

Jet Zero™



LIGHTING ENVIRONMENTAL ASSESSMENT



Jet Zero Australia – Project Ulysses

LIGHTING ENVIROMENTAL ASSESSMENT REPORT

Prepared for: Jet Zero Australia

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About Rubidium Light

Rubidium Light is a specialist lighting design consultancy that collaborates with stakeholders throughout all stages of development, from concept to final construction. Since 2011, Rubidium Light has leveraged its extensive knowledge of lighting and its application in technically challenging solutions. The company prides itself on its ability to respond swiftly and cost-effectively, delivering outcomes that are both responsible to the environment and beneficial to its clients.

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1. Executive Summary

Jet Zero Project Ulysses: Environmentally Responsible Lighting Strategy

Jet Zero Project Ulysses, a bio-jet fuel production facility in Townsville, faces distinct challenges in developing an environmentally responsible lighting plan. Given its proximity to sensitive marine and terrestrial habitats, the project must carefully balance industrial functionality, ecological protection, and compliance with Australian environmental and lighting standards.

Rubidium Light has prepared a Lighting Environmental Assessment Report outlining mitigation strategies to minimise environmental impact, reduce energy consumption, and maintain operational safety.

Key Lighting Strategies

- **Optimised Luminaire Distribution** – Light is precisely directed to operational areas, preventing unnecessary spill into sensitive zones such as intertidal areas and migratory bird habitats.
- **Reflected Light Control** – Asymmetrical lighting and carefully planned mounting heights minimise upward reflection, reducing sky glow.
- **Dynamic Lighting Control** – Adaptive dimming and switching systems adjust lighting in response to real-time operational and environmental conditions.
- **Low-Impact Light Sources** – Warm white 2200K LED luminaires significantly reduce blue light emissions, mitigating disturbances to marine and nocturnal wildlife.
- **Environmental Enhancements** – Shade sails and directional shielding further limit light spill and reflection, protecting both natural habitats and the night sky.

Key Discussion Points

- **Existing Conditions** – Industrial development in the area has contributed to elevated background light levels. The report outlines advanced lighting controls to mitigate this issue.
- **Ecological Considerations** – Lighting impacts on wildlife (bats, migratory birds, mammals, insects) and human health are assessed, with a focus on spectral tuning to minimise disruption.
- **Mitigation Controls** – Selection of energy-efficient LED luminaires, advanced control systems (e.g., constant luminous flux, dimming), and strategic luminaire placement enhance sustainability.
- **Specific Applications** – Tailored solutions for flare systems, continuously occupied areas, intermittently occupied areas, and car parks maintain safety while reducing ecological impact.
- **Luminaire Construction** – Corrosion-resistant materials, explosion-proof designs, and advanced thermal management ensure durability in harsh industrial and coastal conditions.

Conclusions & Recommendations

The proposed lighting strategy aligns with environmental best practices and regulatory standards, ensuring the facility operates efficiently while preserving surrounding ecosystems. Key recommendations include:

- Prioritising low-impact lighting solutions, such as 2200K LEDs and directional shielding.
- Implementing advanced lighting controls, including dimming and adaptive switching, to optimise efficiency.
- Minimising reflected light and sky glow through improved luminaire design and mounting strategies.
- Evaluating lighting design during the Front-End Engineering Design (FEED) phase to refine controls before implementation.

By adopting these measures, Project Ulysses can serve as a benchmark for environmentally responsible industrial development, balancing operational requirements with sustainability and ecological stewardship.

2. Introduction

Project Overview: Sustainable Aviation Fuel (SAF) Biorefinery



The proposed Project Ulysses biorefinery, designed to produce Sustainable Aviation Fuel (SAF), will be located within the Townsville State Development Area—approximately 8 km from Townsville city and 2.5 km from the nearest residences. Positioned adjacent to major industrial developments and sensitive intertidal and terrestrial environments, the project presents both unique challenges and opportunities in lighting design.

Rubidium Light has been engaged to develop a comprehensive lighting strategy that balances environmental considerations, operational safety, and aesthetic objectives. Given the biorefinery's proximity to potential nesting and foraging habitats for migratory bird species and a listed bat species, artificial lighting must be carefully designed to minimise ecological disruption while ensuring compliance with Australian Standards (AS/NZS 4282) and maintaining energy efficiency.

Challenges and Opportunities in Lighting Design

Existing industrial developments in the area—including Sun Metals Refinery, JBS Abattoir, and Glencore Copper Refinery—were established before modern lighting standards were in place, contributing to elevated background light levels and associated impacts. This project presents an opportunity to incorporate environmentally responsible lighting design from the conceptual stage, setting a benchmark for future industrial developments.

Mitigation Strategies and Lighting Controls

To optimise lighting performance and minimise environmental impact, the report outlines a range of targeted mitigation measures, including:

- Precise Light Distribution & Mounting Strategies – Carefully directing light to operational areas while minimising spill and glare into surrounding sensitive habitats.
- Advanced Luminaire Technology & Control Systems – Utilising energy-efficient LEDs and automated dimming controls to prevent excess light emission and reduce power consumption.
- Customised Ecological Solutions – Tailored approaches to mitigate light pollution's impact on avian and bat species, ensuring minimal disruption to local ecosystems.

Industrial projects across Australia are increasingly committed to complying with environmental lighting requirements outlined in the National Light Pollution Guidelines for Wildlife, the Australian Dark Sky Alliance Best Practices, and the International Dark Sky Association Guidelines. Many of these projects are in turtle-sensitive areas and adopt the same obtrusive lighting control methodology proposed in this document to minimise ecological impacts while ensuring compliance with best practices for sustainable lighting.

Commitment to Sustainable Lighting Design.

By integrating these principles into the engineering design process, the project aims to balance industrial functionality and safety with environmental stewardship. Thoughtful lighting design will enhance energy efficiency, operational performance, and compliance with environmental regulations, while protecting the surrounding natural ecosystems.

3. Light Spill Explanation

Light spill refers to the unintended dispersion of artificial light into areas beyond its target. This phenomenon can be categorised into **direct light** (light that spreads into unintended areas near the source) and **sky glow** (light scattered in the atmosphere, causing a diffuse glow in the night sky). Both forms of light spill can have potentially significant environmental, ecological, and human impacts, especially with the increasing prevalence of outdoor lighting in urban and industrial settings.



Direct Light – Example Image only

Direct Light

The impact of direct, uncontrolled lighting is a common issue in many coastal developments at night. Such lighting makes buildings visible from great distances, including the horizon, as illustrated in the example to the left. In this case, existing structures lack adequate light control and are positioned with minimal setbacks.

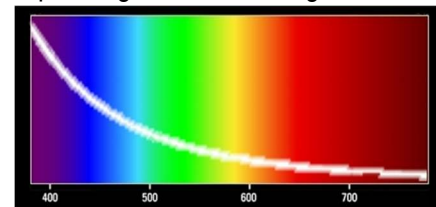
Uncontrolled light sources can include road lighting, exterior building illumination, and substantial interior light escaping through windows. This uncontrolled lighting can have adverse effects on local fauna, potentially disrupting their nesting and foraging behaviours. Moreover, it detracts from the quality of the surrounding environment and contributes to light pollution, diminishing the natural night sky that is the pre-anthropogenic light level.

Sky Glow

"Glow" refers to light reflected off surfaces or emitted directly into the night sky, often becoming visible due to interaction with airborne particles. Uncontrolled light sources, especially those emitting light above the horizontal plane, significantly contribute to this phenomenon. Glow is less noticeable under clear environmental conditions since it depends on particles in the air to scatter light. However, in areas with higher concentrations of aerosols, the extent and intensity of glow can increase.

Given the coastal location of the Project, airborne particles are expected to be abundant due to coastal and weather processes and the dispersal of oceanic sea spray into the atmosphere, as well as industrial particulate emissions. Light emitted or reflected upwards interacts with these particles, amplifying the overall glow effect.

Poor selection of light source types can exacerbate glow. The Earth's atmosphere—comprising nitrogen, oxygen, argon, and water vapor—absorbs, scatters, or transmits light depending on its wavelength. White light, composed of a spectrum of colours, is separated into its components through refraction, such as with a prism. Similarly, the atmosphere selectively scatters light. Shorter wavelengths, particularly from the blue end of the spectrum, are scattered more efficiently, which is why the sky appears blue during the day.



Scatter of light relative to its wavelength



White Light Split by prism

This scattering phenomenon has critical implications for lighting design. By minimising blue-rich light sources and selecting options with low blue light output, we can significantly reduce atmospheric scatter and the resulting glow. The careful choice of lighting solutions will be further addressed in subsequent sections of this report.



Sky Glow – Example image only

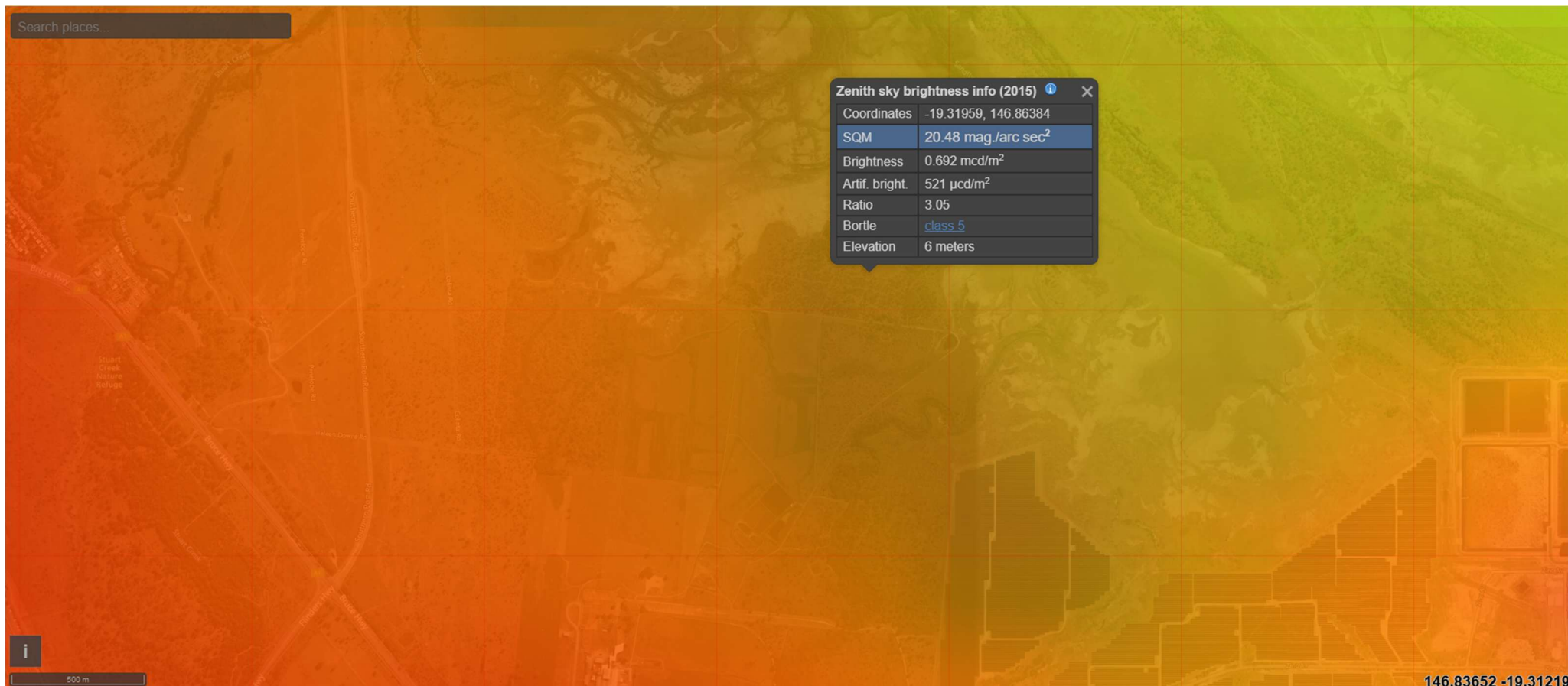
4. Existing Conditions

The proposed site is shown below on <https://www.lightpollutionmap.info/> at the edge of the greater Townsville area where Zenith sky brightness is at approximate magnitude of 20 magnitude/arc-second², meaning that the sky is moderately bright due to light pollution.

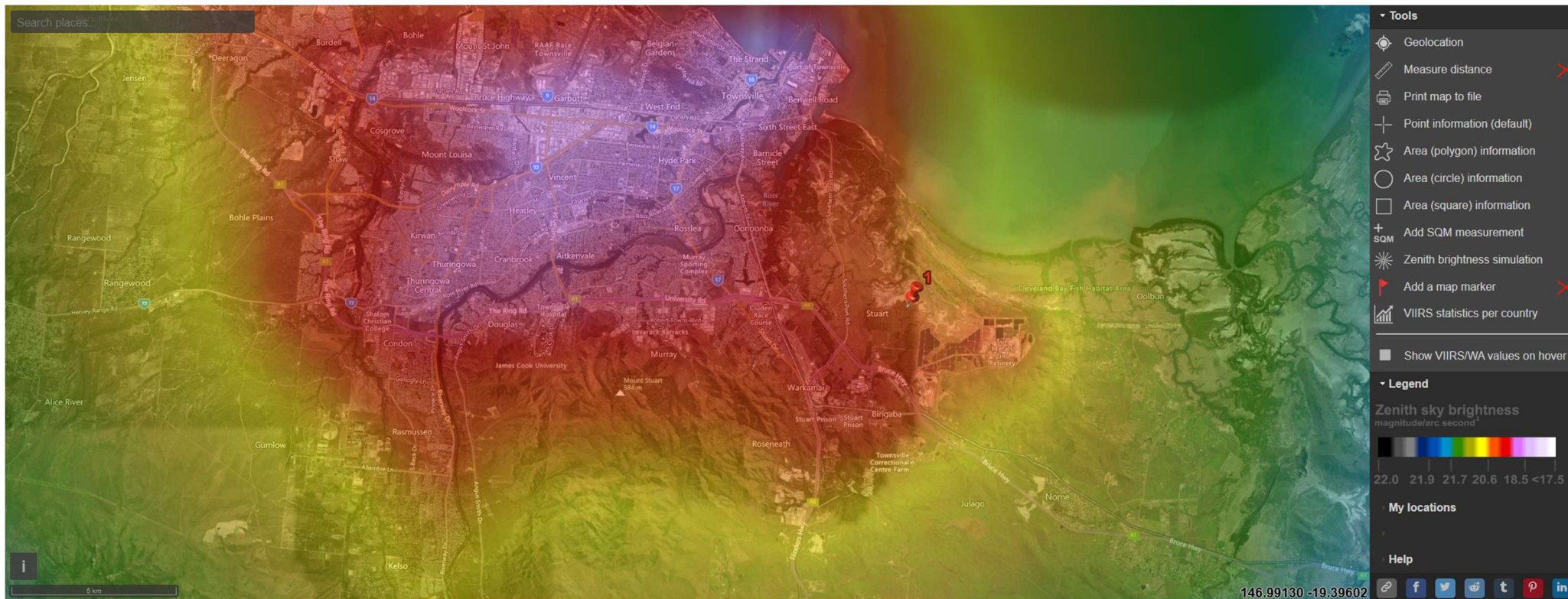
This means the sky is moderately dark, but not pristine. It suggests some light pollution, as truly dark skies (like in remote locations) are typically 21.5+ mag/arcsec².

For context, Townsville CBD is approximately 19 magnitude/arc-second²

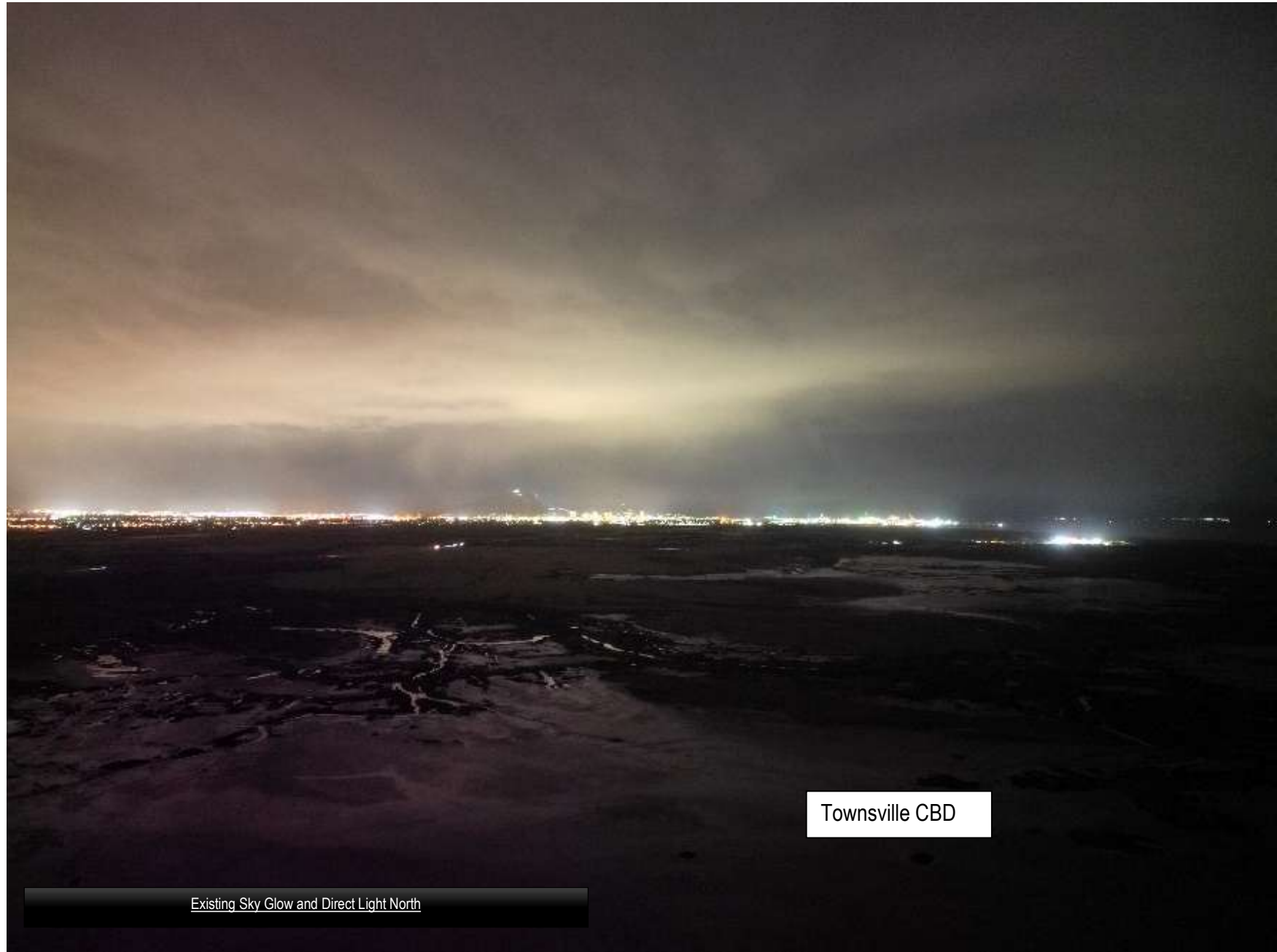
Sky Brightness (mag/arcsec ²)	Sky Description	Visibility Conditions
17	Bright urban sky, severe light pollution	Few stars, planets visible, sky is washed out
18	Urban sky, only brightest stars visible	Only brightest stars and planets visible
19	Suburban sky, faint Milky Way, noticeable glow	Major constellations visible, but faint stars lost
20	Semi-rural sky, Milky Way visible but weak	Milky Way barely visible, moderate skyglow
21	Dark rural sky, Milky Way prominent	Milky Way easily visible, good for stargazing
22	Pristine dark sky, no visible light pollution	Perfect for astronomy, high contrast night sky



Excerpt from www.lightpollutionmap.info of immediate area surrounding site

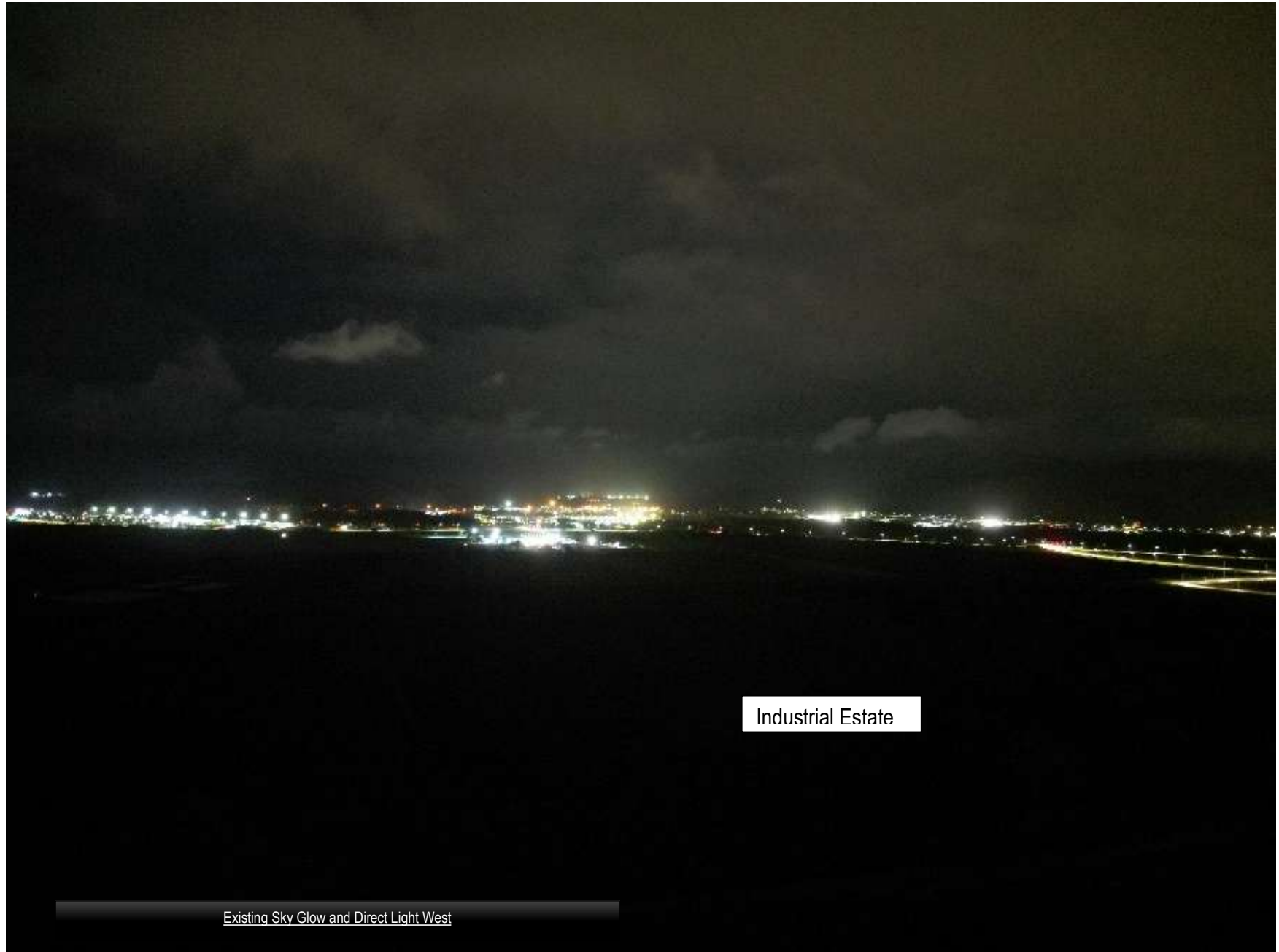


Excerpt from www.lightpollutionmap.info of wider area surrounding site



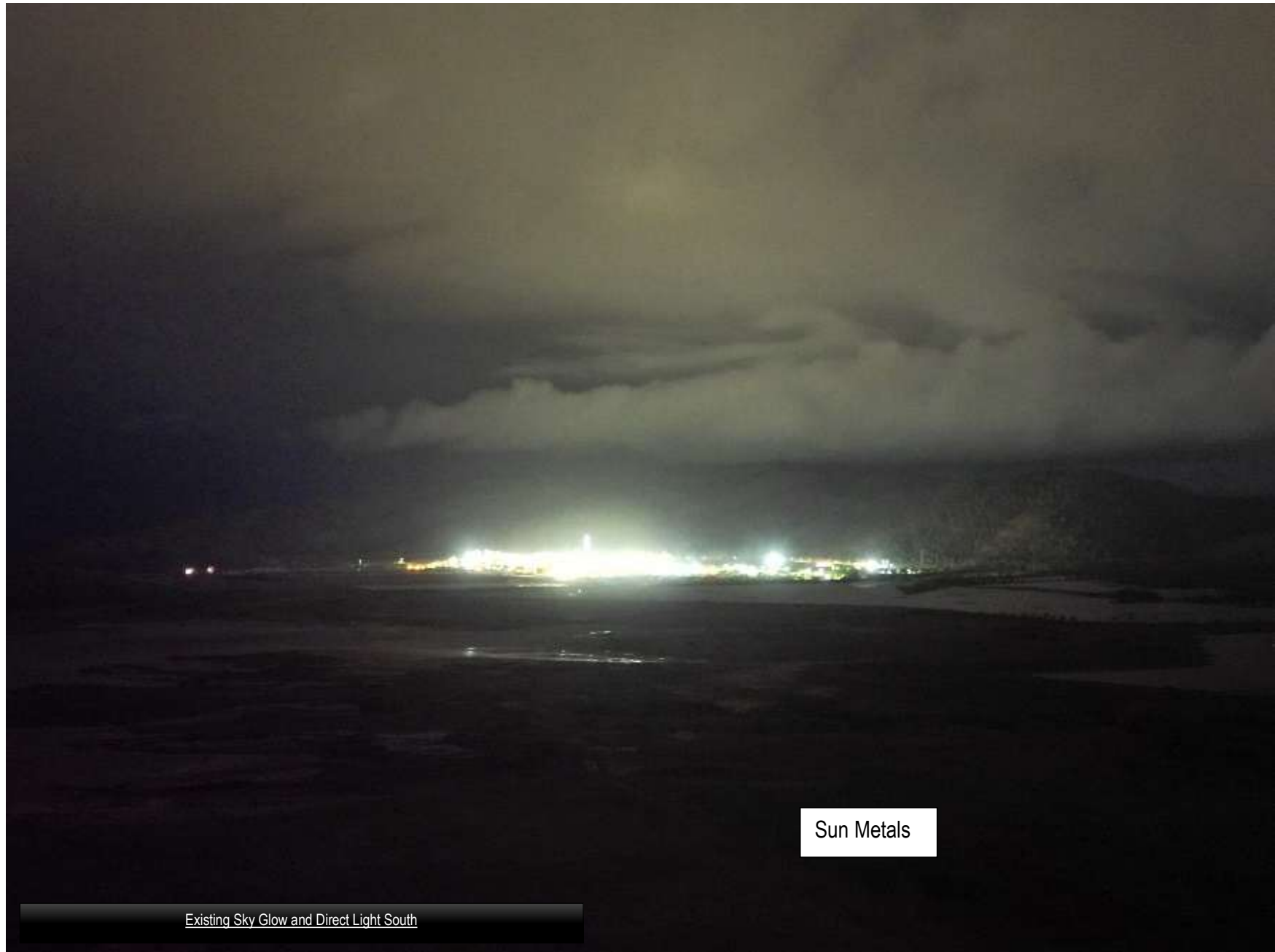
Townsville CBD

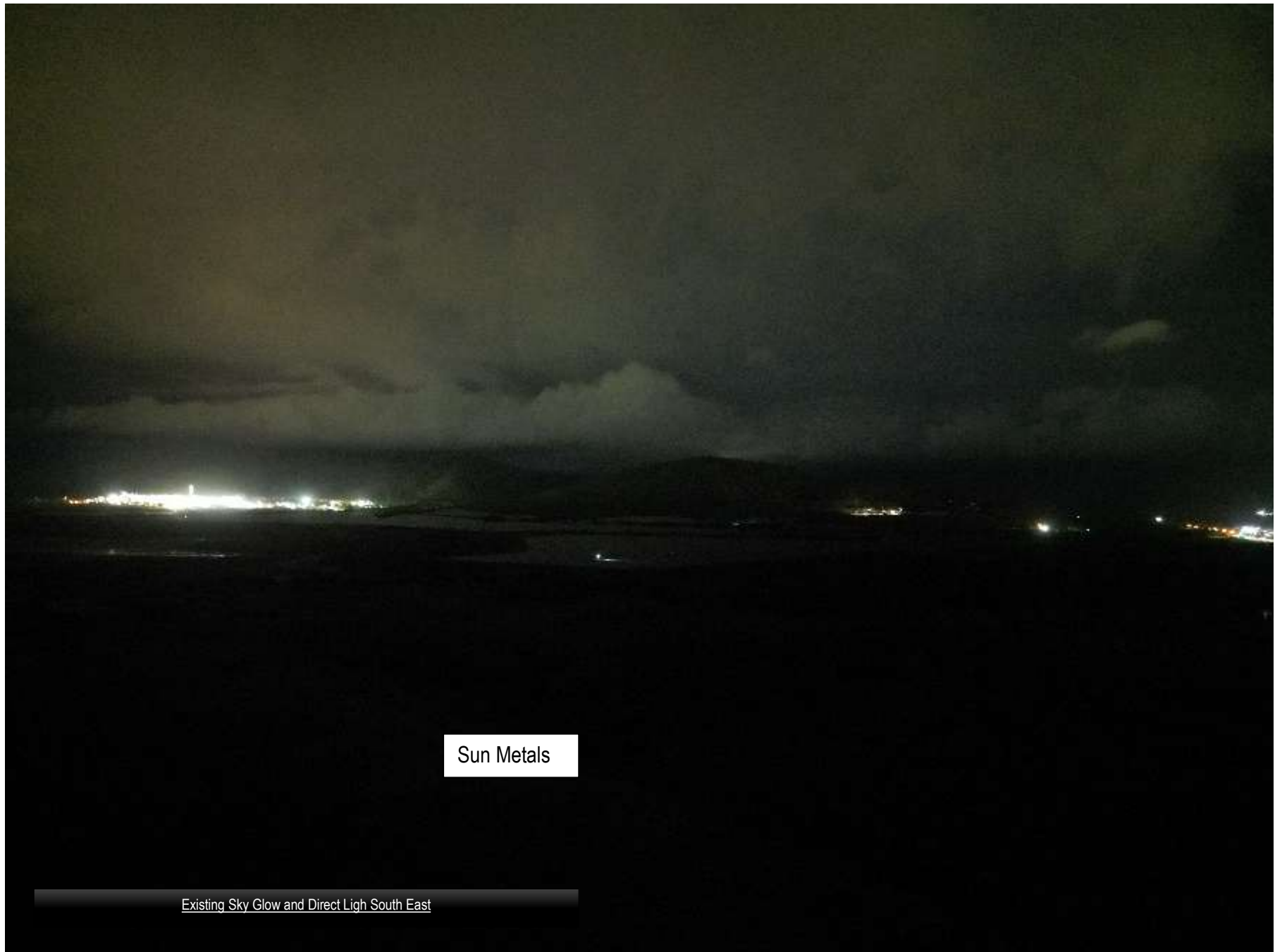
Existing Sky Glow and Direct Light North



Industrial Estate

Existing Sky Glow and Direct Light West





Sun Metals

Existing Sky Glow and Direct Ligh South East





Industrial Estate

View to West



Sun Metals

Ark Energy
Solar Farm

View to South



View to East

5. Vision

The spectral response of fauna refers to how they detect and interpret light across the electromagnetic spectrum. This capability is essential for various biological functions, including navigation, foraging, and communication. Humans, like most mammals, have a trichromatic vision system, whereas other fauna can exhibit a wide range of spectral sensitivities. This section explores the differences in spectral response between humans and various fauna, emphasising evolutionary adaptations and their functional significance to the Project.

Background on Fauna Spectral Response

Fauna displays an incredible diversity in spectral sensitivity, shaped by environmental needs and evolutionary pressures.

Several species can detect ultraviolet light (UV) (<400 nm), which humans cannot. Examples include:

- **Insects** UV vision aids in locating nectar by identifying patterns on flowers invisible to humans. Insects are applicable to the Project for bat foraging / feeding, and the attraction of insects to the plant's lighting.
- **Birds** Many birds have a fourth cone photoreceptor for UV, enhancing mate selection and foraging.
- **Bats**
- **Mammals**

Infrared detection (>700 nm) is rare but occurs in some species:

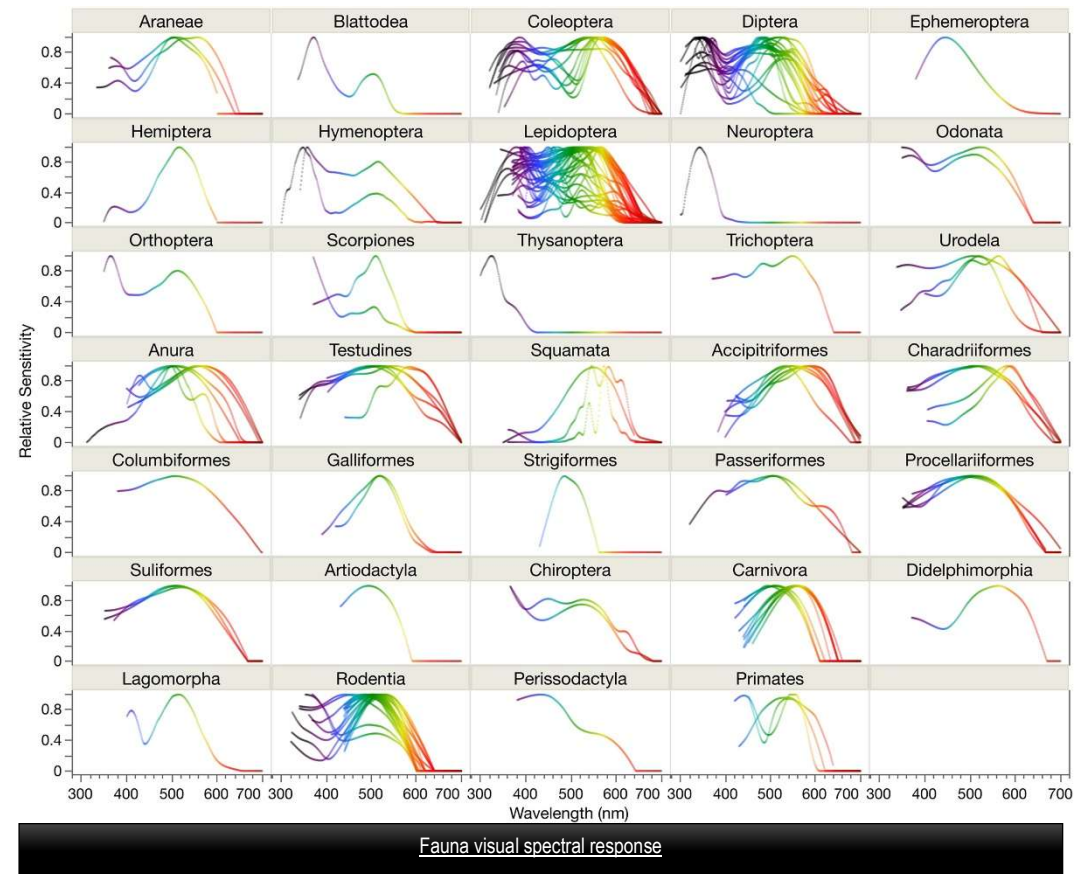
Pythons Infrared-sensitive pit organs detect warm-blooded prey.

Beetles Detect infrared radiation from forest fires for habitat selection.

Expanded Visible Range

Fish: Many species have broader visible ranges, often extending into UV or near-infrared, to navigate turbid or deep-water environments.

Cephalopods (e.g., octopuses): Though they lack colour vision, their spectral response is highly sensitive to polarization, aiding in camouflage and hunting.



Specific Identified Species

For the purpose of this report, we considered the visual response of the expected specific species in the area immediately surrounding the proposed site. This consisted of birds (closely represented by procellariiforms), bats (chiropteran), mammals (Echidna - Tachyglossidae, dingo – Canidae) and insects (hexapod invertebrates).

Mammals of the order chiroptera (specifically microbats), have limited colour vision and rely upon red-dominated retinas, which are highly sensitive to low-light conditions. Spectral sensitivity peaks in the UV (~350–400 nm) and blue (~450 nm) range, with some species also showing sensitivity to green (~530 nm).

Spectral sensitivity is not documented septically for the **Bare-rumped Sheathtail bat** (*Saccolaimus saccolaimus nudicluniatus*) however general research on nocturnal mammals indicates that they often have peak spectral sensitivities ranging from 350 nm to 557 nm, with a notable sensitivity around 496 nm (blue-green light) [cms.int](https://www.cms.int/). This suggests that artificial lighting, especially in the blue spectrum, could potentially impact their behaviour and ecology.

The **Eastern Curlew** (*Numenius madagascariensis*) likewise does not have any specific documentation available, however, as a shorebird, it is likely to have vision adapted to its foraging and migratory habits, potentially with sensitivity to a range of wavelengths that facilitate these activities. It is suggested that lighting solutions be implemented that minimize emissions in the UV and blue spectra, opting for amber or red lights which are less likely to interfere with the visual systems of these birds. Research on various shorebird families, including Scolopacidae (the family to which the Far Eastern Curlew belongs), has identified species with VS-type SWS1 opsins. For example, the Common Sandpiper (*Actitis hypoleucos*) exhibits VS-type sensitivity. This suggests that the Eastern Curlew may also possess VS-type visual pigments, with peak sensitivity around 400 nm. royalsocietypublishing.org

The **Short-beaked Echidna** (*Tachyglossus aculeatus*) possesses a dichromatic colour vision system, facilitated by two types of cone photoreceptors:

- Long-Wavelength Sensitive (LWS) Opsin Peak Sensitivity (λ_{max}): Approximately 570.2 nm, corresponding to the yellow-green spectrum.
- Short-Wavelength Sensitive 2 (SWS2) Opsin Peak Sensitivity (λ_{max}): Approximately 451.7 nm, corresponding to the blue spectrum.

This spectral sensitivity range suggests that echidnas can perceive colours from the blue to yellow-green regions of the light spectrum. The absence of sensitivity to longer wavelengths (e.g., red) indicates that red hues are likely indistinguishable to them. Studies have shown that the LWS opsin in echidnas has a peak absorbance at 570.2 nm, while the SWS2 opsin peaks at 451.7 nm. These findings highlight the evolutionary adaptations of the echidna's visual system to its ecological niche. pmc.ncbi.nlm.nih.gov

Humans

Humans, like other animals, have evolved to suit their environment. Since humans live on land and have different needs, such as hunting and gathering, our spectral response to light has adapted accordingly. Recent research has identified a strong correlation between exposure to shorter wavelengths of light (blue light) and its effects on human sleep and circadian rhythms. Studies indicate that blue light, particularly in the 400–500 nm range, can suppress melatonin production, delay sleep onset, and disrupt natural sleep cycles, leading to potential health implications such as reduced sleep quality, cognitive impairment, and metabolic disturbances. lrc.rpi.edu

Notable studies, including those by Rensselaer Polytechnic Institute, have demonstrated that prolonged exposure to blue light at night can interfere with the body's internal clock, influencing overall well-being and productivity. These findings reinforce the importance of spectral tuning in lighting design, particularly in industrial and environmental applications, to minimise blue light exposure while maintaining functional illumination. news.rpi.edu

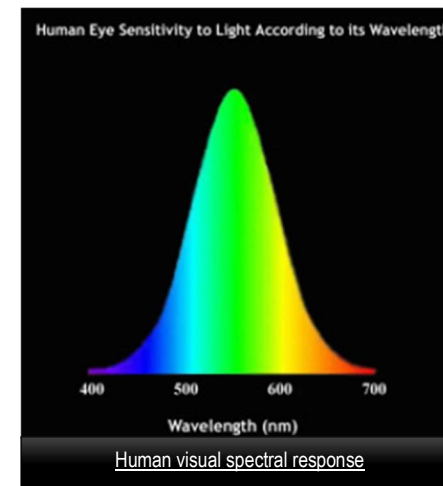
In addition to its ability to influence emotion, light can reset the circadian clock and change locomotor behaviour. These effects are most strongly elicited by blue light, which is detected by melanopsin-expressing retinal ganglion cells found in the eye. One does not have to be able to see objects to be influenced by blue light; it is only the intensity that matters. blogs.biomedcentral.com

By implementing the control systems outlined in this document, we can create an environment that not only minimises the impact of development on fauna but also promotes outcomes favourable to humans.

In 2016, the American Medical Association (AMA) issued guidance recommending the reduction of high-intensity blue-rich lighting in outdoor settings. The AMA highlighted concerns that such lighting can disrupt human circadian rhythms, suppress melatonin production, and increase glare, potentially affecting both human health and environmental ecosystems. They advocate for minimising blue light emissions by using lighting with a correlated colour temperature (CCT) of 3000K or lower and ensuring proper shielding to reduce glare and light trespass. ama-assn.org

This guidance aligns with broader efforts to mitigate the adverse effects of blue light exposure, especially during nighttime, by promoting lighting practices that consider both energy efficiency and health implications.

This may also hold true for other animal and insect species and is discussed in more detail in the following section.



Discussion

The differences in spectral response between humans and fauna highlight the remarkable diversity of evolutionary adaptations to environmental challenges. While humans are optimised for a narrow band of the visible spectrum, many animal species have evolved to perceive ultraviolet (UV), infrared (IR), and other spectral ranges, enabling specialised functions essential for survival. These adaptations influence behaviours such as foraging, navigation, predator avoidance, and communication.

Recognising these distinctions not only deepens our understanding of biodiversity but also informs the development of environmentally responsible lighting strategies. By considering the unique visual and physiological responses of fauna, we can mitigate potential adverse effects while ensuring that lighting solutions maintain both ecological balance and the safety and usability of human-occupied spaces.

Research indicates that exposure to artificial blue light can significantly impact animals' circadian rhythms and overall health. Studies have shown that constant light exposure can disrupt circadian rhythms by desynchronising clock neurons, leading to altered behavioural patterns in animals. [pmc.ncbi.nlm.nih.gov](https://pubmed.ncbi.nlm.nih.gov)

Furthermore, the effects of blue light in the environment on wildlife include similar disruption of biological clocks, and may affect plant growth, pollination, reproduction, and other ecological processes. [royalsociety.org.nz](https://royalsocietypublishing.org/journal/rsos)

These findings underscore the importance of considering the spectral composition of artificial lighting in environments inhabited by animals to minimise potential disruptions to their natural behaviours and physiological processes.

6. Mitigation Controls

Selection of light sources

Optimising Light Control Through LED Luminaires: A Strategic Approach

The selection of light sources plays a pivotal role in achieving the precise light control required for this Project. Rubidium Light consider that LED luminaires are recommended for use on the proposed Project Ulysses biorefinery due to their numerous advantages, as explained below:

High Efficiency LEDs offer energy efficiency comparable to high-intensity discharge (HID) sources. When integrated with effective design elements such as optimised mounting heights and strategic placement, they deliver superior overall project efficiency, minimising energy waste while maximising performance.

Flexible Output Options LEDs provide unparalleled flexibility in selecting light output tailored to specific applications. This allows for precise control over illumination levels, ensuring each area receives the exact amount of light required, enhancing functionality and reducing excess.

Customisable Spectral Output LEDs enable tuning of spectral output to reduce unwanted glow and light pollution. While LEDs inherently emit higher levels of light in the blue spectrum, this can be mitigated through:

- Selecting lower total outputs.
- Utilising carefully engineered luminaires. Further details on this customisation are provided in subsequent sections of this document.

Compact Design The small physical size of LED sources allows for the development of compact, cost-effective luminaires. This enables superior light control by directing illumination precisely where it is needed, significantly reducing light spill and waste.

Advanced Control Capabilities LEDs offer exceptional ease of control, including:

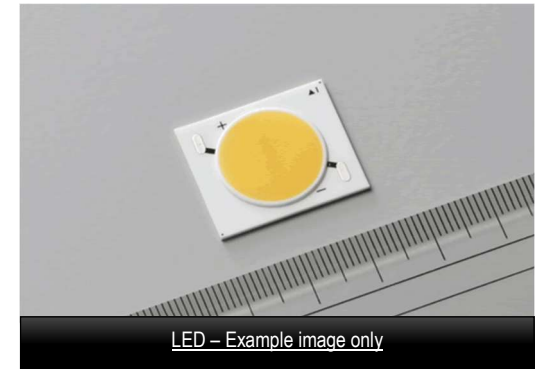
- Instant dimming capabilities.
- Immediate restart following power outages.

These features provide superior adaptability, ensuring consistent and efficient lighting operation.

Extended Lifespan High-quality LED sources have a significantly longer lifespan compared to HID lamps, resulting in:

- Reduced need for replacements, leading to cost savings.
- Lower environmental impact through decreased waste generation.

Reduced Maintenance The durability of LEDs minimises maintenance requirements, especially in challenging environments. With fewer interventions needed, risks such as water ingress due to gasket failures during routine maintenance are significantly reduced, extending luminaire longevity.



Discussion

The comprehensive benefits of LED luminaires—including efficiency, precise control, and durability—make them the optimal choice for achieving the high level of light control demanded by this Project. Their ability to balance performance with sustainability aligns perfectly with the lighting objectives.

The use of 2200K LEDs will provide:

- excellent visual conditions for operators – colour rendition will be maintained
- reduced ongoing energy costs – LED efficacy is around 140lm/W, whilst HPS is approximately 90lm/W - Energy savings: 40-50% reduction in power usage for the same light output
- reduced emission of blue-wavelength light which minimises the effect on sky-glow and fauna.

LED Colour Temperature

Spectral Tuning to Minimise Glow: Recommendation for 2200K LED Light Sources

To mitigate the effects of sky glow, RL proposes tuning the spectral output of white LED light sources by reducing emissions in shorter wavelengths, particularly in the blue spectrum. For this Project, RL recommends exclusively using **2200K (very warm white)** light sources for all external areas. This represents the warmest white light currently available without compromising the colour rendering quality of the source.

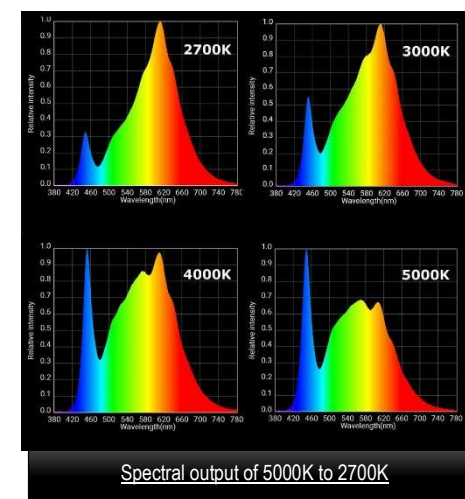
Understanding LED Colour Temperatures

White LED light sources are available in a range of colour temperatures, from warm to cool tones. These descriptors reflect the visual appearance of the light, which is determined by the spectral wavelengths emitted by the LED. Cooler LEDs emit higher levels of blue light, while warmer LEDs emit proportionally less blue and more light in the longer wavelengths, such as red and yellow.

Advantages of Warm White (2200K) LEDs

Reduced Blue Light Emission: Warm white LEDs emit significantly less blue light compared to cooler LEDs, as illustrated in the accompanying spectral distribution diagram. This reduction minimises:

- **Night Sky Glow:** Lower blue light levels reduce atmospheric scattering, a primary contributor to sky glow. Several studies have examined how blue light contributes to atmospheric scattering and sky glow. Research indicates that shorter wavelengths of light, such as blue light, scatter more readily in the atmosphere, leading to increased sky brightness and sky glow. This scattering effect is more pronounced with blue-rich light sources, which can significantly enhance the brightness of the night sky compared to sources with less blue light. [researchgate.net](https://www.researchgate.net)
Additionally, the International Dark-Sky Association has highlighted that the atmosphere scatters shorter wavelengths to a much greater degree than longer wavelengths, contributing to increased sky glow. [darksky.org](https://www.darksky.org)
- **Ecological Impact:** Warmer light is less disruptive to nocturnal species sensitive to blue light, supporting less direct light emission that could be disruptive to fauna.



As noted elsewhere in this report, typical species that are regular visitors to this site are the **Bare-rumped Sheathtail** bat (*Saccolaimus saccolaimus nudicluniatu*s), **Eastern Curlew** (*Numenius madagascariensis*) and **Short-beaked Echidna** (*Tachyglossus aculeatus*), which are representative of bats, shorebirds and mammals respectively. Each of these will benefit from the use of warmer light with reduced blue light component.

- **Improved Compatibility:** The selected 2200K LEDs maintain excellent colour rendering capabilities, ensuring accurate visual representation of materials and finishes without distortion.

Supporting Data

The spectral distribution diagram to the right demonstrates the comparative blue light emissions of cool white LEDs versus very warm white LEDs. As shown, warm LEDs significantly reduce blue wavelength intensity, making them the ideal choice for minimising glow and its associated adverse effects.

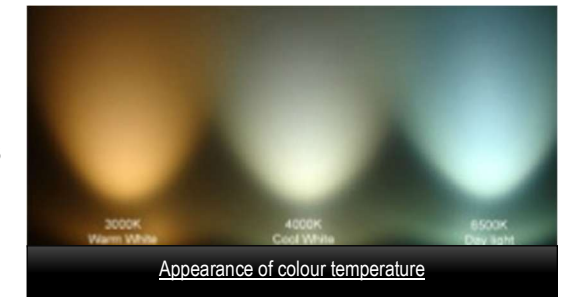
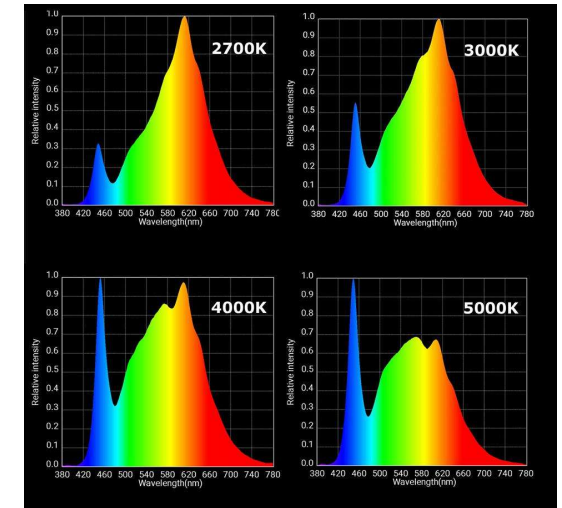
Discussion

By prioritising 2200K LED light sources, the Project will achieve optimal light quality while mitigating ecological, atmospheric, and aesthetic impacts.

As mentioned above, RL advise the spectral output of white LED light sources to reduce the effect of glow by lowering output in the shorter wavelengths (blue). RL recommend using 2200K (very warm white) light sources exclusively for all external areas. This is the warmest white light possible with current technology without affecting the colour rendering of the source.

White LED light sources are available in a range of "whites," from warm to cool. These terms describe the light's appearance, which is determined by the wavelengths emitted by the LED.

To minimise glow, RL use a warm colour temperature white LED to reduce the amount of blue light emitted. The diagram to the right illustrates the spectral distribution of cool (top) and very warm (bottom) LEDs. As shown, warm LEDs emit significantly less blue light, which helps reduce night sky glow due to atmospheric scattering and other potential adverse effects on all animal species.



Luminaire Control

Effective luminaire control is a cornerstone of modern lighting design, enabling precise illumination management to meet functional, environmental, and aesthetic objectives. This document outlines key considerations for luminaire control, focusing on three critical aspects: dimming capabilities, light distribution, and mounting heights. Together, these factors play a pivotal role in optimising energy efficiency, reducing light spill, and enhancing user experience.

Dimming

Dimming allows for dynamic adjustment of light levels based on ambient conditions, occupancy, or specific application needs. It not only supports energy conservation but also reduces glare, minimises light pollution, and extends the lifespan of luminaires.

Motion Detection

By detecting the absence of workers in an area, lighting can be dimmed or extinguished to save energy.

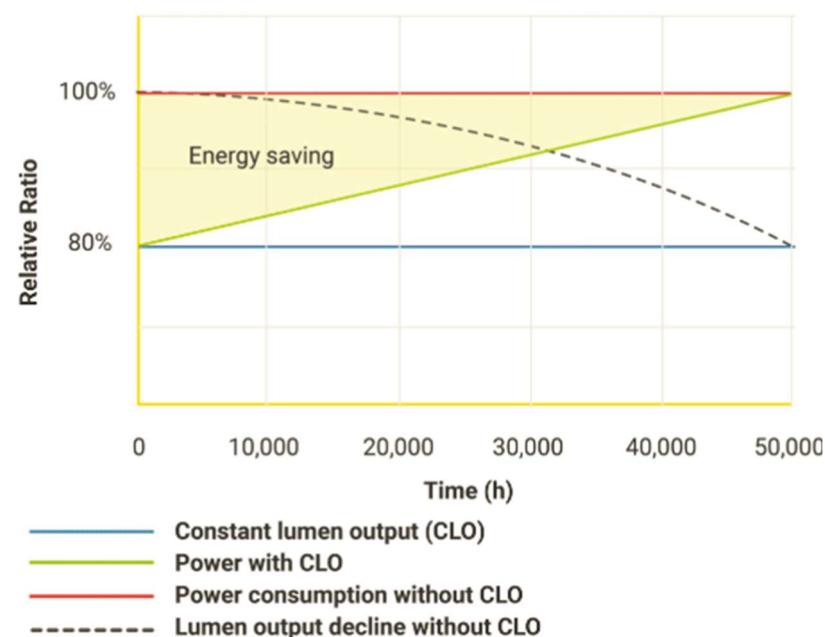
Motion detectors offer significant energy savings, lower operational costs, increased safety, and improved compliance with NCC energy efficiency regulations. They play a critical role in smart lighting solutions by ensuring sustainability, convenience, and security in modern building designs. It is recommended that any intermittently occupied areas/rooms on the Jet Zero site be fitted with motion detectors.

Constant Luminous Flux

Constant Luminous Flux Control (CLFC) is an advanced lighting management strategy that maintains a consistent light output from luminaires over their operational life. This system compensates for the natural decrease in luminous efficacy (lumen depreciation) that occurs as light sources age. Without CLFC, most lighting systems experience a gradual reduction in brightness, requiring over-lighting at installation to ensure compliance with design specifications over time. CLFC dynamically adjusts power levels to maintain optimal illumination, preventing excessive initial brightness and avoiding premature failure due to overdriving.

Lumen Output Decline Without CLO (Dashed Black Line) - Starts at 100% but gradually declines to ~80% by 50,000 hours due to lumen depreciation. This means that traditional lighting systems experience a gradual reduction in brightness over time. (based on L80/B50 LED life).

Constant Lumen Output (CLO) (Blue Line) - Maintains 100% light output throughout the 50,000-hour period. Ensures that illumination levels remain consistent and meet design requirements without over-lighting.



Power Consumption Without CLO (Red Line) - Remains at 100% power consumption from the start. Since lumen output decreases, this results in wasted energy over time.

Power with CLO (Yellow-Green Line) - Starts at a lower power level (~80%). Gradually increases to 100% over time to compensate for lumen depreciation. Results in significant energy savings (shaded area) in the first half of the operational life.

Key elements of constant luminous flux control include:

Compensating for Lumen Depreciation: As light sources age, their ability to emit light diminishes. CLFC counteracts this by gradually increasing power input to sustain consistent lumen output without over-lighting at the start of the luminaire's lifecycle.

Energy Optimisation: In the early stages of a luminaire's life, when its light output is at its peak, CLFC reduces energy consumption by supplying only the power needed to achieve the target light level. This results in significant energy savings over time.

Extended Component Lifespan: By operating luminaires at reduced power levels initially, CLFC minimises thermal stress and wear on components, prolonging their functional life and reducing maintenance costs.

Enhanced Lighting Quality: Consistent luminous flux ensures uniform lighting conditions, improving visual comfort and maintaining the intended design aesthetics of the illuminated space.

Discussion

CLFC is particularly advantageous in applications where consistent lighting is critical, such as the Project Ulysses refinery roadways, carparking, truck loading and offloading facility, and SAF process plant.

By ensuring a predictable and stable lighting performance, this approach aligns with goals for energy efficiency, sustainability, and operational efficiency.

Instead of providing excess initial brightness to account for depreciation (a standard industry practice), CLFC smoothly compensates for light loss over time, improving efficiency and not over-lighting the spaces.

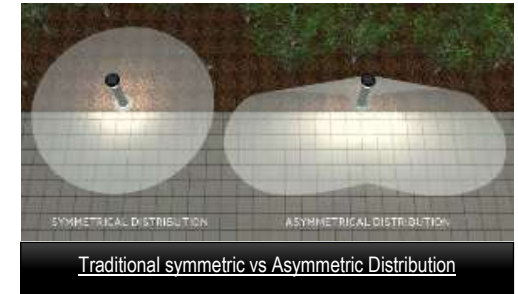
It is recommended that any intermittently occupied areas/rooms on the Jet Zero site be fitted with motion detectors to comply with NCC requirements and to minimise the effects of obtrusive light outside the site. The areas that will be fitted with motion detectors and dimming systems are to be determined engineered during the FEED process.

Luminaire Distribution and Mounting Heights

Proper luminaire distribution and mounting height are critical to achieving efficient, safe, and environmentally sensitive lighting in biorefinery plant such as the Project. These elements influence the functionality, safety, and environmental impact of the lighting system.

Precision in Light Distribution

Ensuring that illumination is directed precisely where it is needed minimises wasteful spill and unwanted glare, key considerations for the Project with sensitive ecological habitat adjacent to the north of the plant. Advanced optical systems, shielding, and luminaire designs tailored to site-specific needs achieve proper light distribution. Asymmetric distribution, for example, can effectively reduce light pollution by directing light away from environmentally sensitive areas, such as the intertidal areas, and focusing it on operational zones within the Project site.

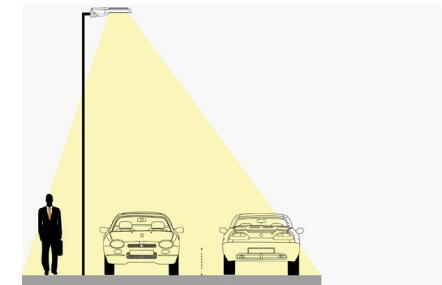


Impact of Mounting Height

The mounting height of luminaires directly affects their light intensity, uniformity, and coverage area. Strategic mounting height selection optimises performance and ensures compliance with safety standards.

Higher Mounting Heights: Provide broader coverage and reduce the number of fixtures needed but can lead to increased light spill and glare.

Lower Mounting Heights: Offer tighter control of light distribution, reduce reflected light escaping into the night sky, and improve energy efficiency by allowing the use of lower-power luminaires.



Advancements in Light Source Technology

The transition from traditional HID (High-Intensity Discharge) lamps to LEDs has revolutionised industrial lighting:

HID Systems: Required mounting heights of 6-10 meters due to their large size and ancillary equipment, often resulting in uncontrolled light spill and glare.

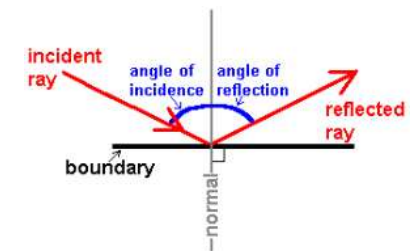
LED Systems: Allow compact, efficient luminaires to be mounted closer to the surface, reducing the intensity of light sources and enabling more precise control over distribution.

Excessive mounting height – Example image only

Reflectance Control for Environmental Benefits

Smart lighting design considers the reflection of light from illuminated surfaces:

- **Minimising Reflected Light:** By understanding that light reflects at the same angle as it strikes a surface, we can design systems to direct reflected light away from sensitive areas and toward less critical zones.
- **Asymmetrical Distribution:** Combined with lower mounting heights, this approach keeps reflected light closer to the ground, reducing its impact on the night sky and surrounding environment.
- **Shade Structures:** Installing shade sails over areas like parking lots can further mitigate spill light and reflected light. By mounting luminaires beneath these structures, light sources are positioned closer to the ground and shielded from the surrounding environment.



Light physics – Example image only

Balancing Safety, Perception, and Environmental Impact

Effective lighting design in biorefinery facilities must balance safety, operational requirements, cost, and environmental considerations. The proposed strategy incorporates:

Sustainability:

By reducing light pollution and energy consumption through modern LED technology and thoughtful mounting strategies.

Safety and Usability: Ensuring adequate illumination for plant operations while reducing glare and obtrusive light.

Environmental light emission: Targeted light distribution and reflection control align with reducing environmental impacts.

Discussion

By combining precise light distribution, optimised mounting heights, and advanced reflectance control, the proposed approach delivers a cohesive lighting strategy tailored to the specific needs of the Project. Detailed guidance on implementing these principles is provided in the following sections to support the design and installation of a high-performing lighting system.

7. Specific Light Applications

Introduction

Reducing the light impact of the plant's flare system involves implementing strategies to mitigate light spill, glare, and sky glow while ensuring compliance with safety, operational, and environmental requirements. The flare is designed to operate only during maintenance, shutdown, or emergency events, rather than as a continuous operation. The current flare design is an elevated flare system (50m height) incorporating integrated hot high-pressure, low-pressure, and cold flare systems within the structure. The final flare design will be determined during the Front-End Engineering Design (FEED) phase.

Key Measures to Minimise Light Impact from Flare

The following measures can be reviewed and implemented during the FEED phase to reduce the light impact of the flare operation:

Flare Shielding and Shrouding

- Implement physical shields or shrouds to reduce direct visibility of the flare flame from surrounding areas.
- Utilise structured enclosures or partial barriers to minimise glare while ensuring adequate heat dissipation.

Optimised Flare Burner Design

- Deploy low-radiance burner tips to minimise visible flame emissions while maintaining efficient combustion.
- Consider steam-assisted or air-assisted flaring to enhance combustion efficiency and reduce luminosity.

Flare Gas Recovery System (FGRS)

- Integrate a flare gas recovery system to capture and reuse waste gases, thereby reducing the frequency and intensity of flaring.
- Optimise operational strategies to limit gas flaring during normal conditions.

Flare Height and Angle Adjustments

- Evaluate adjustments to flare stack height to reduce direct visibility from sensitive receptors while ensuring safe dispersion of combustion products.
- Assess flare orientation options to minimise glare in high-sensitivity areas.

Use Of Advanced Combustion Technologies

- Implement enclosed ground flares where applicable to significantly reduce visible light emissions.
- Utilise advanced combustion control systems to ensure optimal flame efficiency and lower light intensity.

Operational Controls and Scheduling

- Establish protocols to minimise flaring during nighttime hours when light impact is most noticeable.
- Implement predictive maintenance and process optimization to reduce unplanned flaring events.

Community And Environmental Impact Assessments

- Conduct light pollution assessments and engage with stakeholders to understand and address concerns.
- Implement monitoring programs to evaluate flare emissions and make necessary adjustments to minimise impact.

Discussion

By adopting these measures, biorefinery facilities can reduce the light impact of flares, mitigating adverse effects on the environment, fauna, and nearby communities while maintaining safety and operational efficiency.

Reference

Technip (2024). *Flare Type Study, 28011007-PR-REP-00004_B.*

These measures will be evaluated and refined during the FEED phase to ensure effective mitigation of light impact while maintaining operational and regulatory compliance.

Lighting of Continuously Occupied Areas

Lighting in continuously occupied outdoor areas of a biorefinery such as the Project must balance safety, operational needs, and environmental requirements. The plant operation demands robust lighting systems that enhance visibility while minimising energy consumption, light pollution, and ecological impacts. This section outlines industry standard practices for implementing environmentally conscious lighting solutions tailored to the unique requirements of this Project.

Key Principles

Safety and Compliance: In designing lighting systems for continuously occupied outdoor areas of the biorefinery, it's essential to adhere to industry standards and regulatory requirements to ensure safety and compliance. The American Petroleum Institute's Recommended Practice 540 (API RP 540) and the Occupational Safety and Health Administration (OSHA) regulations provide pertinent guidelines.

API RP 540: Electrical Installations in Petroleum Processing Plants

API RP 540 offers comprehensive guidance on electrical installations within petroleum facilities, emphasising the prevention of accidental ignition of flammable substances. It addresses specific requirements for electrical systems to maintain safety and operational continuity in petroleum processing environments.
STANDARDS.GLOBALSPEC.COM

OSHA Regulations on Workplace Lighting

OSHA mandates specific illumination levels to ensure safe working conditions in various settings:

- General Construction Areas: A minimum of 5 foot-candles. (~50 lux)
- General Construction Areas, Concrete Placement, Excavation and Waste Areas, Access Ways, Active Storage Areas, Loading Platforms, Refuelling, and Field Maintenance Areas: A minimum of 3 foot-candles. (~30 lux)
- First-Aid Stations and Infirmaries: A minimum of 30 foot-candles. (~300 lux)
- Warehouses, Walkways, and Exits: A minimum of 10 foot-candles. (~1000 lux)
- Underground Shafts and Tunnels: A minimum of 5 foot-candles. (~50 lux)

These standards are outlined in OSHA's regulations under 29 CFR 1926.56. [osha.gov](https://www.osha.gov)

By integrating the guidelines from API RP 540 and adhering to OSHA's illumination requirements, the Project can develop lighting solutions that ensure safety, operational efficiency, and environmental compliance.

Energy Efficiency: Utilise LED technology, which offers high energy efficiency, long operational life, and reduced maintenance in demanding environments. Integrate smart controls such as motion sensors, timers, and automated dimming to reduce energy usage during low-activity periods.

Minimization of Light Pollution: Use full-cutoff or shielded luminaires to direct light precisely where needed, reducing glare and skyglow. Select lighting with appropriate colour temperatures (e.g., 2200K) to balance visibility and environmental impact, particularly in ecologically sensitive areas.

Design Considerations

Lighting Levels and Uniformity: Ensure lighting levels comply with safety and operational requirements, providing uniform illumination to minimise shadows and dark spots. Conduct a lighting audit to determine site-specific needs, avoiding over-lighting while maintaining worker safety and task visibility.

Strategic Placement: Position fixtures to optimise coverage while reducing the number of lights required. Use poles, wall mounts, or elevated fixtures as appropriate for the site layout.

Avoid placing lights that emit directly into the inter-tidal areas north of the plant to minimise ecological disturbance.

Monitoring and Maintenance

Performance Monitoring: Employ advanced lighting control systems to monitor performance, energy use, and faults in real time.

Analyse data periodically to identify opportunities for further energy savings and system optimization.

Scheduled Maintenance: Implement a proactive maintenance schedule to clean, inspect, and replace lighting components as needed, ensuring optimal performance.

Emergency and Redundant Lighting: Backup Systems

Ensure emergency lighting systems are powered by renewable energy sources or backup generators for uninterrupted operation.

Hazardous Location Adaptation: Use explosion-proof and corrosion-resistant materials for emergency lighting to maintain functionality during critical incidents.

Discussion

Environmentally responsible lighting for continuously occupied outdoor areas in biorefinery plants enhances safety and operational efficiency while reducing environmental impact. By integrating energy-efficient technologies, renewable energy, and thoughtful design, these facilities can meet their sustainability goals while ensuring compliance with industry regulations.

Intermittently Occupied Areas

Lighting in intermittently occupied outdoor areas of biorefinery plants must ensure operational safety and environmental sustainability. These areas often have sporadic activity, making them ideal candidates for advanced lighting controls like occupancy sensors to minimise energy use and environmental impact. This section outlines a strategic approach for implementing environmentally responsible lighting solutions that leverage sensor technology.

Key Principles

Safety and Compliance: Ensure lighting complies with industry safety standards such as AS/NZS1680 series *Interior and workplace lighting* & AS/NZS1158 *Lighting for roads and public spaces*, and hazardous area classifications.

Use explosion-proof and weather-resistant fixtures suitable for biorefinery environments, where flammable or corrosive substances may be present.

Energy Efficiency: Deploy LED luminaires with low energy consumption and long life to reduce maintenance frequency and costs.

Use occupancy sensors to activate lighting only when needed, conserving energy in unoccupied areas.

Minimization of Light Pollution: Install full-cutoff fixtures to prevent upward light spill and reduce glare, preserving the night sky and avoiding ecological disturbances.

Select colour temperatures of 2200K to provide effective illumination while minimising disruption to local fauna.

Occupancy Sensor Integration

Sensor Technology: Utilise motion-detection sensors, such as passive infrared (PIR) or microwave sensors, to detect activity and control lighting activation.

Implement adaptive sensitivity settings to ensure reliable operation in challenging conditions like wind, heat, or debris.

Zoning and Control Systems: Divide the area into lighting zones with separate sensors for each zone, allowing localised control to avoid unnecessary illumination.

Connect sensors to a centralised lighting control system to monitor usage patterns and optimise settings remotely.

Response Times and Dimming: Configure sensors with appropriate delay times to prevent frequent on/off cycling, which can shorten fixture lifespan.

Incorporate gradual dimming options to transition lights smoothly between active and standby states, reducing energy spikes.

Design and Placement

Strategic Fixture Placement: Position fixtures and sensors at optimal heights and locations to maximise coverage and effectiveness, avoiding blind spots or redundant overlap. Ensure that sensor fields of view align with primary activity areas such as walkways, equipment zones, and access points.

Illumination Levels: Design lighting to meet minimum illumination requirements for safety during occupancy, while minimising unnecessary brightness in idle periods.

Focus on uniform lighting to avoid shadows or glare that could obscure hazards.

Fauna and Ecological Considerations

Minimise Ecological Disturbances: Configure lighting to avoid illumination spillover into natural habitats, particularly in areas near sensitive ecosystems.

Choose fixtures with minimal blue light emissions to reduce impacts on nocturnal fauna.

Monitoring and Maintenance

Smart Monitoring Systems: Integrate occupancy sensors into a smart monitoring platform to track energy usage and identify system faults in real-time.

Use analytics to refine sensor settings and lighting schedules based on actual usage patterns.

Regular Maintenance: Establish a preventive maintenance program to clean, test, and recalibrate sensors and fixtures.

Use modular lighting systems to simplify replacement and reduce waste.

Discussion

Implementing an environmentally conscious lighting approach for intermittently occupied outdoor areas in biorefinery plants enhances safety, reduces operational costs, and aligns with sustainability goals. By leveraging occupancy sensors and advanced control technologies, facilities can minimise energy consumption, light pollution, and ecological impact without compromising functionality.

Truck Loading / Offloading and Administration Car Park

Effective trucking areas and car park lighting enhances safety, usability, and security. However, it is crucial to adopt environmentally responsible practices to minimise energy consumption, light pollution, and ecological disruption. This section outlines industry best practices and design considerations for implementing environmentally responsible truck and car area lighting.

Key Principles

Energy Efficiency: Use energy-efficient lighting fixtures, such as LED technology, which consume less power and have longer lifespans compared to traditional lighting. Incorporate smart lighting controls, including motion sensors, dimmers, and programmable timers, to reduce energy use during low-traffic periods.

Minimisation of Light Pollution

Design lighting systems to reduce upward light spill, glare, and skyglow using full-cutoff fixtures that direct light downward.

Choose appropriate colour temperatures (e.g., warm white light with a correlated colour temperature of 2200K to minimise the impact on human vision and fauna).

Design and Placement

Site-Specific Design

Conduct a lighting needs assessment to determine optimal illumination levels in compliance with local safety regulations while avoiding over-lighting.

Position lighting fixtures strategically to cover maximum areas with minimal overlap, thereby reducing the number of fixtures needed.

Zoning

Divide the car park into zones based on usage patterns (e.g., high-traffic areas, pedestrian pathways) and adjust lighting intensity accordingly.

Implement adaptive lighting controls that adjust brightness based on the time of day, weather conditions, or activity levels.

Monitoring and Maintenance

Regular Maintenance

Establish a schedule for cleaning and inspecting fixtures to maintain efficiency and performance.

Promptly replace failing components to prevent unnecessary energy use from malfunctioning equipment.

Discussion

Adopting an environmentally conscious approach to truck and car park areas not only reduces ecological impacts but also delivers economic and social benefits through energy savings, enhanced safety, and alignment with sustainability goals.

8. Luminaire Construction

When designing luminaires for a biorefinery near a coastal environment, it's critical to consider factors such as high levels of corrosion, exposure to hazardous gases, and the potential for explosive atmospheres. Find below construction discussion and recommendations to ensure safety, durability, and compliance with industry standards:

Material Selection

Corrosion Resistance:

Use high-quality, corrosion-resistant materials such as:

- **Marine-grade aluminium:** Treated with anodising or epoxy/polyester powder coating for enhanced resistance to salt and humidity.
- **Stainless steel (316L) or high-grade carbon steel:** Ideal for mounting hardware, screws, and enclosures.
- **Polycarbonate or tempered glass lenses:** Resistant to UV exposure, salt spray, and chemical corrosion.
- **Sealing Gaskets:** Use gaskets made from silicone or EPDM to ensure long-term sealing against moisture and salt ingress.

Ingress Protection (IP) Rating

Ingress Protection (IP) ratings are defined by the International Electrotechnical Commission (IEC) under the standard IEC 60529, titled "Degrees of Protection Provided by Enclosures (IP Code)." This standard classifies the level of protection that enclosures provide against the intrusion of solid objects (including body parts like hands and fingers), dust, accidental contact, and water. iec.ch

IP67 or higher: To protect against dust, water, and salt spray. Ensure the luminaire housing is sealed to prevent ingress of airborne contaminants, which are prevalent in coastal and industrial environments.

Thermal Management

Use heat-dissipating designs (e.g., finned housings) to ensure the LED module and driver operate within safe temperature ranges. Verify thermal management performance for high ambient temperatures, which are common in biorefinery plants.

Cable Entries and Connections

Use **cable glands** and connectors rated for hazardous locations (e.g., explosion-proof, corrosion-resistant). Ensure cables are suitable for harsh environments, such as armoured or sheathed cables resistant to UV, oil, and chemicals.

Finish and Coatings

Apply a **marine-grade protective coating** (e.g., Triglycidyl Isocyanurate (TGIC) powder coating or polyurethane-based paint) to prevent oxidation and wear, in accordance with AS/NZS 2312.1:2014 *Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings*, and AS 4312:2019 *Atmospheric corrosivity zones in Australia*.

Consider using **anti-UV coatings** for areas with high sun exposure to maintain the integrity of the luminaire.

Light Source and Driver

Use **LED technology** for high efficiency and long lifespan. Ensure the driver is encased in a corrosion-resistant, IP-rated enclosure. Select luminaires with **dimming or control options** to improve energy efficiency and allow integration into plant-wide monitoring systems.

Mounting Hardware

Use brackets and fasteners made of 316L stainless steel or hot-dipped galvanised steel for enhanced corrosion resistance. Ensure vibration-resistant mounting systems to withstand equipment and operational vibrations.

Maintenance and Accessibility

Design luminaires with modular, tool-free access for routine maintenance. Incorporate surge protection devices to safeguard against electrical transients.

Compliance with Standards

Adhere to standards such as: **IEC 60598** for general luminaire safety, **ISO 9223** for corrosion classification in marine environments, **AS/NZS3000**, **API RP 500** or **NFPA 70 (NEC)** for electrical systems in hazardous areas.

The **IEC 60598** series is an internationally recognised set of standards that specifies safety and performance requirements for luminaires. Developed by the International Electrotechnical Commission (IEC), these standards ensure that lighting fixtures operate safely and effectively across various applications.

Key Components of IEC 60598:

1. **IEC 60598-1: General Requirements and Tests:** This part outlines the general requirements for luminaires, including aspects such as classification, marking, mechanical and electrical construction, and photobiological safety. It applies to luminaires designed for operation with supply voltages up to 1,000 V. The latest edition introduces significant technical revisions to enhance safety and performance standards.
2. **IEC 60598-2: Particular Requirements:** This section comprises multiple parts, each addressing specific types of luminaires or particular applications. For instance:
 - **IEC 60598-2-3:** Focuses on luminaires for road and street lighting, specifying requirements for public outdoor lighting applications.
 - **IEC 60598-2-22:** Specifies requirements for emergency luminaires intended for use with electrical lamps on emergency power supplies not exceeding 1,000 V

ISO 9223:2012 Corrosion of metals and alloys — Corrosivity of atmospheres — Classification, determination, and estimation, establishes a framework for classifying the corrosivity of atmospheric environments. It identifies key factors influencing atmospheric corrosion, including the temperature-humidity complex, sulfur dioxide (SO₂) pollution, and airborne salinity. The standard defines corrosivity categories based on the first-year corrosion rate of standard specimens and provides dose-response functions for estimating these categories.

The American Petroleum Institute's Recommended Practice 500 (API RP 500) provides guidelines for classifying locations at petroleum facilities where flammable gases or vapours may be present, to ensure the safe selection and installation of electrical equipment. This practice focuses on facilities classified as Class I, Division 1, and Division 2, as defined by the National Electrical Code (NEC).

AS/NZS 3000, commonly known as the Australian/New Zealand Wiring Rules, includes provisions for electrical installations in hazardous areas. Specifically, Section 7.7 of AS/NZS 3000 addresses the requirements for such installations. It mandates that hazardous areas be classified in accordance with AS/NZS 60079.10.1 for explosive gas atmospheres and AS/NZS 60079.10.2 for combustible dust.

Hazardous Location Certification

ATEX, IECEx, and UL Class I, Division 2/Zone 2 are standards and certification systems designed to ensure the safe operation of equipment in hazardous environments where flammable gases, vapours, or liquids may be present.

ATEX (Atmosphères Explosibles):

ATEX is a European Union directive that regulates equipment intended for use in explosive atmospheres. It classifies hazardous areas into zones based on the frequency and duration of the presence of explosive atmospheres:

- Zone 0: An area where an explosive atmosphere is present continuously or for long periods.
- Zone 1: An area where an explosive atmosphere is likely to occur during normal operation.
- Zone 2: An area where an explosive atmosphere is unlikely to occur during normal operation and, if it does, will exist only for a short time.

Equipment for Zone 2 must meet specific requirements to prevent ignition in these environments.

IECEx (International Electrotechnical Commission System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres):

IECEx provides a global certification framework based on IEC standards, facilitating international trade of equipment used in explosive atmospheres. It uses a similar zone classification as ATEX and ensures that equipment meets rigorous safety standards.

UL Class I, Division 2/Zone 2:

In North America, the National Electrical Code (NEC) defines hazardous locations using a Class/Division system:

- Class I: Locations where flammable gases or vapours are present.
- Division 1: Hazardous substances are present during normal operations.
- Division 2: Hazardous substances are present only under abnormal conditions, such as equipment failure.

The NEC also recognises a Zone classification system, aligning more closely with international standards:

- Zone 0: Explosive atmosphere present continuously.
- Zone 1: Explosive atmosphere likely under normal conditions.
- Zone 2: Explosive atmosphere unlikely under normal conditions and, if it occurs, is short-lived.

The luminaire must meet **ATEX, IECEx, or UL Class I, Division 2/Zone 2** standards for biorefinery applications. Enclosures must be explosion-proof or flameproof as per the zone classification.

Discussion

By adhering to these recommendations, the lighting system will ensure operational safety, reliability, and long-term performance in the harsh conditions of a biorefinery plant near the saltwater environments.

9. Conclusion and Recommendations

Conclusion

The lighting strategy for Jet Zero Project Ulysses exemplifies a holistic and environmentally responsible approach to industrial illumination. By integrating advanced lighting technologies, precise control measures, and ecological mitigation strategies, the project successfully balances operational functionality, safety requirements, and environmental sustainability.

This approach minimises light pollution, enhances energy efficiency, and reduces ecological disruption, ensuring compliance with Australian Standards (AS/NZS 4282) and alignment with industry best practices for sustainable lighting solutions.

Commitment to Ecological Lighting Design

Given the project's proximity to ecologically sensitive habitats, intertidal zones, and migratory bird pathways, the lighting strategy has been designed with environmental preservation at its core. A strategic, data-driven approach has been adopted to:

- Mitigate unnecessary light emissions
- Reduce blue spectrum exposure
- Ensure precise illumination control for both functional and ecological considerations

Key Mitigation Strategies

To achieve these objectives, the lighting strategy incorporates a range of targeted mitigation measures, ensuring that illumination remains efficient, effective, and environmentally sensitive:

Selection of Light Sources

- 2200K Warm White LEDs – The exclusive use of low blue-light-emitting LEDs significantly reduces sky glow and minimises disruption to nocturnal and marine wildlife.
- Customisable Spectral Output – Spectral tuning strategies are implemented to further reduce emissions in shorter wavelengths, mitigating ecological and atmospheric impact while optimising visual performance.
- Compact and High-Efficiency Design – The use of compact LED luminaires allows for precise light distribution, ensuring that illumination is targeted only where necessary, reducing spill light, glare, and energy waste.

Optimising Light Control & Luminaire Placement

- Directional and Reflective Light Control – Asymmetrical optics and low mounting heights ensure that light is contained within operational areas, preventing unnecessary spill into sensitive ecological zones, such as wetlands and nesting habitats.
- Advanced Control Systems – Dimming controls, motion sensors, and adaptive switching enable real-time lighting adjustments, enhancing energy efficiency while maintaining visibility, security, and operational safety.
- Reflectance Control & Shade Structures – Minimising secondary reflections through the use of shade sails, low-reflectance materials, and strategic luminaire placement helps to reduce unwanted environmental light spill, supporting dark sky preservation and habitat protection.

Luminaire Control & Distribution

- Dimming & Adaptive Controls – Dynamic lighting adjustments based on occupancy, operational needs, and ambient conditions reduce unnecessary energy consumption while maintaining consistent, high-quality illumination.
- Constant Luminous Flux Control (CLFC) – This ensures that luminaires maintain stable light output throughout their lifespan by compensating for lumen depreciation, extending the operational life of the system.
- Strategic Mounting Heights & Distribution – Higher mounting heights are balanced with targeted light distribution strategies to reduce glare and excessive illumination, improving both visibility and environmental protection.

Pioneering Sustainable Industrial Lighting

By integrating these cutting-edge lighting solutions, Jet Zero Project Ulysses is pioneering a new standard for sustainable industrial lighting. This approach extends beyond regulatory compliance, actively enhancing energy efficiency, reducing operational costs, and mitigating light pollution to protect both the local environment and the broader ecosystem.

This strategy directly contributes to:

- Energy Efficiency & Sustainability – The combination of high-performance LED technology, adaptive control systems, and optimised luminaire design significantly reduces energy consumption and operational costs.
- Reduced Environmental Light Emissions – Minimising blue light exposure, controlling reflected light, and implementing luminaire shielding ensures that wildlife, local communities, and the night sky remain undisturbed.
- Long-Term Cost & Maintenance Savings – The use of durable LED luminaires and advanced lighting control strategies results in fewer replacements, lower maintenance costs, and improved long-term system reliability.

A Benchmark for Future Industrial Developments

By prioritising responsible lighting design, Jet Zero Project Ulysses is setting a new industry benchmark for environmental stewardship in industrial development. The project demonstrates that cutting-edge, low-impact lighting solutions can successfully coexist with operational excellence, ecological preservation, and energy efficiency.

By adopting this holistic and innovative approach, Jet Zero Project Ulysses serves as a model for future industrial projects, proving that environmentally conscious lighting design is not only feasible but essential for the future of sustainable industrial development in Australia and beyond.

A stylized, handwritten signature in black ink, appearing to read 'Dutton'.

Trent Dutton FIES RLP
Principal Lighting Engineer
Rubidium Light

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National Fire Protection Association (NFPA)	2023	NFPA 70: National Electrical Code (NEC)	Standard	https://www.nfpa.org/product/nfpa-70-code/p0070code
Standards Australia	2022	AS/NZS 3000: Australian/New Zealand Wiring Rules	Standard	https://www.standards.org.au/standards-catalogue/sa-snz/electrotechnology/el-001/as-slash-nzs--3000-colon-2018
Standards Australia	2014	AS/NZS 2312.1: Guide to the Protection of Structural Steel Against Corrosion	Standard	https://www.standards.org.au
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