Response to:
LED Streetlighting: Environment & Safety Impacts, Frith, Jackett & Chisnall

By SoftLights.org

This paper addresses issues in the paper *LED STREETLIGHTING: ENVIRONMENT & SAFETY IMPACTS* presented to the New Zealand Transport Agency March 2019.[1]

Page 1, Introduction - ***"Replacement of High Pressure Sodium (HPS) streetlights with Light Emitting Diode (LED) streetlights has been happening around the world. This has been led by the superior energy efficiency of LED lighting, its greater longevity, its lower need for maintenance and its ability to be dimmed and strengthened according to varying temporal needs."***

The claim of *"superior energy efficiency"* is unqualified and not factually correct. LEDs are a directed-beam source of light with non-uniform luminance and are incompatible with the human central nervous system, whereas HPS has uniform luminance and is biologically compatible with human biology. Therefore, a claim of "superior energy efficiency" cannot be made, as the two types of light are not like-for-like.

Incandescent has an energy efficiency of 10 lumens per watt. HPS has energy efficiencies from 80 to 150 lumens per watt. LED is approximately 120 lumens per watt. These efficiency values vary wildly depending on the source of the information, but it is clear that High Pressure Sodium is already an energy-efficient light when compared to incandescent, so even if it were possible to compare the energy efficiency of the two types of light, in comparison to incandescent, both HPS and LED are similar and, discarding all other parameters, stating that LED has "superior energy efficiency" is not true.

The claims *"Greater longevity and lower need for maintenance"* are also unqualified. LEDs last about twice as long as HPS, but an LED lamp, which requires all the electronics and hardware to be replaced since there is no bulb to change out, costs about 15 times more than and HPS bulb. Once the cost of changing the ballast of HPS is factored in, both HPS and LEDs cost about the same to maintain.

The claim of "ability to be dimmed" is also not qualified. HPS can be dimmed, and LED can be dimmed, so there is little reason to choose LED over HPS when considering this parameter.

Page 1, Introduction*: Correlated Colour Temperature(CCT) is a rough guide to the percentage of blue light emitted by a source and it is generally agreed that streets should not be lit by lights of colour temperature above 4000K.*

[1] https://az659834.vo.msecnd.net/eventsairaueprod/production-harding-public/d560c9df614941e2bd35d8cff55bcbf9

The claim of "*it is generally agreed*" is unfounded. At this time, the International Dark Sky Association has set 2200K as their recommended maximum color temperature, and the American Medical Association set their recommendation at 3000K in 2016, when less was known about the harms of LED lights. We know of no research source that sets 4000K as a maximum. The only reason that we are aware of to limit color temperature to 4000K is because the streetlighting industry makes LEDs at exactly 4000K because that is the least expensive product to manufacture.

There are many reports of people suffering epileptic seizures, migraines, and psychological trauma from exposure to LED streetlights, with higher color temperatures being me more harmful than lower color temperatures.[2] For some people, there may be no safe level of exposure to LED.

Page 2, The impact of spectrum on lighting - *"As lighting levels reduce below 3 cd/m^2 the cones progressively lose their dominance and the rods become more important."*

The value and units "*3 cd/m^2*" are not connected here to the measurement which is "*luminance*". Luminance is a measure of the light density and is a critical value that is missing from most studies on LEDs. The value 3 cd/m^2 as the transition point from rods to cones is a significant value and must be remembered as we discuss LEDs further. In addition, most papers assume that luminance is referring to the reflected light from a flat surface, whereas with LEDs, there is also the source luminance from the flat chip that must be considered.

Page 3, Spectral Power distributions of several light sources of equal lumen output.

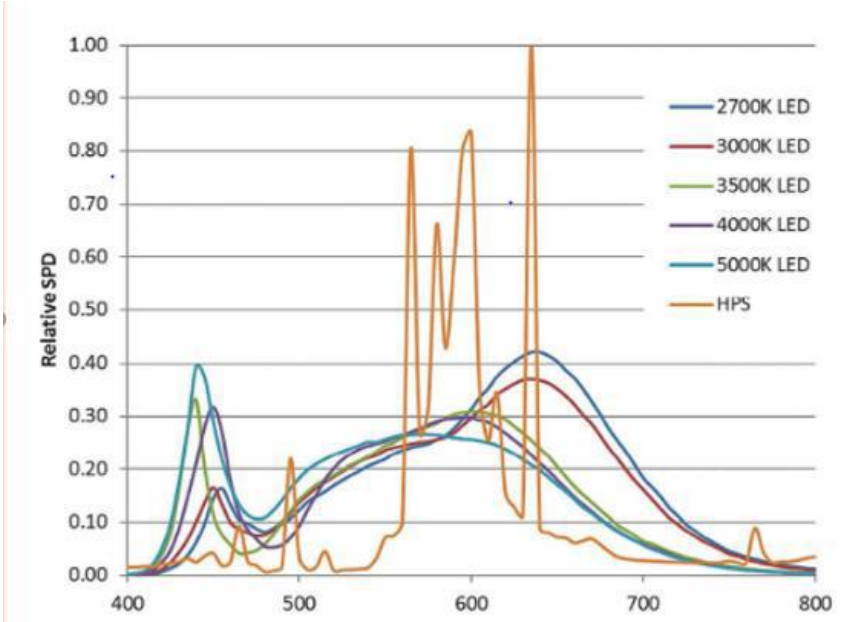

Figure 1

[2] www.softlights.org/stories

The graph in Figure 1 shows two different types of light on the same graph, using a Relative Spectral Power Distribution. This is inappropriate for least two reasons.

First, one of the key issues with LEDs is the large spike of blue wavelength light. By placing the LED SPD onto the same graph as the HPS, it makes it appear that LED is somehow flatter, and it becomes difficult to see that a 5000K LED has a huge spike of blue wavelength light that has much more energy than the rest of the visible wavelengths. Second, by using only a relative SPD, rather than the actual energies, and by not specifying the power of the devices, it is not at all clear whether these two graphs are even comparable. The use of this graph feels like an attempt to tell a certain narrative, rather than carefully exploring the differences between HPS and LED.

Page 4, Visibility of objects to drivers - ***"It is obvious from Figure 4 that the LED has lower reaction times throughout the mesopic region and that the two sources' reaction times converge as the photopic region is approached. The colour temperatures of the HPS and LED were not discussed by the researchers."***

The use of this study to imply that driver reaction times are better under LEDs is inappropriate. In most situations where LED streetlights are used, there are many other sources of light such as street signals, LED signs, store flood lights, parking lot lights, and vehicle headlights. In these situations, the driver will be using photopic vision, and not scotopic or mesopic. In addition, since the color temperatures of the LEDs used in the study were not mentioned, the study itself is invalid for making any inferences about whether HPS or LED is better for central vision.

Th photo in Figure 2 shows multiple light sources, from the fuel station lights in the side mirror, the streetlight, the parking lot light, the sign, and the vehicle headlights. This is a typical city scene and there is so much light, the driver is surely using photopic vision.

Figure 2

Page 4, "Detection distance comparison of Seattle Luminaries-using wet and dry road data"

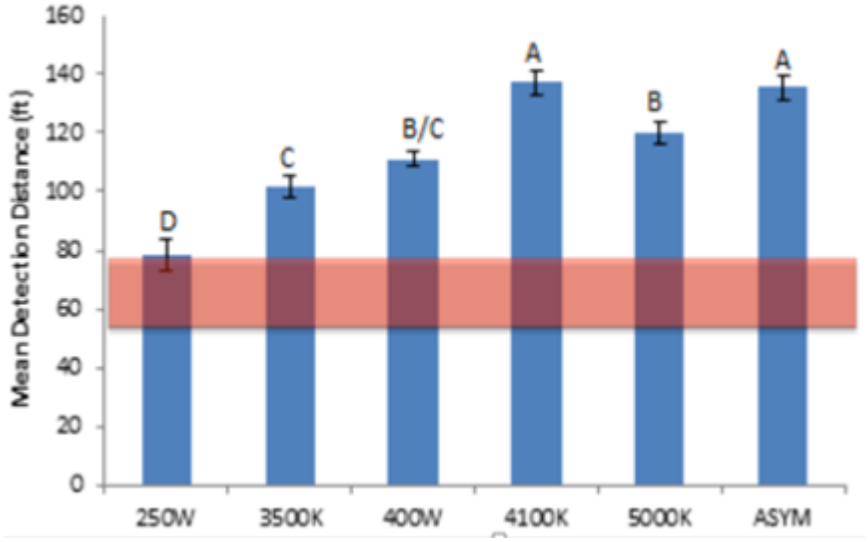

Figure 3

As the authors allude to, the graph in Figure 3 is basically unusable because of the *"lack of information available on the relative lumen output of the various light sources, their spectra and their light distribution."* The graph compares some lights by wattage and others by color temperature. In addition, the color temperatures are 4100K and 5000K, which exceeds the authors contention that "*it is generally agreed that streets should not be lit by lights of colour temperature above 4000K."* We therefore wonder why this chart is included in this paper.

Page 5, *"The average luminance of the road surface was about 2 cd/m2, within the range of mesopic vision."*

This reference to the road conditions hides the true nature of driving. It is possible that the road surface has a luminance of 2 cd/m^2, but in city driving, this value is essentially irrelevant.

Figure 4 shows a typical city street scene with vehicle traffic, storefronts, houses, and streetlights. Every one of these light sources has luminance far greater than 2 cd/m^2. LED streetlights may be 500,000 cd/m^2. LED vehicle headlights may be 100,000,000 cd/m^2. The vehicle taillights and the storefront have very intense lights with high luminance. It makes little sense to discuss a 2 cd/m^2 light from the pavement when the driver is overwhelmed by all the other light sources.

It should be clear to the reader that the problem is not that there is not enough light, but that there is far too much light and far too many light sources.

Figure 4

Page 5, "*In conclusion, LEDs appear to be generally superior to HPS for both on road and off-road visibility.*"

This conclusion is not supported by the research discussed in this paper or anywhere else and we do not see how this conclusion could have been reached.

Page 6, *"According to Van Bommel (2015), the spectrum of a light source has nil or very little impact on disability glare. Thus, the spectrum of an LED used to replace an HPS source should not be an issue."*

We fail to see how Van Bommel or the authors of this paper could conclude that the spectrum of the source is not an issue for disability glare. Figure 5 shows an example of high color temperature LED streetlights in Christchurch, New Zealand.

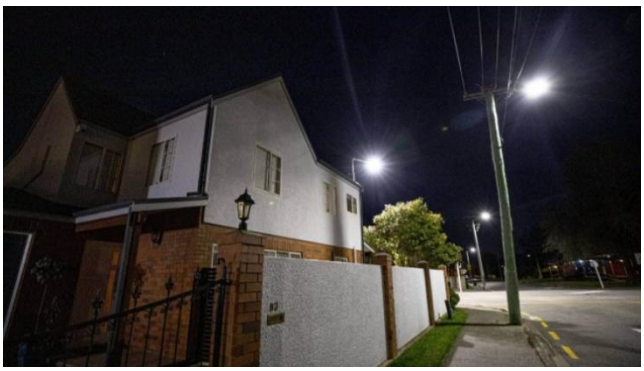

Figure 5

The horrendous glare is caused by the large spike of high energy blue wavelength in the 5000K LED streetlight. Since the amount of glare-causing blue wavelength light decreases with decreasing color temperature, it makes no sense to claim that the spectral distribution has no contribution to disability glare.

As another example, consider these 6500K LED headlights. Clearly the glare is disabling and reducing the color temperature would reduce the glare.

Page 7, *"Street lighting undoubtedly contributes to this impact but its contribution to total sky glow is not well established"*

As research has continued since 2019, it is now well-established that LED streetlights have increased light pollution by as much as 400% due to the high energy blue wavelength light and directed-beam nature of LEDs.[3]

Page 7, *"The International Dark Sky Association has recently revised its previous "fixture seal of approval" for outdoor light sources of 4100K or lower down to 3220K (measured value) and lower."*

The IDA now uses two numbers. The first number is 2200K and is their recommended maximum.[4] The second number is 3000K or 3220K for their Fixture Seal of Approval program, in which vendors pay IDA to have their lights certified. Recommending 2200K but certifying 3220K seem like incompatible actions and a deference to the lighting industry.

[3] https://www.mdpi.com/2072-4292/13/16/3311/htm
[4] https://www.darksky.org/our-work/lighting/values-centered-outdoor-lighting/

Page 8, "It is difficult to precisely translate the US experience to NZ but the most likely outcome of using 4000K LEDs in place of HPS luminaires is a net reduction in sky glow on Category P roads and a net increase in sky glow for Category V roads.

Figure 6 shows a fuel station in Sherbrook, Canada and Figure 7 shows streetlights in East Angus, Canada.

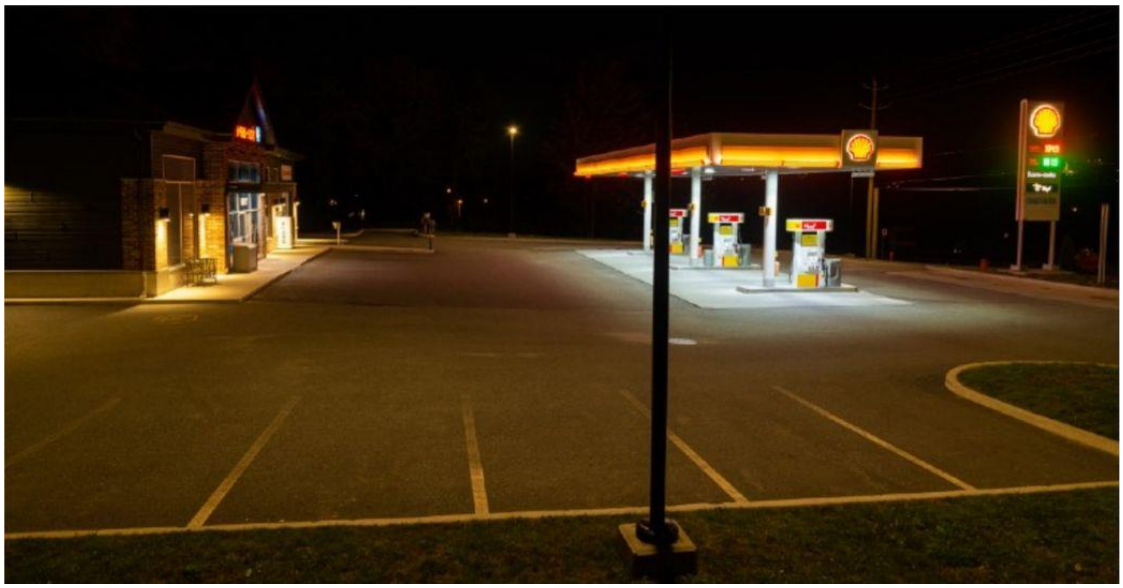

Figure 6

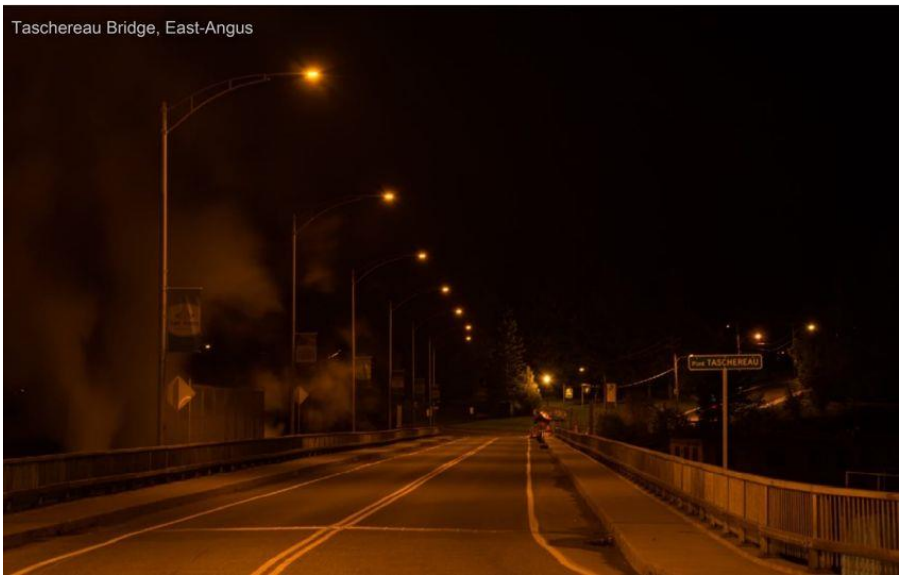

Figure 7

These photos show a more rational approach to streetlighting, where the fuel station or roadway and sidewalk are lit, but without overwhelming glare. There is little color rendering

with the bridge lights, but color perception is not a necessary nighttime function, and the perception of color would require the use of the less efficient cone cells.

The use of 4000K LED streetlights, with or without shielding, would greatly increase light pollution versus shielded HPS.[5]

Page 10, *Impact on wild life*

The section on the impacts of streetlighting on wildlife is exceedingly short. The referenced photo Figure 8 shows a disastrous configuration of industrial lights at high color temperatures and high luminous flux with no shielding; something of a worst possible lighting scenario.

Figure 8

An August 2021 study showed that LED lights cause greater harm to insects than HPS lights and that any artificial light is exceedingly detrimental to insect populations and thus to the interconnected web of life.[6]

While the impacts of artificial lights on bats was discussed, there was no reference to low color temperature bat-friendly LED lights such as those used in Worcestershire, England and shown in Figure 9.

[5] https://www.mdpi.com/2072-4292/13/16/3311/htm
[6] https://www.science.org/doi/10.1126/sciadv.abi8322

Figure 9

Page 10, Impact on Human Health - ***"However, the research quoted is animal related. Ian Ashdown (chief scientist, Lighting Analysts) describes it as involving an "exposure time necessary to do damage equivalent to staring at the tropical noonday sun for 15 minutes without blinking. This obviously has no relation to street lighting which is in the mesopic range.***

The dismissal of blue light hazard by the authors is unwarranted. Toxicity equals dosage x exposure. Whether the person is exposed for 15 minutes straight or exposed over 15 years is extremely important. Blue wavelength light causes permanent retinal cell damage which is cumulative over time. Looking at a 500,000 nit peak luminance LED streetlight even briefly will cause pain, indicating eye damage. The authors have no justification for ignoring the toxicity of LED lights. Consider this warning label on a tiny model version of a streetlight shown in Figure 10: "CAUTION: Do not look directly into the LED lights when in operation." [7] Certainly, if a tiny streetlight is a hazard, then so are full-size streetlights.

Figure 10

[7] https://woodlandscenics.woodlandscenics.com/instructions/JP5659inst.pdf

Page 11, Age related macular degeneration – "*Blue light exposure has also been implicated by medical researchers in age-related macular degeneration (AMD), a leading cause of vision loss in older people. Often quoted is Taylor et al, 1990 where 838 Chesapeake Bay fishermen were chronically exposed to sunlight. This research found only a marginal association. Again, this obviously has little relation to street lighting which is in the mesopic range."*

Here again, the authors claim little relation between a study showing that blue wavelength light is involved with macular degeneration "in the mesopic range" and harm. But as we have already shown, drivers and pedestrians are being inundated with artificial light and are using photopic vision. The use of photopic vision at night in the built environment is also substantiated by the Illuminating Engineering Society.

Page 11, Human sleep patterns and circadian rhythms

There appears to be an attempt by the authors to minimize the significance of blue light on the critical circadian rhythms. Dr. Mario Motta, lead author of the 2016 American Medical Association report that set the AMA recommended maximum at 3000K has continued to work on this issue. In 2021, Dr. Motta assisted the United Nations in working towards adopting 2200K as the recommended maximum color temperature. Dr. Motta stresses that even tiny amounts of blue wavelength for even for short periods of time will impact human sleep.

Figure 11 shows 4000K streetlights in Florida. The sleep of the residents has been severely impacted by the lights.

Figure 11

Page 11, Conclusions - "*There is no evidence to support any health disbenefits from melatonin depletion or blue light hazard or age related macular degeneration from standards compliant road lighting installations in New Zealand, be they HPS or LED"*

Given the large volume of research showing that artificial light and blue wavelength light at night are extremely detrimental to humans, including significant increases in risk of thyroid cancer, breast cancer, prostate cancer, mood disorders and premature births, we see no justification for the authors' conclusions that artificial light or artificial light or blue wavelength light is not harmful.[8]

Page 11 ***"Both LED and HPS light sources impact on wildlife but in different ways. There is no evidence to suggest one is better than the other and the evidence for such impacts from streetlighting is mixed."***

This conclusion is directly contradicted by the research.[5]

Page 12 - ***"There is no hard data from crash studies to show whether white LED light is safer than yellow HPS light but intuitively and from limited visibility and contrast studies white LED light provides a superior visual environment to HPS light. More blue light may help drivers stay alert but no firm evidence yet exists."***

Choosing to use "intuition" rather than research invalidates this conclusion. Consider this documented conversation from September 2021:

Question: Is it just me, or do the bright cool headlights impair depth perception and judgment on their speed?

Response: You're Not imagining this. Sometimes I'm also a pedestrian & I've noticed the same thing. They are indeed much more difficult to accurately gauge distance & speed than on a vehicle equipped with Halogen Headlights.

Page 12 – ***"The International Dark Sky Association is promoting 3000K or lower for street lights but the difference in sky glow between a well-controlled 4000K LED and a 3000K LED is small.***

As mentioned earlier, the IDA recommends 2200K.

[8] www.softlights.org/resources

Conclusion by SoftLights.org

It is our opinion that the paper reviewed here cannot be used to justify LED streetlights. Based on the research through 2021, LEDs have been shown to be toxic, dangerous, and discriminatory.

Not discussed in this paper were the impacts of LEDs on people who are sensitive to light, such as those with epilepsy, migraines, and autism. There are many reports of people suffering epileptic seizures, migraines, and psychological trauma due to the non-uniform luminance, Lambertian shape of LED light.[9]

Not discussed at all in this paper were the impacts of LED flicker.

Also not discussed were the non-uniform luminance of LEDs and the impacts of peak luminance in the range of 500,000 nits from streetlights. LEDs have horrible uniformity, and yet uniformity is a highly recommended quality for streetlighting, as stated in such standards documents such as the IES RP-8-18 Roadway Lighting document.

For energy savings, NZTA should look first to discontinue the use of streetlights, as artificial light pollution is now overwhelming the ecosystem. For any continued use of streetlights, NZTA should consider that replacing a 100-watt HPS with a 50-watt HPS will save 50% in energy use, with no loss of safety.

Additional information can be found on our website at www.softlights.org.

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[9] www.softlights.org/stories