OFFICER'S RESPONSE TO QUESTIONS FROM THE HEARINGS PANEL

DATE: **13 January 2022**

HEARING: **Light**

HEARING DATE: **18 January 2022**

PREPARED BY: **Vicki Barker - Consultant Planner**

Introduction

The purpose of this report is to provide a written response to the questions posed by the Hearings Panel on the respective section 42A report for the Light Chapter.

Questions and Answers

Paragraph or Plan reference	Question from the Hearings Panel
8 Chapter Overview 8.3 Table Waka Kotahi	It appears that some very important driver safety provisions were omitted from the PDP Objectives, Policies, Rules, Rule Requirements and Matters. This is evident by the amount of Waka Kotahi submissions points that have been accepted by the s42A report (i.e.) accept (9), accept in part (3), reject (2). Please explain why these very important safety provisions were omitted, many of which are fairly obvious to road users?
Officer response:	*LIGHT-O1 - The term 'work' was originally considered broad enough to also enable transportation. Safety is addressed in clause 1. of the objective. Refer to para 9.4 of s42a report.* *LIGHT-P1 - This policy was originally drafted to refer to glare onto roads but not light spill, which links with the drafting of LIGHT-REQ1 which excludes light spill onto roads. The policy and rule requirement were drafted in this way as glare was considered the main effect with respect to roads based on earlier technical advice from a separate technical expert. Based on Mr Muir's recent technical advice and the Waka Kotahi submission points, amendment is now recommended to both LIGHT-P1 and LIGHT-REQ1 to address light spill onto roads. Refer to para 10.6 and 18.6-18.7 of s42a report.* *The remainder of the Waka Kotahi submission points are considered minor and are not related to light spill or safety.*
10 Light P1	The report states:

Paragraph or Plan reference	Question from the Hearings Panel
10.4	*It is therefore recommended that additional policy specific to infrastructure activity is not inserted into the Light Chapter as it would duplicate policy in the GIZ chapter which is already considered to satisfy the submitters relief. Overall, it is recommended that this submission point be rejected.* Is there any merit in providing a cross reference to that Chapter?
Officer response:	*There is considered no need to cross-reference to the GIZ Chapter as the Light Chapter is a district-wide chapter which needs to be read in addition to every zone chapter when lighting is proposed as part of any development. The 'How the plan works' section also explains this to plan users.*
10.5	The report states: *With respect to the Fonterra processing plant, the DPZ objectives and policies recognise that dairy processing activities and facilities are important infrastructure which contribute to the economic vitality and wellbeing of the region, whilst also managing adverse effects.* Is the wellbeing of the region in this sentence based on economic vitality? *It is also of note that the spill light lux levels that apply to GRUZ land adjoining DPZ is higher than that recommended by AS/NZS4282:2019 to provide these established factories and important infrastructure with some greater leniency.* Please clarify - is the reason why spill light levels are higher than the standard AS/NZS4282:2019 in the DPZ, is because the DPZ contains important infrastructure that contributes to the economic vitality and wellbeing of the region and because the DPZ is in the rural area and therefore less people will be affected by light spill?
Officer response:	*'Economic vitality and wellbeing' is the wording utilised in DPZ-O1. My interpretation of this objective is that economic vitality contributes to wellbeing, but that wellbeing is wider than economic vitality, i.e., the dairy processing activities and facilities provide employment and in turn social wellbeing.* *It has been recommended that the spill light levels in GRUZ adjoining the DPZ are higher than AS/NZS 4282:2019 because the DPZ contains well-established existing infrastructure that contributes to the economic vitality and wellbeing of the district and wider region. The spill light levels proposed are the same as those in the Operative Plan and there are a limited number of neighbouring property owners surrounding the DPZ. Also refer to para 18.6 of the s42a report.*
10.6	The report states:

Paragraph or Plan reference	Question from the Hearings Panel
	Accordingly, it is recommended that the policy reference the management of light spill onto adjoining sites including roads to make this specific. The addition of "effective" in addition to efficient is considered to add clarity While the safety aspect is well understood, how can lighting be said to have an impact on the 'effective' use of roads. In other words what type of evidence would be brought before a decision maker to establish that excessive light spill affects the effective use of a road?
Officer response:	*As noted in the s42a report, a similar change was also recommended with respect to EI-P3 in the EI s42a report (see para 15.3 of the EI report). "Effective" is the degree to which something is successful in achieving a desired result which is separate to "efficiency", which is achieving an outcome with the least amount of wasted time, money and effort or competency in performance. Both terms are considered relevant to land transport infrastructure and the provision of network utilities and lighting within roads.* *It is also of note that the CRPS refers to both 'effective and efficient' operation of infrastructure, i.e., 5.1.4, 5.4. The Canterbury Regional Land Transport Strategy 2012-2042 also makes such reference.*
12 Light-P3 12.9	Also a Question for Mr Muir: Please explain the evidential basis for controlling sky glow to protect people's and the ecosystem's health (item 3 below): Minimise potential upward light that causes sky glow, whilst ensuring the safe, effective and efficient operation of roads, public pedestrian access and public sports courts and grounds, by controlling new artificial outdoor lighting to: maintain people's ability to view the night sky; and maintain the distinct character and amenity values of the district's night sky; and 3. protect the health and well-being of people and ecosystems.
Officer response:	*There are publicly available documents and research studies that show that 'blue light' has a detrimental effect on people's health and wellbeing and that of the ecosystem, i.e., disruption to body clock and contributing to poor sleep and affecting habitats and ecosystems.* *With respect to street lighting which is a primary source of blue light within the District, the Council commissioned a report by Steve Muir to address the implications of changing 4000K Correlated Colour Temperature (CCT) LED streetlights to 3000K or 2700K (the lower the CCT the lower the blue light). This report addresses the health and safety implications of blue light among other matters and is attached as* ***Appendix 1*** *to this report.*

Paragraph or Plan reference	Question from the Hearings Panel
	The Council is committed to a LED streetlight renewal programme where all existing streetlights are being changed to 4000K. The above-mentioned report was commissioned to address 4000K LED street lighting versus 3000K or 2700K lighting to assist in assessing the cost implications as well as the environmental effects. *The conclusions of Mr Muir's report are that when evaluating blue light from streetlights we should not just consider the CCT value (i.e., 4000K vs 3000K) and that the luminaire BUG (Backlight, Uplight, Glare) rating is important regardless of CCT, as is the use of flat glass, the tilt and aiming angle, and upward light component.* *This report informed the drafting of LIGHT-R2 and is referenced in the s32 report. On the basis of this report a CCT value was not utilised in the rules (as SDC is committed to a 4000K streetlight rollout and can swap these out in select areas for lower 3000K or 2700K lighting or use dimming where required, i.e. for dark sky accreditation purposes), and LIGHT-R2 instead references the other matters identified as important to managing sky glow identified by Mr Muir.* *A maximum CCT value was also not specified in other sky glow rules (aside from LIGHT-REQ5) as this is an impractical requirement for most plan users to understand and implement (i.e. 3000K or 2700K luminaires are difficult to source) compared to the more simplistic requirement of directing lighting downward and shielding it from above, requiring residential security lights to be motion activated, and for non-residential lighting not to operate between 2200-0600 (LIGHT-REQ3). LIGHT-REQ5 references a maximum CCT value as these provisions reflect international guidelines with respect to sports courts and grounds lighting distinct from street lighting, and such lighting will be designed by a lighting engineer.* *The report also references the International Dark Sky Accreditation or partial accreditation requirements which was a further consideration in the drafting of the Light provisions to ensure that the provisions do not undermine such a process.*
16 Light-R4 16.4	The report states: *In the EI Chapter, EI-R6 permits the operation, maintenance and repair of existing above and below ground network utilities, without being subject to any lighting provisions. Therefore, emergency repairs or maintenance of network utilities involving any outdoor artificial lighting is already permitted by EI-R6. On this basis it is considered there is no need to amend LIGHT-R4 and that the submission point be rejected.* Please confirm is it always the case that if the EI does not cross reference Light, or other chapter rules, then those rules will not be relevant?

Paragraph or Plan reference	Question from the Hearings Panel
Officer response:	*The EI Chapter has been designed as a stand-alone chapter and where EI does not cross-reference other chapter rules then the intention is that they are not relevant.* *The EI s42a report at paragraph 8.10 also notes that the structure of the EI Chapter has been dictated by the Planning Standards which require that provisions relating to energy, infrastructure and transport that are not specific to the Special Purpose Zone chapters or sections must be in the EI Chapter.*
23 Light - Mat 1 23.3	The report states: *Given that LIGHT-REQ1 is now proposed to apply to roads (as per the recommendation at paragraph 8.17), it is recommended that LIGHT-MAT1 also enables consideration of the effects of spill lighting on roads.* Would an alternative option be to instead add LIGHT-MAT2 to the matters of discretion for LIGHT-REQ1?
Officer response:	*Yes, that could be an alternative option.*
25 Light -Mat3 25.4	The report states: *Rather than singling out activities, a new clause like LIGHT-MAT1.1 is preferred as it is more encompassing and is considered to address both submitters relief in principle. The recommended amendment is* 1. *<u>Whether the artificial outdoor lighting is location-specific and necessary to provide for the safe operation of sites, security for buildings and to enhance the health, safety and wellbeing of people</u>.* In what instances would outdoor lighting not be "location-specific"?
Officer response:	*'Location-specific' could be removed from the recommended amendment as in most situations it will be location-specific, and the key consideration is whether it is necessary or not.*

Appendix 1:

Implications of changing 4000K LED streetlights to 3000K or 2700K, ELC – Essential Lighting Consultancy Ltd, 2020

2020

Implications of changing 4000K LED streetlights to 3000K or 2700K.

STEVE MUIR

ELC – Essential Lighting Consultancy Ltd
21 Russ Drive,
Lincoln 7608.
Ph 021 343662
Email; muirs@xtra.co.nz

Executive Summary.

SDC are currently approximately 35% to 50% of the way through a new LED renewal program where they plan on changing all existing old luminaires to 4000K LED. This correlated colour temperature (CCT) for LED's is still considered the optimum by many because of its lumen output, efficacy, competition and distribution.

This changeover is leading to immediate energy and maintenance cost savings. Luminaires are ordered and the contractor is currently installing with project completion expected on or before June 2021. This program involves replacing approx. 6000 old streetlight luminaries with new 4000K units at an estimated cost of $3.2 million. The NZTA are subsidizing this work at 80% related to the savings in maintenance, operating cost benefits it creates. The Councils already existing 4000K LED streetlights are not being replaced in recent new subdivisions provided originally by developers.

4000K LED luminaires have a higher lumen output of approximately 3% to 8% more than 3000K and a further 5% to 7% over 2700K resulting in a total efficacy improvement of 8% to 15%.

Cost difference between 4000K/3000K is little (1% to 2%) if any. However, the cost difference between 3000K/2700K is unknown because there is less competition from less suppliers offering this option hence additional costs per 2700K luminaire are estimated to be 5% to 10%.

As LED technology continues to improve the efficacious of the 3000K/2700K chip is expected to get closer to that of the 4000K chip.

When considering LED CCT or evaluating the performance of different LED's with respect to the amount of "blue light" it is important to not just consider the CCT value but to also look at the spectrum power distribution (SPD) curve. This is because two light sources can have considerably different blue peaks as seen between Moonlight and 4000K as shown on Figure 2.

CCT is only one technical parameter. Others such as glare, upward light, backlight, (all jointly known as BUG rating), tilt angle and optic distribution are also considered important attributes that have an impact on sky glow.

UK research shows there is little difference in atmospheric scatter from blue light from 4000K/3000K LED's. There is also research that shows there is little difference in surface luminance from blue light striking different surfaces.

Comments on possible detrimental effects to our sleep patterns and eye health from over exposure of blue light from LED street lighting is disputed by Public Health England (PHE).

NZTA's current position on changing from 4000K to 3000K/2700K is open minded based on technical advice and results from quality designs complying with current standards. They are willing to consider 3000K on slower speed environments but are still to be convinced to change on higher speed roads based on current evidence relating to eye adaptation / human response.

To replace SDC's complete streetlight network throughout the district it is estimated to cost $6.8m to $7.5m and take around 3 years. If Dark Sky Accreditation is sought by the Council which requires 3000K/2700K, costs are estimated to be in the order of $800,000 to $900,000 to replace streetlights in areas more suitable for Accreditation (i.e. ONL, Coastal Areas and West Melton Observatory Area). The NZTA would not be expected to subsidise any replacements as it is not road or road safety related and therefore Council would need to meet the full cost. The NZTA would also need to agree to replace its own state highway streetlights with LED units if full Dark Sky accreditation was sought.

Implications of changing to 3000K for new subdivisions is expected to be minor and readily achievable, however changing existing infrastructure is expected to lead to greater non-compliance with NZ Standards (up to 12%). Further lowering to 2700K variant is likely to have cost implications

on subdivisions due to less lumen output resulting in closer design spacings. Plus, the likely increase in non-compliance on existing infrastructure the 2700K variant is considered unacceptable based on current technology.

Based on the previous 5 years numbers, the network is increasing by approximately 350 lights/year from new subdivision installations hence any change to 3000K or 2700K CCT is likely to have little impact on the overall effect of the night sky for some years. It is highly likely more significant gains could be achieved by controlling obtrusive light from private sources other than street lighting. This is trying to be addressed via the upcoming District Plan Review.

Another option to control brightness and switching of street lights is via a Central Management System (CMS) which has also been considered in this report, but it is important to note this will not alter the colour temperature - it will only give switching and brightness options. This can also be extended to other technologies in the future if required. An indication of cost to add this to the existing (4000K) lights over the entire network could cost $3.7m or $525,000 within the Outstanding Natural Landscape (ONL) areas only.

Table of Contents

2.0 Introduction.

The purpose of this report is to consider the implications of providing for new street lighting or changing the existing streetlight network from 4000K luminaires to 3000K, or indeed 2700K conducive with the International Dark Sky (IDS) Accreditation or partial accreditation requirements. It is noted that existing private lighting is not under Council's control to achieve change.

This report is also relevant to the District Plan Review and will be used to inform the drafting of planning provisions relating to street lighting. Technical information in this report is relative to the street lighting network only and is based on performance, along with safety considerations and costs analysis based on the following:

- ***Technical performance –*** what are the advantages and disadvantages of changing to a different correlated colour temperature (CCT) LED luminaire. Also consider blue light, Bug Rating and Atmospheric scatter.
- ***Health and Safety concerns –*** Exposure to blue light from LED street lighting and its impact on sleep patterns. Also, any possible effects on insects, fauna, animals and wildlife.
- ***NZTA*** - consider NZ Transport Agency's (NZTA) current position and or any new or proposed research.
- ***Cost Analysis –*** what it could cost to replace all existing luminaires now or as soon as possible over the entire network or partial areas of the district. This would involve a new LED luminaire utilising a 3000/2700K chip mounted on existing infrastructure. The implications of 3000/2700K with respect to new subdivision development.
- ***Control system*** - There is another option where the existing luminaires can be utilized via the removal of the shortening cap and the addition of a new lighting control unit (LCU) on top of each luminaire. While this will not alter the colour temperature it will enable further control of brightness and on/off switching options.

3.0 Background.

The outdoor lighting industry has undergone huge advances in the last 12 years with many NZ Territorial Authorities (TA's) well advanced with changing their street lighting networks to LED assisted by the NZTA providing a subsidy rate of 80% to encourage this. This has resulted in 50% to 70% savings in energy use and operational costs, improved lighting performance on delivering light to where it is required (on the road) and less obtrusive light into the environment.

When LED's were first introduced into streetlights the higher colour temperature LED's (5000K to 6000K) were considerably more efficient but had a harsh appearance due to their high "blue light" content. Very few of these were ever installed in New Zealand as the New Zealand Transport Agency (NZTA) had the foresight of recommending 4000K luminaires as the optimum performance and efficacy via the introduction of their document M30 - Specification and Guidelines for Road Lighting Design[1]. Refer to https://www.nzta.govt.nz/resources/specification-and-guidelines-for-road-lighting-design/ (section 27.2).

SDC adopted this recommendation early when they first considered the change to LED's approximately 5 years ago when a business case was undertaken to obtain the NZTA subsidy. This stance is a realistic and practical approach where this decision is considered acceptable as a good overall choice for optimum performance and safety as well as being environmentally acceptable. It also aligned with the standards adopted by the neighboring Christchurch City Council at the time for consistency.

Technology is advancing and the energy savings and lumen performance is continually improving and the gap between 4000K and 3000K is getting closer. However, there is limited data available to assess the performance of 2700K, but it is estimated today that there is at least a further 5% to 12% reduction in lumen output based on similar power use between 4000K and 2700 chip.

Blue Light.

As technology has developed the 3000K chip variant has become more efficacious[2] with 3% to 8% reduction in lumen output from the 4000K chip from several manufacturers. Attached in Appendix A is the Photometric Testing and Evaluation Reports from Cree[3] and LRL[4] for 4000K and 3000K LED's. Data from 2700K wasn't available in time for the preparation of this report from these two suppliers but data for 2700K was available in an SPD curve format from Orangetek.

Summary of these reports is referenced in the following Table 1.

On close examination of Table 1 below and these reports there is only one attribute that favors the 3000K LED and that is the amount of "blue" light or where the peak wavelength is occurring. For 4000K the peak wavelength occurs in the blue region around 445nm whereas the 3000K has a peak wavelength in the warmer red area around 595nm.

3000K is the current requirement to achieve Dark Sky Accreditation but it is understood that this may be reduced to 2,700K soon.

---

[1] Refer to NZTA web site; www.nzta.govt.nz/assets/resources/specification-and-guidelines-for-road-lighting-design/docs/m30-road-lighting-design.pdf

[2] Efficacy – is the number of lumens delivered per watt of power used to generate this output.

[3] Cree are an international manufacturer of LED chips as well as an international luminaire manufacturer.

[4] LRL (LED Roadway Lighting) are a Canadian street light luminaire manufacturer.

	Cree sample LED		LRL sample LED	
Attribute	**CCT 4000K**	**CCT 3000K**	**CCT 4000K**	**CCT 3000K**
Date of test	7-3-18	16-3-18	31-8-19	7-5-18
Model	XSP street luminaire	XSP street luminaire	NXT-72M HB	NXT-72M 2ES
Driver current			700mA	600mA
Luminous flux	11370 lm	10548 lm	17942	14278
Measured CCT	3984K	3007K	4020K	3070K
Efficacy	120 lm/W	112 lm/W	117 lm/W	110 lm/W
Colour rendering index (CRI)	72	71	75	73
S/P Ratio	1.48	1.19		
Wattage	94.5W	94W	153W	130W
Max intensity	9350 cd	5210 cd	10152	9356
Angle of max intensity (horizontal)	75°	77.5°	70°	70.5°
Angle of max intensity (vertical)	67°	69°	66.5°	72.5°
Peak wavelength	445nm	595nm	445nm	595nm
Dominant wavelength	580nm	583nm	585nm	595nm
BUG rating	B2-U0-G2	B3-U0-G2	B3-U0-G2	B3-U0-G2

Table 1 Summary of Photometric Lab Testing Reports.

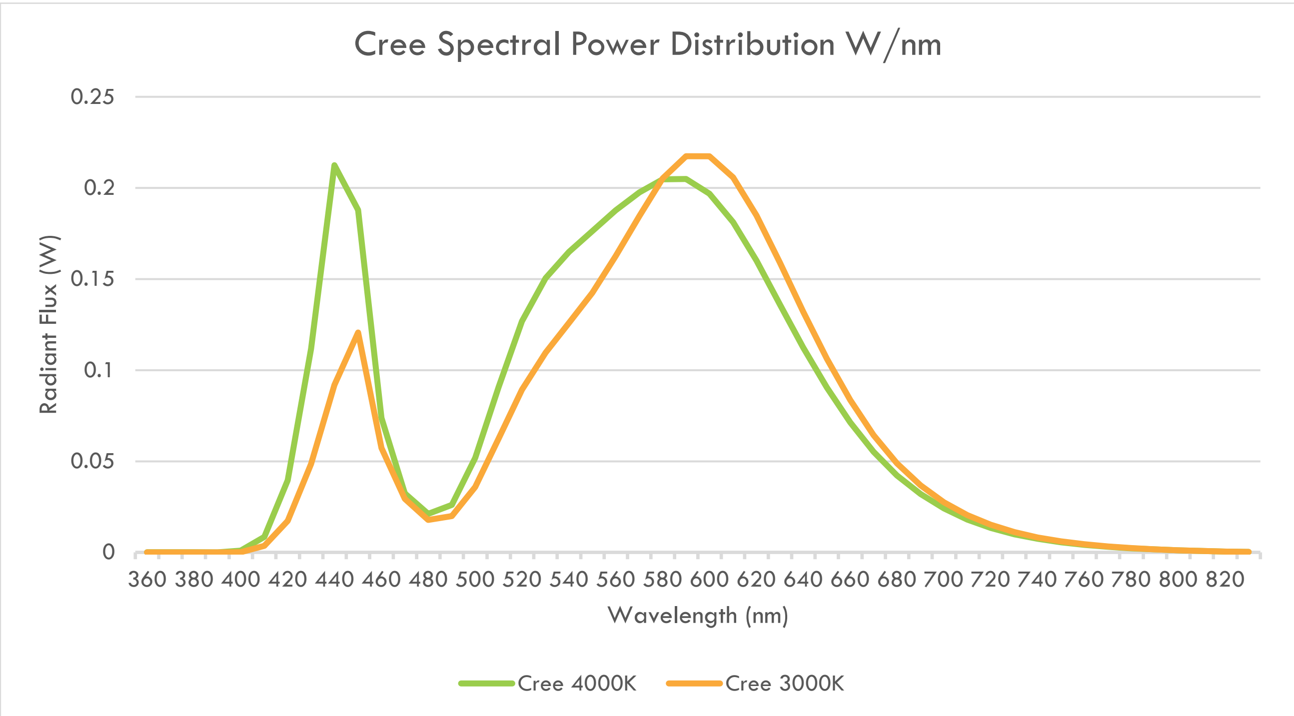

Figure 1 Cree Photometric Lab Test Results.

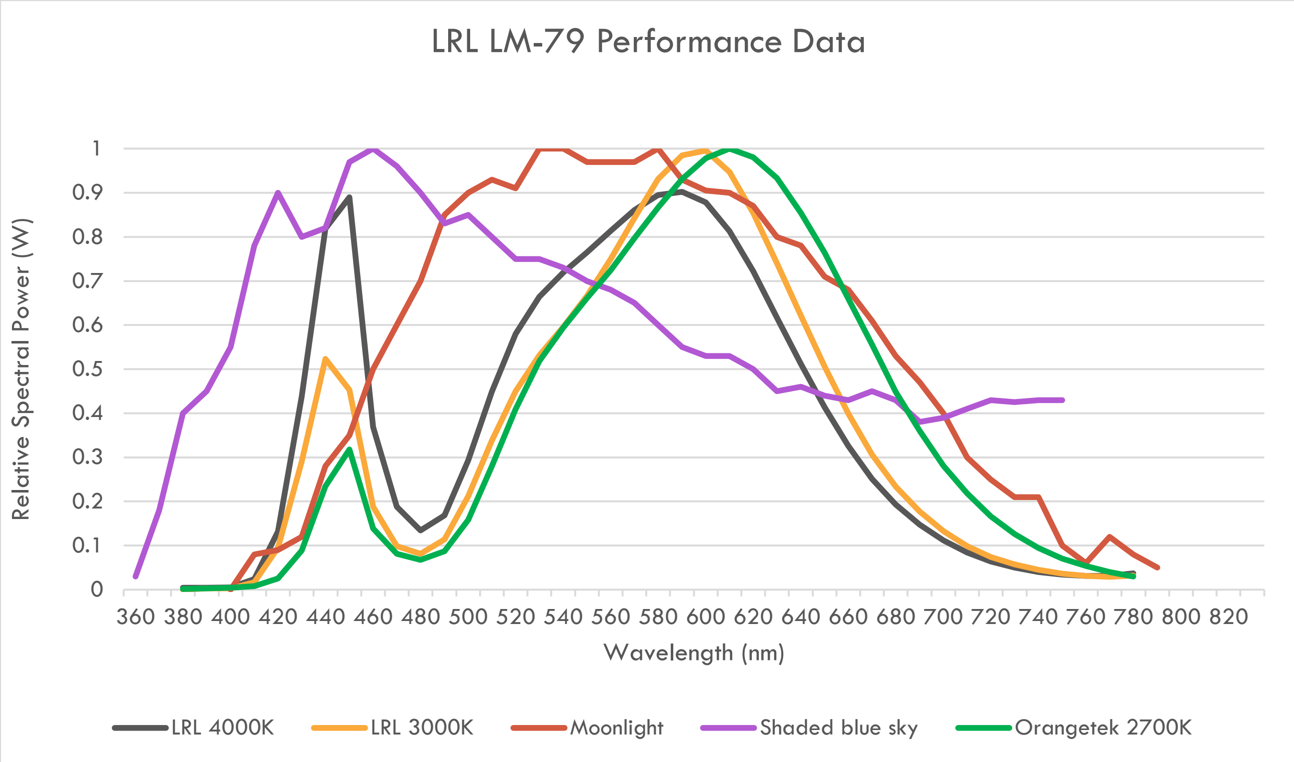

Figure 2 LM 79 Performance Data and approximated Moonlight and Shaded Blue daylight Sky Overlay.

On review of the above figures 1 & 2 it can be seen that there is more "blue" light (440nm region) from the 4000K than the 3000K. This is neither good nor bad when comparing 4,000 and 3,000K. Rather, it is an indication or a gauge on the wavelength of all the colours used to manufacturer that light source. Because of this, astronomers can filter out more "blue" light from a 3000K LED than they can from a 4000K LED because there is less "blue" light to start with. This means it has slight advantages for night sky viewing by astronomers, but it can be difficult to tell the difference for the average person viewing the night sky and other design parameters also affect sky glow.

When comparing the different wavelengths in natural daylight (shaded blue sky) and moonlight the two (4000K/3000K) are a compromise. Hence 4000K is considered "neutral" rather than cold and 3000K is considered "warm".

Two light sources may have approximately the same CCT but that doesn't mean they have the same spectrum power distribution (SPD). Moonlight is considered to have a CCT of 4050K – 4100K. When moonlight is overlaid on the SPD of 4000K chip it has a higher blue content at 440nm. See figure 2 above.

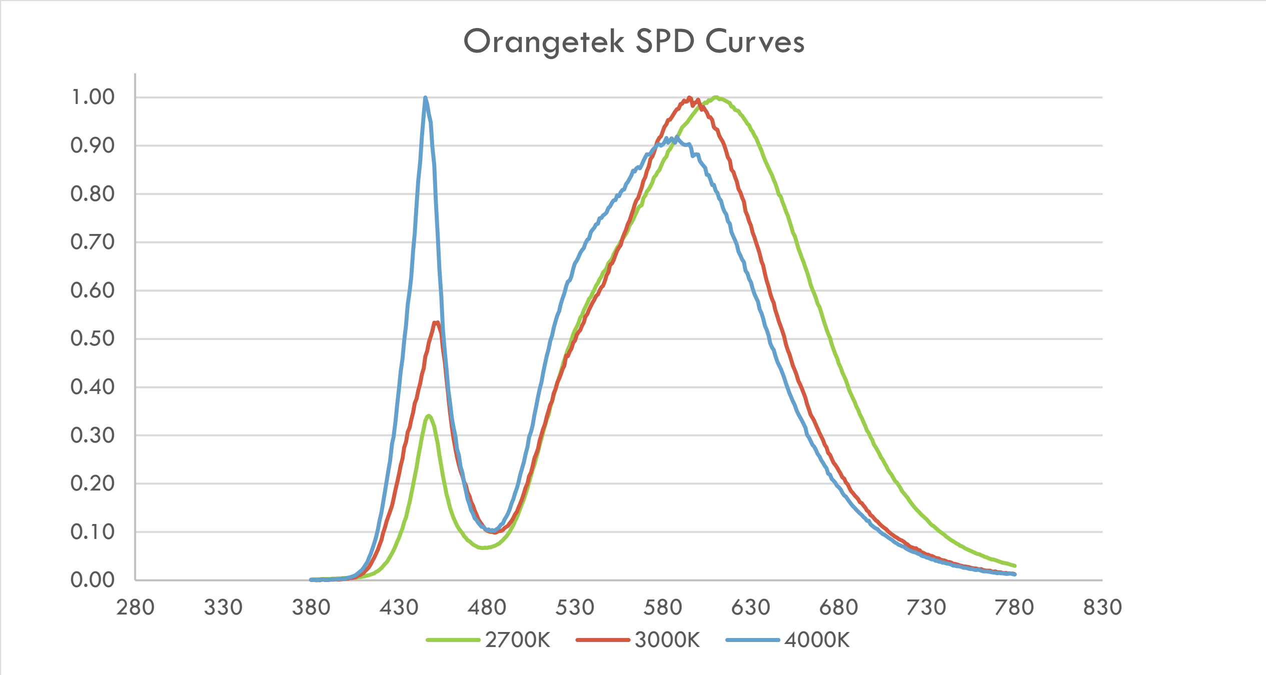

Figure 3 - Orangetek SPD Curve.

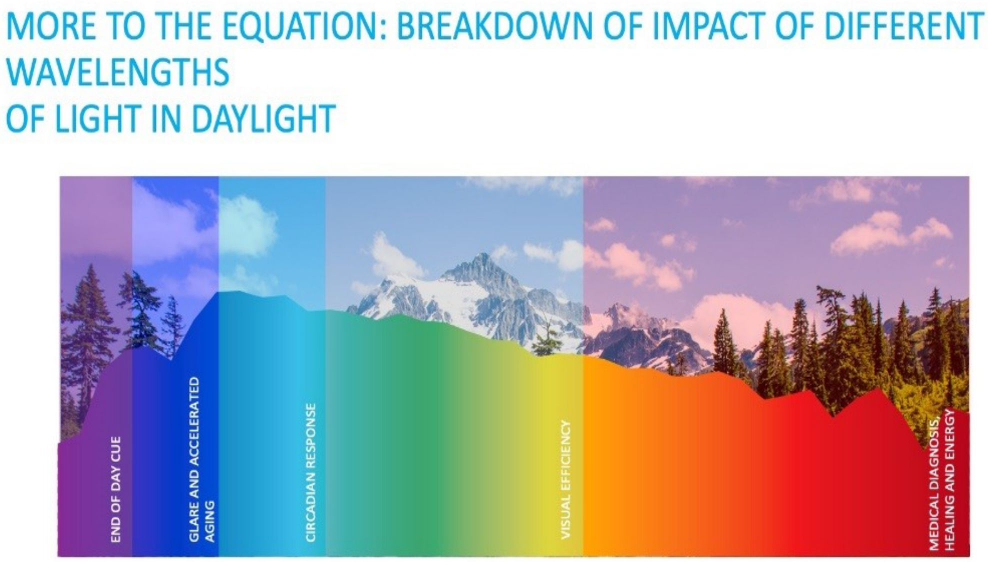

Figure 4 Different wavelengths of natural daylight. Source OSIN and Robert Soler presentation.

From Figure 4 above humans are the most visually efficient during daylight hours. Hence if one was to overlay figures 2 & 4 the luminaires that are the closest match to that of daylight is what we would want to use at night. From a safety aspect we can accurately identify colours and objects better and quicker under artificial light conditions that most closely resembles natural daylight conditions.

Hence in conclusion, when evaluating “blue light” we shouldn’t just consider CCT we should also check the spectrum distribution curve to identify where and what the values of all the colour wavelengths are.

__Bug Ratings.__
This is an international recognized luminaire classification system that allows quick identification of Backlight, Upward light and Glare based on angles of distribution. Hence a luminaire with a Bug rating of B2-U0-G2 has less backward spill light behind the luminaire than a fitting with a bug rating of B3-U0-G2. Figure 5 below shows the various angles of evaluation from all segments.

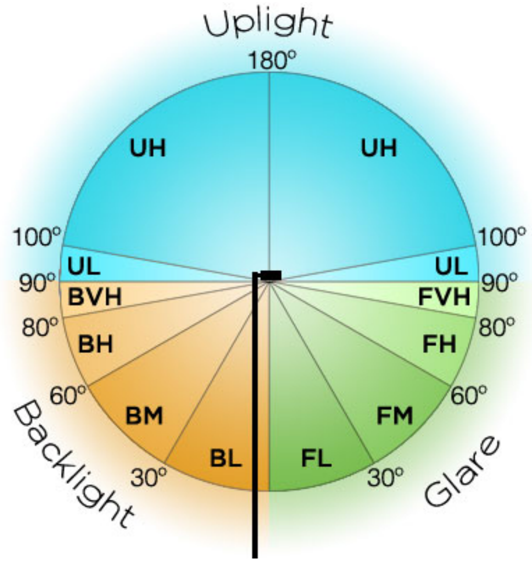

Figure 5 BUG Rating luminaire classification diagram.

__Atmospheric scatter.__
It is often said that light pollution from artificial light and the conversion of road lighting to LED has led to increased atmospheric scatter of sky illuminance. This can be commonly referred to as 'Sky Glow'. An article by Chris Baddiley[5] in the ILP Lighting Journal July/August 2019 somewhat disputes this (see Appendix B).

Most LED designs are installed with the intention of aiming light downwards and hence any light that reaches the sky is from reflected light off the ground, road or grass verge. The difference between scattering of light in the night sky between 4500K and 3000K LED is minimal as seen in the graph in Figure 6 below.

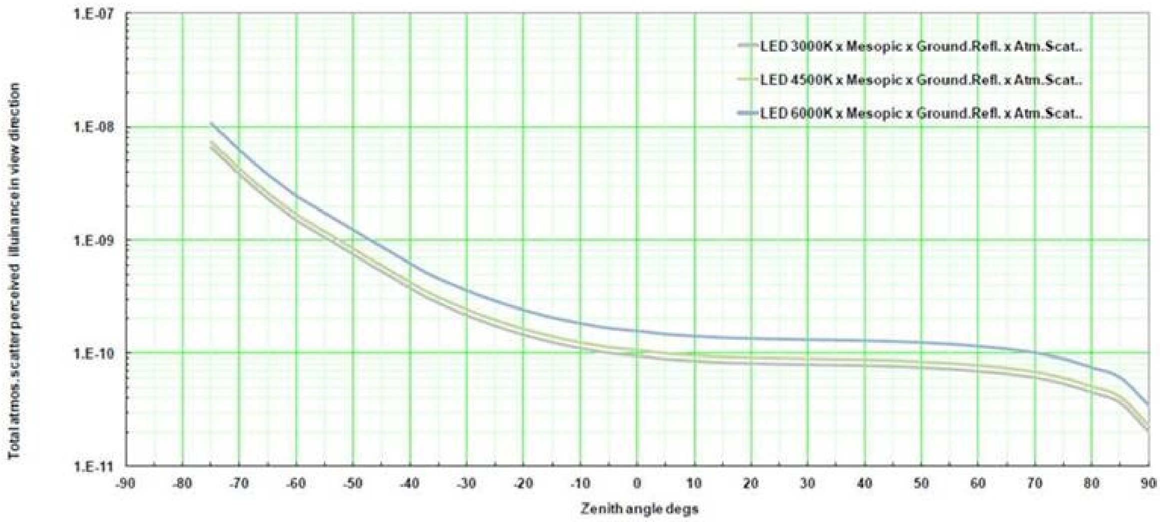

Figure 6 Atmospheric scatter sky illuminance. Source - ILP Lighting Journal July/August 2019 – Light Pollution Modelling.

[5] Chris Baddiley is a scientific advisor to the British Astronomical Association for Dark Skies and is a retired Physician. www.baddileysuniverse.net/aboutMe.aspx.

Frith and Jacket (2019) (see Appendix D) considered the absorption of “blue” light from different road surfaces. They concluded along with Van Bommel (2015) that there is little difference in surface luminance between 2800K and 4000K LED’s.

The afar view of sky glow from LED’s is not so much CCT (colour) dependent. It is often other poor performing light technical parameters such as tilt angle, upward light component, poor optic choice, poor aiming or mounting angles, or unchecked or obtrusive light installations. As discussed above, the ability to use flat glass luminaires that can be easily provided by using LED technology provides one of the main benefits to reduce light scatter and sky glow. The article in Appendix B by Chris Baddiley also supports these technical parameters. CCT can help improve the night sky but I believe it is only one consideration as well as other more important design considerations such as a flat glass luminaire requirement, tilt and aiming angles, as well as identified luminaire BUG ratings.

Street lighting is only one source of exterior lighting and all other forms of exterior lighting should be addressed e.g. factories, dairy plants, exterior building and house lighting. Aside from street lighting, currently there is a lack of availability of everyday lights (at or below 3000K) at competitive prices with excellent performance attributes readily available at retail, commercial or hardware outlets throughout NZ.

Summary of key points:

- Luminaire BUG rating is important regardless of CCT.
- Light scatter difference between 4000K and 3000K is minimal
- CCT is only one parameter for consideration. Other key parameters include flat glass, tilt angle, aiming angle, upward light component, optic choice and installation situations and checks.
- Other sources of exterior lighting need to be controlled and are important to the overall effect.

4.0 Health and Safety Concerns.

Lighting for roads and public spaces.
The major purpose of public lighting in residential areas in NZ is to assist pedestrians to orientate themselves, detect potential hazards and to discourage crime while protecting the integrity of the environment through the control of glare, spill light and upward light. This is mostly achieved via compliance or non-compliance with AS/NZS1158.3.1. known as category P. Depending on the situation there are several subcategories identified relating to mixed vehicle and pedestrian traffic based on high, medium or low pedestrian/cycle activity, risk of crime or the need to enhance an area.

Vehicular roads known as category V usually carry greater volumes of traffic and or can be at a higher speed where the visual requirements of the motorists are predominated. To accomplish these objectives higher lighting levels are usually required to clearly identify the road ahead, kerb, footpaths, stationary traffic, adjoining properties, traffic management devices, surface hazards and other road users. This is mostly achieved via compliance with AS/NZS1158.1.1 with more attention given to compliance with high, moderate or low, vehicle volumes, vehicle speed, pedestrian traffic, stationary vehicles, pedestrian volume and the number of abutting properties.

In order to cover all these lighting objectives, 4000K streetlights were recommended by NZTA as the ideal compromise between efficiency, power use, colour identification, expected life, maintenance, environmental impact and cost.

A recently adopted standard AS/NZS4282 (February 2019) has been introduced into NZ to Control the obtrusive effects of outdoor lighting. The purpose of this standard is to control the obtrusive effects of outdoor lighting by identifying and controlling light technical parameters by appropriate design. It focuses on nearby residents, users of adjacent roads, transport signaling systems and astronomical observations.

Sleeping patterns.

There have been several worldwide comments made about the possible detrimental effects of outdoor LED lighting and how our sleep patterns and circadian rhythms can be affected by over exposure to LED street lighting. This has been dismissed by many others Public Health England (Appendix C) and Safety, Health and Environmental Implications Frith/Jackett 2019 (Appendix D). Any impacts are likely to affect people between the ages of 20 – 25 years more than those between the ages of 60 - 69 because their eye lenses have not yet yellowed.

The American Medical Association (AMA) made a claim about the detrimental effects of LED lighting and the best counter claim to this topic is from a report prepared by the Public Health England (PHE) see Appendix C – Human responses to lighting based on LED lighting solutions.

John O'Hagan, senior scientific group leader of PHE's radiation dosimetry department, has stated that the risk of glare from LED streetlighting is "minimal". He added that references to high levels of blue light damaging the retina refers to blue light in general rather than that emanating from streetlights.

"Exposure to blue light in excess of internationally agreed exposure limits may result in retinal injury". However "most people are *unlikely* to experience blue light levels that are anywhere near the exposure limits," Mr. O'Hagan added. In conclusion, Mr. O'Hagan emphasized: "There is **no** risk of eye damage from LED street lighting."

Spokesperson and optometrist, Farah Gatrad, explained that looking at blue light for extended periods of time can increase eye strain and affect sleep patterns, but there is no evidence to suggest that it can cause permanent damage to the eye.

The Association of Optometrists (AOP) position on blue light can be found on its website; www.aop.org.uk/ot/science-and-vision/research/2018/04/07/phe-moves-to-quell-led-streetlight-fears.

The likely effects of blue lighting interfering with sleep patterns are more likely to come from electronic devices without blue light filters than LED street lighting.

NZTA Feedback.

During the preparation of this report contact was made with Julian Chisnall, Team Leader Road Safety at NZTA on 18th December 2019 seeking feedback on the differences between 4000K, 3000K and 2700K. Feedback from these discussions is summarised below.

The question was asked if NZTA has any imminent intention to accept 2700k on their SH network in the future? (M30 currently allows the use of 3000k provided the efficacy is not more than 7% compared to a 4000k equivalent). Response to this question was it will depend on evidence and on the need of most Territorial Authorities (TA's). Currently there is not any evidence (that NZTA is aware of) that justifies a drop below 3000K. As 3000K chips become more efficacious then they see more of a trend toward 3000K as a default for lower speed environments pedestrian areas (category P areas), but they do see 4000K remaining the default for high speed roads (category V) based on current evidence relating to eye adaptation/response times.

Has NZTA undertaken any research on the safety aspects of reducing the CCT or do you know of any international research available? Is it possible the results of this research could be made available to public? There has been limited work done about reductions in CCT and many sources suggest CCT is not a particularly robust light technical parameter for LED lighting. There has been some work done in relation to crash rates and white light LED vs HPS (see attached Appendix D) and they are working on adding these reports and some others to the NZTA web site. Overall the conclusion has been that 4000K is fine, 3000K will be okay when the efficacy is improved, and LED is better than HPS.

In order to better control "blue" wavelength peaks in higher wattage LED luminaires NZTA has the intention to develop a Spectral Power Distribution (SPD) envelope. This will be a better technical measure where the flux output has a limit over a range of wavelength distributions. Hence the overall CCT will not be the restricting and confusing parameter.

The American Medical Association (AMA) have been vocal about blue light from LED streetlights. Do you have any thoughts and/or are these likely to be addressed by NZTA in the future? Best counter to the US AMA is the Public Health England report (attached Appendix C). There is no evidence of adverse effects from outdoor lighting and there is also a quote in this document that states there is no risk of damage to one's eyes from exposure to street lighting.

Constant light output (CLO), better performing optics e.g. flat glass, correct mounting and zero-degree tilt installations are often used as better attributes to control "obtrusive light". Apart from the current standard AS/NZS1158 and AS/NZS4282 are there any other controls NZTA are considering from a safety perspective? No, if we can get all designs to comply with the basics (AS/NZS1158 and AS/NZS4282) we'd make significant progress towards managing obtrusive effects including glare and Upward Waste Light (UWL). "Safety" as regards issues with light need to be managed at a policy level. Controls are just tinkering with the energy savings or managing public issue with light intrusion after hours. The hardware is out of our control. NZTA is also concerned about the uncontrolled static sources such as car yards, security lighting, private sports facilities and waste light from commercial buildings.

As part of the Selwyn District Plan Review contact was made with Richard Shaw, Team Leader Consents and Approvals at NZTA on 22nd September 2019 seeking feedback on their preference of using 4000K, or 3000K and 2700K LED's on new projects within their SH network. Feedback from these discussions is summarised below.

Richard talked to their network advisors on these matters and concluded that their standard would require luminaires to have a nominal colour temperature near 4000K. When they are considering new projects and any retrofit for the State Highway, they would be lighting the corridor to this standard. They have negotiated specific departures to these requirements for sky glow reasons in other Dark Sky accredited areas but the minimum their have negotiated down to in the past has been 3000K. There have been cost implications with this reduced level because of total system wattage used and reduced expected life. Potential safety impacts haven't been confirmed but the primary reason for SH lighting is safety with the need to light obstacles and structures in the road corridor.

Given that the SH network is generally high volume and high speed the risks are possibly exacerbated. Richard is not aware of any advice that the setting of the level at 2700K is acceptable to NZTA.

5.0 Cost Estimates.

Over the past five years the number of 4000K LED lights installed in new subdivisions by developers has averaged 333 per year. The following cost estimates are based on numbers derived from the spreadsheet provided in Appendix E and the authors knowledge of the current LED renewal project underway by SDC.

The areas shown on the attached map (see Appendix F) have been used to assess the cost of replacing luminaires over the complete network and alternatively over a smaller number of areas.

Cost to supply street lighting luminaires.
As LED technology continues to develop the cost difference between 4000K and 3000K luminaires is getting closer because of increased competition and now most of the larger manufacturers have lower CCT chips available as an option. This was not the case 3-5 years ago where the buyer had limited options and the cost difference between different CCT's was significant, typically (10% to 20%).

Today many suppliers can supply 4000K or 3000K chips at the same or similar cost. If there is any cost difference it will be as low as 1% or 2% especially at lower wattages where there is more competition.

Based on recent purchase and installation charges over the past 2 years plus 20% increase to allow for inflation, less competition at higher wattages, contractors margin, storage/insurance, shortage of resources, plus an allowance for time delay to order/install the following costs have been used in this analysis;

- luminaire supply =$575
- Install and materials = $375
- Total =$950/fitting + GST.

Numbers ascertained from spreadsheet in Appendix E to replace all streetlights with 3000K

- **Outstanding Natural Landscape** (ONL) includes Arthurs Pass, Castle Hill, Coalgate, Glentunnel, Glenroy, Lake Coleridge, Springfield, Whitecliffs, Windwhistle = 261 x $950 ≃$247,950
- **Sky Glow Area –** includes ONL areas plus Annat, Bankside, Brookside, Burnham, Charing Cross, Courtney, Darfield, Dunsandel, Greendale, Halkett, Hororata, Kirwee, Sandy Knolls, Sheffield and Waddington = 1072 x $950 ≃ $1,018,400
- **Coastal Area –** includes Ellesmere, Greenpark, Motukarara and Tai Tapu = 114 x $950 ≃ $108,300
- **West Melton Area –** includes West Melton township and Weedons rural = 469 x $950 ≃ $445,550
- **Township Area –** includes Broadfields, Doyleston, Farrington, Irwell, Ladbrooks, Leeston, Lincoln, Prebbleton, Rolleston, Selwyn, Southbridge, Springston and Templeton. = 5500 x $950 ≃ $5,225,000
- **Total Network** **=7155 x $950≃ $6,797,250 OR $6.8m.**

The current LED replacement program involves approximately 5000 luminaires for an approximate cost of $3.2m. Hence the reason why the above figure is likely to cost more is because of increased costs plus it includes replacing the previous existing LED streetlights supplied by developers.

The additional cost to replace the total network streetlights with 2700K instead of 3000K is likely to incur an additional estimated cost of 5% – 10% above this giving a total for the entire network upgrade = $**7.5m**.

The NZTA are subsiding Councils the current $3.2 million LED streetlight program to replace approx. 6000 old inefficient streetlights with modern 4000K LED units. This is for less maintenance, more efficiency and better road safety benefits this will bring. This work is being subsidized by the NZTA by 80% as it is in accordance with their current requirements and criteria for LED streetlight renewals that include using 4000K CCT units.

The NZTA would not fund another district wide replacement program just to provide for "Dark Sky" type outcomes (as this is not road or road safety related), therefore the Council would have to meet the full cost of such an endeavor. Even if this funding was provided it would take 4-5 years to replace all of Councils streetlights (including those currently being installed) based on the rates in the current replacement program. It is expected that the current LED luminaries will have a 20-25-year life expectation. It would be more sensible that these luminaries are replaced with lower CCT ones when that times comes. Other technology advances that may occur in the meantime may result in even more opportunities to provide for Dark Sky outcomes and/or to improve yet further on any sky glow pollution beyond what can be contemplated at present.

In my opinion this cost will provide little overall benefit to SDC if NZTA do not replace their network with 3000K or indeed 2700K. However, if SDC were to replace lights in the Outstanding Natural Landscape, Coastal Area and the West Melton Observatory area for example this could cost around **<u>$800,000 - $900,000.</u>** (From above figures ($247,950 + $108,300 + $445,550) x 1.1).

While this is a significant cost it could allow SDC to apply for Dark Sky Accreditation in those areas where there is significant night sky viewing opportunities. It is noted however that NZTA would also need to agree to replace their state highway streetlights with 2700K versions where the State Highway network falls within potential Dark Sky Accreditation areas. As advised previously Accreditation is also dependent on changes/controls on any private exterior lighting beyond what street lighting can provide undertaken by Council. The extent of how private lighting may need to change is beyond any ability to be assessed currently to achieve Accreditation. Rules in the District Plan could be introduced to control any new lighting, but this could not be retrospective.

<u>Subdivisions Implications.</u>

In order to assess the effects of changing the streetlighting from 4000K to 3000K on a new subdivision development a recently installed subdivision in Rolleston was re-assessed that has 154 LED streetlights.

The findings from this redesign assessment is summarized in Table 2 below. Original lighting calculations were re-calculated using the same road parameters but I-Tables and lumen output for 3000K variants were used with the results summarized below.

Street name & classification	Design width	Arrangement	4000K max. design spacing	3000K max. design spacing	Reduction in design spacing
Road 03A,04 & 07 (P3)	20m	Staggered	51.5m	49.7m	3.6%
Road 05A, 05B, 06 & 23 (P3)	17m	Staggered	52.4m	50.9m	2.9%
Road 11,12,13,14 & 20 (P3)	13m	Staggered	54.6m	52.6m	3.8%
Road 11,12,13,14 & 20 (P3)	13m	Single sided	52.6m	49.2m	6.9%
Road 1 (V4)	11m	Staggered	43m		
Road 2 (V4)	11m	Staggered	43m	42m	2.4%
Road 2 (V4)	24m	Staggered	39m	37m	5.4%
Springston Rolleston Rd (V4)	9m	Single sided	60m	60m	0%
Pathway (P4)	2.5m	Single sided	50.5m	50.5m	0%

Pathway (P4)	3.0m	Single sided	50.5m	50.6m	0%

Table 2 Summary results of redesign of recent subdivision in Rolleston.

In many lab situations the lumen output and efficacy of a 3000K variant is usually lower by approximately 3% to 8%. This is confirmed in Table 1 above and indicated within Appendix A. A further reduction of lumen output between 3000K/2700K is estimated at 5% - 7% giving a total possible reduction of 8% - 15%. As technology advances this is likely to improve and it is anticipated to get closer between the 4000K and 3000K variant somewhere between the years 2020 and 2025 (source Figure 9 Van Bommel, 2015, page 138 and Frith/Jacket 2019 (refer to Appendix D), and the authors current knowledge of available product information).

However, when this is translated into calculated results the maximum design spacing between luminaires can result in less than 7% difference as indicated in column 6 in Table 2 above. When these results are further transposed to actual road layout situations it can result in minimal increase (if any) in actual number of additional lights required. This is because the calculated maximum design spacings are reduced to allow for intersections, roundabouts, kerb layouts, driveways and general section layout.

Using the results of a 3000K variant from Table 2 above and relating these to a possible new layout a comparison of actual fittings required is shown in Table 3 below.

Street name	Original 4000K design	Alternative 4000K design	Anticipated 3000K design
Road 2	20	19	20
Road 23	4	4	4
Road 6	6	6	6
Road 5A & 5B	15	15	15
Road 7	5	5	5
Road 20	5	5	5
Road 11	5	5	5
Road 12	7	7	7
Road 13	5	5	5
Road 14	11	9	11
Road 03A	16	16	16
Road 04A	11	11	11
Road 15	2	2	2
Pathway	27	24	27
Springston Rolleston Rd	15	15	15
Totals	**154**	**148**	**154**

Table 3 – Design layout summary table.

Notes regarding design analysis shown in table 3 above.

1. No two designers are likely to design a subdivision in the same way hence it is common to get a difference in number of columns/lights used in any final layout.
2. A further number of lights could have been reduced on the Pathway layouts by using higher columns (7.5m).
3. I-Tables for a 2700K variant were unavailable for analysis. It can be seen from Tables 2 & 3 above that the design spacing is reduced by 0% to 7% but this fact alone has none or little impact on the final number of lights required due to actual positioning of lights within this subdivision because of intersections, roundabouts, general kerb and road or section layout. I don't believe this would be the case of allowing the use of a 2700K variant.

Conclusion: Changing from 4000K to 3000K has little or no cost implications on changing in a "Greenfields subdivision" situation. This is **NOT** likely to be the case when replacing existing infrastructure equipment as indicated below.

Non-compliance using existing infrastructure.

When the original MV, MH, fluorescent and HPS streetlights were replaced with 4000K luminaires under the current renewal program they were mounted on existing infrastructure (overhead poles and underground supplied columns) over the entire network. This reduced the overall project cost and incurred a nominal 7.3% non-compliance with current standards (AS/NZS1158).

How this is derived is information taken from the current renewal program and summarized in Table 4 below.

	Zone 1 Leeston Area	Zone 2 Darfield Area	Zone 3 Rolleston, Lincoln, Prebbleton Area	Average
Compliant using 4000K luminaires.	85.8%	84.6%	92.5%	87.6%
Compliant but via the 10% clause AS/NZS1158.	5.9%	5.2%	4.2%	5.1%
Non-compliant.	8.3%	10.2%	3.3%	7.3%
Total	100%	100%	100%	100%

Table 4 Summary of non-compliance from 4000K luminaires.

In addition to this nominal non-compliance value (7.3%) there is another 5.1% that utilizes clause 3.1.2 within AS/NZS1158 where the individual design spacing can be exceeded by not more than 10% provided the non-complying spacings do not occur for more than two consecutive spans.

It is therefore feasible if the network is changed from 4000K LED's to 3000K today the reduced lumen output of 3% to 8% reduction could incur an additional area of non-compliance approaching 5%. Therefore, it is realistically possible that the overall non-compliance over the entire network could rise to 7.3% + 5% $\simeq 12.3$ %.

This may lead to more complaints, more accidents (probably of a minor nature such as slips or falls), unforeseen objects being hit on the road and a general reduction in lighting service.

Conclusion: In my opinion it is possible to replace lights from 4000K to 3000K in certain areas of Selwyn District but is not practical over the entire network and would make negligible difference to sky glow. It is likely to be achievable in residential or pedestrian areas but not on higher speed roads or vehicular roads due to lack of research. This research and safety considerations are important aspects for NZTA. The 2700K variant is likely to be more detrimental (cost more, less performance) than the 3000K.

Control system via existing lights.
The existing LED lighting being installed (4000K) has been future proofed by installing dimming drivers with a shortening cap added on the top of each luminaire. What this means is that each luminaire can have an additional Lighting Control Unit (LCU) added along with suitable software to give improved individual control. While this will not change the colour appearance it will enable more brightness control and or various switching options.

Each LCU (luminaire) talks to others via a Gateway. Typically, one Gateway can control up to 500 lights and is usually restricted to communicate between gateways for a distance up to 5 km apart.

A radio frequency network is preferred over a cellular network for better future compatibility reasons. Software then controls each gateway and in turn allows brightness control or switching options of each individual light. Additional software can be added for other technologies as and when required in the future.

Christchurch City Council (CCC) is currently installing a control system on each of their lights in the city and this is being investigated to being extended over the Banks Peninsula area. NZTA owned lights in their area are likely to be added in the future hence there is no reason why SDC/NZTA owned lights in Selwyn District could not be added to this network in the future.

No design of a suitable control system has been undertaken for SDC and a business case would need to be provided to NZTA for consideration of them funding or partial funding such a control system under the present 80% FAR subsidy.

Approximate cost estimates of Central Management System (CMS) over the whole network:

- Each LCU = 7155 x $150 = $1,073,250
- Installation and commissioning of LCU on all existing luminaires
  = 7155 x ($300 - $350) = $2,504,250
- Gateway – say 12 off = 12 x ($5000 - $7000 each) = $84,000
- Software = $40,000 to $60,000 = $60,000
- Total = $3,721,500
  Say $3.7m

However, if SDC were to add controls to lights in the Outstanding Natural Landscape, Coastal Area and the West Melton Observatory areas this could cost around:

- Each LCU (261+114+469 = 884) = 844 x $150 = $126,600
- Installation and commissioning of LCU on all existing luminaires
  = 844 x ($300 - $350) = $295,400
- Gateway – say 6 off = 6 x ($5000 - $7000 each) = $42,000
- Software = $40,000 to $60,000 = $60,000
- Total = $524,000
  Say $525k

A Central Management System (CMS) is not justified based on energy and maintenance cost savings alone, hence there is a need for other reasons to consider the installation of a fully integrated CMS.

Appendix A. Cree AND LRL 4000K and 3000K lab reports. Orangetek SPD Curve for 4000K, 3000K & 2700K.

Appendix B. Chris Baddiley article in Lighting Journal on Light Pollution Modelling.

Appendix C. Public Health England report on Human responses to LED lighting solutions.

Appendix D. Implications of adopting LED over High Pressure Sodium road lighting. (NZTA report by Frith / Jackett (January 2019).

Appendix E. RAMM database spreadsheet.

Appendix F. Selwyn District Sky Glow Area map.

References and Acknowledgements.

AS/NZS1158 series of standards Lighting for Roads and Public Spaces.

AS/NZS 4282 Control of the Obtrusive Effects of Outdoor Lighting.

NZ Transport Agency (2014) M30 Specification and Guidelines for Road Lighting.

SDC RAMM data base.

SDC Sky Glow Area map.

Cree NVLAP Photometric Testing and Evaluation Report for 4000K and 3000K LED XSP luminaires.

LRL NVLAP Test Reports LLI-18211-3 & LLI-18119-4 for 4000K and 3000K LED NXT luminaires.

OSIN and Robert Soler presentation on Circadian Lighting.

Orangetek 4000K, 3000K, & 2700K SPD Curve.

WSP Opus Research – Frith / Jackett (January 2019) report for NZTA on The Safety, Health and Environmental implications of adopting LED over HPS road lighting.

Public Health of England – Human Responses to Lighting based on LED Lighting Solutions CRCE-RDD (April 2016) by LLA Price, M Khazova and JB O'Hagan.

ILP Lighting Journal (July/August 2019) Light Pollution Modelling by Chris Baddiley.

Julian Chisnall – Operational Policy, Planning and Performance (OP3), Team Leader Road Safety

Richard Shaw – Team Leader – Consents and Approvals.