

Light Pollution Abatement: The Feasibility of Light Retrofitting for
Trent University

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Introduction

“There are two kinds of light - the glow that illuminates, and the glare that obscures” (Thurber, 1961). When thinking of methods to improve the surrounding environment and structure of Trent University's campus, one does not typically think about lighting as a source of negative impact. The issue of light pollution has not made its way to the list of top priorities with respect to mitigating our impact on the environment, yet growing concerns about night light emissions have brought the negative social, environmental, and economic implications to surface. As an institution host to a prominent array of environmental programs and courses, it may be argued that Trent University has an obligation to consider all impacts the campus may have on multiple aspects including ecology of the surrounding environment, issue awareness, resource/energy consumption, human health and culture, as well as the social impression of the university's practices on the Peterborough community and recruiting potential of future students/employees that look to the institution as a source of academic and economic enlightenment.

This greening research project was directed at highlighting the issue of light pollution from multiple areas of study, presenting a wide range of studies, research, and case examples that have already addressed the issue, bringing it to a local context of the Trent campus, presenting visual and quantitative data of the local context (although limited), suggesting the feasibility of making alterations/improvements, and providing an understanding of the future direction the University is headed in.

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What is Light Pollution?

Imagine you are driving down a road and there is a car coming towards you. The cars high beams on and as it drives closer you realize that the driver does not plan to turn down their lights. The light is now painfully shining right into your vision distracting you from the road and your surroundings. In this situation anyone would think that it was rude of the other driver to keep their high beams on. This is the same as what light pollution is to those who are affected. 'Light pollution is the unwanted and unwarranted glow and glare of outdoor lighting on everything outside of the intended target area' (Peterborough Astronomical Association 2013). Light pollution is a broad umbrella term associated with four major areas of potential concern. These include light trespass, glare, clutter and urban sky glow (Shaflik 2012). *Light trespass* can be described as light from improperly shielded and aimed light fixtures, that result in light falling where it is not intended, wanted, or needed (Florida Atlantic University 2015; Peterborough Astronomical Association 2013; Shaflik 2012). For example street lighting should only illuminate streets and sidewalks, not shine into people's bedroom windows, on top of roofs, tree branches or the sky (Florida Atlantic University 2015). *Glare* is when the ability to view a light source, such as a light bulb, is compromised because of the intensity of the light being created is too bright (Peterborough Astronomical Association 2013). It can also be described as the "sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted to" (Florida Atlantic University 2015). There are three types of glare (blinding glare, disability glare and discomfort glare) all with different levels of brightness that creates an unnerving, oppressive, annoying, discomforting feeling that can cause a loss in our visual performance (Florida Atlantic University 2015; Shaflik 2012).

Clutter is simply a grouping of light sources, commonly found in over-lit urban areas that are too close together resulting in urban sky glow, trespass and glare (Florida Atlantic University 2015; Peterborough Astronomical Association 2013). Cluster lighting can usually be seen at competing businesses such as car dealerships who are usually trying to outshine

each other (Florida Atlantic University 2015). The end result is usually an offensive, ugly, and blinding mess (Florida Atlantic University 2015). Lastly, *urban sky glow* is the combination of stray light that is being scattered in the atmosphere brightening the natural sky (Shaflik 2012). The light that escapes into the atmosphere could have come from unshielded light, up light which is light that goes directly up into the night sky and is "lost in space" serving no purpose, or from the combination of all light reflected off of what is meant to be illuminated (Florida Atlantic University 2015; Shaflik 2012). All the lost light in the sky creates a glowing dome over a city that can be seen from the adjacent countryside from miles away (Peterborough Astronomical Association 2013). All four forms of light pollution result in wasted energy and a number of environmental, social, human health and safety concerns.

The Light Pollution Abatement Movement

In addition to the obvious impacts that light pollution has to the quality of the night sky used and valued in the studies astronomy, the multiple impacts of light pollution have recently been published for wide-spread education as a result of the astronomy driven movement to identify the issue and emphasize the importance of mitigating it. The impacts of light pollution are exacerbated with the limits of our visual acuity in the face of light pollution, especially related to aging and to reduce the benefits of Artificial Light at Night (ALAN) (RASC, 2012). ALAN has a more profound impact than most of the public is aware of and scotobiology provides a focus for understanding the biological and ecological effects of ALAN and places such effects in a broader context, while relating the issue to human health being identified as critical due to the homocentric social policies (RASC, 2012).

Lighting Pollution's Effect on the Environment

Trent is a university that prides itself on its contribution to incorporating the environment into its campus, education and culture. Yet Trent's impacts on the environment when it

comes to light pollution is nothing but disastrous. During an interview with local resident and past Light Pollution Abatement Director of Peterborough Astronomical Association (PAA), Mark Coady had a lot to say about the lack of effort Trent has put into its outdoor lighting plans. Mr. Coady commented that Trent has the most “beautiful campus, but the most awful lighting”. And there is good reason as to why we should be worried about how our campus lights affect our surrounding natural environment. Outdoor lighting pollution has its own unnoticed implications to flora and fauna alike.

Night and Evolution:

Although the Moon is the dominant light source at night, its limited duration allows some animals to temporarily modify their behaviour (ex restricting foraging) then recover during following 3 weeks of dark time (Beier, 2006). The biochemistry and behaviour of all life has evolved to tolerate and even depend on these photo cycles as cues to seasonal change (cycle of light and dark is the one constant characteristic of Earth's environment). The biochemistry in plants and the detection of threshold illumination in our eyes are cues to nightfall, as it resets circadian rhythms, to compensate for slow diurnal drift as seasonal variations - making these cues with artificial light makes animals and plants ill prepared for seasonal changes - especially in temperate latitudes of North America and Europe that have highest density of artificial light at night (Beier, 2006).

Evolution and adaptation:

Species have both innate subconscious behaviour and conscious learned behaviour thus altering their natural environment; can lead to their misapplication and inappropriate behaviours (Rusak et al. 1975). More wildlife is active after dark than during the day, as many foraging species eat primarily plants, scavenge, and take advantage of the autonomy of darkness to avoid predation, also interpreting longer nights as a cue of the winter season (Richerson et al. 1999). Although nocturnal species are adapted to the night, they still need to navigate across their foraging grounds. Insects use distant lights to determine direction

(Wehner, 1984), birds use the northern stars for orientation during migration, resorting to secondary cues only when it is cloudy (Emlen, 1975). Studies had proven that artificial lights are being misread as stars or can change the appearance of ground navigation features, confusing wildlife (Emlen, 1975). Other effects that night light has on wildlife is that when there are tall illuminated structures, birds will sometimes fly directly into them at night or circle the buildings until they end up dying of exhaustion (Florida Atlantic University 2015; Mortillaro, N. 2013). Frogs will refrain from singing their mating songs while under the glare of artificial lighting and while many insects are attracted to lights at night making them easy prey, luminescent creatures such as fireflies are unable to use their glow to communicate under the glare of night lights (Florida Atlantic University 2015). Precious foraging time is lost, as animals compensate to find their way and such delay is sometimes lethal when caught in the open by predators, thus urban lighting sky glow is a problem with isolated rural lights that are not directed/shielded also impacting wildlife (Beier, 2006).

Sea Turtles - A Disruption to Biological Processes:

Of the many ecological disturbances caused by human beings, light pollution may be among the most manageable when considering other more complicated issues such as non-renewable energy consumption and population growth. Light pollution on nesting beaches is found to be detrimental to sea turtles because it alters critical nocturnal behaviors, namely, how sea turtles choose nesting sites, how they return to the sea after nesting and how hatchlings find the sea after emerging from their nests (Witherington et al. 2000). Both circumstantial observations and experimental evidence show that artificial lighting on beaches tends to deter sea turtles from emerging from the sea to nest and because of this, effects from artificial lighting are most likely to be revealed by a ratio of nests to false crawls (tracks showing abandoned nesting attempts on the beach).

How Lighting Pollution is Blocking Our Skies

When a 1994 earthquake knocked out the power in Los Angeles, many anxious residents called local emergency centers, such as the police and fire department, to report seeing a strange “giant, silvery cloud” in the dark sky. What they were really seeing for the first time was the Milky Way, long time obscured by the urban sky glow (Chepesiuk, 2009; Mortillaro 2013). With respect to our view of the night sky, light pollution at Trent has not only been affecting the surrounding environment but the education offered directly on campus. During an interview with Dave Patton, a PhD professor in the Department of Physics, he explained the problems lighting has had on his ability to facilitate astronomy classes. Every year Prof. Patton gives his students studying the PHYS 1510H (Introductory Astronomy) the opportunity to go to the roof of the Environmental Science Building and use telescopes to study the night sky. He commented that in the 14 years he has been teaching at Trent, every year it is getting increasingly difficult to see the night sky. This is because Trent has created its own artificial sky glow that over hangs the campus, washing out almost all ability to see the stars in most conditions. For all astronomers, light pollution has become an increasing problem “decreasing the signal-to-noise ratio”. This means that artificial lighting is acting just like how fog works for our own vision, obscuring and washing out astronomers’ ability to see faint nebulas, galaxies and even the stars, that should be regularly seen in the night sky (Florida Atlantic University 2015). The inability to see the night sky affects more than just astronomers. According to a report on global light pollution published in the *Monthly Notices of the Royal Astronomical Society*, “two-thirds of the U.S. population and more than one-half of the European population have already lost the ability to see the Milky Way with the naked eye” (Cinzano et al 2001; Florida Atlantic University 2015). To put this problem into further perspective “63% of the world population and 99% of the population of the European Union and the United States (excluding Alaska and Hawaii) live in areas where the night sky is brighter than the standard for light-polluted status set by the International Astronomical Union” (Cinzano et al 2001; Florida Atlantic University 2015). Figure one illustrates the gradual differences in the number of stars that can be seen due to varying levels of background light pollution (Florida Atlantic University 2015).

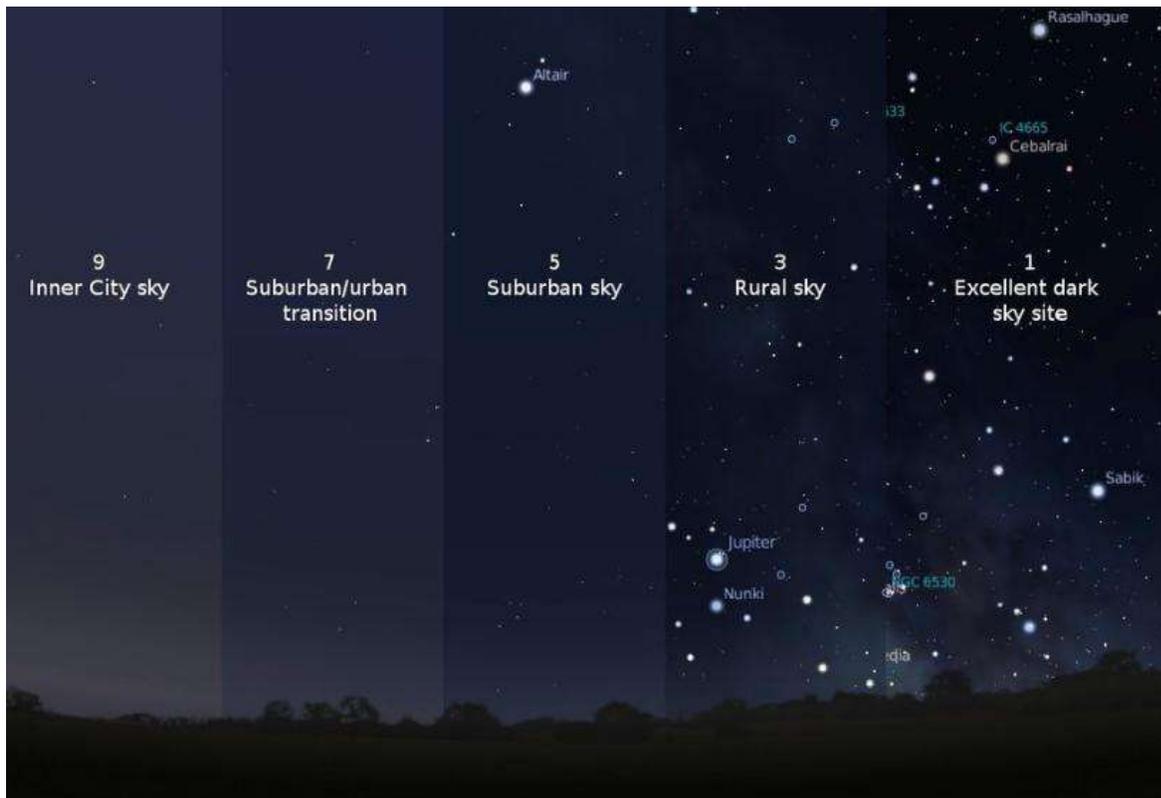


Figure 1 shows the changes of the night sky as light pollution increases (<http://gizmodo.com/>)

Observatories around the world are battling the constant threat of light pollution. Usually built on top of mountains or in dark areas to allow for a clear view to the stars, many observatories are having to close their doors because of rapid urbanization and the lighting that follows. Palomar Observatory in southern California is an example of an observatory which has had to deal with the light pollution problem. Built in the 1930's on Palomar Mountain which held perfect dark skies, the operation started having to deal with artificial lighting in the 30's, as towns started to encroach on the base of the mountain (Palomar Observatory 2015). This directly impacting the effectiveness of the 200-inch telescope and the astronomical research that could be conducted (Palomar Observatory 2015). Thankfully the Palomar Observatory was able to deal with the problem by working with the surrounding communities to decrease the amount of light pollution (Palomar Observatory

2015). Another observatory that was able to deal with the increasing light pollution problem was Arizona's Kitt Peak Observatory. Over 50 years old now, Kitt Peak was built near Tucson to allow for easy access to the universities and a reasonable metropolitan area (Jensen 2001). The astronomy research conducted in Arizona is built on 1 billion dollar infrastructure and is estimated to bring in over 250 million dollars in economic benefit each year (NOAO 2010). Therefore when the observatory threatened to close down unless Tucson did something about the increasing lighting pollution, the city was quick to react. In 2012 the city of Tucson and surrounding Pima County put together an outdoor lighting code. The purpose of the code was to “preserve the relationship the residents of the city have with their unique desert environment through protection of access to the dark night sky” (City of Tucson 2012). The code corrected any non directional lighting for residents and the industrial sector, switching all lights to full cutoff fixtures, as well as creating a lighting curfew and covering such fine details as the colour of outdoor lights allowed. The Code is so complex and is taken seriously with its maximum \$750.00 fine for individuals and \$10,000.00 fine for corporations (City of Tucson 2012). The direct action has allowed the night skies of Tucson to stay dark and allow for the Kitt Peak Observatory to keep running.

Light Pollution Linked to Human Health

For many, astronomy was the key to getting them involved in the issue of lighting pollution. This was the case for Rick Stankiewicz who dedicates his time as the Light Pollution Abatement Director for the PAA. Rick commented that “Ever since the lights have been coming on!” a statement directed to the awareness an individual gains once you start to notice the increasing amount of light pollution surrounding the city. Without astronomy Rick does not know where he would be today on the subject of light pollution, but ever since he has become more aware and more passionate. While decreasing the amount of light pollution is a win for all astronomers, Rick agrees that it is a win-win situation for everyone. This is because light pollution is not just affecting the environment or our ability to see the night sky; it is also affecting our own personal health. The circadian clock is the

cyclic 24-hour daylight and dark night exposure we are all exposed to. The clock affects physiologic processes in almost all organisms, meaning it affects how organisms, organ systems, cells and bio-molecules carry out their daily chemical or physical functions in biotic systems (Chepesiuk 2009; Roberts 2012). For humans the circadian clock is regulated by both our internal clocks and environmental stimuli (Roberts 2012). A few of the many processes affected by the circadian clock include brain wave patterns, hormone production and cell regulation (Chepesiuk 2009). Artificial light is to blame for causing minor to larger disruptions in our circadian clocks. This is because we are exposing ourselves to more light than what is natural. This happens gradually for people who are night owls or sleep with the light of a street light pouring through their window. In addition to those who are exposed to artificial light at night through light pollution, people who engage in working night shifts are risking repeated and usually long term circadian disruption (Navara & Nelson 2007). Problems such as sleeping disorders, depression, insomnia, cardiovascular disease and cancer, start to happen when our circadian clocks are changed or altered (Chepesiuk 2009). Studies are showing that people who work night shift jobs who are constantly working under artificial lighting have an increased risk of developing breast and colon cancer (Anisimov 2005; Pauley 2004; Chepesiuk 2009). A report in the *Journal of the National Cancer Institute*, reported that nurses who worked night shifts at least 3 times a month for 15 years or more had a 35% increased risk of developing colorectal cancer (Chepesiuk 2009). The effects of exposure to artificial lighting also has a lasting effect on our eyesight. A report in the *Journal of The Royal Astronomical Society of Canada*, explained that light at night will lead to further degradation of our vision due to the combined effects of altered spectral composition and unwanted veiling glare reducing our ability to see details (Chou 2012). This is why it is of great importance to follow the proper use and colour of both indoor and outdoor lighting, to reduce interference with normal circadian rhythms in plants and animals, as well as our ability to see (Pauley 2004).

Light Pollution: Illuminating or Blinding?

Socially, both Rick Stankiewicz and Mark Coady, PAA's both past and present Light Pollution Abatement Directors, agree that there is a stigma around night lighting that "more and brighter is better". This relates to both lighting of highways and roads for safe driving as well as in public areas to discourage criminal activities. This has led to over-lit service stations, parking lots and security lights on industrial buildings (Peterborough Astronomical Association 2013). Even here at Trent we can see the result of excessive outdoor lighting to protect the safety of students. Yet the truth is that the reverse is true. Overly bright, unshielded lighting creates "hot spots", areas where a light is so bright that it creates hard shadows outside of its lighting range. The bright light reduces our night vision by shining into our eyes and constricts our pupils, which makes us unable to see past the light hotspots into the dark. These bright outdoor lights have now created the perfect dark areas for a criminal to hide while also making the victims and/ or property easier to see. A study conducted by the Illinois Criminal Justice Research and Analysis Unit showed that there was actually a correlation between brightly lit alleyways and increased crime (IDA 2015; Morrow & Hutton 2000). Individuals who conduct crimes such as vandalism and graffiti, know that bright lights act as a shield to hide in the dark and they use them to their advantage (IDA 2015). To further highlight this issue a study conducted in 2011 by the University of Maryland concluded that there is no solid evidence to support that increased lighting will not reduce or prevent crime from occurring (Gottfredson 1997). Instead "the U.S. Justice Department has shown that crime rates decrease in areas with responsible, full cutoff lighting and go down even further in areas with little to no outdoor lighting" (Peterborough Astronomical Association 2013). Therefore bright unshielded light not only helps promote crime but it increases the risk of being temporarily blinded while driving. This is because light that is unshielded or poorly directed causes drivers to deal with glare. Glare causes reduced visual performance as light rays are scattered or reflected within the eye reducing the contrast of images on the retina (Shaflik 2012). This causes discomfort (squinting) and

temporarily blindness (Peterborough Astronomical Association 2013). Such effects “dramatically worsen as the human eye ages, contributing to poor night vision and difficulty in driving at night for older drivers” (Shaflik 2012).

LEDs in Outdoor Lighting

For a century and a half, incandescent bulbs have dominated as a symbol of our modern world of electricity, while the continued development of lighting is revolutionized as Light Emitting Diodes (LED) are being promoted as lower-power light sources that rival the light output of older options (Schanda, 2008). Commercially available LEDs are not much better than modern high-intensity discharge (HID) bulbs such as high-and-low pressure sodium (HPS, LPS) and metal halide (MH), yet near term developments are expected to push LEDs to the lead (Narukawa. et al. 2010). LEDs being so different from older bulbs in terms of their components and how they operate, LEDs require a change in light fixture design, if the transition to a new lighting strategy is successful, adoption of LED technology can reduce light pollution (Schanda, 2008). Incandescent bulbs use the electrical resistance of tungsten wire to create light, as the resistance to current flow raises the temperature of a filament to several thousand degrees and the surface of the filament emits light as thermal radiation that has a temperature dependent spectrum (Narukawa, et al. 2010). With a maximum temperature around 3500K (over 3200 C), its spectrum peaks in the infrared (0.83 microns), but since our eyes cannot see beyond 0.7 microns most of the light emitted by an incandescent bulb exists as heat, not visible light and this inefficiency in light production has incentives to phase out the use of incandescent bulbs for energy conservation (Schanda, 2008).

HID bulbs use a different system, as electrodes excite gas sealed in an ampoule, and this gas emits light as the characteristic wavelengths of the fill gas, with the addition of other gases changing the emitted spectrum and thus changing the colours. A modification of HID is a fluorescent bulb that has a phosphor coating in the inside surface of the ampoule to further

refine the emitted colour by spreading out the emitted spectrum, whilst such 3 types of light bulbs are based on heating the emitter to high temperatures, considerable efforts to maintain a reliable seal between the hot metal electrodes and cool glass ampoule are required, making the bulbs susceptible to breakage if mishandled (Narukawa et al. 2010). LEDs operate on a different system that frees them from the limits of the high-temperature filaments (Schanda, 2008). Unlike ordinary incandescent bulbs, they don't have a filament that will burn out and such extreme and wasted heat is not created. They are illuminated only by the movement of electrons in a semiconductor material, and they last just as long as a standard transistor. The lifespan of an LED surpasses the short life of an incandescent bulb by thousands of hours (Harris et al. 2002).

Campus Situation - Current vs. Potential Benefits

Although the efficiency of LEDs are dependent on a number of variables, including the temperature of the surrounding environment, the energy output of the LED and the brand/size/cost of the LED, it is simple to visualize the benefits of a lighting retrofit for both exterior and interior lighting schemes. For the sake of a simplified example the table below depicts the variables involved with 3 different lighting strategies:

	LED	CFL	Incandescent
Expected Lifespan	50,000	10,000	1,200
Watts Per Bulb	10	14	60
Cost Per Bulb	\$35.95	\$3.95	\$1.25
KWh of Electricity Used over 50,000 hrs	500	700	3000
Cost of electricity (@0.10/KWh	\$50	\$70	\$300
# of bulbs needed for 50k of use	1	5	42
Equivalent 50k hours bulb expense	\$35.95	\$19.75	\$52.50
Total cost for 50k hours	\$85.75	\$89.75	\$352.50

Table 1. A hypothetical comparison of 3 different lighting technologies. One can see the short term savings of implementing LEDs.

The above table merely shows the short term savings of higher quality LED technologies in a simplified situation. If one were to apply this to a campus situation the savings would become multiplied over time. With the challenge of a significantly higher cost to buy into the newer LED technology (let's say a higher output streetlight for the parking lots and

bridge = \$150), a 60 watt LED replacing a 150 watt Incandescent results in lower wattage requirement along with reduced replacement costs because of a longer LED life-span. It is also important to note the projected decrease in costs of LED technology.

Sky Quality at Trent University's Campus

Using a Unihedron - Sky Quality Meter, commonly used by astronomers to measure the clarity of the night sky, we were able to go about campus and measure the quality of the night sky seen at different campus locations. A reading of 15 represents a complete lack of visibility of the nights sky, while 21 represents a highly clear sky visibility.

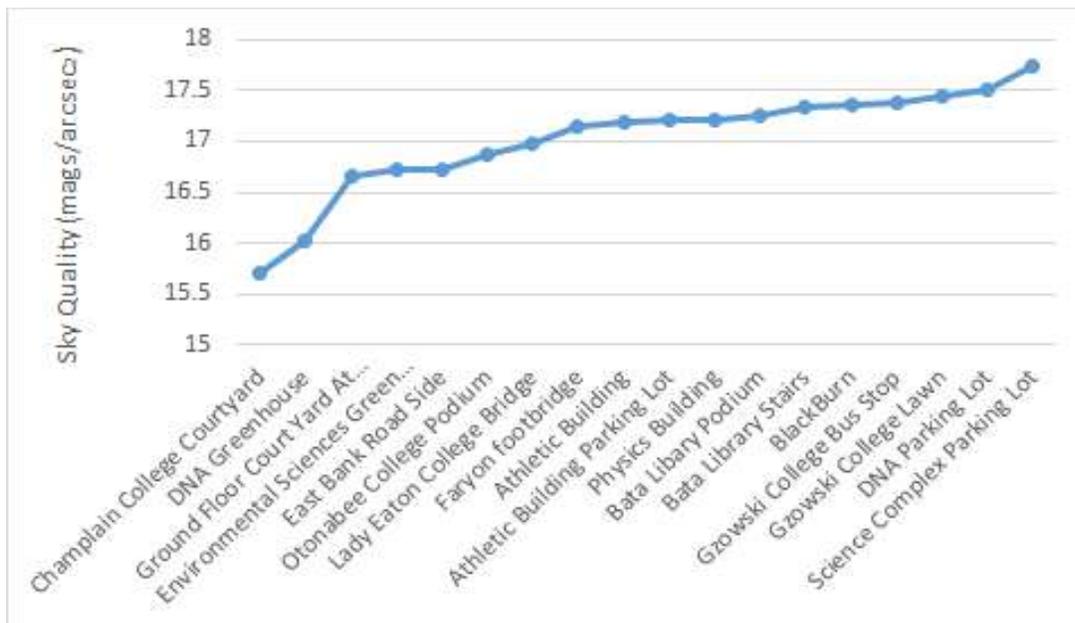


Table 2 shows sky quality measurements (magnitudes per square arcsecond) for different areas around Trent University's Campus. (Third to the Left "Ground Floor Courtyard at Environmental Sciences Building")

As seen in Table 2, there is a range in sky quality found at Trent University. Places such as the Science Complex's parking lot (17.74 mags/arcsec²) and the DNA Building parking lot (17.51 mags/arcsec²) had the best sky quality. But a sky quality measurement in the high 17's is still representative of a light filled sky. On average the campus held a sky quality in the high 16's to low 17's. The two significantly poorest areas on campus for

having the worst sky quality were by the DNA Buildings greenhouse and in the Champlain College courtyard. Essentially, no sampled area on campus received a quality reading by the Sky Quality Meter.

Conclusion & Recommendations

Scotobiology shows that artificial light at night, with constricted use, need not significantly impact an ecosystem, not only is it inexpensive to change this human behavior, it will also offer benefits of reduced energy consumption, scaled down power distribution systems and improved health. Although recent products are not much better than current HPS bulbs, LEDs hold great promise to change the nature of artificial lighting, as the brightness can be adjusted and directionality of emitted light can be more easily tailored to a specific distribution pattern, resulting in a reduction of light trespass and glare, and if their sensitivity to temperature can be greatly reduced, the useful longevity could eventually exceed that of current alternatives of over 20,000 hours (in some of the newest technologies over 50,000 hours).

Taking all negative aspects of light pollution into consideration, the need for an improved lighting strategy, both interior and exterior within the campus property, is justifiable and in the long term economically feasible. The effects of excessive and wasted light on social, environmental and financial aspects of Trent University warrant the investment into a lighting-retrofit project. If light pollution is mitigated through LED technology and directional lighting, the campus will lower its impact on the surrounding biological processes (mammals, insects, human rest), and the initial investment of a lighting overhaul would expect to be paid off through energy savings and reductions of maintenance costs in a matter of years. Upon viewing the campus at night in a variety of environmental conditions, we confidently put emphasis on the need for directional lighting complementary to a change in light bulbs. The benefits of full cutoff fixtures further reduce the distribution of indoor and outdoor lights into the atmosphere and also reduce horizontal dispersal. Thus, if the campus adopts directional lighting by having full cut-off

light fixtures, the amount of light intensity required to illuminate the desired areas on campus would be reduced, resulting in further reductions in energy consumption.

Trent's Bright Future

All negative impacts of lighting aside, this paper has a happy ending. This is because change is coming for Trent and the man in charge is Martin Kennaley. New to the seat as Trent's Supervisor of Mechanical and Electrical Maintenance in the Physical Resources Department, the department is working towards making big changes to improve our university. With little spare time, Martin agreed to sit down with us for an interview. To our great surprise Martin did not only share our interest in light pollution, but informed us that the institution was already moving towards an improved lighting plan. Though not officially signed off by the Board of Directors, Trent is about to see its lighting change. If approved, the university will have all its indoor and outdoor lighting switched to LED light bulbs that are directional, a project which has been in the making for over a year. The project is in partnership with Ameresco Canada, a business leading in energy efficiency and renewable energy solutions for facilities throughout North America. The LED lights will use less energy, look brighter even though they use less watts and decrease the need for maintenance. The two year project to upgrade Trent will be federally funded and the cost of the project will pay for itself in two years just from deferred maintenance cost and energy savings. Martin's team is also looking into retrofitting Trent's greenhouses with LED cut off lighting seeing as how the DNA's greenhouse is so bright that it can be seen from the International Space Station! Martin was eager to express that the project to clean up Trent's energy act will be going beyond just the lights. Fridges are going to be replaced, eight new boilers were just added into the university to replace old, high energy heating units and that is just the start to Martin's goals. "This is an exciting time for Trent" commented Martin. Martin suggested we come back after our graduation to see the changes that will be happening for Trent, but even if we never see them we can leave knowing that Trent will be preserving the sky for future students.

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Works Cited

- Anisimov, V. N. 2005. Light pollution, reproductive function and cancer risk. *Neuro endocrinology letters*, 27(1-2), 35-52.
- Beier, P. 2006. *Effects of Artificial Night Lighting on terrestrial Mammals*. Island Press.
- Chepesiuk, R. 2009. Missing the dark: health effects of light pollution. *Environmental Health Perspectives*, 117(1), A20-A27.
- Cinzano, P., Falchi, F. and Elvidge, C.D. 2001. The first World Atlas of the artificial night sky brightness. *Monthly Notices of the Royal Astronomical Society*, 328: 689–707.
- Chou, B.R. 2012. *The Eye and Visual System: a Brief Introduction*. The Royal Astronomical Society of Canada. *Environmental Impact of Light Pollution and its Abatement*.
- City of Tucson. 2012. *City of Tucson/Pima County Outdoor Lighting Code*. 8-17

Clark, B.A.J. 2005 Is artificial light at night too much of a good thing?

Emlen, S. The stellar-orientation system of a migratory bird.

Florida Atlantic University.2015. Light Pollution Hurts the Night Sky for Astronomy.
Department of Physics, Boca Raton, Florida

Gaffney, A.J., Binns, A.M, Margrain, T.H. 2012. Aging and cone dark adaptation.

Gottfredson, D., MacKenzie, D., Eck, J., Reuter, P., Bushway, S. 1997.Preventing crime: What works, what doesn't, what's promising: A report to the United States Congress. Washington, DC: US Department of Justice, Office of Justice Programs.

International Dark Sky Association (IDA).2015. Lighting, Crime and Safety.<http://darksky.org/>

Jensen, M. 2001. Light pollution in Tucson. Tucson Citizen

Morrow, E. N.,Hutton, S. A. 2000. The Chicago Alley Lighting Project: Final Evaluation Report. Illinois Criminal Justice Information Authority.Research and Analysis Unit

Mortillaro, N. 2013. Saving the night: Light pollution a serious concern for human health and wildlife. Global News. <http://globalnews.ca/>

National Optical Astronomy Observatory (NOAO). 2010. Kitt Peak Night Sky is Still Dark. Association of Universities for Research in Astronomy (AURA). www.noao.edu

Navara, K. J.,Nelson, R. J. 2007. The dark side of light at night: physiological, epidemiological, and ecological consequences. *Journal of pineal research*, 43(3), 215-224.

Palomar Observatory. 2015. Light Pollution and Palomar Observatory. California Institute of Technology.

Pauley, S. M. 2004. Lighting for the human circadian clock: recent research indicates that lighting has become a public health issue. *Medical hypotheses*,63(4), 588-596.

Peterborough Astronomical Association. 2013. Light Pollution: Major Problem, Simple Solutions. www.peterboroughastronomy.com

Roberts, J.E. 2012. Light and Dark and Human Health. The Royal Astronomical Society of Canada. Environmental Impact of Light Pollution and its Abatement.

Shaflik, C. 2012. Light Pollution: Environmental Effects of Roadway Lighting. University of British Columbia. Department of Civil Engineering

The Astronomical Society of New South Wales Inc. N.A. Light Pollution.
<http://www.asnsw.com/>

Thurber, James. 1961. Lanterns and Lances. NY, Harper Publishing.

Witherington, B. E., & Martin, R. E. 2000. Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches.

Appendices



Figure 2. The Environmental Science Building's Greenhouse illuminates more than just the plants inside at night. Nikon D3200, 18-200mm Lens, 1/6-second, f/10, ISO 1600.



Figure 3. Example of un-directional lighting, the light posts on Faryon Footbridge illuminate the sky as well as the walkway. Nikon D3200, 18-200mm Lens, 1/4-second, f/8, ISO 1600.



Figure 4. So bright you can see it from space, the DNA buildings greenhouse sheds large amounts of light into the surrounding environment. Nikon D3200, 18-200mm Lens, 1/10-second, f/13, ISO 1600.



Figure 5. Perhaps one of the brightest buildings on campus, the Bata library's indoor and outdoor lighting shine upon the river and shore line. Nikon D3200, 18-200mm Lens, 1/4-second, f/8, ISO 1600.



Figure 6. As seen in this photo, Trent University's most recent addition to the campus, Gzowski College is not a steward of light pollution abatement. Nikon D3200, 18-200mm Lens, 1/2-second, f/8, ISO 1600