UBC Social Ecological Economic Development Studies (SEEDS) Student Report

UBC Campus Outdoor Lighting: Challenges and Opportunities

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University of British Columbia

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CHALLENGES AND OPPORTUNITIES

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Disclaimer

The information and recommendations provided in this report do not constitute a professional advice and or opinion of the authors; this body of work has been produced by Master of Engineering in Leadership Graduate Students. And should only be used at an academic capacity.

Acknowledgments

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The Team

This project has been a collaborative effort that is drawn from 25 years of combined professional experience in the design, and construction industries.

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Executive Summary

The objective of our report is to stimulate discussions with regards to campus outdoor lightings.

This report:

- provides a brief historical overview of the evolution of artificial light,
- examines the current technological trends of outdoor lighting,
- outlines some of the potential negative impacts of outdoor lighting, and
- provides recommendations for campus stakeholders and future policy makers to implement.

The significance and importance of light in our lives is undeniable. Light provides us with more than just an illumination in the dark. Its significance is evident from history and in modern day researches done on the subject of light. The white light we see is a combination of a spectrum of colours and this spectrum is further reflected in the many ways light affects people, nature and the world.

Recent advancements in technology, from more efficient lighting components to increasingly sophisticated controls, offer attractive opportunities for making the most of outdoor lighting systems. Hence, the team makes the case for the University of British Columbia to shift to using LED technology.

The team recommends before determining what type of lighting should be installed or retrofitted, it is important to ask the basic question: Is Lighting needed? If no reason for lighting can be found, it is more practical to remove the current lighting than replacing it with a new technology. we also recommend the following:

1. luminance for all new lights should be equal or less than the maximum value recommended by Illuminating Engineering Society.

2. integration of bi-level control systems as it is unnecessary to keep the street lighting at maximum illumination during periods of low traffic.

3. all new lights installed anywhere on campus to be properly shielded. These shields should ensure that light is directed downwards - not upwards or to the side.

4. a campus lighting strategy to establish a method for assessing future lighting solutions. We recommend combining the individual assessments for each of the four components to determine whether the proposed lighting solution is acceptable.

5. comprehensive integration of CPTED strategies: to improve poor design features such as isolation, lack of sight lines, and hiding and entrapment spots, it will contribute to a safer and more appealing campus environment.

1.0 Lighting the Way

CREATE A SAFE ENVIRONMENT

Outdoor lighting has the power to improve urban livability, economic vitality and the perception of public security.

Today, we, as a society, are wrestling with competing issues involved in artificial lighting. Recent advancements in technology, from more efficient lighting components to increasingly sophisticated controls, offer attractive opportunities for making the most of outdoor lighting systems.

Outdoor lighting has the power to improve urban livability, economic vitality, and the perception of public security. Therefore, artificial lighting cannot be designed in isolation as its glow affects the greater urban environment; it illuminates dark corners and facilitates the safe passage of pedestrians; artificial lighting also highlights architecturally significant structures and open-spaces. Artificial light can transform an open public space into a canvas of shadow, colour and motion.

On academic campuses, for various reasons, lighting has received a great deal of attention over the years. With nighttime activities, it is very important that lighting design provides adequate coverage and brightness levels in order to provide safety and security for students, staff, and campus visitors.

The objective of our report is to stimulate discussions in regard to campus outdoor lightings; the report:

- provides a brief historical overview of the evolution of artificial light,
- examines the current technological trends of outdoor lighting,
- outlines some of the potential negative impacts of outdoor lighting, and
- provides recommendations for campus stakeholders and future policy makers to implement.

UBC CAMPUS

STUDY, WORK, LIVE

The University of British Columbia (UBC) Vancouver campus has increasingly become a place where people study, work, and live. Located 30 minutes from downtown Vancouver, the campus has become one of the must-see destinations. The campus homes more than 40,000 undergraduates and about 10,000 graduate students (UBC Campuses, n.d.). Therefore, they need to be able to circulate safely at all hours of the day and night. Consequently, for major transit hubs and key public destinations, lighting needs to meet the following key objectives:

- enhance the safety and security for students, staff and the public,
- contribute to a comfortable night environment,
- create a unified character, and create inviting entrances.

2.0 Out of Dark

THE LED CLEAN REVOLUTION

LEDs have been taking the streets since the 1990s, when cities throughout North America and Europe began replacing incandescent-based lights with highly energy-efficient solid state fixtures. Today's LED Technology is poised to cross the next municipal frontier and tackle the challenge of street lighting.

While incandescent light bulbs lit the 20th century, the 21st century will be lit by LED (Light Emitting Diodes) lamps, as shown in Figure 1. Isamu Akasaki and Hiroshi Amano, from Nagoya University, Japan, and Shuji Nakamura, of University of California - Santa Barbara are the three scientists who developed the first blue LED light in 1993 (Naik, 2014). They transformed lighting technology forever.

Blue was the missing link; an accomplishment that had defeated scientists for more than 30 years. Red and green (and yellow) LEDs had been in commercial use since the 1960s. But without blue, there could be no white light (2014). So when the elusive blue light from their semi-conductors, the bright white LED light was born.

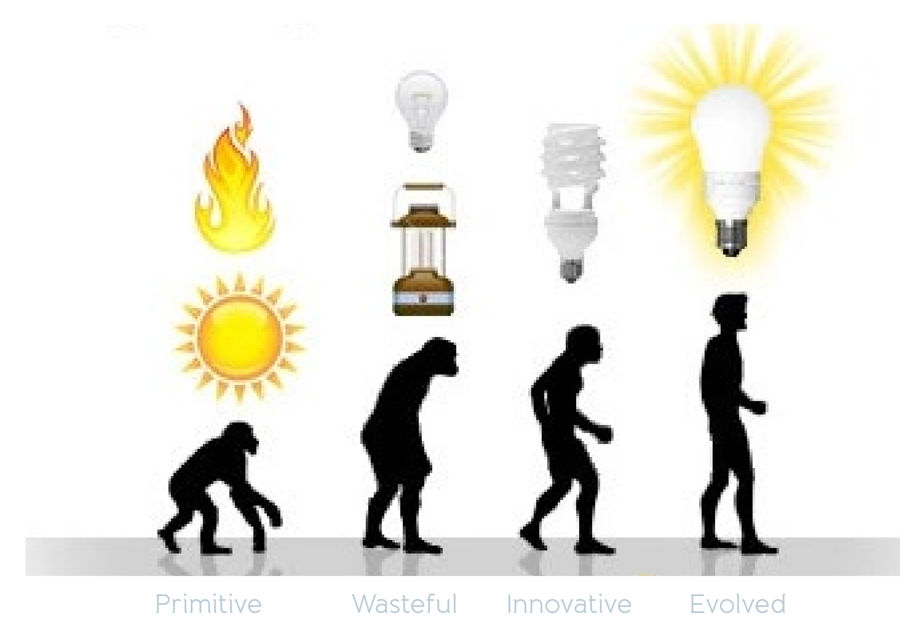


Figure 1: Evolution of Artificial Light.

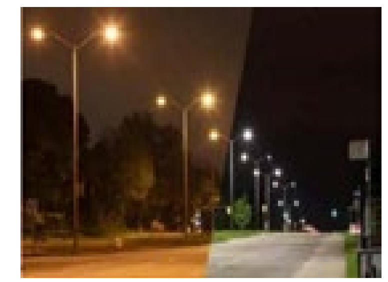
This photo is courtesy of microecos.files.wordpress.com

THE LED ODYSSEY

Light has become an integral element of place-making and energy-saving initiatives alike. Currently, one of the major market barriers to LED roadway luminaire adoption is the initial cost of LEDs, which tends to be much higher than HID sources. It is important, however, to understand that economic estimates of LED implementation is sensitive to site-specific variables such as maintenance and energy costs, and to LED luminaire cost; estimates are also dependent on assumptions for LED luminaire lifetime, which is a function of the life of all parts of the luminaire. Manufacturers' claims for luminaire lifetimes are highly variable (*Lighting: The clean revolution*, 2012).

There is an obvious ability to increase power savings by not running lights at a high output level when they do not have to be. Second, as LED lights operate better at lower temperatures, an LED light operating at a reduced power setting will last longer; this means the projected lifespan of the unit can be increased thus reducing the capital depreciation (2012).

With the emergence of smart cities, some new lighting technologies are emerging, where the level, intensity and impact of light can be controlled and adapted to environmental cues, behaviours or pre-programed schedules. These adaptive lighting environments are already an emerging trend within the buildings industry. At the municipal scale, however, smart lighting systems are still in their infancy (Rethinking the Shades of Night, 2015). Such systems range from basic sensors that detect vehicular and pedestrian motion and ambient light, to more intelligent autonomous light controls controlled by complex Wifi networks.



As the campus and technology evolve, additional lighting needs to be developed. The problems of pedestrian lighting occur with all technologies, but LEDs offer optical options and opportunities the industry has never had before. As LED lights have an ability to respond instantly to on/off instructions there is little concern the correct amount of light not be available when needed; furthermore, in contrast to some of the dimming programs adopted thus far in LED upgrades, the use of adaptive lighting guarantees to provide the same level of service to a motorist, pedestrian or cyclist regardless of whether they are using the city's streets during an arbitrarily determined 'peak' or 'off peak' period (Simpson, 2003).

While completely turning lights off is often unacceptable for various reasons, switching between high and low light levels based on space occupancy, traffic patterns, or level of daylight maintains sufficient light, reduces light pollution and maximizes energy savings (Rowh, 2014). Adaptive lighting uses technology to control the amount of light used to suit the purpose to which it is being applied. One option is using photocells; with no regard for actual traffic patterns or occupancy, this option is used to control light by photocells.

Another option is the use of bi-level dim control; this means lights can be dimmed or turned off when there is no need to provide lighting. The light fixtures can be outfitted with motion sensors, and when the area is unoccupied, the lights remain in a dim state with only a 30% to 50% light output. Once motion is detected, full brightness is activated; and the light fixture will stay in this setting for a pre-set duration (Berst, 2013).

This photo is courtesy of http://www.tvilight.com

AUTONOMOUS LIGHT CONTROL

Using a Passive Infra-Red (PIR) sensor attached to each pole, a street light can be turned up from a dimmed setting when motion is detected. After a pre-set duration the street light will return to its dimmed state. What makes the CitySense system unique is that it can enable street lights to be configured in a way that increases lighting outputs progressively with movement (Walsh et al., 2005).

Like more basic systems, it is also capable of reporting faults. As the system is based on an open platform, it can be developed to allow an interface with hardware from other third-party providers. Unlike other systems currently available, the CitySense approach does not require cameras or any other intrusive mechanism to enable the city to maintain a high level of service in providing street lighting services (2005).

Currently, the high initial cost of LED street lights has been a challenge for the economic case, but energy savings and projected maintenance cost savings throughout the luminaire lifetime have both improved LED street light economics. However, intelligent features combined with the potential for high-energy savings has given the LED technology the following advantages: substantial operating energy and cost reductions, longer life, and lower overall heat generation. Another feature that allows for dramatic appearance and productivity benefits now and in the future, involves the color temperature (Robert S. Simpson, 2003).

INFO

SWOT Analysis

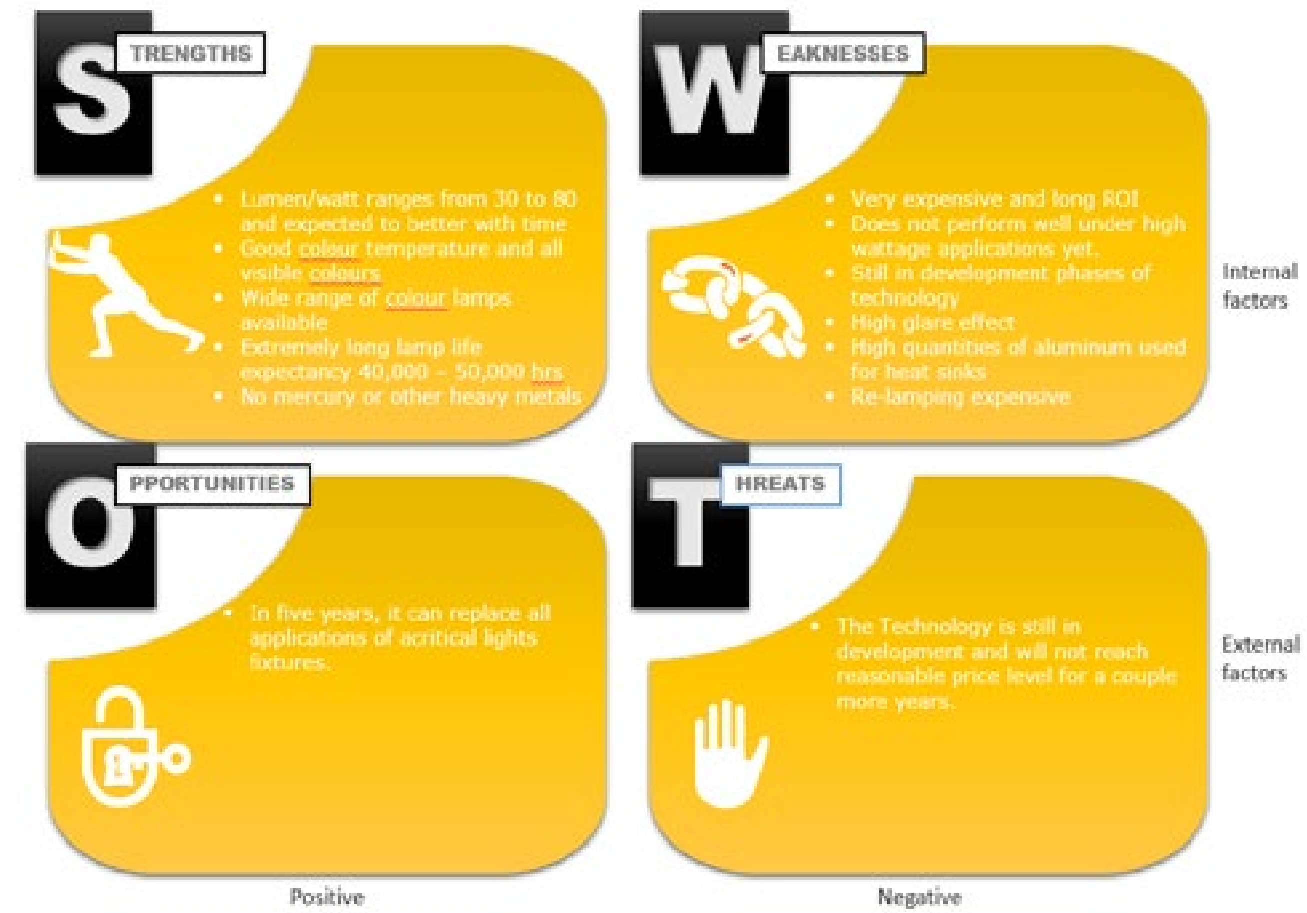


Figure 2: LED SWOT Analysis.

EXHIBIT

COMPARISON: STREET LIGHTING TECHOLOGIES (*LED*, 2015)

It is important, however, to understand that economic estimates of LED implementation is sensitive to site-specific variables such as maintenance and energy costs, and to LED luminaire cost; estimates are also dependent on assumptions for LED luminaire lifetime, which is a function of the life of all parts of the luminaire. Manufacturers' claims for luminaire lifetimes are highly variable.

light technology	life time	lumens per watt	color temperature	CRI (color rendering index)	ignition time	considerations
incadescent light	1.000 -5.000	11 - 15	2.800K	40	instant	very inefficient, short life time
mercury vapour light	12.000 - 24.000	13 - 48	4.000K	15 - 55	up to 15 min	very inefficient, ultraviolet radiation, contains mercury
metal halide light	10.000 - 15.000	60 - 100	3.000-4.300K	80	up to 15 min	high maintenance UV radiation, contains mercury and lead, risk of bursting at the end of life
high pressure sodium light	12.000 - 24.000	45 - 130	2.000K	25	up to 15 min	low CRI with yellow light, contains mercury and lead
low pressure sodium light	10.000 - 18.000	80 - 180	1.800K	0	up to 15 min	low CRI with yellow light, contains mercury and lead
fluorescent light	10.000 - 20.000	60 - 100	2.700-6.200K	70 - 90	up to 15 min	UV radiation, contains mercury, prone to glass breaking, diffused non-directional light
compact fluorescent light	12.000 - 20.000	50 - 72	2.700-6.200K	85	up to 15 min	low life / burnout, dimmer in cold weather (failure to start), contains mercury
induction light	60.000 - 100.000	70 - 90	2.700-6.500K	80	instant	higher initial cost, limited directionality, contains lead, negatively affected by heat
LED light	50.000 - 100.000	70 - 150	3.200-6.400K	85 - 90	instant	relatively higher initial cost

EXHIBIT

LED PERFORMANCE ASSESSMENT

FIGURE 3: CANADIAN URBAN INSTITUTE'S ASSESSMENT OF ROI

The B.C. Climate Change Secretariat has developed a comprehensive business model that enables the user to calculate cost savings, return on investment (ROI), and the simple payback period for investments in LED street lighting retrofits. The model incorporates granular information on street lighting assets, unit and volume pricing of LED replacements for seven categories of lighting assets, ballast losses for the baseline lamps, and inputs for electricity rates, discount rate, inflation, incentives, and carbon pricing that can be set by the user.

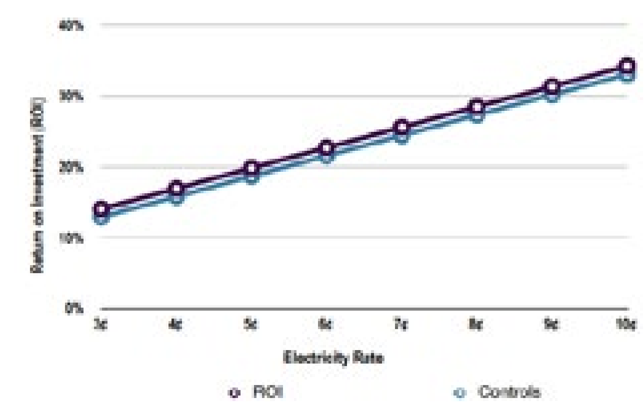
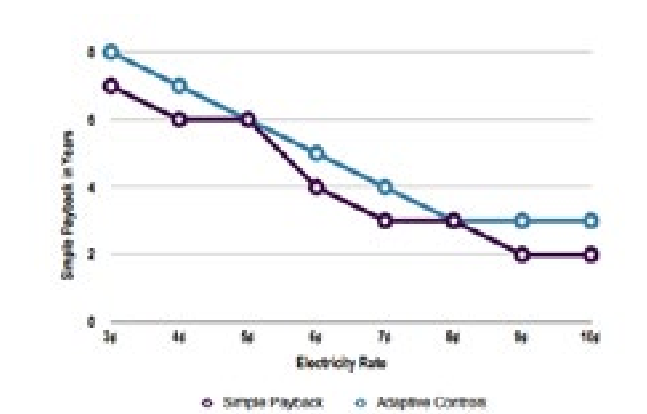


FIGURE 4: CANADIAN URBAN INSTITUTE'S ASSESSMENT OF LED PAYBACK

In terms of simple payback, the analysis indicates that investment in LED retrofits can achieve simple payback between two and eight years, depending on the electricity rate, which varies between $0.03 and $0.10 in the analysis. In terms of ROI, the annual return on the same investment varies between 12 percent and 33 percent, again depending on the same range of electricity prices



– Source: Canadian Urban Institute

3.0 Resources

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

"The American Association of State Highway and Transportation Officials (AASHTO) provides guidelines for street lighting based on traffic volumes and other criteria, as well as for luminaire design and construction. Its primary publication is the Roadway Lighting Design Guide (2005), an update to the 1984 An Informational Guide for Roadway Lighting. Cities may also look to the following resources for additional guidance."

ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA (IESNA)

"The Illuminating Engineering Society of North America (IESNA) has two publications: the 10th edition Lighting Handbook (2011) and American National Standard Practice for Roadway Lighting."

U.S. DEPARTMENT OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION (FHWA)

"The United States Federal Highway Administration's (FHWA) study on lighting design concepts is the Roadway Lighting Handbook."

INTERNATIONAL DARK-SKIES ASSOCIATION (IDA)

"The non-profit advocacy organization International Dark-Skies Association (IDA) has several free publications including Municipal Guidelines for Lighting in the Right-of-Way (2008) and Outdoor Lighting Code Handbook (version 1.14, 2002). The IDA and the Illuminating Engineering Society (IES) recently."

ASSOCIATION OF OUTDOOR LIGHTING PROFESSIONALS

"The Association of Outdoor Lighting Professionals' mission is to promote and advance the landscape and architectural lighting industry for lighting designers and installers, distributors and business-to-business manufacturers."

CANADIAN URBAN INSTITUTE

Cities may also look to the following resources for additional guidance. The Urban Institute works in partnership with members of our extensive networks in the private, public, academic and civil society on projects in the following themes:

- Infrastructure Optimization
- Good Density
- Vital Places
- Enabled Teams.

ECHELON WHITE PAPERS

"Echelon offers a sophisticated, comprehensive, open standards-based approach to outdoor lighting control that makes it easy and affordable for lighting owners to increase the efficiency, safety, and versatility of their municipal and commercial lighting systems."

INFO

UBC CAMPUS PLAN – OUTDOOR LIGHTING SPECIFICATIONS

PERFORMANCE CRITERIA	MINIMUM STANDARD
Lighting System Efficiency	75% efficiency or higher
Lamp Efficacy	60 lumens per watt or higher
Lamp Life	Rated average 14,000 hours minimum; 20,000 hours preferred.
Colour Temperature	White lamps 3000K - 4200 K, for white light
Lamp Colour Rendering Index	80 or higher
Durability	System and components to meet national and electric codes, IP 65 waterproof, rated for outdoor use, and higher thermal dissipation properties
Ease of Maintenance	Samples to be submitted to Campus + Community Planning for confirmation of lamp access
Luminaire Optical Design	To incorporate optical shielding to limit view to direct lamp images, outdoor luminare optical design shall meet the luminaire classification system (LCS) of three composite (BUG) ratings of Backlight, Uplight, and Glare (<10% to front light very high (FVH), <10% to backlight very high (BVH), and 0% uplight high (UH). All new pole mounted lights over 15 feet height are to meet LEED cut-off standards of the LZ3 lighting Zone to address dark sky light pollution concerns.

4.0 A Secure Environment

LIGHTING AS A DETERRENT

A brightly lit area makes it more difficult for a crime to go unnoticed because gives no shadows for a criminal to hide in. Proper lighting has the potential to inhibit crime and may have an intimidation effect on a would be perpetrator. Criminal activities tend to focus on areas which are dark, isolated and unprotected. The following design features have been identified as unsafe:

- inadequate lighting,
- poor sightlines (not being visible to others due to corners and other barriers),
- no access to help,
- hiding and entrapment spots, or
- poor security.

As a major obstacle to criminals and potential intruders, lighting is one of the most economical and efficient crime prevention tools. Research has shown that a lighting system that optimizes visibility and visual comfort after dark can promote a sense of safety and improve security (CPTED ontario | crime prevention through environmental design.). Traditionally, however, street lighting has been designed for the driver, rather than the pedestrian; as a result, a shift to using a proactive design philosophy can lead to a pedestrian friendly environment.

Studies have shown, a pedestrian inviting environment needs to:

- minimize the risk for tripping/falling,
- reduce the risk for being hit by vehicles, bicycles, or skateboarders,
- minimize unwanted light in residential windows, and
- minimize glare that causes discomfort, is disabling, or affects viewer adaptation level

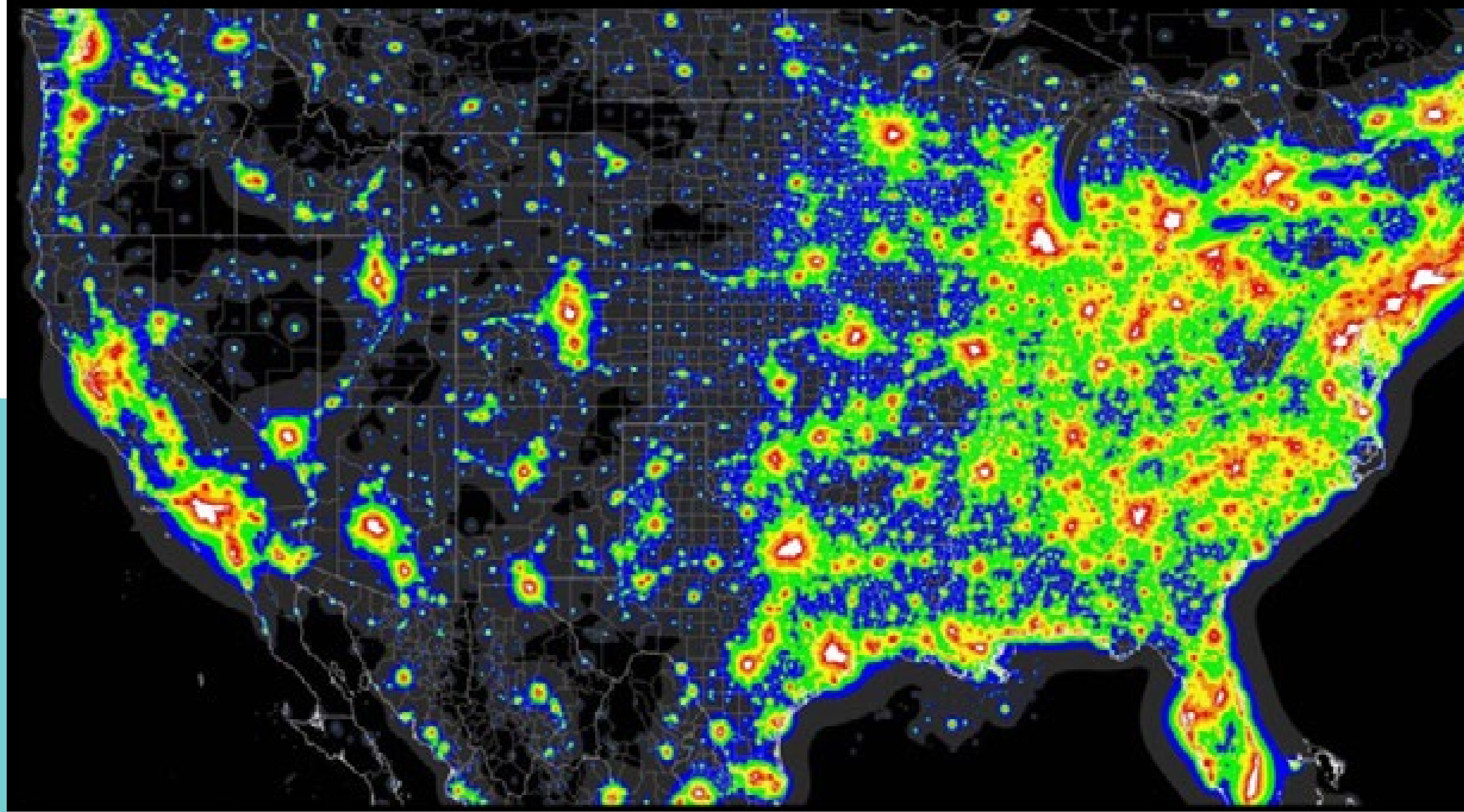
According to CPTED, their strategies can be applied to identify and remove potential problems by correcting issues in the physical environment that may invite crime; for example, UBC can improve the perception of security and safety by:

- maximizing the pedestrians (staff, students, visitors) ability to view public spaces,
- designing roadways to discourage through-traffic,
- providing appropriate lighting for streets, paths, alleys, and parks,
- encouraging residents to watch over each other, and
- avoiding placing dark, and or hidden areas near activity nodes.

CPTED STRATEGIES

Table 1 Summary of CPTED Stratgies (CPTED, n.d.)

STRATEGIES	EXPLANATION
Lighting	• Provide adequate visibility for the area intended for night time use • Fence off the paths or spaces which is not intended for night use to avoid mislead users that the place is safe and being used • Keep consistency of lighting to avoid excessive glare cause by contrast between illuminated are areas and shadows • Specifically design outdoor spaces and lighting for night time use • Protect light fixtures • Light fixtures should be designed for ease of maintenance and operation to provide visibility
Sight lines	• Design visibility in the built environment; avoid isolated or hidden places • Special consideration for the visibility of problematic spaces • Take into consideration future sight line impediments of plants
Isolation	• Encourage natural surveillance of isolated routes and public spaces • Provide parking for problematic routes to create natural surveillance from residents of surrounding areas • Indicate telephones, emergency telephones, or panic alarm by signs to provide surveillance • Increase activities to incorporate visibility by users
Activity generators	• Introduce complementary uses to conduct surveillance • Reinforce activity generators, such as food vendors or street vendors • Plan and design for programming activity mix • Encourage ground-level activity



5.0 Environmental Impact

"In order to understand lighting in cities you need to understand the city in general."

However, excessive light will cause negative impacts on the surrounding environment: ecosystems, astronomy, and human. Thus, the color composition of the illumination can make a considerable difference in how well we see (Paskovic,). When we start to look at how artificial light interacts with the rest of our environment, we find even greater variations, based on the spectral properties of the light created by the various light sources we use. To achieve the most effective outdoor illumination and to minimize harmful side effects from that lighting, we need to have an understanding of the nature of light, the effects of various types of light, and the light sources we use.

This section will provide an overview on:

1. colour temperature,
2. colour rendering index (CRI),
3. aesthetic value, and
4. light pollution.

COLOUR TEMPERATURE

If you've ever tried to match white paint, you know that there are actually many different shades of white.

Colour temperature describes the shade of white light emitted. While incandescent, fluorescent, LED, and other light sources all emit White light, they can look very different from one another. This colour appearance of light sources is described by the lighting industry in terms of colour temperature and is measured in terms of degrees Kelvin. As shown in Figure 2, the higher the colour temperature, the cooler or more blue the light source appears.

Studies have even shown that light colour affects our daily sleep cycles. Cooler colours promote wakefulness and productivity, while warmer colours tend to promote relaxation; section 7 provides more details (Color temperature, n.d.).

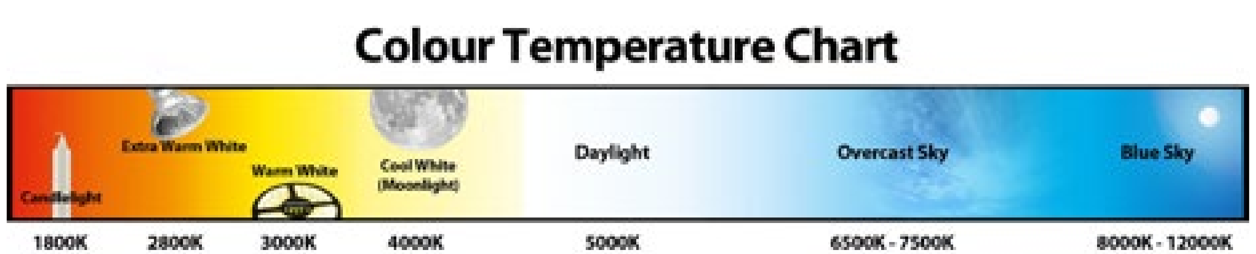
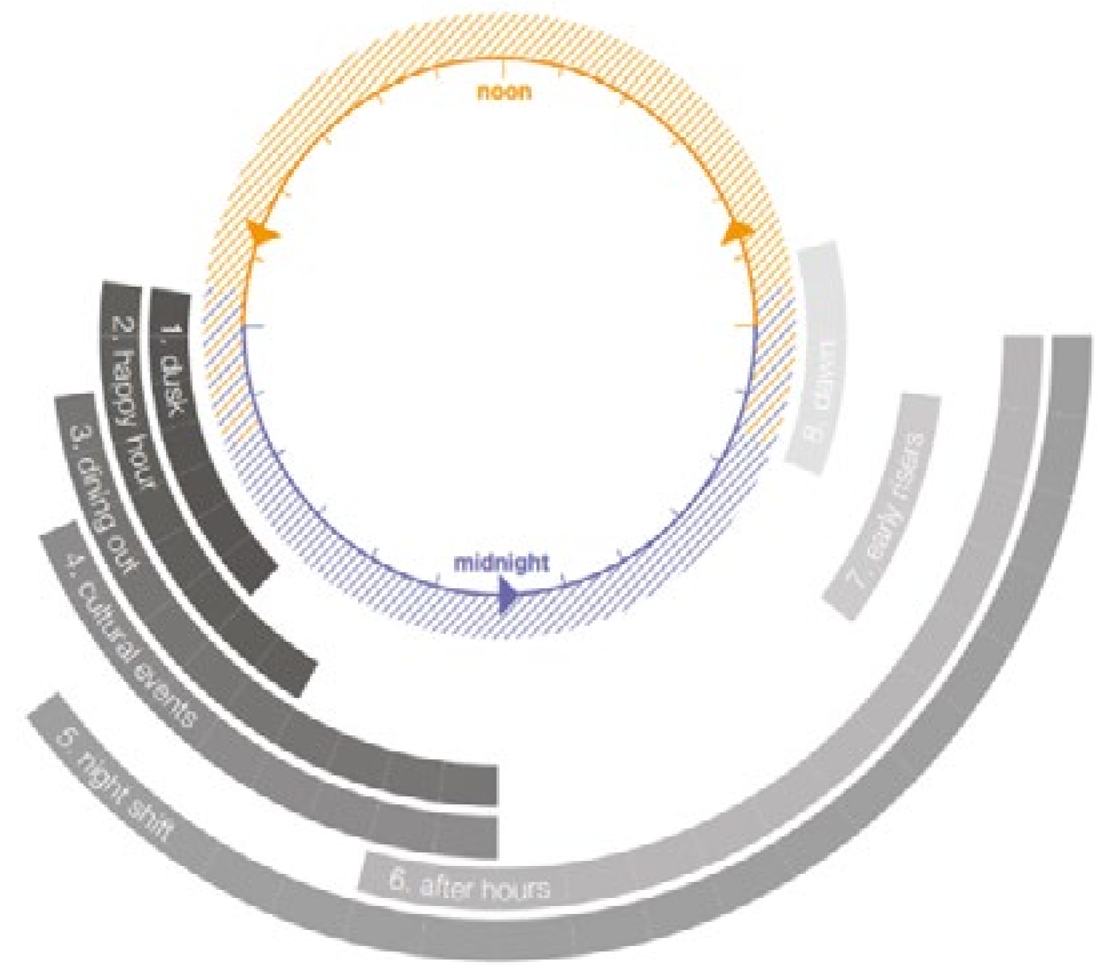


Figure 5: Illustrates the Colouor Temperature Spectrum of Aritifcal Lighting (LED)

EXHIBIT

360°: 24-hour Colour Temperature



This photo is courtesy of LED Magazine

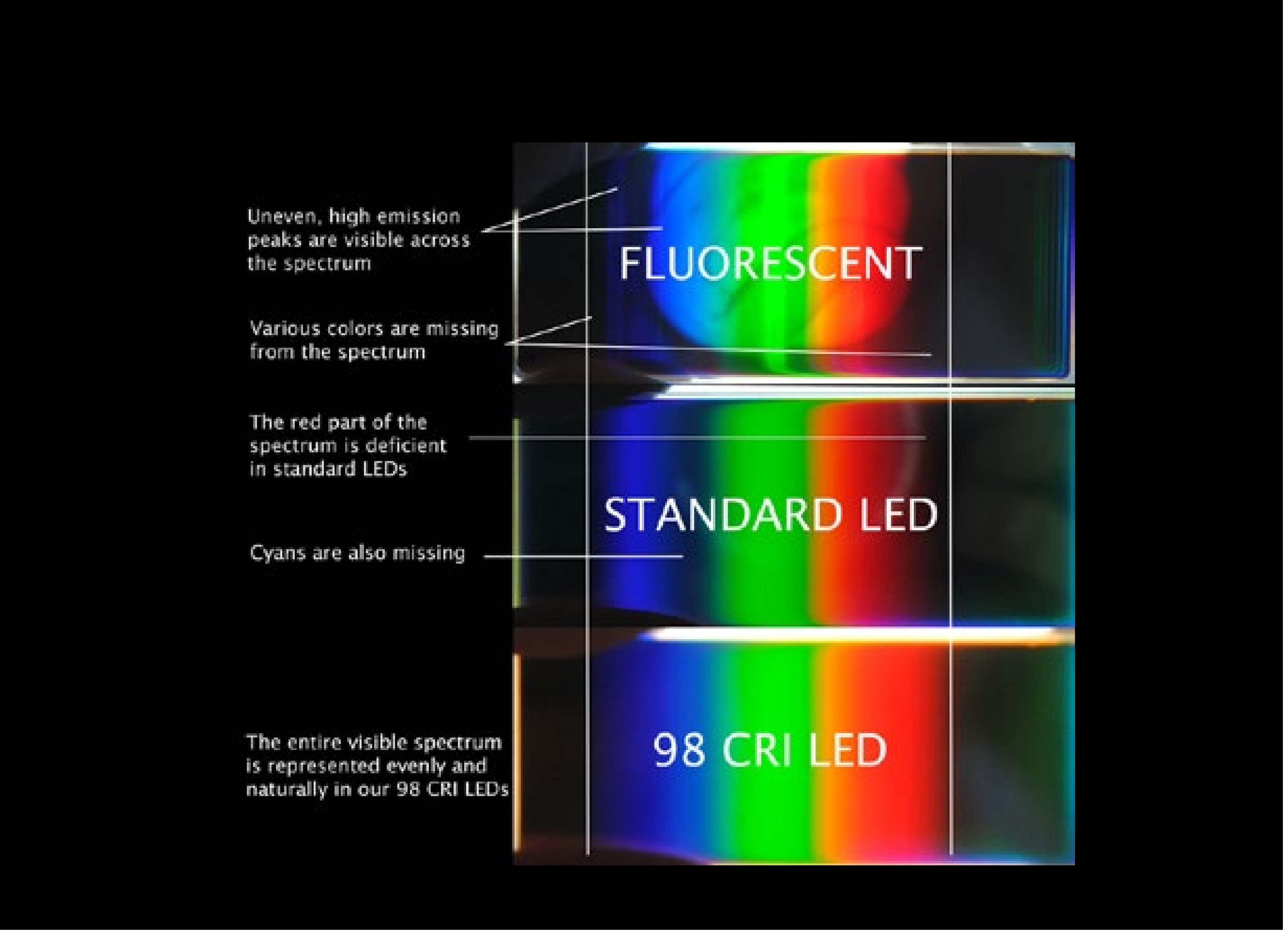


Figure 6: Visual Comparison: Fluorescent vs. LED Lights.

COLOUR RENDERING INDEX

Not all white light is the same.

Many of the incandescent and halogen "replacement" LED lights currently on the market use less energy but are not true replacements as the white light they emit is of relatively poor quality.

The measurement of light's ability to properly render colours is called the Colour Rendering Index or CRI.

Colour Rendering Index (CRI) rates the ability of the light to accurately portray colours in the area being lit. It involves measuring the extent to which a series of eight standardized colour samples differ in appearance when illuminated under a given light source. The highest possible score is 100, defined as the CRI of standard incandescent lamps and the sun.

AESTHETIC VALUE

Light has become an integral element of place-making and energy-saving initiatives alike.

The appearance of a university or college campus can make lasting impressions by creating a unique personality differentiating it from others; visitors' opinions about the educational institution may form based on its grounds and the functionality of its structures. Also, with economic development and the accelerated pace of life, night work has become a modern urban people's way of life.

Since more and more people enjoy night life, aesthetic requirements for a vibrant night light environment is greatly increasing. As the meaning of modern artificial lighting has already surpassed the traditional scope of a mean of illumination, light design has become an integrated discipline which is combined with architecture, physiology, psychology, and aesthetic.
To ensure the creation of a bright road lighting for the campus area and an elegant atmosphere for the district during the day, lamp type should be selected to be coordinated with the architecture and atmosphere of the university; and strive to make "light and shadow" combination melodic.

INFO

Integration of Light: People, Technology, Space, and Process

People	Create intelligent lighting environments that are sensitive to the behaviour of people and responsive to changes in the environment Identify, quantify and communicate the diverse social benefits of lighting, including non-visual impacts on health and wellbeing
Technology	Assess the potential of emerging technologies and design approaches in the context of human factors to move beyond pure functional performance Invest in smart lighting infrastructure that has the capability to be reprogrammed according to future needs and developments
Space	Explore the spatial, social, functional and historical context of urban spaces to identify how design opportunities relate to local requirements Consider the diversity of end-user requirements of spaces at night and anticipate a broad range of use patterns in the early stages of projects
Process	Encourage cooperation between stakeholders, harness shared knowledge and establish interdependencies between different parties Employ a strategy to manage the ownership of light, with a focus on integrating private and public sources of light

LIGHT POLLUTION

Urban landscape lighting has rapidly developed, especially the widely used high power and high-intensity discharge lamps in architectural landscape and road lighting. This rapid development is inevitably followed with increased light pollution and a likelihood of inefficient use of resources and energy. Light pollution results from lighting above the level required from the task, or by inappropriate lighting practices such as: lighting when not needed, insufficient control, and using inappropriate spectral (Light pollution2016).

As shown in Figure 5, There are different forms of light pollution: sky glow, glare, light intrusion, and the over brightness of buildings. Light pollution not only disrupts ecosystems and astronomy, but also has negative impacts on human health. More details on the health impacts are provided in section 7 of the report.

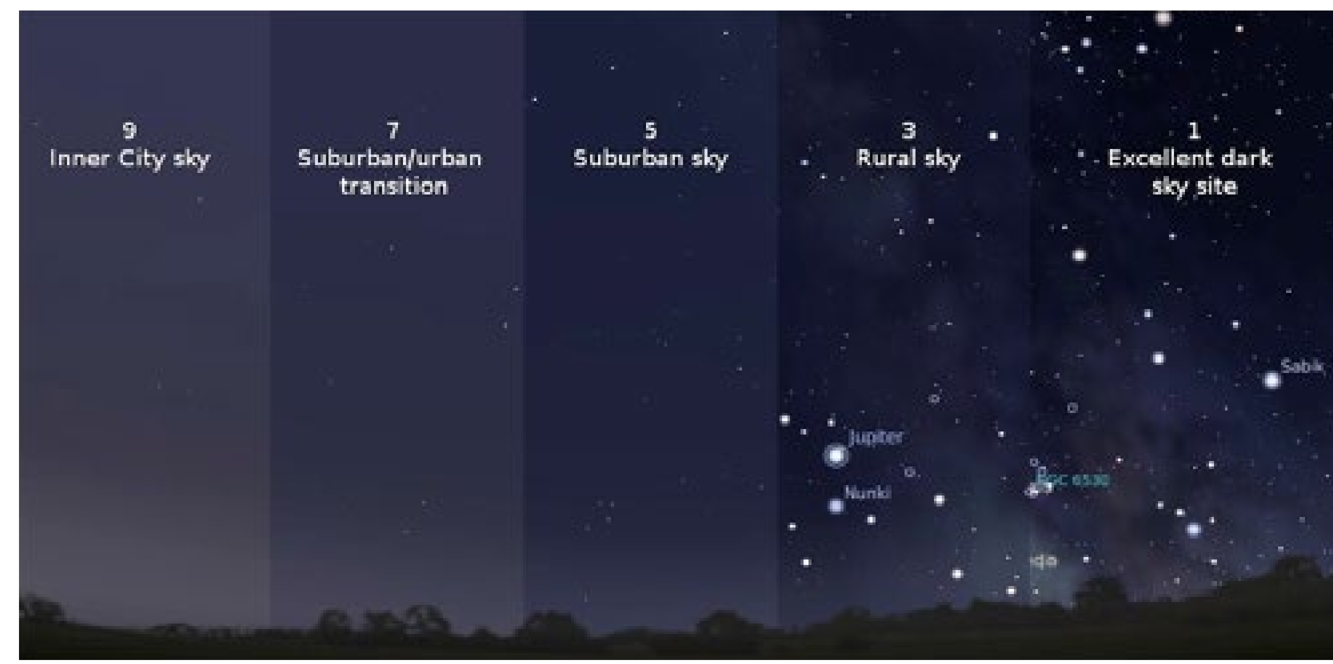


Figure 7: Shows the changes of the night sky as light pollution increases (LED)

Light pollution not only disrupts ecosystems and astronomy, but also has negative impacts on human health. More details on the health impacts are provided in section Six of the report.

As shown in Figure 8, There are different forms of light pollution: sky glow, glare, light intrusion, and the over brightness of buildings.

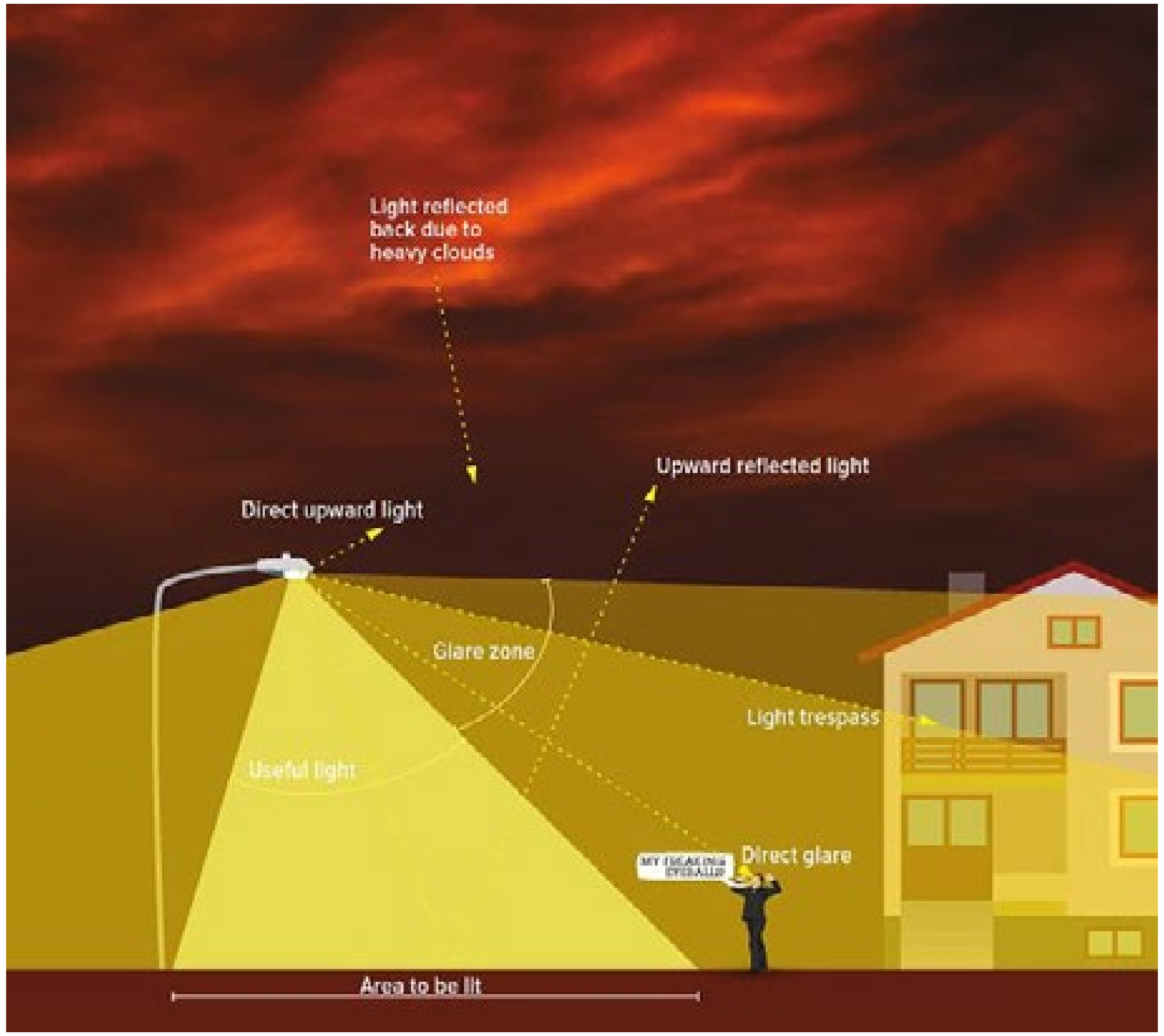
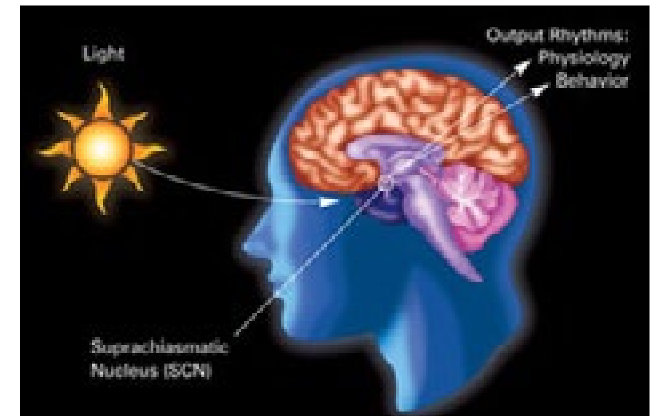


Figure 8: Various Forms of Light Pollution.

- Sky glow occurs from both natural and human-made sources.
- Light trespass is light being cast where it is not wanted or needed.
- Over-illumination is the excessive use of light.
- Glare can be thought of as objectionable brightness.
- Light clutter is the redundant lighting found in many urban centres results in a clutter of lights that contributes to sky glow, trespass, and glare while destroying the ambiance of our night-time environment.

6.0 Health Impacts



There has been increasing number of studies sugThere has been increasing number of studies suggesting that artificial light has adverse effects on human health; for example, it has been well established that the circadian rhythm in our bodies plays a critical role in maintaining our health. Our body reacts to external stimuli. And light, in fact, is the main factor that can advance or delay the circadian rhythm. The Sun is responsible for regulating this mechanism and serves as the basis for our circadian rhythms. Researchers have found that there is a positive correlation between artificial lighting and the suppression of Melatonin production in our bodies. Melatonin, also known as the "hormone of darkness", is mainly controlled by light (Chepesiuk, 2009).

Additionally, studies suggest that light has a considerable effect on people's feelings. The direct psychological impact is caused by the physical stimulation from the colour of lighting. For example, the reaction of brainwave to red is alert, but to blue is relax. Therefore, red lighting environment induces an elevated blood pressure; and it makes people become more excited; in contrast, blue lighting environment can slow pulse and calm emotions (Implications.).

Furthermore, artificial lighting can shape our behaviour. According to Ginthner, if two paths have equal illumination, 69% of the people chose the right; however, if the level of illumination of the path to left was increased to a higher level, 75% people changed their decision and chose the left (Implications). Additionally, warm tone colours, such as orange and yellow, give people a warm feeling. Whereas cold tone colours, such as blue and green, make people feel cold. Moreover, bright colour creates a space which makes people feel pleasant, spacious, and relaxed, but dim colours produces an unpleasant, unrefined, and tense impression.

INFO

Table 2: Summary of Key Studies and their Key Findings.

Study	Study type/setting/subjects	Key findings
ANSES (2010)	LEDs review	Blue light could harm retina, with certain populations at greater risk
Chepesiuk (2009)	Review, light pollution not specifically LEDs	Limited evidence for light pollution's effects on human health
Falchi et al (2011)	LEDs	LEDs are the most polluting light source, contributing to melatonin suppression bands five time more than present levels
Fonken et al (2009)	Non-human subjects (mice) constant lights, not clear if LED or other	Constant exposure to artificial light can induce increased depressive and reduced anxiety symptoms
IES (2010)	Not specifically LEDs	Exposure to exterior light has not been shown to lead to cancer or other life threatening conditions
Pauley (2004)	Review, not LEDs specifically, does focus on blue wavelength light	Light at night could harm health, but need for further research to clarify. Blue light implications on health.
Rea et al (2012)	Light at night, streetlights including LEDs	1 hour exposure to LEDs in practical scenarios results in a 12-15% melatonin suppression
SCENIHR (2012)	LED lights	Low probability artificial light used for visibility purposes results in acute pathological conditions
IOM (2013)	HNA	No evidence that LED street lighting specifically has any additional health and wellbeing effects beyond that found for artificial lighting in general

7.0 Benchmarks

Next-generation lighting demands a combination of exceptional The world of artificial lighting is undergoing an evolution. Next-generation lighting demands a combination of exceptional color rendering, high brightness, high reliability, long life, and energy conservation. LEDs (Light Emitting Diodes) deliver – and also offer a number of design advantages over incandescent, halogen, or fluorescent light sources. So, why not make the switch?

CANADIAN CITIES

There are many Canadian cities that have begun the transition to LED streetlights. In the lower mainland, the City of Vancouver and Surrey have become one of the first Canadian cities to embark on a full conversion of street lighting to LED lights.

Moving East, Ottawa is looking to fully convert all of its streetlights to LEDs. LEDs have been used in several of their pilot projects.

ACADEMIC INSTITUTES

So what are other campuses in North America are doing? Like the University of British Columbia, other academic institutes have been consistently implementing plans to reduce operating and maintenance costs, reduce carbon emissions and increase the number of sustainability initiatives. This section outlines some of the initiatives that other academia has taken:

ACADEMIC INSTITUTES

"PRINCETON UNIVERSITY has initiated The Facilities Organization Project, which could contribute as much as 15 percent toward the Princeton Sustainability Plan of reducing carbon emissions. According to the Director of Sustainability, Shana Weber, "[t]his project has the potential to make this approach more accessible to other college campuses, and may even influence the choices our University community members make at home" (Lillja, 2014)."

- Source: Princeton University

"NEW MEXICO STATE UNIVERSITY, Carlsbad, improved lighting performance by retrofitting outdated HPS luminaries to LED. The retrofitting created cost savings due to reduced maintenance and re-lamping; it also improved nighttime visibility and enhanced campus safety (Kennal, 2013)."

- Source: New Mexico State University

"UNIVERSITY OF CALGARY: the move is on to replace over 1,200 outdoor lights on campus to improve safety and sustainability. Buildings, roadways, pathways and planter lights are being upgraded now, with parking lot and residence lighting to be improved as funds become available.
"The drivers for this project were the safety of our students, faculty, staff and visitors, the replacement of our fixtures that had reached the end of their life and the energy savings potential of new LED fixtures," says Mike Rogers, director, Capital Renewal, Facilities Development."

- Source: University of Calgary

"At STANFORD UNIVERSITY, the lessons drawn from the Stanford pedestrian mock-ups showed that users cared about the daytime appearance of the luminaire. At night, they found lower illuminances than delivered by their existing post-top lights to be acceptable, providing there was little glare, a soft-edged distribution of light, and a warm color (2,700K to 3,000K) with CRI of 70 or higher. Diffusion was an important characteristic of optical systems that were deemed less glaring. LEDs or clear metal halide arc tubes exhibit an extreme spatial gradient of luminance. That is, the maximum luminance is very high over a very small visual angle, flanked by a sharp-edged drop to much lower luminance. Diffusion that smoothed out that luminance transition was described as less glaring."

- Source: Stanford University

8.0 Ecosystems Impacts

HARMFUL TO WILDLIFE

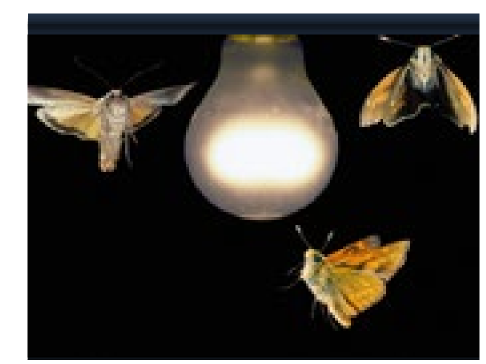
Artificial light in the wrong places has definite, harmful effects on the natural world around us.

For example, one nocturnal activity which artificial lighting has been shown to disrupt is migration. This effect is frequently seen in night-flying birds. The unnatural glow from artificial sources, whether they are individual lights, bright buildings, or entire towns or cities, can overwhelm a creature's senses, and send it off course. If the migrator does not get to where it was heading, it will not complete the natural cycle, whether the destination was a place to feed, spend a season, or reproduce (*Light pollution effects on wildlife and ecosystems*, n.d.).

That same light, spreading from unfortunately all-too-common wasteful lighting installations, also represents the wasteful consumption of huge amounts of electricity. The generation of that electricity creates its own, massive load on our environment.

This photo is courtesy of www.bbc.co.uk

This photo is courtesy of www.tvilight.com



This photo is courtesy of images.northrup.org

9.0 Recommendations

The best solutions will vary from one project to another depending on the client's needs, user needs and site specific needs. We can only provide recommendations which are meant to stimulate discussion.

RECOMMENDATIONS

Before determining what type of lighting should be installed or retrofitted, it is important to ask the basic question: Is Lighting needed? If no reason for lighting can be found, it is more practical to remove the current lighting than replacing it with a new technology. Therefore, it is important to:

1. take all negative aspects of artificial lighting into consideration: social, environmental, and financials,

2. equire that lighting standards to have provision of light at an intensity no greater than the minimum necessary to deliver the intended benefits and that the light should be directed at only those areas which are intended to be illuminated.

3. continue the research, and monitoring of the biological effects of light pollution on human wellbeing and natural ecosystems are desirable, this may not be an issue which requires greater scientific confidence to justify corrective action.

4. establish recommendations based on a multi-year implementation plan for effective long-term solutions that address security, safety, appearance, economy and pollution; and to integrate a light ing strategy that is not only justifiable, but also,inthelongtermeconomically,feasible.

5. minimize light pollution by adopting best practices suggested by bodies such as the International Dark-Sky Association.,

6. provide sufficient levels of illumination at building entrances and along routes between campus buildings, parking lots, bike racks, bus stops, campus entrances, and isolated areas so users can travel safely at night.

7. establish a lighting selection criteria that balances energy efficiency with security, appearance, economy, and light pollution.

RECOMMENDATIONS FOR UBC

As for UBC, there are five areas where we think the artificial lighting requires attention. We have classified all five of these areas as having the highest priority need for improvement. The areas are as follows:

- the Irving Barber Tower Garden (low lghting level),
- the pedestrian pathway along Agriculture Road (low lghting level),
- the Michael Smith Laboratory (low lighting level),
- the Gerald McGavin Building (Togo Cars Parking, no lghts) ,and
- Lower Mall Street (too bright)

In addition to the above, we also recommend the following:

1. luminance for all new lights should be equal or less than the maximum value recommended by Illuminating Engineering Society.

2. integration of bi-level control systems as it is unnecessary to keep the street lighting at maximum illumination during periods of low traffic.

3. all new lights installed anywhere on campus to be properly shielded. These shields should ensure that light is directed downwards - not upwards or to the side.

4. a campus lighting strategy to establish a method for assessing future lighting solutions. We recommend combining the individual assessments for each of the four components to determine whether the proposed lighting solution is acceptable.

5. comprehensive integration of CPTED strategies: to improve poor design features such as isolation, lack of sight lines, and hiding and entrapment spots, it will contribute to a safer and more appealing campus environment.

Finally, we believe that there is an opportunity for a Capstone-design type competition where students perform a comprehensive design of the campus lighting.

10.0 Conclusion

➔ The digital era of street lighting offers many opportunities for campuses and municipalities to maximize the capability of their street lighting network.

Therefore, the era to keep the lights running all night has gone because of a number of reasons such as: energy inefficiency, ecological disruption, health concerns... etc. To increase the perception of safety, be safer, we need to review what makes a public space on campus a target; and address those issues.

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12. Appendices

Appendix A:
Additional Resoureses