

Pittsburgh Lighting Analysis

By SoftLights.org

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Executive Summary

The city of Pittsburgh, Pennsylvania has generated a Request for Proposal for an LED streetlighting project with the goal of reducing energy use and light pollution. Our analysis shows that the RFP requiring LEDs will fail to reduce either energy use or light pollution, and will discriminate, impair human central nervous systems, and increase risk of disease. We recommend that the city abandon the current RFP and replace it with a new RFP based on protecting the natural night resource and human health.

Public Comments

The city of Davis, California began installing LED streetlights in 2014 and soon, many cities followed their lead. Much has been learned since that time. It is now known that LEDs are toxic to human health, violate civil rights, and do not produce the energy reductions or cost savings that were claimed. Pittsburgh is in a good position to learn from the actions of earlier adopters of LEDs.

Here is sampling of comments regarding LEDs that have been installed in Pittsburgh and other cities.



“I have serious issues with glare and flare from LED lights which are too bright. It is so bad for me that it is a dangerous situation when I am driving in areas where the lights are too intense.” – Pittsburgh resident.

“Pardon my French but how in the f... do we stop this dumpster fire of stupidity?”

“Government officials and businesses need to be told this isn't what we want”

“Anybody can put a light. That’s the problem. Plumbers are licensed as are electricians, etc. anybody can put up a light.”

“We wouldn't have anywhere near the amount of complaints of light pollution, trespass, discomfort or pain if our streets and footpaths hadn't been vandalized with this absolutely reckless misuse of technology.”

“Stopped at road construction and can't look out without my visor blocking these flashes without a possibility of getting a migraine.”

“Many people, unfortunately, are totally brain-dead, and these lighting companies exploit this to their advantage.”

“I live in the country also and new neighbors put up a scorcher light. I can see my shadow on my house from it and they are a 10th mile away. Total BS. Self-centered people never think how things they do affects others.”

“It's so sad. Because these are so readily available, and people fall for the “security” they think it provides. I live in a neighborhood that has (for now) orange sodium vapor lights at the intersections. That is enough!”

The Natural Night Resource

The natural night resource is a critical necessity for all biological life here on earth. This resource is being severely damaged by artificial light and now is the time to reverse that trend.

As the natural night degrades, the risk of disease increases. Artificial light has been clearly shown to greatly increase the risk of prostate, breast and thyroid cancers, premature births, and mood disorders.¹ Loss of quality sleep reduces worker productivity and treating sickness is expensive. The health costs of artificial light must be quantitatively compared to any benefits from artificial light pollution.

There is a strong possibility that there is a connection between Artificial Light at Night and transmission of viruses to humans. Artificial light has impacted the health of bats, which harbor viruses. As the immune system of the bats decays, the viruses have more opportunity to mutate and jump species.² Since this streetlighting project is to be paid for with COVID-19 federal funding, it would be contrary to the goals of this federal money to increase the risk of disease by adding additional artificial light devices. We therefore recommend that the COVID-19 federal funding be spent on creating a master plan for protecting the natural night resource to improve human health, the health of nocturnal creatures, and to help reduce the spread and risk of disease.

To start, the city must take baseline readings to determine how much light pollution currently exists. The city may use Sky Quality meters to measure Sky Brightness or use satellite data. A sky brightness reading of less than 20.5 magnitudes per square arcsecond should be considered polluted by artificial light.

¹ <http://www.softlights.org/resources/>

² <https://www.frontiersin.org/articles/10.3389/fendo.2020.00622/full>

Prior to authorizing the installation or replacement of streetlights, the city must develop a long-range plan for how to reduce light pollution throughout the city to meet the 20.5 mpsas goal. Sources of artificial light include streetlights, street signals, business lights, residential lights, light from windows in office buildings and residences, LED billboards, vehicle headlights and flashing lights.

Figure 1 shows a night sky that will lead to the better health outcomes versus a light polluted sky.



Figure 1 - Natural Night Sky³

The Sierra Club has recently updated their Light Pollution Policy to address the current light pollution crisis.⁴ The Sierra Club's policy is superior to the International Dark Sky Association's recommendations. For example, the Sierra Club states, *"The right of all living species to benefit from natural light and darkness, and to not experience fear or harm from artificial anthropogenic light."*

Toxicity

Research shows that Artificial Light at Night is a toxic pollutant, just as sewage in a river and pesticides are pollutants. ALAN has been linked to large increases in the risk of thyroid, breast and prostate cancers, mood disorders, and premature births.^{5,6,7} The root of this increased cancer risk from ALAN is that blue wavelength light suppresses the hormone melatonin which is needed for cell repair. When the night is filled with artificial light, human melatonin levels are kept artificially low, which greatly reduces the effectiveness of cell repair. Even small amounts of artificial light have a strong impact.

³ <https://www.osprey.com/stories/7-peaceful-stargazing-spots-near-tucson-with-summit-hut/>

⁴ <https://www.sierraclub.org/policy/pollution-waste-management/light-pollution>

⁵ <https://academic.oup.com/sleep/article/44/3/zsab016/6158960?guestAccessKey=216f85c9-9b0d-4ea3-b7ef-ff3f390a0120>

⁶ <https://acsjournals.onlinelibrary.wiley.com/doi/abs/10.1002/cncr.33392>

⁷ <https://onlinelibrary.wiley.com/doi/epdf/10.1002/soej.12477>

The eye contains cone cells for seeing color during the day and these cone cells have an efficiency of 250 lumens/watt. The eye also contains rod cells for seeing at night in low light conditions and have an efficiency of 1700 lumens/watt. Figure 2 shows the cones in false-green, and the rods in false-orange. A small percentage of retinal ganglion cells contribute little or nothing to vision, but are themselves photosensitive; their axons form the retinohypothalamic tract and contribute to circadian rhythms and pupillary light reflex, the resizing of the pupil.⁸

In a natural night, the cone cells would do less work and the rod cells would do more work, but with artificial light, this process is disrupted. This interruption may lead to eye disease because of the lack of rest for the cone cells.

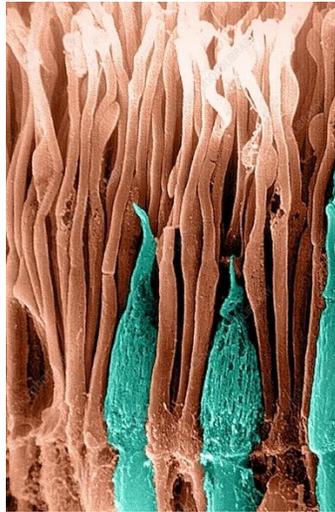


Figure 2 - Rod and Cone Cells

A goal of any outdoor streetlighting project should be to keep the Color Rendering Index low so that the cone cells are not used. Also, the luminous flux should be kept low so that the eye does not need to use energy switching between rod and cone cells. Figure 3 shows the extreme contrast between the black sky and the white LED lights. This is an example of poor design because it is exhausting for our eyes and mental health.

⁸ https://en.wikipedia.org/wiki/Retinal_ganglion_cell



Figure 3 - Extreme Contrast

Light Emitting Diodes emit radiation and the radiation they emit is in the visible part of the electromagnetic spectrum. The digital on/off nature of LEDs, the high intensity, and the non-uniform shape of the light interferes with the human central nervous system and vision. High powered LEDs such as used in streetlights are unfit for the purpose of illumination because of the harms to human health. These LED lights have already been installed in other cities, and this has led to epileptic seizures, debilitating migraines, and psychological trauma because LEDs are not compatible with human spatial and temporal systems.

Because of the toxicity of artificial light, especially LEDs, the goal of the city must be to restore the natural night resource, limit light pollution, and reduce or eliminate the use of LED lighting to protect the health of city residents.

Eye Hazard

A major issue of LEDs is the directed-beam property that creates the Lambertian shape of LED lights. Any lighting vendor must be required to provide the peak luminance value, in candela per square meter, for the proposed lights.

Figure 4 shows a tiny model LED streetlight. There is a safety warning that comes with this tiny LED streetlight that says, “CAUTION: Do not look directly into the LED lights when in operation.”⁹



Figure 4 - Model Streetlight

It stands to reason that if a low powered LED may cause eye damage, then high powered LEDs used in full sized streetlights will pose an even greater risk to eye safety. The city must study the amount of eye damage, both instantaneous and cumulative, that can occur with LED streetlights.

Another example of this warning appears on the box of a FEIT Electric LED light bulb, 2700K, 450 lumens, 5 Watt bulb, dimmable, frosted glass. The warning says, “Do not look directly into the light.”



Figure 5 - Eye Damage Warning

The warning for this LED flashlight in Figure 6 says, “To avoid eye injury, do not stare directly into the light beam or shine the beam directly into anyone’s eyes.”

⁹ <https://woodlandscenics.woodlandscenics.com/instructions/JP5659inst.pdf>

WARNING: To avoid eye injury, do not stare directly into the light beam or shine the beam directly into anyone's eyes. This product is not designed, intended, or recommended for children or hazardous environments.



Figure 6 - Flashlight Eye Warning

Figure 7 shows a bridge in Pittsburgh that has already been retrofitted with LEDs. The glare captured by the camera is also glare in the eye of the driver or pedestrian. Direct exposure to a bare-diode LED that is undiffused and unshielded will result in some amount of eye damage.



Figure 7 - Pittsburgh Bridge with LED¹⁰

The proposed streetlight luminaires offer no radiation shielding to protect the eyes. A full cutoff will not prevent the directed beam light from shining directly into a person's eyes. Many people have already experienced the pain of accidentally looking directly at an LED streetlight and being struck by the beam of peak luminance that may be in excess of 500,000 nits. Residents should not have to be worried about protecting their eyes from artificial light that the city is responsible for, and the city should not

¹⁰ <https://www.edgarsnyder.com/blog/2016/10/17-pittsburgh-led-problems.html>

need to worry about the liability issues of eye damage. We therefore recommend against the installation of LED streetlights on tall poles.

Equity

The federal Americans with Disabilities Act was passed in 1990. The Americans with Disabilities Amendment Act was passed in 2008 to strengthen the ADA.¹¹

As stated in the ADA, Section 3.1 of the ADA states that a “disability” means a physical or mental impairment that substantially limits one or more major life activities of an individual. Section 3.2 specifically lists major life activities and bodily functions.

“(A) IN GENERAL. —For purposes of paragraph (1), major life activities include, but are not limited to, caring for oneself, performing manual tasks, seeing, hearing, eating, sleeping, walking, standing, lifting, bending, speaking, breathing, learning, reading, concentrating, thinking, communicating, and working.

“(B) MAJOR BODILY FUNCTIONS. —For purposes of paragraph (1), a major life activity also includes the operation of a major bodily function, including but not limited to, functions of the immune system, normal cell growth, digestive, bowel, bladder, neurological, brain, respiratory, circulatory, endocrine, and reproductive functions.

The ADA states that the priority in accommodation must be towards seamless integration for a person with a disability. LED lights will discriminate because they create barriers to access for those with light sensitivity disabilities. Specifically, the following three Americans have light sensitivity disabilities, which represent approximately 20% of the population that has a light sensitivity disability.

MarieAnn Cherry – Epilepsy – LED lights have caused Ms. Cherry hundreds of life-threatening seizures, some of which have resulted in broken bones and lost teeth.

Mark Baker – Autism – LED lights cause emotional trauma. The repeated exposure to LEDs has led to Complex PTSD.

John Moody – Migraines – LED lights cause migraines which force him to remain in his house for as long as three weeks after exposure.

Pittsburgh’s RFP for the street light project is missing the requirements for ensuring that the streetlights do not substantially limit major life activities for people with light sensitivity disabilities such as those with epilepsy, migraines, autism, PTSD, Highly Sensitive Persons, Bipolar Disorder, and others. Federal law requires any new project, especially one where a drastically new technology is being used, to study the impacts of the project on those with disabilities. Since LEDs have been shown to cause seizures, migraines, and psychological disturbances, among other effects, a switch to LEDs without proper accommodations and protections for the disability community would be discriminatory in nature and would make the city vulnerable to an ADA lawsuit.

We recommend using the concept of “Inclusive Design” for this project, which places the needs of all residents, especially those with disabilities, first in the design process. Once the design has been shown to meet the needs of all, then the appropriate technologies would be selected. This idea is the

¹¹ <https://www.eeoc.gov/statutes/ada-amendments-act-2008>

opposite of the current proposal where the technology was selected first, and human needs were an afterthought. Inclusive Design has been shown to have a wide range of benefits for all members of society, not just those in the disability community.

Public Safety

On August 13, 2021, at 3:30am, the police responded to a ShotSpotter alert on North Homewood Avenue in Pittsburgh. News station WPXI posted the photo below, apparently from the scene of the shooting.



Figure 8 - Shooting in Pittsburgh¹²

We observe that the street is well lit. There appear to be two bluish metal halide streetlights. On the cross street, we see softer, amber HPS streetlights. There is also light from businesses and street signals. Artificial lighting did not stop the shooting and may have contributed to the incident.

Figure 9 shows another example from New York City, August 16, 2021. The area is lit nearly as bright as day, and yet the police are roving the area due to shootings. There are hundreds of examples since the installation of LED streetlights in other cities showing that lighting is not a crime deterrent and should not be used for that purpose. In fact, the evidence appears to show a correlation between artificial light, especially digital LED light and blue wavelength light, and an increase in violence. This is not surprising when we realize that LED lights interrupt the proper functioning of the central nervous system and that artificial light is promoting activity, rather than sleep.

¹² <https://www.wpxi.com/news/top-stories/police-investigating-shooting-pittsburgh-neighborhood/XJ66CSS2UBF3NJAXSNIWTAFCBE/>



Figure 9 - Shooting in New York

The purpose of these examples is to address the issue of the value of streetlights. Since the streets are well lit, but the shootings occurred regardless, it follows that a well-lit street does not reduce violence. Numerous research studies also support the theory that streetlights do not reduce crime, nor do they reduce vehicle crashes.¹³

If streetlights do not reduce crime or reduce vehicle crashes, then the only legitimate purpose for a streetlight is to allow for human navigation during the night. Human scotopic vision is well adapted to low-light conditions, but the installation of high luminous flux lighting will cause people to use their photopic vision which is far less efficient and creates a much higher contrast ratio between the natural night and the artificial light. The city must strive to restrict artificial light to levels that induce little photopic response.

Legal

The law firm of Edgar Snyder and Associates, located in Pittsburgh, is aware of the issues of LED lights and wrote a blog post in 2016.¹⁴ The City of Pittsburgh should be aware that law firms are learning about the dangers of LED lights and will not hesitate to sue for large sums, once they have a stronger understanding of the lack of regulation of LED lights, the extremely large peak luminance values, and effects such as epileptic seizures and glare. As of August 2021, we are aware of legal proceedings in the state of New York on behalf of a person with epilepsy who has already suffered seizures from LED lights.

Request for Proposal

In this section, we will analyze some of the key criteria from the City's RFP.

CRI and Color Temperature

"Be a minimum 60 CRI & Operate at CCTs ranging not to exceed 3,000K;"

LEDs cannot be measured with a Correlated Color Temperature due to the non-uniform luminance nature of LEDs. The overlapping cones of light emitted from the chip create a spectral power

¹³ <http://www.softlights.org/resources/>

¹⁴ <https://www.edgarsnyder.com/blog/2016/10/17-pittsburgh-led-problems.html>

distribution that is different at each angle. However, it is common for the lighting industry to ignore this science and to use CCT without defining how it is calculated for non-uniform luminance LED sources. Forcing people to see color at night is exhausting for the eye, and exceedingly harmful to nocturnal creatures.

By specifying “not to exceed 3,000K” the city will most likely receive bids for exactly 3000K. Existing HPS streetlights have a CCT of approximately 2000 Kelvin. The city has not quantified any advantage for increasing to 3000 Kelvin, which greatly increases the amount of dangerous blue wavelength. The American Medical Association, The Sierra Club, International Dark Sky Association, and the Illuminating Engineering Society all recommend using little or no blue wavelength light for outdoor lighting. By increasing the correlated color temperature from 2000K to 3000K, the city will increase light pollution and greatly increase health risks, all of which is contrary to guiding principles for protection of the natural night resource. We recommend that the city only select lighting that is 2200K or less.

Human daytime vision uses the cone cells of the eye (photopic vision), which provide excellent color rendering and a maximum efficiency of 250 lumens/watt. Human nighttime vision uses the rod cells of the eye (scotopic vision) which are extremely efficient at 1700 lumens/watt. The purpose of this RFP is to reduce energy use, so any streetlighting should rely on human rods for vision which will best match the natural nighttime environment.

By specifying a “minimum 60 CRI”, the city reduces the energy efficiency of any streetlight proposal because the color rendering will require more photopic vision, which decreases efficiency. The city did not define why color rendering at night is important. We have heard stories from other cities such as the need for emergency responders to distinguish blood from oil, or that the police need to be able to see the color of a person’s shirt or skin during a chase. We find these rationales to be exceedingly marginal and we recommend that they be ignored by decision makers. We recommend that the city remove any CRI requirements, and instead focus on protecting the natural night resource and increasing energy efficiency.

Shielding

The City’s RFP describes the ability to add retroactively add shielding. The use of shielding is critically important for reducing light pollution and must be a requirement in the RFP. We recommend that shielding be applied to all cobra head lights, to keep the light focused on the sidewalk and street, rather than wasting the light as pollution.

New Lighting

“The city has studied the distribution of streetlights in Pittsburgh neighborhoods and estimates that between 3,000 and 15,000 new LED lights are necessary to achieve an average distribution of lights throughout the city.”

The goal of this project is to reduce energy consumption, so it makes little sense to add additional new sources of energy use as part of this project. This City’s goal is to be equitable, but since artificial light is a toxic pollutant, we do not agree with the concept of adding additional toxicity to areas that currently have a more protected natural night resource.

However, this is also an opportunity to use inclusive design to plan a built-environment nightscape that protects the natural night resource and allows for human navigation with the least toxic

amount of artificial light. For example, a study may conclude that using bollards with red/amber light would increase the sense of safety, improve navigation, and increase the aesthetics and economic viability of the area, while not harming the natural night resource.

Specified Technology

The RFP has specified a specific technology, Light Emitting Diode, and cobra head fixtures. Our analysis shows that the use of energy efficient High-Pressure Sodium may be a safer choice with increased energy savings over LED. We also recommend bollard lights instead of tall poles for better light pollution control, safety, and reduced maintenance costs.

The lighting vendor MUST provide the following specs for any LEDs: Flicker rate, rise time, source peak luminance and absolute spectral power distribution and these values MUST be assessed for health impacts.

Marketing Claims

Many claims are made on the city’s website about the benefits of artificial light at night and LED lighting specifically. Many of these claims are unsubstantiated and/or false.¹⁵

Claim: The City of Pittsburgh is seeking proposals to convert its existing inventory of 35,000 overhead streetlights to LED, which will provide long-term savings, and reduce energy usage and light pollution.

Based on our analysis, the claim that LEDs “will provide long-term savings, and reduce energy usage and light pollution” is untrue. We discuss this in detail in a later section.



This Photo by Unknown Author is licensed under CC BY-SA

Figure 10 - New vs. Existing Streetlights

¹⁵ <https://engage.pittsburghpa.gov/streetlights>

We will address each claim from Figure 10.

“High pressure sodium” – Most of the city streetlights are HPS, although some have already been converted to LED.

“Energy intensive” – This claim is unsubstantiated because it lacks a comparison “as compared to what?”. If HPS is compared to incandescent, then HPS is quite energy efficient. HPS lights can have an efficiency of 90 lumens per watt compared to 16 lumens per watt for an incandescent.

“Shine into sky and residents’ windows” – This is a feature of the fixture, not necessarily the light emitter and light trespass and skyglow can occur with both HPS and LED. However, high energy blue wavelength light from LEDs can increase light trespass and skyglow because of the directed nature of the light.

“Poor color rendering, hard to see” – This claim conflates two different concepts. Color Rendering is an assessment of how an object’s colors appear as compared the color appearance when lit by the sun. Since these streetlights will be used at night when humans will be using scotopic (nighttime) vision, color rendering that is like daylight could be psychologically disturbing. “Hard to see” refers to the ability of the observer to discern shapes and movement. Human scotopic vision is well adapted to low-light vision.

“Frequent maintenance required” – This claim is unsubstantiated because “frequent” is not defined and the “as compared to what?” is missing. The definition of “maintenance” in this case is also unclear because it could include bulb replacement and/or fixture repair. One way to reduce maintenance costs is to bollards rather than tall poles requiring a bucket truck.

“70% less energy consumed” – First, 70% less energy is deceiving because HPS already saved 80% in energy use compared to incandescent. For example, if an incandescent uses 100 watts, then the equivalent HPS light would use 20 watts, saving 80 watts. Taking 70% of 20 watts results in a savings of only 14 additional watts. Second, our calculations do not support the value 70% since we calculate, at most, a 33% reduction in energy versus HPS. Finally, since the RFP calls for adding an additional 15,000 lights, our analysis shows that there will be an overall increase in energy consumed.

“\$1 million+ utility savings per year” – This calculation appears to apply only the direct savings on energy and does not consider the capital costs and maintenance costs. Nor do these costs account for the medical costs of cancer, mood disorders, premature births, lost productivity, and ecosystem damage caused using artificial light.

“Reduce Light Pollution” – The directed-beam nature and high energy blue wavelength light do not reduce light pollution. The city is missing any way to verify the claim.

“Better visibility” – This claim cannot be made in isolation. Too much light, especially light aimed into the eye, will decrease visibility. As drivers approach an LED streetlight, the peak luminance may shine directly into the eye of the driver, greatly reducing visibility. Streetlights that compete with other light sources such as vehicle headlights, street signals and floodlights may also decrease visibility.

“Longer lifespan” – There are caveats to this statement. If the LEDs are part of the fixture, then replacement requires replacing the entire fixture, whereas if an HPS bulb burns out, only the bulb must be replaced. An HPS bulb costs about \$8, whereas an LED fixture costs about \$150.

Dark Sky Benefits

Claim: *Streetlights provide much needed illumination to our streets and sidewalks.*

This claim is unsubstantiated. For example, “much needed” is unqualified and does not reference a baseline. Removal of the words “much needed” would increase the veracity to this claim.

Claim: *Pittsburgh's LED streetlight upgrade will address these [light pollution] issues by ensuring that all new streetlights adhere to "dark sky" best practices*

The dark sky “best practices” as described by the International Dark Sky Association were written before the invention of LED lights, which have vastly different physical characteristics than uniform luminance lighting. To address LEDs, the International Dark Sky Association has collaborated with the Illuminating Engineering Society on their 5 Principles guidelines. This collaboration with IES significantly diluted the strength of the recommendations. The IDA is often referenced when speaking of dark sky best practices, but the IDA does not have a monopoly on these practices, and the IDA insufficiently addresses the peak luminance and radiation power of LEDs. Other groups and agency’s best practices, such as from the National Institutes of Health, US Access Board and Sierra Club, should be referred to as part of this project.

Streetlights and Energy Consumption

Claim: *By switching to LEDs, the energy needed for streetlights will be reduced by up to 70%, saving the city more than \$1 million per year in utility costs.*

The phrase “by up to 70%” has no meaning and is deceptive use of language. With this type of language, the street lighting project could reduce energy by just 1% and still meet the claim. In addition, our analysis shows that the city will not save any energy via this streetlighting project in its current form.

Energy Use

In this section, we focus on the City’s goal of reducing energy use of streetlights.

Additional Lights

A story in a business journal stated, *“Pittsburgh plans to use \$12 million to fund the addition of 8,000 new LED streetlights that “were found to be missing during the light equity analysis.”*¹⁶ The RFP states that an additional 3,000 to 15,000 streetlights should be installed. This will increase energy use, which is contrary to the goals of the project.

As stated in the RFP, a primary objective is “reducing energy use”. The idea of adding additional streetlights is contrary to the primary objective of the project. The goal of reducing

¹⁶ <https://www.bizjournals.com/pittsburgh/news/2021/06/28/city-of-pittsburgh-plan-to-spend-covid-funds.html>

energy use is important, and therefore we recommend removing the addition of LED streetlights from this project, as this will increase energy use, discriminate (reduce equity), and damage the natural night resource.

Electricity Usage

Duquesne Lighting Company does not measure the electricity use for each light. Instead, DLC maintains a list of lighting types, and charges a flat fee, depending on the light type. If the city were to turn off the 35,000 HPS lights to save energy, there would be zero cost savings, unless the poles were physically removed.

Efficiency

HPS lights generate somewhere between 80 lumens/watt and 150 lumens/watt. LEDs are listed at about 120 lumens/watt. Switching to LED could lead to as high as a 33% increase in energy efficiency. On the other hand, switching to energy efficient HPS at 150 lumens/watt would increase energy efficiency by almost 50%. However, we really cannot compare these two types of lights directly because LEDs are a directed-beam light, meaning that the light falling onto the street is not uniform, leading to quality and discrimination problems.

For vision, human eyes use two types of cells. Cone cells are primary used during the daytime and the three subtypes, red, green, and blue, are used for color detection. The theoretical maximum efficiency for cone cells is detection of 250 lumens/watt. Rod cells are primarily used during the nighttime. The rod cells are about 7 times more efficient than cone cells, with a theoretical maximum of detecting 1700 lumens/watt. Therefore, one way to increase energy efficiency is to reduce the amount of artificial light such that the viewer uses rod cones rather than cone cells.

Another efficiency mechanism is the pupil of the eye. When there is excess light, the pupil contracts, reducing efficiency because less light is let into the eye. When there is less light, the pupil dilates, allowing more light into the eye, thus increasing efficiency.

Based on this information, we recommend increasing energy efficiency by reducing the amount of light at each emitter. This will achieve the primary goal of reducing energy use.

Radiant Flux (Power)

The largest percentage of city HPS lights are 100 watts, although some are as high as 400 watts and some as low as 50 watts. A 100-watt HPS lights produces 10,000 lumens. This is far more than is needed. By replacing all city 100-watt HPS lights with 50-watt HPS lights, the city would have a 50% reduction in energy use, which far exceeds the proposed LED conversion savings.¹⁷

Luminous Flux

An example of reducing the amount of light is shown in the photo below. At a 50% reduction, the difference to the human eye is negligible. At 80% reduction, there is still more than enough light to see by. We must remember that human rod cells for nighttime vision are

¹⁷ <https://www.1000bulbs.com/fil/categories/high-pressure-sodium-lamps#:~:text=100%2Dwatt%20HPS%20bulbs%20provide,and%2010000%20lumens%20of%20light.>

approximately 7 times more efficient than cone cells, so reducing the amount of light also increases the efficiency of our vision.

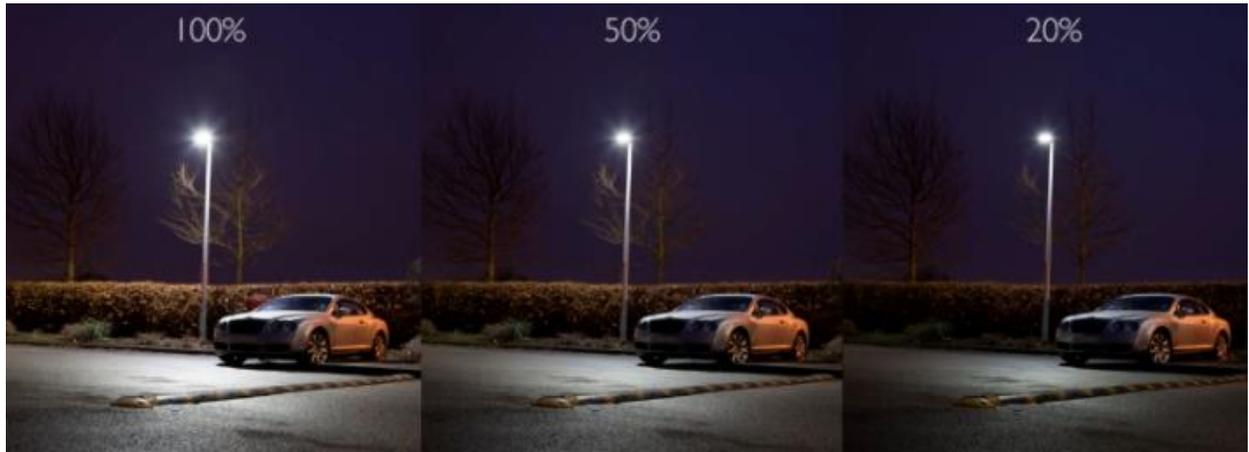


Figure 11 - Reducing Lumens¹⁸

Energy Sinks

Figure 12 shows the Pittsburgh downtown at night. The first thing we observe is a tremendous amount of waste light that is pollution. The number of light sources from the buildings far exceeds the amber streetlights. This leads to the following concepts.

- 1) The development of a plan to vastly reduce or eliminate use of light in buildings when not in use would reduce Pittsburgh's overall energy use.
- 2) Removal of the streetlights in this area would also reduce energy use, with little impact on visibility.



Figure 12 - Pittsburgh Buildings¹⁹

¹⁸ <https://www.softlighthouston.com/education>

¹⁹ <http://davedicello.com/wp-content/uploads/2011/11/pittsburgh-reflections-colors-at-night-west-end-overlookjpg.jpg>

Costs

Material Costs

LEDs last about 12 years and cost about \$160. On the other hand, an HPS lamp costs about \$8 with a lifetime of 6 years. The ballast costs about \$80 and lasts about 6 years. The total cost for 12 years would be about \$196 for conversion to energy-saving HPS.

In other words, material costs between LED and HPS are quite similar and, by itself, would not be a reason to use one technology over the other.

Energy Costs

The average power use of the existing HPS lights is 148 watts. By switching to LED, the average power use can be reduced to 99 watts, a 33% reduction. However, as was stated earlier, the quality of LED is poor since most of the energy is directed into a peak beam and the illumination is non-uniform.

Instead of switching to LED, we recommend taking the following two steps:

- 1) The existing HPS lights are already paid for. By throwing them away, the city is wasting money. Since their lifetime is 6 years, we recommend waiting until an existing light expires, then replacing the existing HPS, which is typically 100 watts or more, with a 50-watt HPS. This is a 50% reduction in energy use without introducing discriminatory technology.
- 2) One of the goals of this project is to reduce light pollution. The use of 3000K LED lights will increase light pollution because of the nature of the directed beam source and the amount of high energy blue wavelength light that will scatter up to 400% more in the atmosphere.²⁰ Therefore, we recommend that the city install shielding on all cobra head lights while the high wattage HPS light is converted to low wattage HPS. A bell-shaped luminaire is even better because it is attractive and keeps the light directed down.



Figure 13 - Shielded Cobra Head²¹



Figure 14 - Bell Luminaire²²

²⁰ <https://www.mdpi.com/2072-4292/13/16/3311/htm>

²¹ <https://calgary.rasc.ca/lp/trafficsafety.html>

²² <https://www.softlighthouston.com/gallery>

Return on Investment

The proposed large capital outlay to replace the 35,000 HPS lights with LED is not supported by the return on investment. Even without considering the harm and discrimination that LEDs cause and the low-quality light that they emit, the city will not make a return on its investment. We therefore recommend 1) adding no additional streetlights, and 2) replacing existing HPS as they fail with quality shielding and low wattage HPS.

Standards

The City of Pittsburgh has Lighting Codes that were written with the presumption that the light source has uniform luminance.²³ An LED light source, however, has a directed beam which creates non-uniform luminance. New codes will need to be written before LEDs can be installed that meet standards and specifications.

The city's Lighting Codes define Luminance as:

LUMINANCE: The quotient of the luminous flux at an element of the surface surrounding a point, and propagated in the direction of measurement. - This definition of Luminance comes from the Illuminating Engineering Society.²⁴

However, a better definition is: *"Luminance is a photometric measure of the luminous intensity per unit area of light travelling in a given direction. It describes the amount of light that passes through, is emitted from, or is reflected from a particular area, and falls within a given solid angle."*²⁵

The IES standards and Pittsburgh Lighting Codes ignore source luminance and only address light reflected from a surface. This is unacceptable for LED light sources because LEDs can have incredibly high peak luminance that must be limited to protect public safety. The photo below from Konica-Minolta shows luminance being measured at the source.



Figure 15 - Luminance²⁶

²³ https://library.municode.com/pa/pittsburgh/codes/code_of_ordinances?nodetid=PIZOCO_TITWELVELICO

²⁴ <https://www.ies.org/definitions/luminance/>

²⁵ <https://en.wikipedia.org/wiki/Luminance>

²⁶ <https://sensing.konicaminolta.us/us/blog/luminance-vs-illuminance/>

The IES, on the other hand, measures luminance from a reflected surface. In Figure 16 from IES RP-8-18, the IES defines luminance as the light emitted from the pavement and into the eye of the driver. Quote: “The light seen by a driver is the portion that reflects from the pavement towards the driver...”

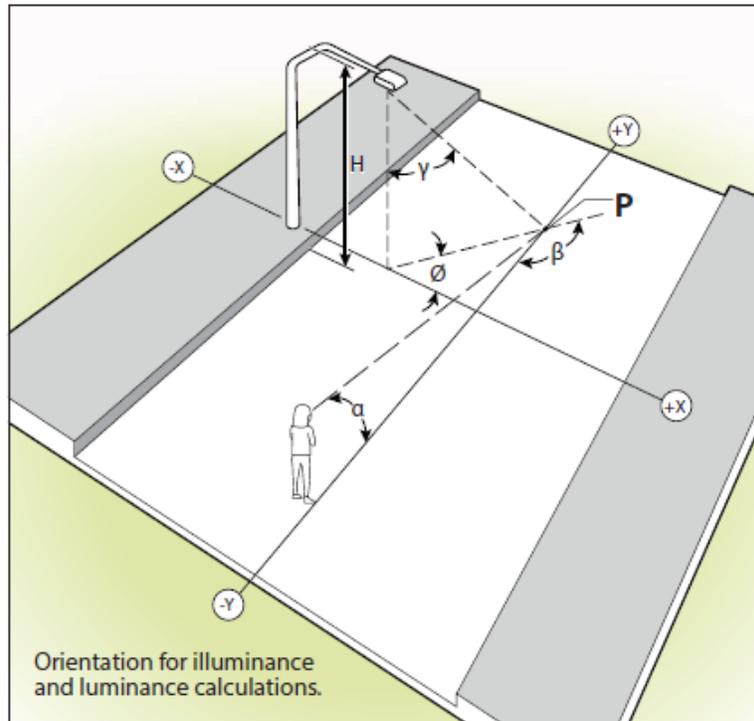


Figure 3-7. Geometric relationships for illuminance and luminance calculations.

Figure 16 - IES RP-8-18

In the IES RP-8-18 standard, which Pittsburgh’s Lighting Codes are based on, the IES claims that LEDs are “point sources” of light. This is a false claim by IES which has led to thousands of discriminatory, dangerous, and harmful lighting installations.

In truth, LEDs are “Lambertian sources” of light. The light is emitted from a flat chip, which causes the light cones to overlap, creating a peak luminance in the middle of the chip. A description of the Lambertian properties of LEDs can be found in this IEEE document by Dr. Khan.²⁷

²⁷ <https://ieeexplore.ieee.org/abstract/document/8879542>

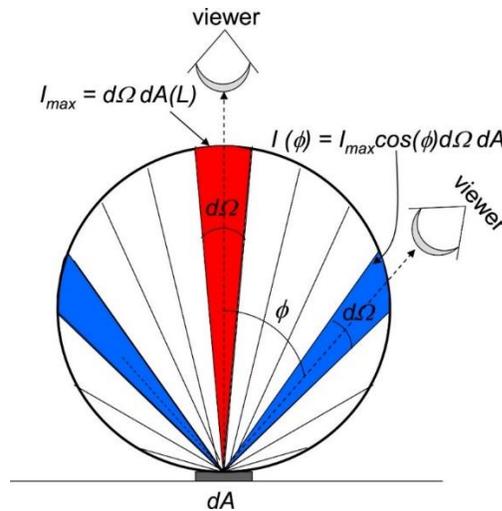


Figure 17 - Lambertian from LED²⁸

This peak luminance shines directly into driver’s eyes from bare-diode LED streetlights, causing glare, pain, and dangerous driving conditions. The IES has no standards for this peak luminance in their IES RP-8-18 document. Since the Pittsburgh Lighting Codes are based on this standard, the Pittsburgh Lighting Codes cannot be used for LED lighting installations.

The Pittsburgh Lighting Codes, Section 1201.07, Table 7B, describe the “Maintained Luminance Values in Candelas per Square Foot”. This luminance table is only for light reflected from a surface, not directly from the source. The largest luminance allowed, which is on a commercial roadway, is 0.1 candela per square foot. This is about 1 candela per square meter, or 1 “nit”. This is a very small value and quite reasonable for human eyes. However, an LED streetlight can emit more than 500,000 nits directly into the driver’s eyes. Therefore, the Pittsburgh Lighting Codes cannot be used for LED streetlights.

Consider that the Pittsburgh Lighting Codes have luminance standards of around 1 nit. Then consider that an LED television might be around 500 nits. A candle may even have a peak of 20,000 nits, as shown in Figure 18.

²⁸ <https://ieeexplore.ieee.org/abstract/document/8879542>



Figure 18 - Candle²⁹

But in 2006, Lumileds claimed a luminance 38,000,000 candela per meter squared (nits) from an LED chip.³⁰ And by 2018, Laser Focus World reported that LEDs were nearing 200,000,000 nits.³¹

The Illuminating Engineering Society and the corresponding Pittsburgh Lighting Codes are not at all equipped to deal with this level of light density, and therefore it would be dangerous and negligent to attempt to use these standards for LED streetlights. Here is a quote from an ordinance in San Antonio, Texas:

- *Maximum Luminance – Urban Areas. No sign covered by this Section shall present a display or any part of a display that exceeds 150 nits between the end of civil twilight in the evening and the beginning of civil twilight in the morning.*³²

Notice the limit of 150 nits. Since LED streetlights are approximately 500,000 nits or more, the discrepancy between Pittsburgh Lighting Codes and the peak luminance of LED lighting is large. Therefore, before any LED lights are installed, city codes must be first updated to address the LED issues of peak luminance, absolute spectral power distribution, and flutter, flicker, and flashing.

Many cities rely on IES RP-8-18 to ensure that they comply with safety and Americans with Disabilities Act requirements. However, because IES RP-8-18 is invalid for LED sources, any city that relies on IES RP-8-18, or similar standards from other groups, will not be in compliance with safety and ADA requirements. This puts the public in danger and the city at risk of liability.

Any lighting vendor that proposes using LED lights must provide flicker, rise time, absolute spectral power distribution and peak luminance data so that the city can assess the impacts on human health.

²⁹ <https://en.wikipedia.org/wiki/Luminance>

³⁰ <https://www.ledsmagazine.com/specialty-ssl/industrial-life-sciences/article/16699576/lumileds-claims-led-luminance-records>

³¹ <https://www.laserfocusworld.com/test-measurement/research/article/16555223/nonlaser-light-sources-highluminance-leds-target-emerging-automotive-lighting-applications>

³² <https://docsonline.sanantonio.gov/FileUploads/dsd/CommentonBrightness.pdf>

Pittsburgh Dark Sky Ordinance

The proposed Dark Sky Ordinance for Pittsburgh is discriminatory and will lead to increased light pollution. We do not recommend approving the darky sky ordinance in its current form.

<https://pittsburgh.legistar.com/LegislationDetail.aspx?ID=5092150&GUID=D37D60F5-F174-4FC6-8744-74A0FD34CDC4&FullText=1>

Additional Lighting

We do not recommend the installation of any new city-owned streetlights because of the harmful effects of artificial light. However, if the city moves ahead anyway, we do recommend the use of bollard-style light fixtures that keep the light close the ground, along with a low luminous flux, red/amber light would improve lighting conditions and reduce light pollution and reduce maintenance costs.

High Pressure Sodium is 80 to 150 lumens/watt.³³, which is just as efficient as LED, but without the psychological harm of non-uniform luminance. The image below is a 50-watt HPS in bollard style, which is 50% less energy usage than existing 100-watt HPS pole mounted streetlights.



Figure 19 - Bollard Lighting with HPS³⁴

The advertising image in Figure 20 shows a 42" bollard "specifically designed for pedestrian safety and to minimize light trespass." LEDs are even more energy efficient, but they may be discriminatory and are possibly intolerable to certain persons. Therefore, before installing any LED lights, the city must assess the impacts of low-luminance, amber/red light on those with light sensitivity disabilities.

³³ <https://www.accessfixtures.com/bollard-light-sources/>

³⁴ <https://www.amazon.com/LIGHTING-D182-50-BZ-Fiberglass-Bollard-Pressure/dp/B0798VXRVN>

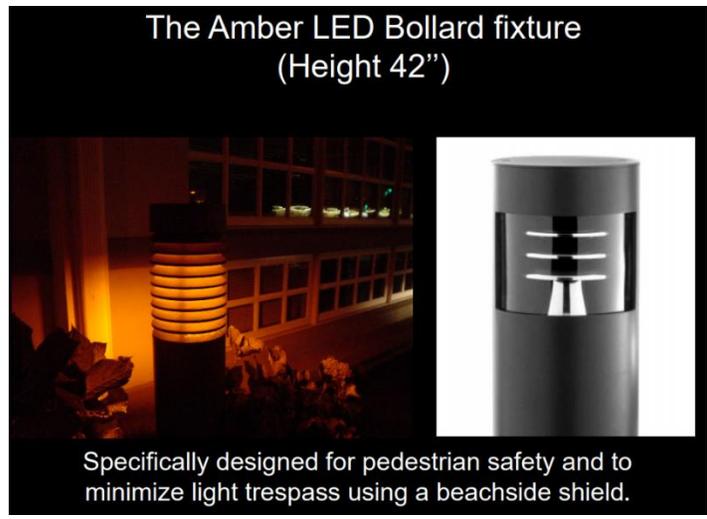


Figure 20 - Bollard Lighting in Amber³⁵

Use bollard-style, red/amber lighting to illuminate navigation paths such as pedestrian sidewalks. The photo on the left shows aesthetically pleasing amber light for well-traveled location. The photo on the right shows enough illumination for navigation. While the photo on the right looks dark, we must remember that our scotopic (nighttime) vision is extremely energy efficient and that very little light is needed for safe navigation.

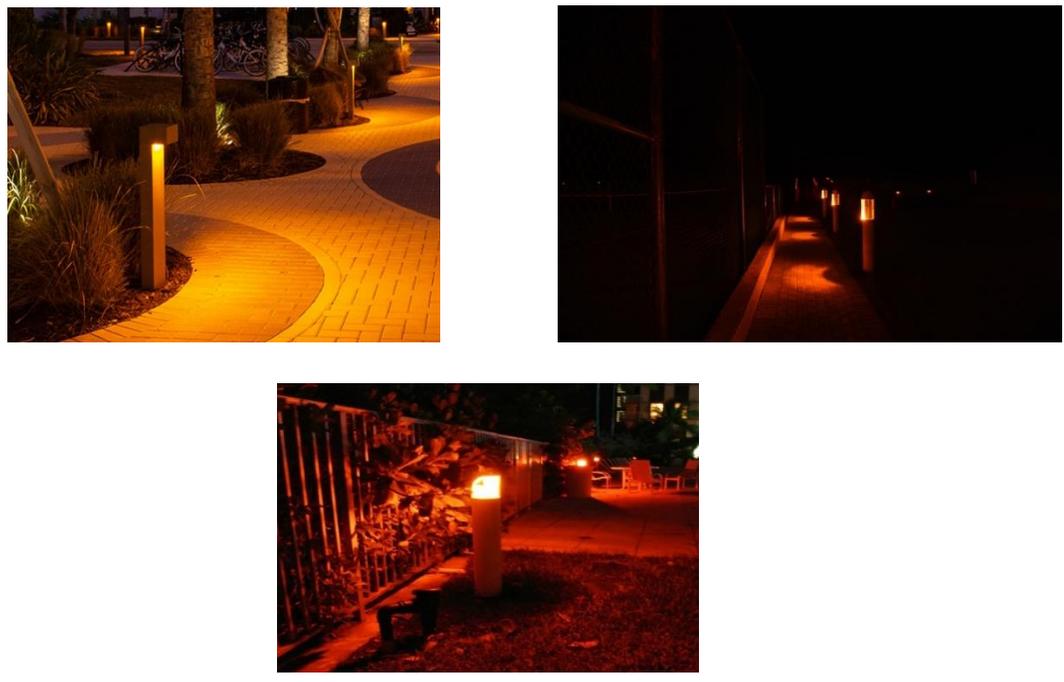


Figure 21 - Red Lighting

³⁵ http://doe.ky/wp-content/uploads/2018/03/Creating-a-Turtle-Friendly-Lighting-Plan_Jennifer-Winters_20-Mar-2018.pdf

Solutions

For the reasons demonstrated above, we recommend that the city not proceed with the street lighting project RFP as written. We believe that the city should stop the project and take these alternate steps.

Natural Night Resource Master Plan

Create a master plan for protection of the natural night resource. This plan would set baselines and goals for Sky Brightness and restrictions on artificial light toxins.

Inclusive Design

Use Inclusive Design to ensure that any artificial lighting that is added to the environment does not create barriers to access for those with disabilities, including those with epilepsy, autism, migraines, PTSD, bipolar disorder, and cancer.

High Pressure Sodium with Shields

Replace existing high wattage HPS streetlights with 50% less wattage HPS and shielding as each existing HPS light burns out.

Contract with Duquesne Light Company

Create a new contract with DLC that rewards the city for using shields, for using lower wattage HPS, and for turning off or dimming lights. For example, if the city turned off every other streetlight, the city should be rewarded financially by DLC.

Redirect Funds

There are other high-visibility projects that will provide a better return on investment.

- 1) Walk-in Health Clinics – Neighborhood clinics can greatly improve the health of the residents. Healthier residents reduce the city's expenses.
- 2) Vitamin Distribution – The National Institutes of Health has reported that antisocial behavior can be reduced by 47% simply by increasing the use of vitamins.³⁶ A reduction in antisocial behavior can lead to reduced crime rates and increased public safety.
- 3) Protected Bike Paths – Bike paths are very popular among constituents, so long as the bike paths are protected by a physical barrier from cars. An increased use of bicycles and a reduction in vehicle use will reduce energy use, reduce the city's carbon footprint, and increase public health.

Conclusion

In conclusion, we recommend that the city replace existing streetlights with low-wattage HPS and quality shielding over time as the existing lights wear out and that the city use the federal funds to

³⁶ <https://pubmed.ncbi.nlm.nih.gov/10706231/>

implement one or more of the suggested programs that will better benefit the residents and guests of Pittsburgh.

Mark Baker, B.S.E.E
SoftLights.org
mbaker@softlights.org