Soft Lights Foundation

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BY EMAIL

Celia Sher, General Counsel
Department of Energy
Celia.Sher@hq.doe.gov

Re: Regulation of Visible Radiation

Dear Celia Sher,

The Soft Lights Foundation was notified that the Department of Energy is considering setting 45 lumens per watt as the backstop requirement for General Service Lamps.[1] In the proposal, *DEPARTMENT OF ENERGY, 10 CFR Part 430, EERE-2021-BT-STD-0005, RIN 1904-AF09, Energy Conservation Program: Backstop Requirement for General Service Lamps*, we note a fundamental misapplication of the definition of *energy efficiency* and an incorrect assignment of Light Emitting Diodes into the category of General Service Lighting. We further note that the DOE document contains no information from the US Access Board or discussion of the Americans with Disabilities Act. In this document we will show:

- **Setting an energy efficiency standard for a single visible radiation emitter does not lead to overall reduced energy use.**
- **LEDs do not qualify as a General Service Lighting device.**
- **LEDs are not energy efficient because they don't do the same job.**
- **LED radiation devices are discriminatory.**
- **LED radiation devices are damaging the natural night resource.**

Radiation Categories

The Soft Lights Foundation has contacted numerous federal agencies to determine which federal agency regulates radiation in the human-visible portion of the electromagnetic spectrum. We have concluded that no federal agency is regulating the radiation in the visible part of the spectrum. This oversight leaves a dangerous hole in the government's regulation of electromagnetic radiation. We have already submitted a request to the Environmental Protection Agency that the EPA regulate visible radiation as part of their regular duties in the Office of Air and Radiation.

[1] https://www.energy.gov/sites/default/files/2021-12/gsl-backstop-nopr.pdf

Figure 1 shows the categorization of radiation. The regulatory meaning of light is confined to spatially isotropic radiation from a spherical emitter in the human-visible portion of the electromagnetic spectrum. Historically, spatially isotropic light has not been treated as radiation for regulatory purposes. However, we now know that artificial light is a toxic and hazardous substance that damages the natural night resource and has significant impacts on the human hormonal and nervous system, and therefore must be regulated.

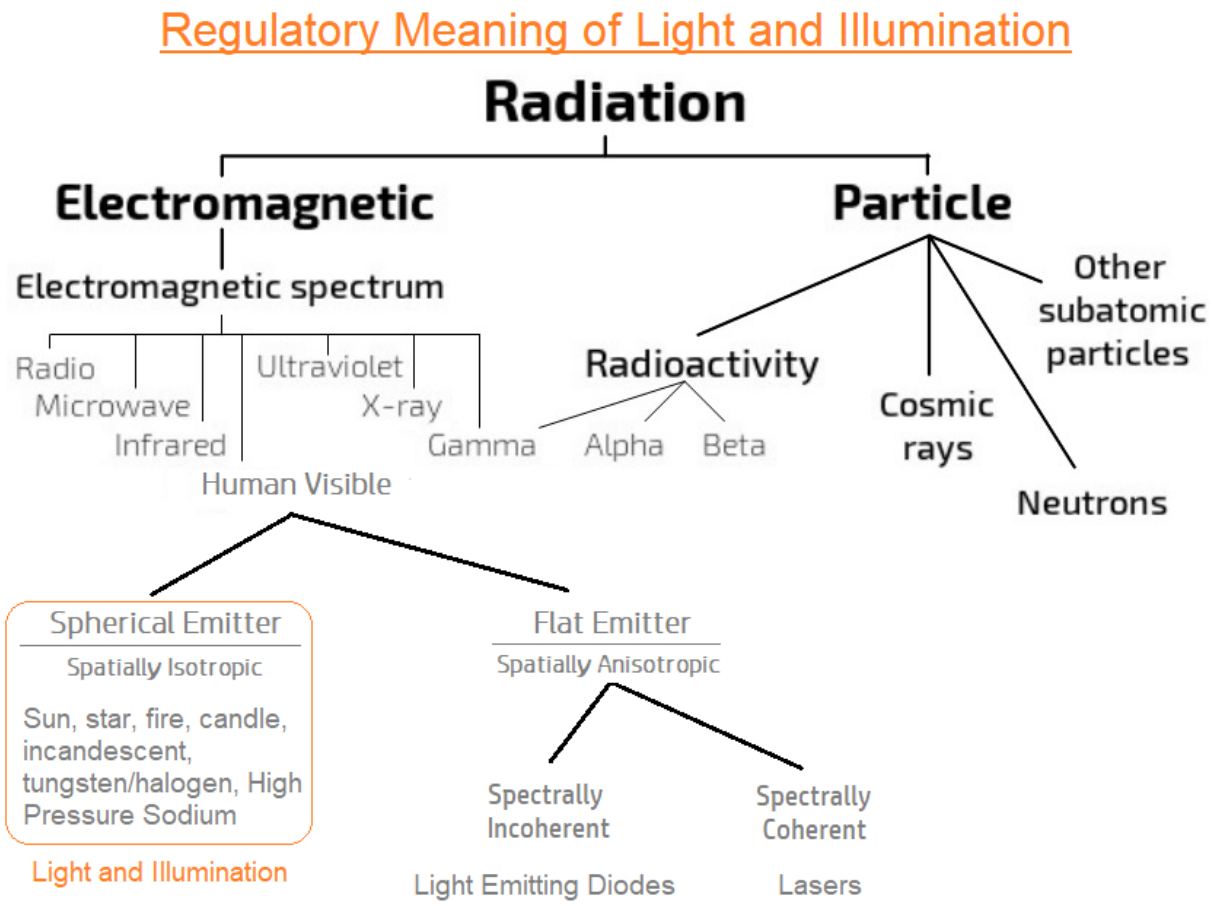


Figure 1 - Categorization of Radiation

In addition, Figure 1 shows that spatially anisotropic visible radiation from flat surface emitters must also be regulated. Whereas spectrally coherent, spatially anisotropic visible radiation (e.g., lasers) is regulated by certain government agencies such as the FAA, spectrally incoherent, spatially anisotropic radiation from flat surfaces (e.g., Light Emitting Diodes) is entirely unregulated by the federal government, and yet this radiation is highly toxic for everything in the environment.

What is the regulatory definition of light?

1. **The natural agent that stimulates sight and makes things visible.** [2]

[2] https://www.lexico.com/en/definition/light

Visible light is electromagnetic radiation whose wavelength falls within the range to which the human retina responds, i.e., between about 390 nm (violet light) and 740 nm (red). White light consists of a roughly equal mixture of all visible wavelengths, which can be separated to yield the colors of the spectrum, as was first demonstrated conclusively by Newton. In the 20th century it has become apparent that light consists of energy quanta called photons that behave partly like waves and partly like particles. The velocity of light in a vacuum is 299,792 km per second. Example: 'the light of the sun'

2. **A source of illumination, especially an electric lamp.** [3] Example: 'a light came on in his room'

Both Definition 1 and Definition 2 are from the same source but note that Definition 1 uses the words "natural agent", while Definition 2 focuses on an artificial source called an electric lamp. For consistency, Definition 1 and Definition 2 can be reconciled by understanding that the "natural agent" refers to spatially isotropic radiation from a spherical emitter in the human-visible portion of the electromagnetic spectrum, and that an electric lamp must produce this natural agent to be considered a source of illumination.

3. Electromagnetic radiation that can be detected by the human eye.[4]

Definition 3 acknowledges that there is a spectrum called electromagnetic radiation, but that only the radiation that is detected by a human can would qualify as light. Electromagnetic radiation such as x-rays, microwaves and radio waves would not qualify as light because the human eye and brain are not evolved to detect those frequencies.

4. A device for producing illumination or the illumination produced by the device.[5]

Definition 4 is from a law website. We see again the reference to illumination

What is the regulatory definition of illumination?

1. The luminous flux per unit area on an intercepting surface at any given point[6]

Definition 1 defines illumination as photons landing on a surface. This definition would seem to preclude lasers and LEDs because of the dense, spatially anisotropic shape of that radiation. Perhaps a laser or LED could be uniformly illuminating an area of 1 square femtometer, but at human scale, a laser or LED does not uniformly illuminate the surfaces of a room.

2. Lighting or light. Example: 'higher levels of illumination are needed for reading'

Definition 2 refers us back to the definition of light.

The key issue here is: What does it mean to illuminate an object with light? It is very clear from the definitions above that particle radiation is not considered to be light, and that only electromagnetic

[3] https://www.lexico.com/en/definition/light
[4] https://www.britannica.com/science/light/The-electromagnetic-spectrum
[5] https://www.lawinsider.com/dictionary/light
[6] https://www.merriam-webster.com/dictionary/illumination

radiation can be defined as light. It is also clear that the definition of light is directly related to the receptors in the human eye and the nerve connections to the human brain. Therefore, microwaves, ultraviolet, and gamma rays are not regulated as light. Finally, the concept of illumination is also connected to human perception which is evolutionarily designed to receive spatially uniform visible radiation such that a room or space would reflect light with uniform spatial energy. On the other hand, spatially anisotropic visible radiation from a flat surface would cause the brain to have to interpret different spatial, spectral, and temporal characteristics of the visible radiation at the same time, which leads to reactions ranging from discomfort and agitation to migraine and seizure.

Therefore, the conclusion is that for the purposes of regulation, light and illumination refer to spatially isotropic radiation from a spherical emitter in the human-visible portion of the electromagnetic spectrum. Lasers and LEDs do not emit the regulatory meaning of light, but rather emit spatially anisotropic visible radiation from a flat surface which is not suitable for the task of illumination.

Spherical Emitter vs. Flat Emitter

Figure 2 shows the angular distribution of radiation within space.

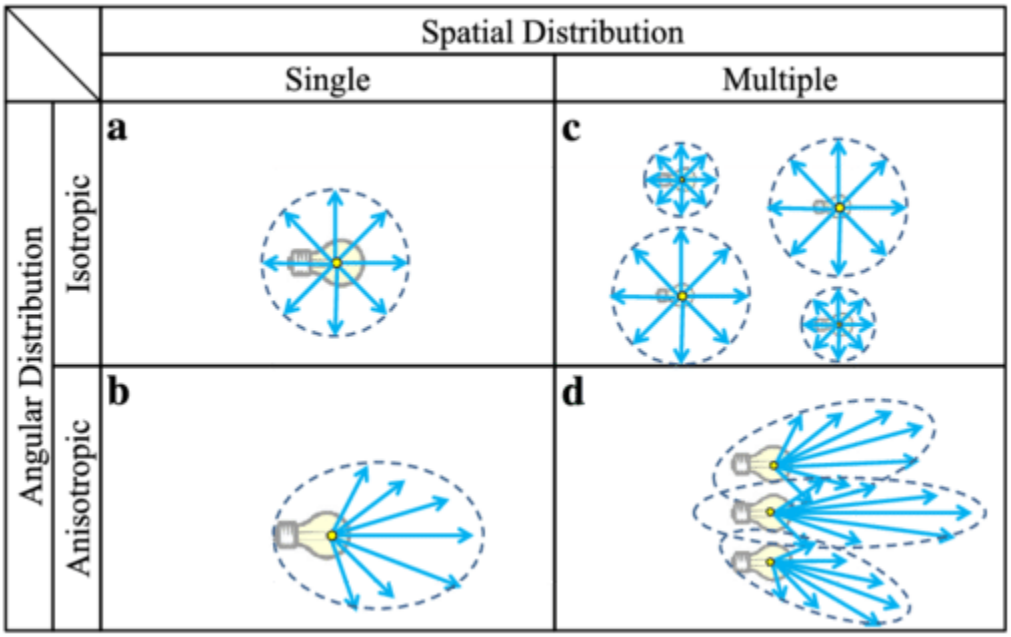


Figure 2 - Angular Distribution of Radiation[7]

Box (a) shows a typical natural light source such as the sun or an incandescent light, which are essentially spherical emitters. Box (c) shows multiple sources of the same uniform radiation. Notice how the blue arrows are each the same length, indicating uniform radiation energy.

[7] https://www.researchgate.net/figure/Categorization-of-light-field-models-a-Isotropic-point-light-source-b-Anisotropic-point_fig1_316007965

Box (b) shows a radiation source emitting radiation from a spherical emitter of different energies, depending on the angle. This can be accomplished with lensing. Box (d) is an example of multiple spherical emitter sources with lensing.

Boxes (b) and (d) can also be used to describe the radiation from a flat LED chip. Box (b) is similar to the photons escaping a hole at different angles. Box (d) is similar to multiple holes emitting photons across the surface of the flat chip. Notice how the blue arrows will eventually overlap. For a flat LED chip, the resulting shape is a Lambertian, where the peak radiance will be at the center of the chip, and the energies at different angles from 0 to 90 degrees will correspond to Lambert's Cosine Law.[8] Figure 3 shows the intensity of spatially anisotropic LED radiation on a normalized scale. Note how the intensity is non-uniform, with the greatest intensity being in the center of the LED chip. **For LEDs that emit visible radiation from a flat surface, this intensity is currently unregulated by any agency of federal government.**

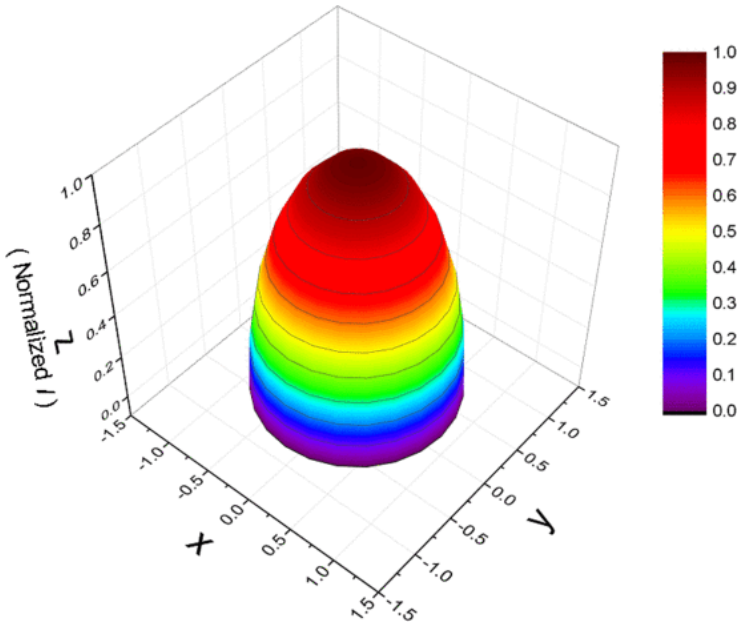


Figure 3 - LED Radiation Profile[9]

With lensing, a spatially isotropic light source can be directed such that it becomes a spatially anisotropic source. A person looking at this light would notice the increased intensity if the light were focused. The difference between lensing a spatially isotropic spherical emitter source, and the lensing-type action of overlapping rays from an LED chip is that the flat surface of the chip creates a radiance profile and peak radiance that cannot be achieved through typical lensing. The intense peak radiance and the large changes of radiance at tiny angles due to the flat surface emitter are an entirely new phenomenon that is unregulated by the government.

[8] https://ieeexplore.ieee.org/document/8879542
[9] https://ieeexplore.ieee.org/document/8879542

Energy Efficiency

As stated on the DOE's Energy Star website, "*Simply put, energy efficiency means using less energy to get the same job done.*"[10] To be energy efficient, a technology must provide the same quality of service and perform the same task as the previous technology. The task in this situation is to provide *light* and uniform illumination while using less energy and not causing harm. Since LEDs do not emit spatially isotropic radiation from a spherical emitter, LEDs are not illumination devices, as the radiation that LEDs emit is not uniform and is extremely dense. Instead, LEDs emit spatially anisotropic visible radiation from a flat surface that is sending people to the hospital, causing eye damage, and violating civil rights.

Figure 4 is a table from the Underwriters Laboratories showing the power conversion for "white" light sources. According to the table, an LED radiation device is twice as efficient as an incandescent light bulb at converting power to visible light. If power conversion to visible light was the only criteria for determining energy efficiency, we might say that LEDs are twice as efficient as incandescent. However, as noted by the DOE, it's not just a matter of using less energy, but using less energy to get the same job done. Since the task is to provide uniform light and illumination, LEDs cannot be quantified as being energy efficient when compared with incandescent because LEDs produce extremely dense, spatially anisotropic, non-uniform light and illumination, which happens to be toxic for humans.

Figure 4 shows that LEDs are about half as efficient as fluorescent and metal halide at converting power to visible light, so the DOE should prohibit conversion of fluorescent or metal halide to LED because LEDs would not save energy.

Power Conversion for "White" Light Sources

	Incandescent† (60W)	Fluorescent† (Typical linear CW)	Metal Halide‡	LED
Visible Light	7.5 %	21 %	27 %	10-15 %
Infrared	73.3 %	37 %	17 %	~ 0 %
Ultraviolet	0 %	0 %	19 %	0 %
Total Radiant Energy	80.8 %	58 %	63 %	10-15 %
Heat (Conduction + Convection)	19.2 %	42 %	37 %	85-90 %
Total	100 %	100 %	100 %	100 %

† IESNA Lighting Handbook, 9th Ed. ‡ Osram Sylvania

Underwriters Laboratories

35

Figure 4 - Power Conversion[11]

[10] https://www.energystar.gov/about/about_energy_efficiency

[11] https://alamembers.com/DesktopModules/EasyDNNNews/DocumentDownload.ashx?portalid=1&moduleid=1059&articleid=232&documentid=42

Figure 5 shows the luminous efficacy for several spatially isotropic, spherical emitters of light.

Spatially Isotropic Visible Light Sources

Light Type	Average Typical Luminous Efficiacy (lumens/watt)
Incandescent	15 lm/W
Halogen	20 lm/W
Fluorescent	60 lm/W
Metal Halide	87.5 lm/W
High pressure sodium	117.5 lm/W
Low pressure sodium	150 lm/W
Mercury vapor	50 lm/W

Figure 5 - Luminous Efficacy[12]

While each of the light types shown in Figure 5 has different spatial, spectral, and temporal characteristics, each of the light sources emits generally spatially isotropic, uniform energies from a spherical source. LEDs, on the other hand, are not included in Figure 5 because LEDs produce a different substance which is spatially anisotropic from a flat surface which is very dense at the center. For the purposes of comparing energy efficiencies, we can only compare emitters that perform the same task of providing uniform light and illumination.

The luminous efficacy of LEDs is in approximately 100 lumens/watt, depending on the characteristics of the LED and the year in which the LED was created.[13] The energy efficiency of LED is similar to High Pressure Sodium, but less than Low Pressure Sodium. What we cannot say is that LED are "more efficient" than incandescent or fluorescent or HPS because LEDs do not provide the uniform illumination that is the required task. The DOE should prohibit the conversion of HPS to LED.

General Service Lamps

Once we understand that the regulatory meaning of light is spatially isotropic radiation from a spherical emitter in the human-visible part of the electromagnetic spectrum, an LED radiation device cannot be categorized as a General Service Lamp because LEDs emit spatially anisotropic visible

[12] https://www.eledlights.com/blog/post/how-to-compare-light-output-fluorescent-led-metal-halide/
[13] https://www.osti.gov/pages/servlets/purl/1421610

radiation from a flat surface which does not adhere to the regulatory meanings of light and illumination. **DOE must remove LEDs from the GSL category.**

Energy Use

If the goal of setting an energy efficiency backstop of 45 lumens per watt for all General Service Lamps is to reduce overall energy use and decrease overall carbon emissions, the goal will not be met because the policy of a minimum of 45 lumens/watt per device ignores the total number of devices, ignores the duration that each device is used, and ignores whether such a device is safe for humans and the natural night resource.

For example, if a street has 5 luminaires with incandescent light bulbs, each using 100 watts for 12 hours per night, then the total energy use is 5 x 100 x 12 = 6,000 watt-hours of energy.[14] If 50-watt incandescent bulbs were installed into the same 5 luminaires, then the total energy use would be only 3,000 watt-hours of energy, even though the devices themselves had the same energy efficiency of approximately 16 lumens per watt.

If we install 100-watt High Pressure Sodium, we will again use 6,000 watt-hours of energy. If we use 50-watt HPS, we will use 3,000 watt-hours of energy. However, because the energy efficiency of HPS is approximately 120 lumens/watt, the illuminated area will be brighter than the same area lit with incandescent because the device will be emitting more lumens for the same amount of energy. Therefore, to keep our comparisons the same, we would use 6-watt HPS to provide the same illumination as incandescent but using much less energy.

On the other hand, if we install 6-watt LED radiation devices rated at the same 120 lumens/watt as HPS, the LED radiation devices would use the same total amount of energy as HPS. The issue here, though, is that the illumination is no longer uniform, and LED does not emit the regulatory meaning of light, and thus the visible radiation that is emitted is not performing the task of uniform illumination. We cannot say that LEDs are more efficient or less efficient than incandescent or HPS. We can only say that LEDs emit a type of visible electromagnetic radiation from a flat surface.

In addition, if we install more LEDs in our attempt to more closely approximate uniform illumination, or if we increase the number of LEDs because we suddenly wish to add rainbow colors to the night, we will increase our total energy use. On the other hand, if we only operate the incandescent lights for 6 hours per night instead of 12 hours per night, we will save 50% in total energy use, without having to change technologies.

Therefore, the idea of setting 45 lumens per watt as a minimum efficiency standard will not help the goal of reducing total energy use because the standard does not include the total number of emitters nor the total duration the emitters are used. **The DOE must set a standard for total energy use**.

[14] https://energyeducation.ca/encyclopedia/Energy_vs_power

Visible Radiation Pollution

The explosion in the number of LED radiation emitters has led to severe damage to the natural night resource. If the goal of switching to LED radiation devices, and away from incandescent lights, was to save energy, then not only was that goal not achieved, but the consequence of the switch to LED technology caused a massive increase in visible radiation pollution and associated negative health and environmental effects.

Figure 6 shows LED streetlights in Lee County, Florida. These LED radiation devices are toxic, hazardous, and discriminatory, causing injury to plants, animals, insects, amphibians, fish, and humans. The natural night is a resource that must be protected. The Soft Lights Foundation has requested that the EPA regulate and protect the natural night resource, just as the EPA currently protects water and air.

Figure 6 - LED Streetlights

Figure 7 shows a typical over-lit urban street. We note that this photo shows a crime scene where someone was shot. The bright streetlights and gas station lights did not make the area safer. Upon inspection on the photo, we can see the toxic visible radiation from the streetlights, the gas station, the police vehicles, street signals, and office buildings.

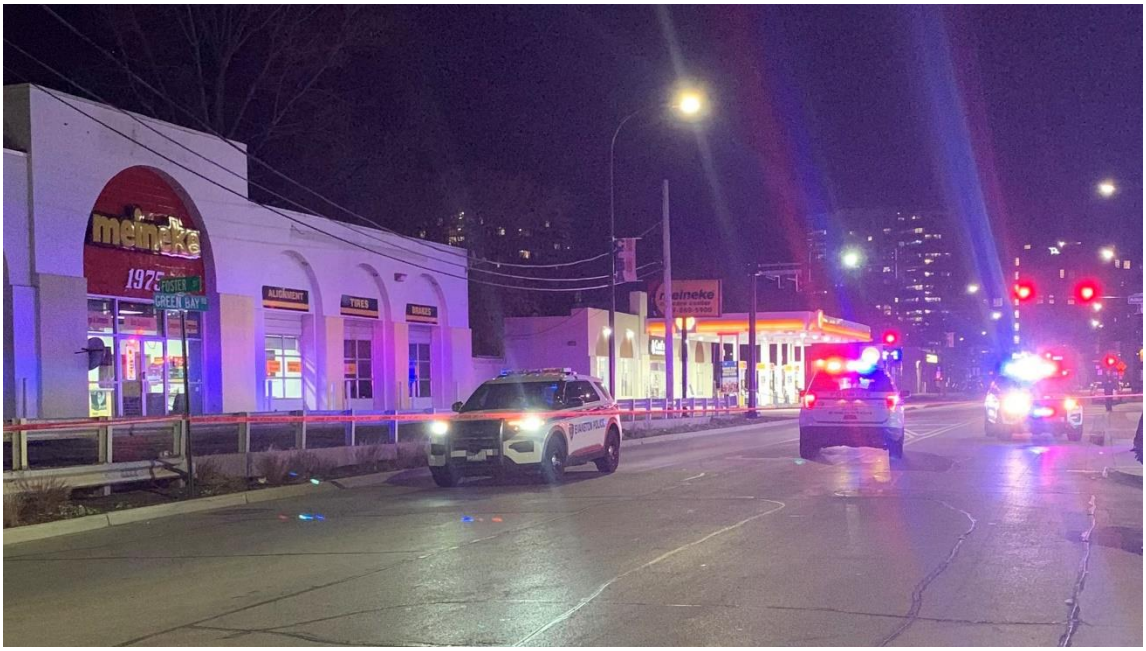


Figure 7 - Urban Street at Night[15]

The DOE must collaborate with the EPA to reduce energy use, regulate visible radiation, and protect the natural night resource.

Harm to Eyes

As an example of how dangerous LED radiation is for the eye, consider this warning shown in Figure 8 from the company Gear Light.

Figure 8 - LED Flashlight

[15] https://wgntv.com/news/chicagocrime/1-killed-at-least-4-wounded-in-evanston-shooting-near-gas-station/

To our knowledge, there are no ocular exposure standards for LEDs. In his 2009 presentation, Senior Engineer Michael Shulman of Underwriters Laboratories wrote, "Currently, neither the U.S. nor Canada have mandatory standards or regulations for ocular exposure to LEDs emitting incoherent visible light."[16] In the research article, titled Light Emitting Diode Induced Retinal Damage[17] the authors state, "*Excessive LED light exposure presents a potential hazard to retinal function.*"

Discrimination

There are several significant federal laws that protect civil rights and prohibit discrimination. These laws include the 14th Amendment of the US Constitution which guarantees the right to liberty[18], the Enforcement Act of 1871 which makes government liable for deprivation of civil liberties[19], the Rehabilitation Act of 1973 which addresses the notion of equal access for all[20], and the Americans with Disabilities Act prohibits discrimination against persons with disabilities, including anything that prevents seeing, thinking, or concentrating.[21] LED radiation violates civil liberties by interfering with the human nervous system, preventing people from seeing, thinking, concentrating, and communicating. LED radiation devices violate these federal laws.

Fluorescent, Compact Fluorescent, and LED radiation devices have spatial, spectral, and temporal characteristics that cause seizures, migraines, nausea, and other harms to certain individuals, typically classified as Risk Group 3. While a compact fluorescent may produce 60 lumens per watt and a fluorescent tube may produce 90 lumens per watt and an LED may produce 120 lumens per watt, the efficiency is irrelevant if the visible radiation makes people sick or interferes with their ability to perform their job at work.

People in Risk Group 3 (those with epilepsy, autism, migraines, photophobia, etc.) are often purposely ignored during the research, invalidating results that might have shown that LEDs are safe. Because the luminance and radiance of LEDs can be exceedingly dense, LEDs are causing eye damage, pain, nausea, psychological trauma, seizures, migraines, loss of vision, distraction, vehicle crashes, and thoughts of suicide.

Here are a few quotes about LEDs from people who have epilepsy.[22]

"...in the brief moment before my brain reacts, the worst LEDs look like a spray of strobing needles"

[16] https://alamembers.com/DesktopModules/EasyDNNNews/DocumentDownload.ashx?portalid=1&moduleid=1059&articleid=232&documentid=42
[17] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5313540/
[18] https://www.constituteproject.org/constitution/United_States_of_America_1992
[19] http://www.antibiaslaw.com/list/enforcement-act-of-1871#n2953
[20] https://www.eeoc.gov/statutes/rehabilitation-act-1973
[21] https://www.law.cornell.edu/uscode/text/42/12102
[22] http://www.softlights.org/wp-content/uploads/2021/11/Quotes-from-adversely-affected-individuals.pdf

"When exposed to LED light sources I experience nausea, vertigo, anomia and sometimes migraine-like, pounding headaches combined with a feeling of reality loss...certain streetlights or LED panels induce very fierce symptoms after only a short exposure.".

"I had no previous health conditions, optical sensitivity or problems with headaches...Bright blueish LEDs also make me feel agitated and nauseous. I'm perfectly well if I stay away from these lights, but that means staying away from my children's school, the health center and hospital, most churches and meeting houses, libraries...much of life as I knew it."

"This situation has recently gotten a lot worse with the introduction of LED street lighting...which causes the worst pain yet."

The DOE must collaborate with the U.S. Access Board on any proposal that includes the use of artificial visible radiation devices to ensure that such devices do not discriminate.

Responses to Proposal

In this section, we address specific quotes within the DOE proposal.

Page 51: While this assessment represents DOE's best effort to analyze the effects of this rule, there are areas where more information would be helpful to DOE as it considers potentially refining the analysis. They are: (1) whether DOE should consider a rebound effect (such as 10%) associated with the purchase of more efficient products; (2) whether there are consumer welfare losses associated with those consumers who prefer incandescent or halogen bulbs to LED bulbs even after taking into account steep price decline in LED bulbs and the energy savings that would accrue to them;

(1) The rebound effect is very real and far greater than 10%. Instead of replacing one incandescent bulb with one LED, consumers, businesses, and governments have replaced one incandescent bulb, with several, or tens, or hundreds of emitters. Visible radiation devices are now everywhere.

Figure 9 shows a house on the left with a single incandescent porch light. The house on the right shows multiple emitters. For protection of human health and protection of the natural night resource, the single incandescent porch light is vastly superior.

Figure 9 - Porch Lights

Figure 10 shows a bridge on the left with a several incandescent lights, providing functional illumination. The bridge on the right shows LED lighting, wasting energy and damaging the natural night resource.

Figure 10 - Bridges at Night

Figure 11 shows a living room on the left with two emitters, providing high quality illumination. The living room on the right shows over 20 emitters with poor quality illumination.

Figure 11 - Living Rooms

(2) The consumer welfare loss related a switch from incandescent and halogen illumination devices to LED radiation devices is massive. The issue isn't just about consumer preference. It's about health

and safety. It's about being able to leave one's house versus being trapped inside. It's about being subjected to a toxic radiation device versus having one's room uniformly illuminated. Here are several quotes from people who have suffered the effects of LED radiation.[23]

Migraines - *"... no longer able to cycle, walk or drive wherever LED streetlights are installed as they instantaneously trigger bad headaches...which quickly develop into disabling migraines, including dizziness, not being able to think straight, some loss of coordination, and a general inability to function... symptoms lasting more than a day."*

Autism – *"I was being tortured by car headlights and daytime running lights, by flood lights, by streetlights, by flashing lights on police cars and utility trucks. Every single day had become a terrifying day. I learned that these are called LED lights and they have a color temperature and a non-uniform luminance that my beautiful brain cannot tolerate. The lights feel Satanic, despite my non-religious nature."*

Lupus – *"Following the imposition of energy-saving bulbs and other newer forms of artificial lighting including LEDs, I became increasingly aware of their detrimental effects on my health and wellbeing. I developed a sunburn-type rash to my face, neck and chest with spontaneous bleeding to my lip."*

Pain – *"A large open plan office block I visited regularly for meetings and to work in had changed overnight to LED strip lights. I immediately felt very uncomfortable and was in pain just looking across the room"*

Research Studies

There is a very long list of research articles that detail the toxicity of visible radiation.

Street lighting has detrimental impacts on local insect populations

First Estimation of Global Trends in Nocturnal Power Emissions Reveals Acceleration of Light Pollution

Light pollution drives increased risk of West Nile virus

Light-Induced Retinal Ganglion Cell Damage and the Relevant Mechanisms

Ensuring safety in LED lighting

Do no harm: the beginning of the age of healthy hospital lighting

The Soft Lights Foundation has many, many more research articles showing that artificial visible radiation is a toxin.[24]

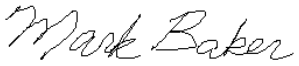
[23] www.softlights.org/stories
[24] www.softlights.org/resources

Conclusion

DOE must take the following actions:

- **Remove LED radiation devices from the category of General Service Lamps.**
- **Set a total energy use standard, not just a single-device efficiency standard.**
- **Collaborate with the US Access Board to ensure that visible radiation devices do not discriminate.**
- **Collaborate with the US Environmental Protection Agency to regulate visible radiation and to protect the natural night resource.**
- **Ensure that incandescent lamps are readily available to the public until a safe, non-discriminatory technology is created.**

Sincerely,



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