is a multifactorial disease and a leading cause of blindness in the patients aged about 65 years or older in industrialised countries (Chu et al., 2013; Wu et al., 2014).

The typical pathology of advanced AMD is described as having two main forms: geographic atrophy (GA) and neovascular (exudative) AMD. Although pharmacologic treatment has changed the visual prognosis of exudative AMD, there is still a limited curative treatment for AMD, and therefore the best option is to prevent its onset by trying to point out possible risk factors which might contribute to further acceleration of the pathologic senescence process of the choroid, RPE and neuroepithelium. A growing number of studies indicate that the effect of oxidative stress contributes to AMD-related pathological changes (Beatty et al., 2000; Lau et al., 2011; Narimatsu et al., 2013). Besides aging and smoking, the main source of oxidative stress can be cumulative light exposure, which may induce abnormal accumulation of reactive oxygen species in the macula. – The SCHEER agrees that oxidative stress from light exposure is cumulative which means that exposure to blue wavelength light must be avoided. 6500K LED vehicle headlights and 4000K LED streetlights are therefore unsafe.

A systematic review and meta-analysis revealed that individuals with high levels of sunlight exposure ("UVR exposure", "visible light exposure" and "blue light exposure" were all regarded as sunlight exposure) are at a significantly increased risk of AMD compared with? (Sui et al., 2013). Furthermore, the risk for cataract extraction, as well as early AMD, is increased in subjects exposed to high levels of sunlight (Delcourt et al., 2014). The cornea and natural crystalline lens absorb the most UVR and only a small fraction of UV-A (315 nm-400 nm) reaches the retina (Sliney, 2001). Although by 20 years of age only 0.1% UVR reaches the retina, due to the metabolites of tryptophan which absorbi UVR (Sliney, 2002), blue light has a better ocular penetration than UVR, and by the age of 60–70 years old, there is still 40% of blue light (460 nm) reaching the retina (Behar-Cohen et al., 2011). – In this paragraph the SCHEER is confirming that adding additional blue wavelength light at close range from LEDs is dangerous and unacceptable. In a night time environment, where it is well known that there are a dramatic ecological reactions to the changes in reflected moonlight from new moon to full moon, the addition of high blue content LED streetlights, LED floodlights, and LED vehicle lights presents an unacceptable risk.

The urban population tends to have longer duration of exposure to artificial lighting indoors rather than sunlight outdoors. However, for even a short period of time outdoors,

the optical radiation exposure from sunlight tends to dominate (Fig. 4). – Natural sunlight is both hazardous and a necessity. To better protect the eyes outdoors, many people use sunglasses. The idea of bringing blue wavelength light to the nighttime environment in the form of LED vehicle headlights and LED streetlights and LED floodlights is dangerous and unacceptably risky.

6.5.4.Vulnerable and susceptiblep opulations

6.5.4.1.Children

The transmission of UV-A and blue light to the retina is higher in young children than in older children (above about three years) and adults. The ICNIRP guidelines (ICNIRP, 2013) suggest that the action spectrum for aphakes may be appropriate for young children, generally considered to be those below about three years of age. This formed the basis of a recommendation on the emission limits for LEDs incorporated into toys (Higlett et al., 2012). – Children are now being exposed to blue light in parking lots, in home lighting, from cell phones, and on public streets. To protect the eyes of children, these sources of blue wavelength light must be removed from the night time environment in public spaces.

6.5.4.2.Adolescent

The studies of Kim et al. (2016) show that smartphone use has dramatically increased in recent years. According to the authors, smartphones may have adverse health effects, particularly on the eyes, because users stare at the screen for a much longer time than with previous generations of mobile phones. The objective of this study was to elucidate the relationship between smartphone use and ocular symptoms among adolescents (n=715). The conclusion was that the increasing use of smartphones can have a negative impact on ocular health in adolescents, although there was no implication that the optical radiation had any direct adverse health effect. – Blue wavelength light from cell phones, LED streetlights, LED billboards, LED floodlights and other sources have been shown to significantly increase the risk of breast, prostate, and thyroid cancers, premature births, autism, and mood disorders. Given that adolescents are already experiencing increased stresses from the modern environment, all efforts must be made to eliminate sources of blue wavelength light from the night time environment.

6.5.4.3. Elderly population

No peer reviewed studies were identified that suggested there was a specific risk to the older population from exposure to the optical radiation from LEDs. However, the ageing eye transmits less blue light to the retina and is more susceptible to light scatter at these wavelengths. – Since damage to the eye from blue wavelength light cumulative, it is anticipated that future studies will show significant eye damage from cumulative exposure to LED light. One example of the many studies of blue wavelength light on older populations is titled Age-dependent effects of blue light exposure on lifespan, neurodegeneration, and mitochondria physiology in Drosophila melanogaster[28] which was published July 27, 2022.

There have been claims that blue rich sources of light produce more glare for the older population. This is likely to be evident for LED displays (for example destination indicators on the front of buses) using blue light and for vehicle LED lighting. – The small size of LEDs and flat surface greatly increase peak luminance, which in turn greatly increases glare. LEDs are not appropriate for vehicle headlights or general illumination tasks for all populations, including the elderly.

Conclusion

Although there are no reliable data to be used for risk assessment of eye-safety of life-time usage of LED light sources, there might be some concern on the potential negative consequences of LED emissions particularly in a susceptible population which already present early signs of pathologic senescence of the macula. However, it should be emphasised that those concerns derive from results obtained in experimental animal models or cell culture models using exposure levels greater than those likely to be achieved with LED lighting systems in practice. – The significant dangers of exposure to blue wavelength light to the eyes and circadian rhythms has been fully substantiated. The SCHEER must present a strongly worded conclusion to government officials that blue wavelength light from LEDs is too dangerous to be permitted in the night time environment and should be tightly restricted in the day time environment.

Exposure to optical radiation from white LEDs may result in severe damage to the outer retina at high levels of retinal radiant exposure. Wavelengths in the blue range are a risk factor that contributes to the risk of photochemical retinal injury. To prevent or decrease this potential retinal damage, lower blue component LEDs for domestic lighting should be used. – LED vehicle headlights, LED streetlights, LED floodlights, LED strip lights, and many other products all have excessive blue wavelength light, which have been introduced into our environment. Government officials must act quickly to protect the public from this technology.

6.6. Skin optics fundamentals
6.6.1 Structure of the skin

[28] https://www.nature.com/articles/s41514-022-00092-z

The layers of human skin, stratum corneum, epidermis and dermis (Figure 8) are composed of different cells as well as acellular structures, such as keratin and extracellular fluids (see Annex III for a short description of the various parts).

Fitzpatrick (1975) originally developed a scale of skin types for use in phototherapy treatment planning. The scale has been more widely adopted (Fitzpatrick 1988) to indicate the sensitivity of the skin to ultraviolet radiation (Annex III).

6.6.2 Optical properties of skin

Optical properties of the skin are complex, and result from reflectance, absorption and scattering of the different wavelengths of incident optical radiation (for reviews see Anderson and Parrish, 1981, Lister et al., 2012, Liu, 2012) (Figure 8).

When optical radiation reaches a tissue, some of the radiation is scattered back from the skin surface (reflection), some is absorbed in different layers, and some is transmitted into layers underneath until the incident energy is dissipated. The first optical interaction with skin occurs at the surface of stratum corneum. Due to the change in refractive index between air (nD = 1.0) and the epidermal surface (nD = 1.55 for the stratum corneum), a small fraction of incident optical radiation is reflected. Reflectance is the proportion of the incoming radiation that either penetrates the skin and is diffusively reflected back (epidermal and dermal backscatter; Figure 8) or that which is regularly (specularly) reflected from the skin surface (CIE, 2011). The regular reflectance from skin is always between 4% and 7% (angle dependent) in the wavelength range 250-3000 nm independent of skin type (Kohen et al, 1995). Transmission is the fraction of incident radiation that penetrates through the skin. Optical penetration depth is highly dependent on absorption (see 6.6.3).

Absorption is a process by which radiant energy is converted to a different form of energy by interaction with matter (CIE, 2011). Absorption of optical radiation in skin by biomolecules including water is wavelength-dependent. An atom or group of atoms that serve as a unit in light (optical radiation) absorption is called a chromophore. The organic molecules that absorb in the UV and visible range often have double bonds (Turro, 1991).

Scattering is a change in the direction, polarization or phase of light and results from either a surface effect (such as reflection or refraction) or from an interaction with molecules/particles with optical properties that differ from their surroundings (particle scatter). The major sources of particle scatter in the skin are the filamentous proteins: keratins within the epidermis, and collagens in the dermis. In addition, other structures/substances such as melanosomes in the epidermis contribute to light scattering in the skin. Scattering is influenced by the size of the filaments; it increases with increasing fibre diameter, and with wavelength (it increases with decreasing wavelength).

The overall optical properties of the skin depend on photon absorption and scattering by a wide range of biomolecules with specific chromophores. Typical UV absorbers in skin are DNA, melanin, 7-dehydrocholesterol (see Annex III) and several amino acids, such as tryptophan and tyrosine (Figure 9). Melanin, almost exclusively located in the epidermis in humans, is one of the major optical radiation absorbers. There are two types of melanin: eumelanin which is black-brown and pheomelanin which is red-yellow. Their absorption spectra are wide, without specific peaks. Melanin absorption

decreases two to three orders of magnitude from the ultraviolet (UV-B, 280 nm) to the near-infrared (1400 nm) spectral regions.

Absorbers in the near-UV/visible wavelength range are vitamin A and riboflavin. In the visible wavelengths the dominating chromophores are oxy- and deoxyhaemoglobin (Figure 9). The absorption spectrum of oxy-haemoglobin shows three peaks: a dominant peak in the blue region (Soret band, near 405 nm) and two further peaks in the green-yellow region (500-600 nm), at 540 and 580 nm, respectively (the combination of the blue and green-yellow bands cause haemoglobin to appear red); deoxyhaemoglobin strongly absorbs near 430 nm and has a weak absorption band at 550 nm (Anderson et al., 1982; Parrish and Jaenicke 1982; Cheong et al., 1990).

Aside from melanin, other biologically relevant absorbers in the visible range are porphyrins. Although abundant in all tissues, water is not a significant absorber of light in the visible region, but absorbs UV (decreasing with increasing wavelength) and infrared radiation (increasing with increasing wavelength).

6.6.3 Penetration of light in the skin

The penetration depth of light in the skin is a function of wavelength and absorption/scattering by skin components (e.g. melanin, keratin, collagen, haemoglobin and fat). In the visible wavelength range, penetration depth increases with increasing wavelength. - Penetration depth is also dependent on the radiance.

Each skin layer has a different thickness; the stratum corneum is~20 µm, the epidermis (the blood free layer), is ~100 µm, but thickness varies, largely depending on body site, and the dermis is 1–4 mm thick (vascularized layer). The average scattering properties of the skin are defined by the scattering properties of the reticular dermis because of the relatively large thickness of the layer and of the comparable scattering coefficients of the epidermis and the reticular dermis (Genina and Tuchin, 2011). The subcutaneous adipose tissue (1-6 mm thick depending of the body site) has absorption defined by absorption of haemoglobin, lipids, and water (about 11%) (Jacques, 2013).

Penetration of light in the skin according to skin layers composition

Epidermis – the epidermis has an important function in absorbing most of the short-range UV-B (280-315 nm) and a significant proportion of UV-A (315-400 nm) radiation. This results both from absorption of UV radiation by melanin and urocanic acid, and from scattering by keratins. An efficient protection against UV is afforded by the thickening of the stratum corneum that results from the epidermal hyperplasia triggered by UV exposures.

Dermis – the dermis is mainly constituted from collagens and elastin and is highly vascularized. Light is absorbed by haemoglobin and scattered by the large collagen fibres (about 10 times larger than keratin of the epidermis).

Sub-cutaneous tissue – the sub-cutaneous tissue is rich in fat and is vascularized. Fat is a highly diffusing optical medium, and haemoglobin absorbs light in blood vessels. But penetration depth of visible light (400-700 nm) in the skin is limited to about 3 mm, and only a small proportion of visible light penetrates sub-cutaneous tissue. – The radiance must be specified when stating penetration depth. The SCHEER must show a chart of LED peak radiance values and the skin penetration depth.

Penetration of light in the skin according to wavelength

UV – Most UV-B incident on the skin is blocked by the epidermis. It is usually considered that only 10% of UV-B reaches the basal layer of the epithelium as opposed to 50% of UV-A. UV-A reaches the dermis.

Visible light – **For visible wavelengths (~400-700 nm) one penetration depth, i.e. when 37% of the incident energy is left, ranges between ~0.1 and 0.8 mm (very fair skin) (Kohen et al, 1995). According to Johnson and Guy (1972), for a sample consisting of epidermis and dermis, the depth of penetration is 0.15–0.2 mm (wavelength 632.8 nm) and 0.21–0.4 nm (wavelength 675 nm).** – This study was not done with flat surface spatially non-uniform light and thus is not applicable to LEDs.

Infrared – **infrared radiation can reach subcutaneous tissue. At wavelengths from 600 to 1500 nm, scattering prevails over absorption and penetration depth is increased to 8–10 mm.**

6.7 Optical radiation effects on skin

The topic is reviewed in the SCENIHR Opinion "Health Effects of Artificial Light" (SCENIHR, 2012). A brief version containing some new information published since 2012 can be found in Annex III.

The SCHEER is unaware of UV-LED sources intended for the general population with the exception of a few devices for certain cosmetic purposes (see Annex III). UV nail lamps and/or LEDs do not appear to significantly increase the lifetime risk of non-melanoma skin cancer. However, data are lacking regarding the possibility of premature skin ageing, and the risk to the eyes of the professional operators should be considered. Assessment of LED sources in medical devices and for occupational use is beyond the scope of this Opinion.

Vitamin D production in human skin following exposure to UV irradiation from LEDs has been studied in vitro via High Performance Liquid Chromatography indicating possibility for synthesis of vitamin D2 and vitamin D3 if the UV LED source is powerful enough. However, UV-B is carcinogenic to humans, and public health organizations, including SCHEER (SCHEER, 2016) do not recommend use of artificial UV radiation to enhance vitamin D levels.

6.7.2 Effects of LED reported in the literature (photodermatoses)

6.7.2.1 Controlled studies

A controlled study (Fenton et al., 2013) investigated photosensitivity after exposure to either a single-envelope compact fluorescent lamp (CFL) (15 W GE BIAXTM Electronic 220–240 V; 50/60 Hz; 120 mA; FLE TBX/XM827 183 JA/S; 900 lumen), a double-envelope

CFL (15 W OSRAM DULUXSTAR Mini Ball 827 Lumilux Warm White 220–240 V; E27; 50/60 Hz; 850 lumen) or an LED lamp (10 W 0026172 Hi-Spot RefLED PAR30; E27; 15 000 h; 100–250 V; 50–60 Hz; 20 lm Warm White 830/3000 K; 400 lumen). The emission spectra of the lamps between 250-400 nm at the distance of patient testing were recorded and presented. Two hundred patients (103 actively photosensitive) were exposed to the single-envelope CFL and of these, 11 patients were exposed to the double-envelope CFL. One hundred and one patients (45 actively photosensitive) were exposed to the LED and, in addition, there were 20 healthy controls. The patients were exposed on untanned skin on the inner forearm while the healthy controls were exposed on untanned skin on the back. All subjects were at a distance of 5 cm from the lamp. One of the exposure sites was covered with UVR-protective film. In the CFL-group 32 patients presented with responses (delayed papules, erythema and immediate urticarial responses), while in the LED-group one patient showed a response. Two of the healthy volunteers showed a positive erythemal response 24 h post-irradiation. The patient showing a positive response in the LED-group was diagnosed with solar urticaria and had visible light sensitivity. The SCHEER notes that the LED irradiance in the full emission range was unknown. The LED's UV emission was negligible compared to those of the CFLs. – Without specifying the peak radiance of the LED chip, the LED portion of the study cannot yield any valid results.

A pilot study (Fenton et al., 2014) investigated the exposure of a compact fluorescent lamp (CFL) (GE BiaxTM Electronic, part number FLE15TBX/XM/827, 220–240 V, 50–60 Hz, 15 W, 120 mA, 900 lumen (GE Lighting, Northampton, U.K.), an energy-efficient halogen lamp (EEH) (Osram Halogen ES Classic Spot R63, part number 64546 R63 ES, 240 V, 42 W, 630 lumen (Osram, Munich, Germany) and an LED (Hi-Spot RefLED PAR30, part number 0026172, 100–250 V, 50–60 Hz, 10 W, 400 lumen (Sylvania, Raunheim, Germany). The emission spectra of the lamps between 250-400 nm at the distance of patient testing were recorded and presented. Fifteen patients with lupus erythematosus (LE) and five healthy volunteers were included and tested for cutaneous responses to repeated exposures from the lamps. The patients were exposed on untanned skin on the back at a distance of 5 cm from the lamp. One of the exposure sites was covered with UVR-protective film. The authors reported that: "No cutaneous LE lesions were induced by any of the light sources. Delayed skin erythema was induced at the site of CFL irradiation in six of the 15 patients with LE and two of the five healthy subjects. Erythema was increased in severity and was more persistent in patients with LE. One patient with LE produced a positive delayed erythema to the EEH. A single patient with LE produced immediate abnormal erythemal responses to the CFL, LED and EEH. Further investigation revealed that this patient also had solar urticaria. All other subjects had negative responses to LED exposure". The SCHEER notes that the LED irradiance, for which UV-emission was negligible compared to those of the CFL and EEH, in the full emission range was unknown. – The LED peak radiance must be used, not irradiance.

6.7.2.2 Case reports

A case of solar urticaria triggered by LED-therapy was reported by Montaudié et al. (2014). A 55-year-old woman with no history of urticarial rash following previous sun exposures was treated with 415 nm LED for mild rosacea (a photo-aggravated dermatosis). Phototesting confirmed the diagnosis of solar urticaria. The SCHEER notes that the irradiance, treatment distance and LED-spectrum were not reported. – The peak radiance of the LED chip must be specified.

A case was reported of a patient with cutaneous lupus erythematosus (CLE) who presented with a rash after dental treatment (Tiao et al., 2015). The patient was allegedly being exposed to "surgical light" emitting UV-B, a wavelength range without purpose for this type of light. The SCHEER notes the spectral characteristics of the source were not given. It is unknown whether her reaction alternatively could have been due to an (photo-)allergy to dental materials, heat effects from the emission of blue light from LED dental curing lights (irradiance typically in the order of thousands mW/cm2) or a drug-mediated photosensitivity reaction (the patient took several medications for her disorder). – There are more documented cases of people with lupus suffering adverse reactions from LED light. Specifying irradiance for an LED chip is not valid. LED light is spatially non-uniform, and therefore does not fall onto a flat surface uniformly. There is no possible method of specifying a single irradiance value without improperly averaging out the peak radiance.

6.7.3 Conclusions

Emission from some types of commercial LED lighting can induce a positive skin response in some patients with solar urticaria when exposed in short distances and at high intensities (compared to e.g. indoor lighting) in controlled environments. The dose that elicits such a response is not known. – The SCHEER must demand that government set comfort, health, and safety standards for LED light.

6.8 Circadian rhythms

Apart from influencing vision, light received by the eye has several non-image-forming functions, such as the pupillary light reflex and providing input to the biological clock. This biological timekeeping system imposes day-night rhythms on many processes in our body, including behaviour (sleep/wake cycle), endocrine regulation, immune response and energy metabolism. Disturbances of our circadian rhythms caused by shift work have been linked with negative effects on health and increased accident risks. The biological clock is highly influenced by external light clues, including artificial light. These results were previously reviewed in the SCENIHR Opinion 'Health effects of artificial light' in 2012. In the current Opinion, the SCHEER focusses on the effects of LED sources. For a summary of the mechanism of generation of circadian rhythms and their normal functions, see Annex V. – Blue/white LED light sources are already ubiquitous and causing significant harm. The updated SCHEER report must call for government action.

6.8.1Synchronisation and regulation of the circadian rhythm by light

The influence of light on the circadian system is dependent on 1) timing, 2) intensity, 3) duration, 4) spectrum of the light stimulus, and 5) of previous light exposure. For intensity and duration, experiments have shown that there is a dose-dependent relationship with response of the circadian system (Duffy and Czeisler 2009). Importantly, relatively low intensity levels (<100 lux) and short durations (seconds to minutes) have been reported to affect the circadian system (Glickman, Levin et al. 2002, for review see Duffy and Czeisler 2009, Lucas, Peirson et al. 2014). With regard to timing and previous light exposure, light stimuli have a greater impact on the circadian system when they are present during the natural dark phase. Light present during the late night/morning will advance the phase of the circadian rhythm, whereas light present during the evening will delay the phase of the circadian rhythm. This is an important concept considering disturbances of the circadian rhythm since chronic light exposure during the evening, causing a phase delay, can result in social jetlag (see 6.8.4: 'Consequences of disturbance of the circadian rhythm by light'). Furthermore, the effect of light is dependent on previous light exposure, since adaptation to light also occurs with regard to the circadian system (Duffy and Czeisler 2009, Kozaki et al. 2016). Finally, the photoreceptors are not equally sensitive to all wavelengths of light; therefore, the spectrum of the light is critical. – Spatial distribution of the light also affects circadian rhythms. This paragraph makes clear that products such as LED vehicle headlights, LED street lights and LED floodlights disrupt hormonal processes, leading to serious health risks. LEDs, therefore, should not be permitted in the night time environment in nearly all cases.

Melanopsin was discovered about 19 years ago, and has since been shown to be expressed in intrinsically photosensitive retinal ganglion cells of the retina (ipRGCs) and to play an important role in providing input to the circadian system and other non-image-forming functions (Hattar, Liao et al. 2002, Duffy and Czeisler 2009, Hatori and Panda 2010, Tosini, Ferguson et al. 2016). In vitro experiments have shown that melanopsin has a peak spectral sensitivity of around 480 nm (Panda, Provencio et al. 2003, Panda, Nayak et al. 2005, Qiu, Kumbalasiri et al. 2005, Torii, Kojima et al. 2007, Bailes and Lucas 2013). However, in vivo, the signals received in ipRGCs from the other photoreceptors also have a role in determining ipRGCs output and the subsequent input to the circadian system. Their relative contribution is still under investigation, which is compounded by the finding that this appears to be context dependent (Lucas, Peirson et al. 2014). Additionally, the spectral composition of the light that is received by the photoreceptor is influenced by the spectral transmission properties of the ocular media, which is, for example, dependent on age (Lucas, Peirson et al. 2014, Gimenez, Beersma et al. 2016). In summary, spectral sensitivity of the circadian system is a complex interplay of external and internal factors, and not yet completely understood. However, experiments have shown that, overall, circadian rhythms are more affected by short wavelength light (460-490 nm) (Duffy and Czeisler 2009, Benke and Benke 2013), with the exact peak probably dependent on the individual and context involved. – The Precautionary Principle dictates that LED lights must not be used in public settings until this research produces a complete understanding of the effects of spatially non-uniform, high blue content, square wave flicker light on biological systems. Existing research confirms that LED light is too toxic for outdoor use.

6.8.3 Influence by optical radiation including LEDs

For details on how human circadian rhythms are investigated in most of the described studies (such as assessing melatonin rhythms), please see Annex V. As described above, the circadian system is regulated by light input. The circadian system is not only influenced by natural light, but also by optical radiation from artificial light sources. Some artificial lighting sources influence the circadian system and, dependent on the timing, support or compete with natural light as a zeitgeber. For example, studies using exposure to artificial light sources reported effects on melatonin rhythms and subsequent sleep (for example, Wright, Lack et al. 2001, Wright, Lack et al. 2004, Cajochen, Frey et al. 2011, Wood, Rea et al. 2013, Chang, Aeschbach et al. 2014, Gronli, Byrkjedal et al. 2016, Rangtell, Ekstrand et al. 2016). This might have health consequences when artificial light is present during the evening and night time, when naturally no light is present. Exposure to light during the evening and night may delay the phase of the circadian clock. This delay might cause a disturbance of the circadian rhythm: see section 'Consequences of disturbance of the circadian rhythm by light' in Annex V for more details. These effects can occur with all types of artificial light, however, recent studies indicate that this effect is amplified for certain types of LEDs. – This paragraph confirms the toxic effects of LED light. LEDs are not fit for night time use and their use must be severely limited.

6.8.3.1 Disturbance of the circadian rhythm by LEDs sources

The widespread use of LEDs is relatively recent. Therefore, only a small number of studies investigated the effects of LEDs vs. traditional light sources during the evening on circadian rhythms. It is important to note that LEDs, as traditional light sources, are not one homogenous class; their influence on the circadian system depends on the specific properties of that particular light source. Some studies have investigated the effect of (blue) LEDs on circadian rhythms and (objective) sleep without a comparison to traditional light sources (for example, Wright, Lack et al. 2004, Kayaba, Iwayama et al. 2014), which indicated that LEDs that emit short-wavelength light influence circadian rhythms, as do other light sources with short-wavelength light. – As per the Precautionary Principle, it is negligent to allow a new technology to be widely introduced into the environment without proper study of the effects of the technology on humans and the environment. We now know that the effects of flat surface light has had devastating consequences, increasing light pollution and disease and human suffering. The SCHEER must clearly state that dangers of LED light and how it significantly increases the risk of cancers, diseases and mood disorders.

Most of the few studies available investigated screens illuminated by LEDs. For example, a study from Cajochen et al. investigated the effect of evening exposure to white light from a commercially-available screen illuminated with LEDs (6953K) or a cold cathode fluorescent lamp (CCFL 4775K) illuminated screen (Cajochen, Frey et al. 2011). Spectral measurements were performed showing that the radiance between 400 nm and 480 nm of the LED screen was higher (0.241 W/(sr.m2)) compared to the CCFL illuminated screen (0.099 W/(sr.m2)). Participants were asked to watch this screen in a controlled laboratory setting for 5 hours during the evening. Relative to the non-LED screen, the LED screen delayed the dim light melatonin onset (DLMO) and enhanced the

suppression of evening melatonin levels for approximately 2 hours. In addition, exposure to the LED screen reduced subjective and objective measures of sleepiness and increased performance on cognitive tasks, relative to the non-LED screen. These results indicate that exposure to screens illuminated with these types of LEDs have a larger immediate influence on the circadian system than the CCFL-illuminated screen. – In this paragraph, the SCHEER admits that LED power and brightness is measured with radiance not irradiance. According to this paragraph, an LED screen emits 0.241 Watts/steradian-meter^2. The SCHEER's updated report must use the the proper metrics of radiance and luminance throughout the report for any source that is LED.

A study from Wright et al. similarly showed that LEDs can phase delay the circadian rhythm in melatonin levels (Wright, Lack et al. 2001). However, in this study the phase delay caused by this type of white LED was not different to the phase delay caused by a traditional white fluorescent light source. In this study, a blue/green LED was also included, which did affect the circadian rhythm in melatonin to a greater extent compared to the white LED or white fluorescent light source. The authors report that the white LED has a narrow peak wavelength at 460 nm and a secondary broader peak wavelength at 560 nm. The blue/green LED has a peak wavelength at 497 nm and a half-peak bandwidth of 485-510. Exposure to the light sources was performed for 2 hours during night time (from 24.00 - 02.00 h). Hence, exposure started when melatonin levels were already high. This is in contrast to the study by Cajochen et al., where exposure was during the evening when melatonin levels start to rise and for a longer period (5 hours). All light sources suppressed the melatonin levels between 24.00 and 02.00 hours. In all experimental groups with an additional light source, a phase delay of the melatonin rhythm was observed the subsequent day. Exposure to light from blue/green LEDs caused the largest delay of 42 minutes. The delay observed after exposure to the fluorescent light box and white LEDs was similar (both 22 minutes). In summary, this study shows that all of the used light sources influenced the circadian rhythm of melatonin with the blue/green LEDs having a greater effect. – Numerous studies have confirmed that LEDs have extremely strong negative effects of circadian rhythms. The SCHEER must state unequivocally to government officials that the disruption of circadian rhythms by LED lights is a major health risk for all of society.

Similar findings were observed in a second study in which exposure to light from blue LEDs was compared to white fluorescent light (West, Jablonski et al. 2011). In this study, irradiance of the blue LEDs ranged from 0.1 – 600 µW/cm2; irradiance of the white fluorescent light was 40 µW/cm2. Results show that there is increased melatonin suppression with increased radiance from blue LED light. Additionally, blue LEDs affect melatonin levels at lower radiances compared to white fluorescent light. – Irradiance is not the correct metric for studying the effects of LEDs. The correct metric is radiance.

Combined, these studies indicate that any additional influence on the circadian system by LEDs is dependent on the characteristics of the emitted optical radiation and of the use of the LEDs (i.e. timing and duration) in a similar fashion as other light sources influence the circadian system. It is important to note that LEDS might have a beneficial emission spectrum compared to traditional light sources as well (Aube, Roby et al. 2013,

Lu, Chou et al. 2016). Effects are depending on the time of day, of exposure and on the characteristics of the LEDs. For example, increased exposure to blue light during the day will enhance circadian rhythms. – The spectral power distribution of a high blue content LED has a large spike of blue and almost no red. This is not at all similar to sunlight which has generally the same power at each wavelength. It is not viable to compare LED light to sunlight because of the large differences in spectral power distribution. In addition, it is extremely unlikely that people will use one light bulb during the day, and then unscrew it and replaced it with a different color temperature bulb for night time use. The result of the use of high color temperature LEDs is that these bulbs will be extremely toxic to human health.

Additionally, there are a few studies that investigated the effect of 'real life' devices in which LEDs are incorporated, such as tablets (Wood, Rea et al. 2013, Chang, Aeschbach et al. 2014, Gronli, Byrkjedal et al. 2016, Heo, Kim et al. 2016, Rangtell, Ekstrand et al. 2016). In these studies, no controls with non-LED devices were made. However, these studies provide some insight to the effects that occur in real life, where the use of screens illuminated by LEDs has increased tremendously over the recent years (Gradisar, Wolfson et al. 2013). Most of these studies observed effects on melatonin onset, levels, sleepiness and/or sleep quality. In one of the studies, no effects of screen use were observed (Rangtell, Ekstrand et al. 2016). In this study, the effect of reading with a self-luminous tablet or reading an ordinary book for 2 hours during the evening was compared. The 'reading an ordinary book' is an important control group, since it controls for the level of (cognitive) activity performed regardless of light. The authors suggest that the lack of effect in their study might be due to bright light exposure during the day for 6.5 hours (Rangtell, Ekstrand et al. 2016). No control group for prior light exposure was included in any of these studies.

The study by Chang et al. (2015) was the first to investigate repeated exposure (for 5 consecutive days) to an LED illuminated screen on circadian rhythms. Similar to the study by Rangtell et al, reading a book using an iPad® or an ordinary book was compared. However, in this study reading occured for 4 hours before going to sleep and a dark adaptation was included for 2 hours beforehand. Effects were observed on melatonin levels, time to fall asleep, subjective and objective sleep measures and sleepiness levels on the morning after. After 5 days of using the iPad® an average delay of the melatonin rhythm of 1.5 h compared to reading an ordinary book was observed on day 6. – A 1.5-hour delay of circadian rhythm is a very large delay. This shows that LED streetlights which subject residents to blue wavelength light every single night must not be used. This also shows that driving for an hour in the winter from work to home will disrupt circadian rhythms due to the effects of exposure to high blue content LED headlights, LED streetlights and LED floodlights and that these LED lights with blue wavelength light must be removed from our environment.

The study by Figueiro et al. (2016) investigated the effect of self-luminous devices in the evening in a home-setting. Adolescent participants (15-17 years old) were asked to wear orange-tinted glasses for 1 hour or 3 hours before bedtime while using any type of self-luminious device for 3 hours. The orange-tinted glasses blocked exposure to short-wavelength light. Melatonin levels were lower when orange-tinted glases were worn only

during the first hour compared to wearing the glasses during all 3 hours of using the self-luminous devices (Figueiro et al., 2015).

In summary, the available studies indicate that white-light LEDs can have larger influence on the circadian rhythm compared to traditional light sources, due to their different spectral emission pattern. Light sources that emit more short-wavelength light, as do most white LEDs, will have a larger effect on the circadian system at equal intensity, duration and timing and after equal previous light exposure. Recently, however, new LEDs have become available that emit lower levels of short-wavelength light, which might decrease effects in the future when use of these LEDs is more widespread. In addition, it is unclear if the effects on the biological clock remain with repeated exposure as occurs in real life. Furthermore, it is important to note that exposure to light with high levels of short-wavelength during the day might enhance entrainment of the circadian clock and attenuate the effect of evening light exposure. It should be mentioned here that several studies present significant limitations in terms of dosimetry. Finally, it is important to note that most of the research described in this section was conducted on screen use and not on lighting in general. – The SCHEER must explicitly call for the prohibition of LED light sources. It is inappropriate for a scientific committee to rely on market forces to solve public health risks.

6.8.4 Consequences of disturbance of the circadian rhythm by light

The studies described above showed that influence of artificial light sources on the circadian rhythm is dependent on the characteristics of the emitted optical spectral radiance. Several of the LEDs investigated in these studies have a larger effect on circadian rhythms compared to traditional light sources, due to their different spectral emission patterns. Currently, there are no studies that investigated the health consequences of use of LEDs during the evening and night. For negative consequences reported for other artificial light sources, please see Annex V. – Hundreds of studies are now available which show that exposure to LED light is toxic, and it is clear that LEDs must be removed from the outdoor environment.

6.8.5 Vulnerable and susceptible populations

It is known that elderly persons have less robust circadian rhythms (Cornelissen and Otsuka 2016) and might, therefore, be more susceptible to circadian disturbance caused by artificial light in general. In addition, adolescents are known to more often have a late chronotype (Roenneberg, Kuehnle et al. 2007). Combination of a late chronotype with artificial light exposure during the evening might result in enhanced effects on sleep. – The SCHEER must clearly state that the needs of children, adolescents, the elderly, and those with epilepsy, migraines, sleep disorders, autism, PTSD, lupus, diabetes and others are just as important as those in other groups and that government officials must set comfort, health, and safety standards to protect the most vulnerable groups.

6.8.6 Conclusions

The currently available studies indicate that artificial light can influence the circadian system, depending on the light characteristics. Light sources that emit more short-wavelength light, as do some types of LEDs, will have a larger effect on the circadian rhythms at equal optical radiance, duration and timing of exposure. Exposure during the evening might result in changed sleep patterns and other adverse effects, although evidence is limited. Several studies suggest a link between desynchronisation of the biological clock and increased metabolic risk factors. However, it is unclear if chronic artificial evening light can cause these effects. – Studies have proven conclusively that LED light is toxic and an unacceptable risk to human health.

However, the current conclusion is based on a limited amount of studies, which were mostly performed in a laboratory setting. An important question that remains is whether light from LEDs and artificial light in general, present in indoor lighting and screens, will have an effect on the circadian system in real life. Moreover, it is currently unknown if the effects on the circadian system remain, enhance or reduce, after repeated and ultimately after chronic exposure, such as currently occurs in real life. – The Precautionary Principle states that LEDs must not be placed into the environment until it has been shown that they are safe. In 2018, the SCHEER Committee stated that they were unsure if LED light is safe. It is now well understood that LED light is not safe, and therefore should be removed from the environment.

6.9 Temporal Light Modulation (Flicker) and potential health effects

Most light sources operating from the electrical mains tend to have a degree of temporal modulation. However, sources such as incandescent lamps have thermal inertia, which means that the degree of modulation is limited to about 10%. LEDs operated from DC sources will not flicker unless modulation is introduced, for example to increase perceived brightness. LEDs operating from mains supplies (50 Hz in Europe) may have a degree of modulation ranging from less than 10% to 100%. Such modulation may also be introduced by dimming systems. – There is also a type of inherent flicker from the LED chip unrelated to the electronics, sometimes known as flutter.

Flicker is usually used to represent modulation of the light source that can be perceived. Some people are susceptible to photosensitive epilepsy, which may be triggered by light modulation or rapidly changing images. The susceptibility is a function of flicker frequency and possibly the proportion of the field of view occupied by the actual or virtual source (which may include reflections from surfaces). Photosensitive epilepsy has an overall incidence of 1.5/100,000 per year, which increases between the ages of 7 and 19 years, to seven per 100,000 per year (Quirk et al., 1995). Concerns over exposure to flashing images on screens have existed since before the use of LEDs in screen technology (Wilkins et al., 2004). No published studies were identified to suggest increased reporting of symptoms as a result of LED technology. The usual trigger of concern for sufferers of photosensitive epilepsy is strobe-like lighting, as used in entertainment, or as experienced when driving through an avenue of trees with the sun to the side. However, there was one recent case study (Brna and Gordon, 2017) of an adolescent who had symptoms triggered by the multiple flash (to reduce "red eye") from a smart phone camera. – Documented cases of epileptic seizures caused by LED products have been recorded, including cases of seizures caused by non-flashing LED lights.[29] The non-uniform luminance and excessively high peak luminance of LED light is likely the primary cause of these seizures. LED flashing lights have triggered violent, life-threatening seizures.[30]

Under a flicker/strobe rate of about 5 Hz and above about 60 Hz, the proportion of patients with photosensitive epilepsy who this might cause to have an episode is less than 5%, with the peak sensitivity at about 20 Hz (Binnie et al., 2002). – The referenced study does not include non-uniform luminance LED flashing lights and thus cannot be used to determine how many people suffer seizures from LED flashing/strobing lights. The SCHEER must state unequivocally that all people must be protected from seizures and that discrimination of people who suffers seizures from LED flashing/strobing lights is illegal and unacceptable in any public space.

Area lighting operating from the mains may exhibit temporal light modulation (TLM), sometimes referred to as flicker, at 100 Hz (in Europe), which is above the frequency of concern for photosensitive epilepsy. However, depending on the degree of modulation, some people may perceive the flicker, especially in the peripheral field of view. Although no published case-studies were identified, there are claims that a small number of people are very sensitive to TLM at about 100 Hz, triggering symptoms such as headaches, migraine and general malaise. The Figure shows the LED lighting assessed in the home of a patient suffering from migraine and face burning when in the vicinity of Potential risks to human health of their kitchen LED down-lighters. Figure 10 shows the lighting operating at full brightness (100%) and when set to 50% on a dimmer switch. – Flicker up to 10,000 Hz can be detected, although not necessarily consciously, and can create headaches, nausea, loss of concentration, and seizures. The SCHEER must clearly state that people must not be harmed by LED flicker in public spaces.

The Institute of Electrical and Electronics Engineers (IEEE) in the US published the IEEE Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers in 2015 (IEEE, 2015). This document provides a plot of the risk of adverse health effects as a function of frequency and percentage modulation. – The IEEE paper states that the risk of epileptic seizure is very high when the luminance change is greater than 20 nits. LED flashing lights such as on police vehicles is likely in the range of 100,000 to 1,000,000 nits. In addition, LEDs produce square wave flicker with a modulation depth at or near 100%, which is significantly higher than the 5% modulation depth that IEEE states is low risk. In other words, LED flashing lights are exceedingly dangerous.

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[29] https://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=21-02623&CaseSearch=Search

[30] http://www.softlights.org/wp-content/uploads/2022/09/MA-Incident-Report.pdf

As the modulation frequency increases, another effect is likely, called the phantom array, an example of a temporal light artefact. This is often experienced when travelling behind a car at night. If the car has LED brake or other rear lights, a sudden eye movement can result in a series of images of the source. The effect can also be produced when driving past a static source exhibiting TLM, such as LED road studs (cat's eyes). Roberts and Wilkins (2013) showed that phantom arrays can be perceived at modulation rates up to about 2 kHz, and possibly higher under some circumstances for some viewers. It is possible that some of the susceptibility to high frequency (100 Hz and above) TLM may be due to the phantom array, even if the array is not perceived.

A major concern following the introduction of fluorescent lamps in industry was the stroboscopic effect, sometimes referred to the "wagon-wheel" effect, where a rotating object appears static. This was addressed in industry by ensuring that fluorescent lamps were on different phases and/or incandescent task lighting was used. LED lighting can produce the same effect, depending on the degree of modulation. However, of greater concern is the use of modulated LED lighting in domestic and other non-industrial environments where awareness is likely to be low. It is reasonably foreseeable that a rotating food mixer blade could appear stationary when the only illumination source is a modulated LED, or a group of LEDs operating at the same frequency. – Flicker, especially square wave flicker, is unacceptably dangerous.

The International Commission on Illumination organised a workshop in February 2017 to consider the implications of temporal light modulation, and how to quantify both the hazard and the risk (CIE, 2017).

It is possible to operate LEDs from essentially DC power supplies. However, even when the temporal light modulation is assessed for a given LED luminaire, there appears to be no guarantee that similar luminaires, even with the same part number, will be identical (CIBSE, 2016). – LEDs were allowed to proliferate in the environment without protective standards for flicker and now there are millions of dangerous LED products in the environment.

6.9.1 Conclusion

LED lighting can produce a stroboscopic effect, depending on the degree of modulation. The use of modulated LED lighting in domestic and other non-industrial environments where awareness is likely to be low is of a concern. Although no published case studies were identified, there are claims that a small number of people are very sensitive to temporal light modulation at about 100 Hz, triggering symptoms such as headaches, migraine and general malaise. – The number of people being harmed by the LED flicker and LED flashing lights is significant and the impacts of these flickering and flashing lights is serious. The SCHEER must clearly state to government officials that strict regulations are needed for flicker and flashing/strobing of LED products and that these regulations must protect everyone, not just some.

6.10 Exposure and health risk scenarios

• Exposure situations in various indoor LED lighting settings

Many people spend significant proportions of the day and evening (and possibly night) staring at screens, which may be LED illuminated. Television screens tend to be viewed at distances of 1 metre or more, computer screens at about 50 cm and tablets or phones viewed at closer distances. There are also applications where a dedicated screen or a smartphone may be viewed within a few centimetres, for example in virtual reality headsets. O'Hagan et al. (2016) assessed the emissions from various screens and concluded that exposure levels were less than 10% of the ICNIRP blue light exposure limit, even for extended use durations. Since the assessment was carried out in terms of source radiance, the assessment conclusion was made independent of viewing distance. – Remove "possibly" from the phrase "possibly at night" – The updated SCHEER report must provide the ICNIRP exposure radiance limits.

The blue light photochemical retinal hazard to the eye from domestic LED lighting is between 10-20% (compared with 14% for a mid-range incandescent lamp) of the relevant ICNIRP exposure limit, assuming viewing longer than about 3 hours) (O'Hagan et al., 2016). – ICNIRP has not yet admitted that LEDs emit non-uniform luminance and ICNIRP is an industry front group whose reports are biased.

Exposure situations in various outdoor LED lighting settings (streets) Many street lights and other street fixtures are being converted to, or replaced with, LED lighting. The main driver for this is energy saving. However, if this factor alone is considered, there are claims that LED lighting may be installed that is poor quality in terms of the emission spectrum, illumination, light pattern and glare. – The claims of "poor quality" are true, and the result is that LEDs do not "save" energy and cannot be claimed to be energy efficient. LED streetlights reduce the cost of operation reducing the quality of the light to unsafe levels. The claim by utility companies that LED streetlights are energy efficient is not supported by the facts.

Correlated colour temperature (CCT) is a measure of the blueness of an optical radiation source: the higher the CCT, the more blue-rich the source is. CCT is the temperature of a Planckian radiator that is the closest match to the emission of the source (CIE, 2011). The CCT of LED street lighting varies from about 7000 K down to about 2700 K. When compared with the sodium lamps that many LED street lights are replacing, the high CCT installations can appear harsh and almost equivalent to daylight. Moonlight has a CCT of about 4000 K, so it could be argued that artificial street lighting should not exceed this value. However, it is important that the lighting installation is appropriate for the use of the road (e.g., motorways may justify higher CCT lighting than residential roads). –There is only one moon, it is very far away and is reflected light from the spherical source sun which emits spatially uniform energy. The lunar cycles are closely synchronized with human sleep.[31] A comparison of the CCT of the moon, which is reflecting sunlight, and the spectral power distribution of an LED streetlight that is shining spatially non-uniform light from only a few meters away is not justifiable. The addition of dozens of LED streetlights and

[31] https://advances.sciencemag.org/content/7/5/eabe0465

floodlights within a given viewing area, situated very close to the viewer, with non-uniform luminance and high contrast in comparison to the natural night has dramatic adverse effects on human sleep and ecological systems. LED streetlights cause unacceptable damage to the natural night resource.

Glare can occur from two main scenarios: the luminance may be too high or the luminance ratios are too high (IES, 2011). Unless it is the purpose of the source, it is good lighting practice to ensure that the source is diffused or shielded from direct viewing to avoid glare. Some LED street lights have exposed LED elements that can be seen by road users within their normal field of view, such as when they are looking ahead. Such sources may contribute to discomfort glare (IES, 2011). Where the LED elements were recessed or diffused in order to reduce the luminance, such concerns were not reported. – There are likely millions of LED streetlights without diffusion and with dangerous high glare. The IES never published standards guide for the installation of non-uniform luminance LED streetlights. Who is responsible for the failure to protect the public from this glare?

Vehicle LED lights, and particularly daylight running lights and headlights, can be a source of either discomfort glare or disability glare. The latter is due to scattering of the light in the eye and in the environment, and is more prevalent for sources emitting high levels of blue light and for older observers. The sources may also produce a higher level of glare during fog. No references were identified with quantified assessments of these issues. – Over 30,000 people have signed a petition to ban blinding LED headlights. In the USA, no vehicle manufacturer applied to the National Highway Traffic Safety Administration for approval to use LED headlights or daytime running lights and no standards for flat surface LED source has been published. No vehicle on US roads that uses LED lighting complies with USA federal safety regulations. A small flat chip source is the worst possible case for the creation of glare, due to the high luminance and the exponential increase in glare that this causes. LED headlights and daytime running lights are unsafe and LEDs are not fit for use as vehicle headlights.

6.11 Overall conclusion:

The SCHEER concludes that there is no evidence of direct adverse health effects from LEDs in normal use (lighting and displays) by the general healthy population. Some people report that they are sensitive to temporal light modulation from LEDs. – This conclusion is not supported by the preceding paragraphs. The updated SCHEER report must definitively state that LEDs are toxic, dangerous, and discriminatory.

Children have a higher sensitivity to blue light and although emissions may not be harmful, blue LEDs (between 400 nm and 500 nm) may be very dazzling and may induce photochemical retinopathy, which is a concern especially for children below three years of age. Older people may experience discomfort with exposure to light that is rich in blue light. – The separation of the undefined "general healthy population" and "children" and "older people" is not justifiable. Each of us travels through these different age groups, so everyone is adversely impacted by LED light during different phases of life. The SCHEER must make it absolutely clear in the updated report that LEDs are unacceptably dangerous.

Either discomfort glare or disability glare can be temporarily caused by vehicle LED lights, and particularly daylight running lights and headlights. – LED headlights are dangerous. An LED is an unacceptable device for a headlight or daytime running light due to excessive glare and non-uniform illumination.

Light sources that emit more short-wavelength light, as do some types of LEDs, will have a larger effect on the circadian rhythms at equal optical radiance, duration and timing of exposure. At the moment, it is not yet clear if this disturbance of the circadian system leads to adverse health effects. – The phrase "some types of LEDs" should be replaced with "most types of LEDs". The large body of evidence leaves no doubt that LED light disrupts circadian rhythms which translates into a high probability of disease.

7. RECOMMENDATIONS FOR FUTURE WORK

The review of the published research conducted by the SCHEER has led to valuable conclusions and identified certain gaps in knowledge on potential risks to human health from LEDs. These gaps could be partially filled if further research is carried out to elucidate unresolved problems as follows:

Effect on the eyes

There is insufficient knowledge about the actual exposure of people to optical radiation from LED sources and the total exposure from all optical radiation sources – information about the exposure of the general healthy population is needed for assessing the potential health effects. It is suggested that the exposure assessments should consider different age groups, i.e. babies, young children, adolescents and adults into old age. – The body of research and collection of epidemiological data shows conclusively that exposure to blue wavelength LED light is highly toxic for the eyes for both acute and cumulative exposures.

It was recognised that early-to-market LED lamps had a significant blue emission. Further research is going into improving LED lamps to make them similar to traditional types of lighting, such as incandescent lamps. The current EN 62471 standard does not take account of population groups particularly sensitive to blue light, hence there are no specific recommendations for population groups whose natural mechanisms for filtering blue light are diminished (children, aphakics and pseudophakics). However, it is recognised that the exposure of the general population to optical radiation from LEDs is likely to be insignificant compared with the exposure to natural light outdoors, but any additional health burden needs to be considered. – The statement that the exposure of the undefined "general population" to optical radiation from LES is likely to be insignificant compared to exposure to natural light outdoors is unjustifiable. The blue light in the sky is the result of spatially uniform light from the sun scattering in a diffuse manner. This is not at all similar to powerful blue wavelength light which is spatially non-uniform and not diffuse, directed straight into the eye. In addition, the addition of blue wavelength light into the natural night resource is dangerous. The only blue wavelength light at night should be from the stars and reflected moonlight. Artificial light containing blue wavelengths is dangerous.

High luminance, temporal light modulation, phantom array and stroboscopic effects are other factors relevant to risk assessment that need to be addressed in further studies. In particular, are some population groups particularly susceptible to modulated emissions from LED lamps, either due to the design of the LED drive circuit or through the use of dimming circuits? The use of high luminance vehicle lighting should be investigated to determine if there are potential adverse consequences for increased accident rates. – The research and data prove that LED flicker and high luminance has serious adverse consequences.

Cumulative exposure over a twenty-four hour time period should be considered, and further research should be done into the reported effects of long-term, low-level exposure on age-related macular degeneration. – Cumulative exposure results in irreversible eye damage. Blue wavelength sources of light must be removed from the natural night environment.

Effects on healthy skin

Depth of skin penetration is primarily dependent upon the wavelength of the optical radiation. Research should be carried out on heat effects on the skin and the relation to skin cancer, if the use of infrared saunas/warming cabinets incorporating infrared LED sources are established. In addition, exposure and dose levels for the induction of effects for patients with certain photo dermatoses should be investigated.

Circadian system

An important question is whether optical radiation from LEDs, and artificial light in general, which is present in indoor lighting and screens, will have an effect on the circadian system in real life. Research will need to consider the wavelengths of emission, time of day and duration of exposure, any confounding factors, such as the activity being carried out, prior light history and the age of subjects. Secondly, it is not yet known if the effects on the circadian system remain the same, accumulate or decrease after repeated and/or chronic exposure, such as currently occurs in real life. Moreover, it remains to be investigated if the potential disturbance of the circadian system, caused by LEDs and/or artificial light, is related to negative health effects, as appear to occur due to other circadian disturbances such as shift work. – LED light disrupts the circadian rhythm with significant negative health impacts and increases in disease.

8. CONSIDERATION OF THE RESPONSES RECEIVED DURING THE CONSULTATION PROCESS

A public consultation on this Opinion was opened on the website of the Scientific Committees from 19 July to 17 September 2017. Information about the public consultation was broadly communicated to national authorities, international organisations and other stakeholders.

84 contributors (providing nearly 300 comments and 22 documents) participated in the public consultation providing input to different chapters and subchapters of the Opinion. The vast majority of comments came from the industry. –

Each submission was carefully considered by the SCHEER and the Opinion has been revised to take account of relevant comments. The literature has been accordingly updated with relevant publications. Some commentators recommended editorial changes to make the Opinion and its basis clearer.

The text of the comments received and the response provided by the SCHEER is available at: **https://ec.europa.eu/health/scientific_committees/consultations/public_consultations/scheer_consultation_05_en**

- This document summarizes an additional four years of data collection and research that confirms all of the SCHEERS concerns about the hazards of LED light.

Recommendations

Based on the evidence provided in this document, we recommend that the European Commission take action to protect the public comfort, health, and safety from the harms of flat surface LED light. The use of artificial light has multiple purposes, including indoor illumination, outdoor illumination, personal displays, large displays, warning, and indicator. Thus, there should be separate regulations depending on the application.

While it is beyond the scope of this document to specify regulations for LED products, we can offer a general starting point.

Illumination

Spatial – No more than 2% difference in radiance level at any point in space.

Spectral – The radiance level at 400-450nm (violet-blue) shall be less than or equal to the radiance level of 480-500nm (cyan) and 555nm (green). The radiance level of 680nm (red) shall be at least 80% of 555nm (green).

Temporal – Flicker modulation percent shall be no greater than 7% at 60Hz, 100Hz, 1000Hz, and 10,000Hz.

Display

Luminance – Maximum of 300 nits.

Warning

Spatial – No more than 2% difference in radiance level at any point in space.

Luminance – Maximum of 300 nits.

Temporal – Flashing modulation percent shall be no greater than 7% at 0.5 Hz, 1Hz, 3 Hz, 5Hz

Indicator

Luminance – Maximum of 10 nits.

Conclusion

The precautionary principle states that if a product, an action, or a policy has a suspected risk of causing harm to the public or to the environment, protective action should be supported before there is complete scientific proof of a risk.[32] While the SCHEER raised multiple questions about the adverse impacts of LED light, the SCHEER's report did not strongly advise proper regulation of LED products. Instead, the SCHEER wrote, "*The SCHEER concludes that there is no evidence of direct adverse health effects from LEDs in normal use (lighting and displays) by the general healthy population.*" As we know from this document, the SCHEER's conclusion was wrong, and the SCHEER did not abide by the precautionary principle in making their conclusion.

[32] https://www.sciencedirect.com/topics/earth-and-planetary-sciences/precautionary-principle

Thus, today we have billions of LED emitters in the environment that are known to be toxic, dangerous, and discriminatory which must now be removed to protect the comfort, health, and safety of the public and the entire ecosystem. We urge that the European Commission adopt strict regulation of the spatial, spectral, and temporal properties of LED products on par with, or exceeding, the regulations for laser products.

Respectfully Submitted,
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