Identifying the economic, environmental, and social impacts of overnight, indoor lighting on Dalhousie University's Studley campus.

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Executive Summary

The objective of completing our research project was to comprehend an understanding of the social, environmental, and economic impacts that interior overnight light wastage has on Dalhousie University's Studley campus. By developing an understanding of these impacts to the university, we aimed to create change and push towards a sustainable alternative to resolve this issue and other associated issues. To help create an understanding of the various social, environmental, and economic impacts we conducted an interview with the Director of Security, Michael Burns. This interview allowed us to identify the university's current policies regarding lighting. We also conducted campus-wide interior and exterior light audits of a number of academic buildings to provide primary data that would answer our research question. From our light audit, we concluded which buildings use the most energy, which ones waste the most energy overnight, and which ones are the most sustainable when comparing the whole sample. The results of our light audit showed that the Killam Library, Life Sciences Centre, Sir James Dunn building, Student Union building, and Weldon Law building were the top five buildings with the highest associated economic costs. We also collected light pollution measurement readings to gain more depth of understanding in regards to the social, environmental, and economic impacts. The results from this showed that areas beside the Student Union building and the Marion McCain Arts and Social Science building showed the highest light pollution levels on campus. After gaining the results on the economic and social impacts, we conducted and produced the results of the environmental impacts of overnight light usage and light pollution. These results showed that the equivalent amount of CO_2 that was created by this energy wastage was approximately 675 689 lbs per year.

Overall, we concluded with the recommendation that Dalhousie University continues with the current retrofitting of lights on campus to increase the use of more efficient products, as well as promote best behavioural practices for all students, staff and faculty on campus to effectively tackle the negative impacts of light waste.

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Introduction

Background

In 2014, the Dalhousie Office of Sustainability completed a progress report on their operational sustainability plan for the University. This included active targets that were achieved to reduce electricity and fuel consumption as well as reduce GHG emissions, increase renewable energy supply on campus, and other energy related initiatives (Dalhousie Office of Sustainability, 2014). However, in the 2015 STARS report on Dalhousie, which received a Gold certification, the energy operations section received a rating of 0/10. Both subcategories of building energy consumption and clean renewable energy were given scores of 0 (STARS, 2015). Wasteful energy practices are not only costly to Dalhousie's $20 million annual utility bill, but also to student costs which saw a 3% increase in facilities fees in 2017, totaling $4 million annually (Dalhousie University, 2016). Additionally, Dalhousie is soon going to replace its 60-year-old energy plant in the Central Services Building (CSB) with a $88 million tri-generation system that will decrease GHG emissions by 25% (Dalhousie University, 2012). With all of these initiatives in place, it is timely and appropriate that Dalhousie assesses higher targets of mitigation and looks to decrease energy waste on campus in any way possible.

As important as decreasing energy waste is on campus, Dalhousie also needs to factor in the impacts that non-sustainable practices have on students as well. This is due to students being the largest population on Dalhousie's campus, and using the most resources. Therefore to increase sustainable practices as a university, the consideration of the student, and the impacts of non-sustainable practices must be accounted for. Examples of the impacts that non-sustainable practices have on students must be clearly laid out before going about fixing them. Looking at the social impacts of a non-sustainable practice, such as light pollution, includes human health impacts and misperceptions of safety. Artificial lighting disrupts the human circadian clock, which has a role in hormone production and brain waves. When continually exposed to excessive artificial lighting at night time, one could gradually develop sleeping disorders, depression, insomnia, vision degradation, and increased risk of cancer (Chepesiuk, 2009).

Environmental impacts of non-sustainable practices, such as light pollution and interior light wastage are very important factors to the well being and quality of life students and faculty receive at Dalhousie University. Artificial lighting has been shown to modify animal behavior by confusing species or disrupting their daily and seasonal cycles with false cues. Such as, in nocturnal animals who forage for food at night time to avoid predation. Birds who use the stars for navigation when migrating and can be misguided by obstructing sky glow. Frogs and insects, that rely on communication methods such as croaking or glowing to find a mate, refrain from doing so in artificial lighting (Chepesiuk, 2009). Lastly, it is also important to consider what source the energy comes from that is being wasted overnight and what are its environmental impacts. Power from the CSB plant on Dal campus uses natural gas combustion to make electricity (McNutt, 2013) while Nova Scotia Power generates 55% of their energy from coal and 17% from natural gas. Only 28% of Nova Scotia Power energy comes from renewable sources (Vaughan, 2017).

With Dalhousie University being known as a Canadian leader in sustainability, and being known internationally for its cutting edge research in medical, marine, and environmental fields; change needs to happen. Dalhousie already has multiple LEED certified buildings on campus (Leadership in Energy and Environmental Design), participates in the AASHE STARS program (Sustainability, Tracking, Assessment & Rating System), has one of the only colleges of sustainability in North America, and has numerous sustainable programs, societies, and initiatives including its own Office of Sustainability. Yet, as many practices and initiatives Dalhousie University participates in, and have committed to following, there are some improvements that can be made across campus to help Dalhousie excel even further in these fields.

Dalhousie should be held responsible for mitigating the effect its campuses have on the surrounding environment at night. Previous research has investigated energy consumption of the campus and individual buildings throughout an entire day, but no research has specifically investigated the quantity and implications of unnecessary lighting overnight on Dalhousie Studley campus. That is why our research project aims to highlight the extent and issue of light energy waste overnight on Studley campus. By drawing from previous research and case examples, as well as bringing in quantitative and qualitative data in the campus context, it will allow us to assess whether it is an issue of sustainability that should be addressed by the University.

Goals

Our goals with conducting this research project is to receive a better understanding of the costs, initiatives, and policies Dalhousie University has in place with regards to overnight light wastage and light pollution in the interior of buildings. From this understanding we aim to find or create solutions that can be presented to the Office of Sustainability to help address the problems or issues we conclude from our study.

Purpose of Research

To analyze, assess, audit, and research the amount of wasted interior overnight light usage on Dalhousie University's Studley Campus and to identify the social, environmental, and economical impacts that come from it.

Methods

The first method carried out was a semi-structured interview with the Director of Security at Dalhousie University, Michael Burns on March 21st 2018. The participant was recruited by emailing members of staff from Dalhousie University's Facilities Management team using the contact information provided on their website and asking if they would be interested in participating. This method was chosen because we felt it would provide us with a basis on which to focus our other research methods. In a study on lighting use in museum institutions, qualitative data obtained from semi-structured interviews was able to add depth to the researchers' understandings of current practices and acted as a valuable resource for those looking to develop future technological lighting innovations (Garside et al., 2017). The data generated from the interview was also consulted when determining locations for light pollution measurements and photographs. It complimented the other data by providing opinions, knowledge and expertise relating to light usage and light pollution on campus. Pilot tests of semi-structured interviews were carried out which enabled us to finetune the recruitment strategy, consent process and interview questions (see Appendix A). An ethics review detailing how we intended to maintain the core values of respect, concern and justice in our research was also carried out. The interview was transcribed and then coded based on a comprehensive coding scheme (see Appendices B and C).

Secondly, quantitative measurements of a component of light pollution called ‘skyglow’ were taken at a number of sites around campus using a REED LX-105 portable light meter. A study by researchers at Trent University employed this technique and they were able to identify which locations had greater light pollution and suggest possible reasons for this (Fyfe and Thomson, 2015). All measurements were carried out on Monday 26th 2018 between 10pm and 1am. Although we had initially planned to also take measurements on a weekend night for comparison, time restraints meant that we could not process a larger quantity of data. Locations were selected based on either being mentioned by Michael Burns in the interview or by ourselves observing them to be key areas of brightness on campus. A lower lux reading represented a higher degree of visibility of the night sky, while higher values represented poor sky visibility. Data was configured into a table for comparison and analysis.

On the same night, we noted the number of areas which appeared to have lights on in all buildings on Studley campus. We observed this from the outside and then compared these numbers with audits done indoors during daylight hours which estimated the number of lights in those same areas of each building. The numbers of lights in each of the following areas of the buildings were collected: stairwell, corridor, common area, classroom, lecture hall and office. These were then multiplied by the number of floors to calculate total estimations. Raw data was compiled into tables and analyzed for trends (see Appendices D and E).

Finally, photographs were taken of various buildings and areas where lighting was being used overnight to provide illustrations to our discussions. These were analyzed using content analysis to identify themes such as direction of lighting, indoor/outdoor lighting, type of lighting and level of glare. An example of how photographs were used to complement other research methods is available in the Trent University study (Fyfe and Thomson, 2015).

Limitations

We recognized that there were some limitations to our study. Firstly, we were only able to interview one member of staff due to time constraints. Therefore, the range and depth of our data was restricted and we were unable to compare the opinions of those who make decisions about lighting on campus. Despite this, we gained some valuable information from the interview which helped inform the remainder of our research. Secondly, the light meter values were very subjective as they varied by which direction the researcher was facing and were sensitive to areas of shade and temperature. The sample sites were chosen subjectively as ones which were near university buildings but far enough away to limit shade affecting the values. Taking measurements and photographs using a random sampling method may have allowed for more reliable comparison. Further, we excluded residence buildings because they are used in a different way to academic buildings, with overnight lighting being generally more necessary. This meant that we could not make generalizations about the economic costs and amount of energy waste of all buildings on Studley campus. Finally, we focused only on indoor lighting and so the social, economic and environmental impacts of outdoor lighting were not analyzed.

Results

Light Pollution

Light pollution measurements of 15 different locations on Studley campus are shown in Figure 1 below. Lux is a measurement of luminous flux (emittance) taking into account the spread of luminance across an area. A higher lux value indicates a higher amount of lumens per square metre. From these results we can see three main trends in the lighting corridors and concentrations across campus. Firstly, the areas of campus directly bordering upon residential streets and buildings had minimal spillover to those residential areas, as indicated by lower lux readings. This is with the exception of University Avenue which borders a few blocks of residential and academic buildings on campus in the North-East corner and the Risley Hall and Steele Ocean Sciences parking lots which have many lamp posts. This ties into the second trend that University Avenue is the brightest corridor of light on campus as well as a main road and an intersection of most paths on campus that go anywhere. It also has many buildings facing into the street, which we surveyed, and numerous streetlights. Thirdly, internal areas in the core of campus, particularly in the South-West end, appear to be darker with lower lux readings. This central area of campus with less lighting consists mostly of the Studley Quad, academic buildings, and parking lots.

Figure 1 Light pollution measurements (Lux) across Dalhousie University's Studley campus (in pink bubbles) between 10:00 pm to 1:00 am at night using a REED LX-105 portable light meter. Data was collected on March 27, 2018 by students in ENVS/SUST 3502. Image by Lamoureux (2017).

Light Energy

Figure 2 compares the estimated total kWh per year of light energy waste in all of the buildings sampled. This is the amount of energy used by combinations of 32 watt T8 Tube Lights and 14 watt CFL bulbs inside the buildings after 12:00 am for up to 7 hours in a night when the average building on campus is closed to general admittance. The highest energy consuming buildings were the Weldon Law Building and Library (39 654 kWh/year), the 2016 extension portion of the Student Union Building (SUB) (34 615 kWh/year), the Sir James Dunn Building (37 119 kWh/year), the Life Sciences Centre (52 848 kWh/year), and the Killam Library (66 869 kWh/year).

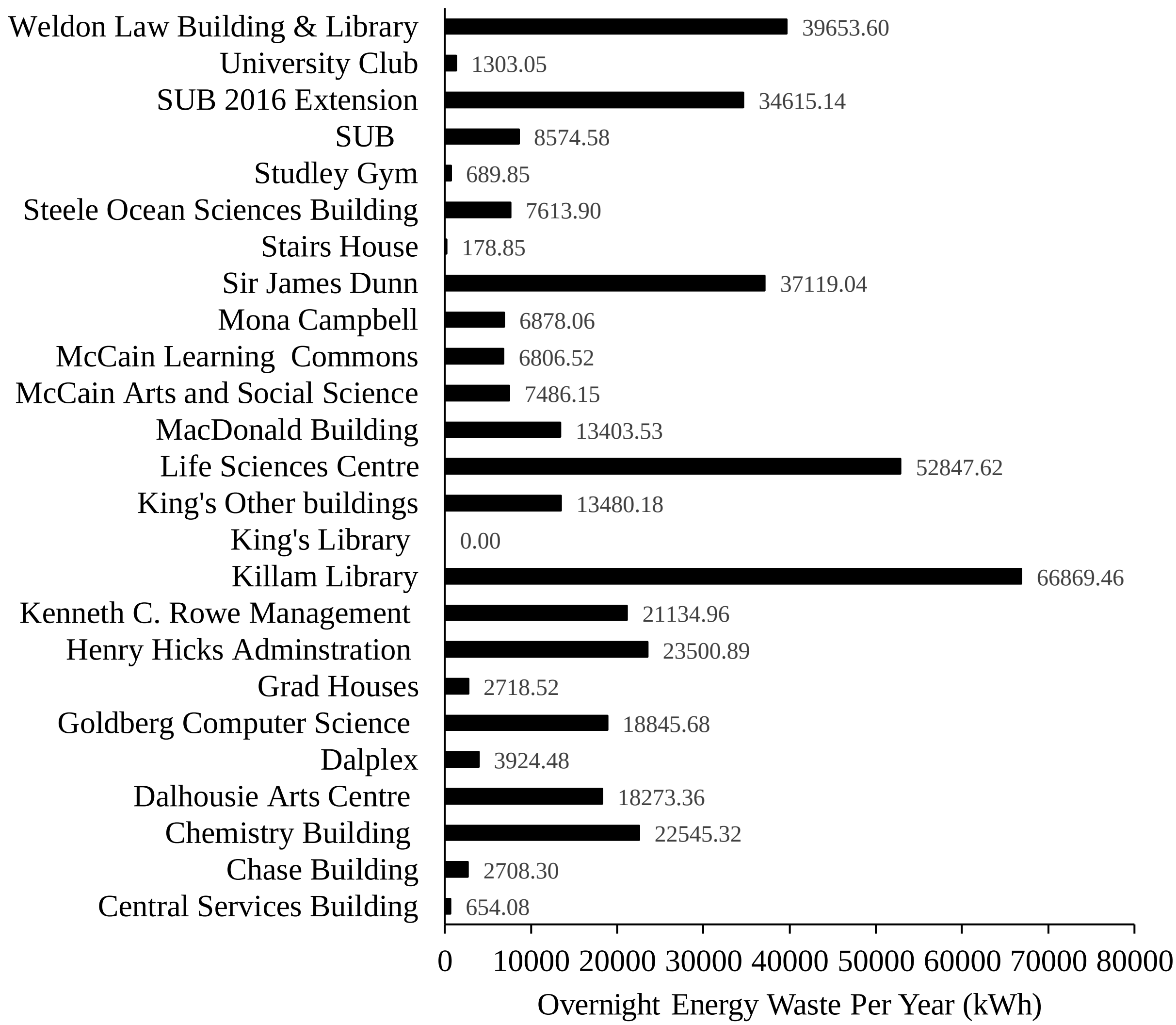


Figure 2 Estimated interior light energy waste (kWh) per year of academic buildings on Dalhousie University's Studley campus while closed overnight (7 hours per day) and assuming that all buildings use a combination of 32 watt T8 Tube Lights and 14 watt CFL bulbs. Data was collected on March 27, 2018, between 10pm and 1am by students in ENVS/SUST 3502.

Energy Costs

The total light energy waste overnight in Figure 2 was used to calculate the approximate cost of this waste in each building on a daily and yearly basis (Table 1). Assuming the Nova Scotia Power off-peak rate of $0.08404/kWh applies, the total estimated cost of unnecessary light energy waste on campus is $94.82 per day and $34 609.78 per year.

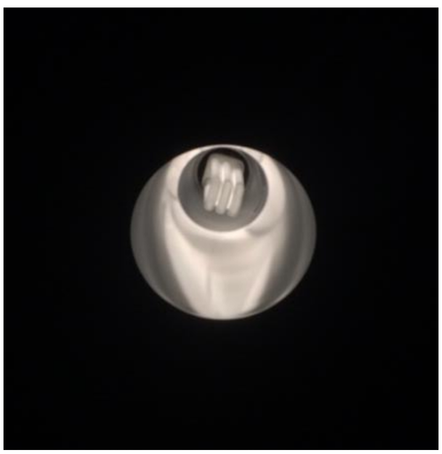
Table 1 Estimated average costs per day and year of light energy waste of academic buildings on Dalhousie University's Studley Campus while closed overnight (7 hours per day). Assuming that all buildings use a combination of 32 watt T8 Tube Lights and 14 watt CFL bulbs, and that the Nova Scotia Power off-peak rate of $0.08404/kWh applies. Data was collected on March 27, 2018, between 10pm and 1am by students in ENVS/SUST 3502.

Building	**Cost / Day ($0.08404/kWh)**	**Cost / Year ($0.08404/kWh)**
Weldon Law Building & Library	9.13	3332.49
University Club	0.30	109.51
SUB 2016 Extension	7.97	2909.06
SUB	1.97	720.61
Studley Gym	0.16	57.97
Steele Ocean Sciences Building	1.75	639.87
Stairs House	0.04	15.03
Sir James Dunn	8.55	3119.48
Mona Campbell	1.58	578.03
McCain Learning Commons	1.57	572.02
McCain Arts and Social Science	1.72	629.14
MacDonald Building	3.09	1126.43
Life Sciences Centre	12.17	4441.31
King's Other buildings	3.10	1132.87
King's Library	0.00	0.00
Killam Library	15.40	5619.71
Kenneth C. Rowe Management	4.87	1776.18
Henry Hicks Administration	5.41	1975.01
Grad Houses	0.63	228.46
Goldberg Computer Science	4.34	1583.79
Dalplex	0.90	329.81
Dalhousie Arts Centre	4.21	1535.69
Chemistry Building	5.19	1894.71
Chase Building	0.62	227.61
Central Services Building	0.15	54.97
Total	**94.82**	**34609.78**

Responsible Lighting

During data collection, we took pictures of various lighting practices and fixtures inside and outside of buildings on campus to compare and contrast their effects on security and light pollution (glare, light trespass, sky glow). Figure 3 depicts the most common types of interior lighting fixtures that were encountered during data collection. Figures 4 and 5 illustrate the differences in glare and light trespass between omni-directional lighting (Figure 3) and uni-directional lighting (Figure 4). Uni-directional lighting like the lampposts in the Steele Ocean Sciences parking lot had less glare and light trespass by directing light in a singular direction, only to where it's needed. Appendix F shows various interior and exterior lighting on campus at night, including some of those buildings with the most light energy consumption as highlighted in Figure 2.

A)



B)

Figure 3 Most common interior light fixtures found in buildings across campus, and counted during data collection, were the single 14 watt CFL bulbs (A) and the double 32 watt T8 tube lights.

A)

B)

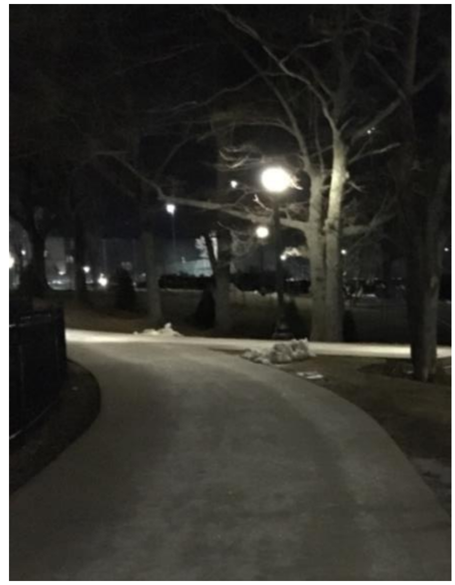


Figure 4 Example of omni-directional lighting on the pathways between the Life Sciences Centre and Henry hicks Buildings (A) and between Shirreff Hall and Wickwire Field.

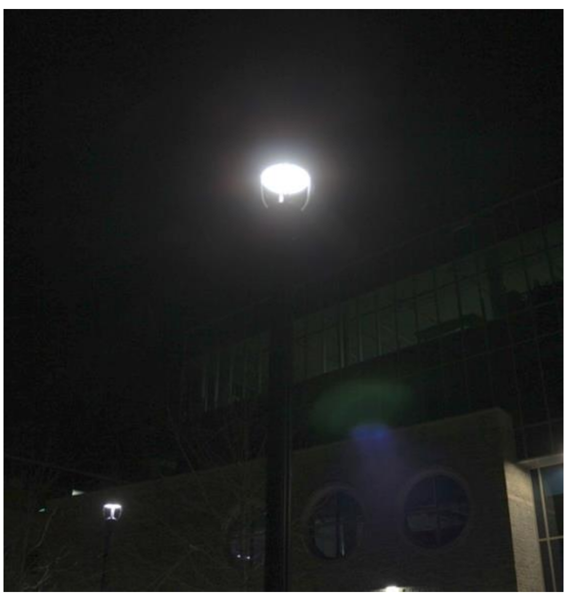


Figure 5 Example of uni-directional lighting in the Steele Ocean Sciences Building parking lot. Note the inset light bulb and the effectiveness of the top cover.

Discussion

Objectives of Research

This research project was focused on determining the economic, environmental and social impacts of light waste and light pollution overnight on Dalhousie University's Studley campus. More specifically, identifying the costs of poor lighting management practices on campus in terms of dollars, health impacts, emissions and other factors. Qualitative methods (an interview and photographs) and quantitative methods (a light audit) within the designated study area were utilized to suggest improvements to maximize the efficiency of Dalhousie University facilities.

Economic Impacts

According to Figure 2, the total overnight light energy waste was 411 825 kWh per year, which when compared with 2014 statistics, would occupy around 0.173% of total building energy consumption (238 621 047 kWh) at Dalhousie University (2014). Moreover, the total cost of overnight light energy was estimated to be $34 609.78 per year (Table 1), which took up about 0.58% of total grid-purchased electricity ($5 922 835.776) yearly (Dalhousie, 2014). When considering this is only one of 4 Dalhousie campuses, the yearly costs are even more significant when applied over all Dalhousie University properties in the long term. It is important to highlight that an average LEED building wastes less energy through lighting than a non-LEED building (Figure 2). The top five buildings with the highest associated costs were all non-LEED buildings. The LEED buildings had relatively low light waste, on average. Although some non-LEED buildings had lower associated costs, this was likely because they were smaller in size and so required less lighting. Cost saving initiatives such as the high-efficiency sensor lighting which allows rejected core heat to be used for perimeter heating in the Mona Campbell building, have been installed and this may have contributed to lower results (McNutt, 2012). Dalhousie University also reduces costs by making its own energy in the Central Services Building power plant on campus. This will soon be upgraded to an $88 million tri-generation system that will decrease GHG emissions by 25%. As well, lighting upgrades are currently taking place on campus to introduce more LED bulbs inside and outside of buildings, however, we predominantly still saw only CFL bulbs in all buildings (Figure 3) (Dalhousie University, 2012). The economic costs not only include the electricity grid purchased but also the cost of energy resources. More specifically, the prime cost will increase as the non-renewable resources become scarce. Michael Burns, the Director of Dal Security, noted that facilities fees, which are covered primarily by students, are increasing again this year. We would expect that these fees will continue to increase as the price of fossil fuels increases. Overall, light energy waste on campus has high economic impacts for the university and its students. Furthermore, a similar case study has been conducted by University of Coimbra. It evaluated the electricity consumption of lighting systems through an energy audit. More specifically, it analyzed the energy saving and economic profit of replacing the low-efficiency bulbs by more efficient light bulbs. In detail, it indicated 40% of energy can be saved, and 3,704 kg of CO_2 can be avoided per year (Soares et al., 2015).

Environmental Impacts

Energy from lighting is primarily generated from natural resources, such as oil and coal. Burning oil and coal can generate millions of tons of CO_2 per year into the atmosphere, which enhances greenhouse effect and global warming issues (Florida Atlantic University, 2013). According to our results, 338 tons of CO_2 will be emitted to the atmosphere for 411 825.12 kWh of light wasted (EPA, 2018). In the course of a year, the amount of light wastage on campus that we estimated would produce emissions equivalent to 65 vehicles driving on the road for a year. Furthermore, about 50 586 Kg hard coal or 35 410 Kg oil was needed to generate that amount of light energy (Unit Juggle, 2018). Moreover, Dalhousie University operate their own electricity grid for lighting with 30% coming from renewable resources and 70% from nonrenewable resources, specifically natural gases. So, about 983 643.948 cubic feet of natural gases would be consumed in this particular situation (Unit Juggle, 2018). The extraction of fossil fuels also has harmful consequences to the environment, including land degradation, hazardous toxins and water pollution. Coal and oil are both nonrenewable resources which are in danger of running out completely as the demand increases. Furthermore, the highest value of light intensity measured by our Sky Quality Meter was 14 Lux and this is a concern because light pollution is likely to influence the growth of organisms which are sensitive to light intensity (Škvareninová et al., 2017). According to Longcore and Rich (2006) “prolonged exposure to artificial light prevents many trees from adjusting to seasonal variations’. In addition, the light pollution can entirely alter the nighttime environment of amphibians, birds, mammals and insects, which interferes with reproduction and population numbers. Therefore, we can conclude that overnight light energy waste has significantly negative effects on the environment.

Social Impacts

We suggest that most residential neighbours living in areas close to academic buildings are not highly affected by light pollution. As highlighted in the light intensity map (Figure 1), most of the measured values around the outskirts of Studley campus were 0 Lux which indicated that there was less light spill over to residential streets. In addition, a report on light pollution by Trent University used a Sky Quality Meter to measure areas around Trent University's Campus at night and found that 21 locations represented the best sky quality, while 15 locations showed poor visibility of the nights' sky. Compared with Trent University, Dalhousie University had relatively less light pollution (Figure 1). Additionally, it is important to mention that most major routes and roads are well lit, and the inner areas of campus are relatively dark. This relates to Michael Burns' remarks about how planners aim to move people through campus within areas of surveillance and where they will be in groups, to improve safety. Furthermore, responsible lighting practices shield and direct light only to where it is necessary, therefore providing light in a safer way with less light pollution. Lighting patterns are created which can direct people toward appointed walkways, therefore maximizing safety and security. However, exposure to too much overnight lighting can negatively affect human health and behavior, increasing risks of obesity, depression and sleep disorders (Stone, 2017). This is a problem especially for the students and staff who live on campus and those who work extended hours. More specifically, indoor artificial nighttime light is likely to affect the circadian clock, and may cause cardiovascular disease and cancer (Chepesiuk, 2009). Moreover, some lamp posts emitted light in all directions and so did not provide directional light (Figure 4 & Figure 5). Too much light may reduce visibility by making harsh shadows. Directional lighting directs light only to where it is necessary, reducing light pollution and increase safety by improving lighting efficiency (ASSIST, 2017). Besides, the glare of bright lights can actually shield criminals and increase crime as shown in a report from the Illinois Criminal Justice Information Authority (Morrow & Hutton, 2000). There is little evidence to support a link between increased lighting and decreased crime rates (Yun Tan, 2016).

Conclusion

Recommendations for Action

In conclusion, Dalhousie University should continue to implement their current initiatives including LED light retrofits across campus, improving lighting corridors at night, and investing into the new and more efficient energy plant in the Central Services Building. Dalhousie is encouraged to use high-efficiency bulbs, such as the Philips MASTER TL-D Eco, to replace low-efficiency ones. More specifically, the Philips MASTER TL-D Eco bulbs are likely to save 10% energy compared to widely used bulbs such as T8 lamps (Soares et al., 2015). Also, they have relatively high efficacy with high lumen maintenance (Philips, 2018). Improving sustainability is highly related to influencing human perceptions so students, faculty and staff should be encouraged to correct their behaviors regarding the wasting of light energy. Forgetting to turn off lights is a common error, therefore switching to motion-sensor or timed lighting systems in study rooms and offices would be more energy-efficient.

Further Research

For further research, in order to get more accurate measurements of light pollution, remote sensing through Landsat imagery could be used to observe bright spots of light pollution at Dalhousie Studley campus at night. Surveying a representative sample of the population of students and staff at Dalhousie to better understand social behaviours and practices relating to lighting among individuals would also be beneficial. It may be valuable to compare Dalhousie's lighting practices to those of other universities and during different days of the week or different seasons. It may be that lighting varies greatly in the summer due to changes in building usage and weather. Additionally, more samples could be selected from each subgroup (classroom, stairwell, hallway, etc.) during data collection, and the average number of light fixtures of the subgroup calculated to more accurately record the number of lights for each subgroup. Asking the permission of Dal security to enter buildings at night during sampling would allow for more accurate data. Finally, a replication of this study could help to obtain more precise results and reduce error.

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Appendices

Appendix A

Interview Guide

Five mins: Introduce ourselves to participant, discuss consent form and allow participant time to read through and sign form.

Questions:

1. What is your role in your department/institution and what type of input do you have into lighting decisions?

2. What are your priorities for lighting for university building use?

3. Are you aware of any policies relating to light usage on Dalhousie's Studley campus?
(a) Are there any which specifically relate to light pollution?

4. Which tools (standards, data, research) are used to select lighting?
   (a) Do you personally have input into which tools are used?
   (b) Do these tools take time periods into consideration (i.e. overnight vs daytime lighting)

5. What, if any, are the economic factors taken into consideration when selecting lighting on campus (such as energy, operational and maintenance costs)?
   (a) Do you feel there are ways of reducing the economic costs of lighting?

6. What, if any, are the environmental factors taken into consideration when selecting lighting on campus (such as carbon emissions, light pollution and energy consumption)?
   (a) Do you feel there are ways of reducing the environmental costs of lighting?

7. What, if any, are the social factors taken into consideration when selecting lighting on campus (such as safety and security)?
   (a) Do you feel there are ways of reducing the social costs of lighting?

8. How do the selection and maintenance of lights vary in different university buildings on the Studley campus?
   (a) Which buildings have most recently had lights installed?

(b) Which buildings are in most need of upgrading lights?
(c) Do you know which buildings have the most sustainable lights installed?

9. What are, if any, your current concerns regarding lighting on Dalhousie's Studley campus?

10. Do you feel that any of these questions pose problems which need attention?

Appendix B

Interview Transcription

Date: 21st March 2018

Participant: Michael Burns, Director of Security

Interviewers: Gemma Watson and Justin Smith

Q: What is your role in your department and what type of input do you have into lighting decisions?

Security services at times get asked to do CPTED audits, Crime Prevention through Environmental Design. Many times, it involves lighting and landscaping, how we can manipulate the physical environment in order to make it safer or at the very least, reduce the rate of victimisation through crime. So maybe if it's a particularly dark area, light it, or if it's a particularly overgrown area with foliage, maybe trim the trees or remove bushes so that there's greater natural surveillance. At times we'll get asked to go look at the lighting in an area to determine if it would be appropriate to increase the level of lighting, leave it the same, or maybe even reduce it. We'll do that from time to time. Usually it is around academic buildings or gathering buildings. You know, you take the library or the Wallace McCain Learning Commons, the Life Science, places where there's a fair amount of traffic… residence facilities.

Q: Do you have any personal priorities for making lighting decisions?

Well, the first is, we try to determine what's the method of use for the facility or the area: is it a high traffic area, the temporal use of the facility and we want to know what time of day is this building open, if there's… if someone wants to, you know, light it up like Fenway park but the building closes at 4 o'clock in the afternoon, it doesn't make a lot of sense. So we would want to know how the building is used, who it's being used by, the time of day, the frequency, the volume of people moving through the area and any particular peculiarities of the building that from our assessment may elevate or decrease the level of risk. So you can imagine that if you had an ATM on the exterior of the building, where people would go to pick up cash, it may necessitate a higher level of lighting and visibility in the area. If it was the back entrance to a building that may not be used after hours and we didn't want to direct people to it, we may talk about decreasing the level of lighting at the secondary entrance and exit points and increasing the lighting in the front of the building where we want people to come and go. If you go look around the Dalplex, we'd want a lot of lighting in the parking lot to guide people to the front of the building and light up the front of the building, almost like a beacon to walk towards. We wouldn't want to necessarily provide a high level of lighting in emergency exits to the building, all the time. We would want the lighting there to be activated at a higher level if there was an alarm, or a fire alarm, or when the door got actuated so that people would go out into the light but the lighting wasn't on all the time. There's the cost, your tuition pays for that lightbulb to come on. There's also neighbours that live behind that wouldn't be overly thrilled with a 1,000 watt LED lamp shining into their backyard. So, you have to take that into account. The other things is that we move people around campus. Like we're looking at 19,000 students, 18,000 in Halifax, another 4,000 to 5,000 faculty and staff, you know there's natural paths that people travel. If you doubt that, just look at the wear on the grass in various areas where people avoid the path. So we know that from the library, and to Sheriff, it's right down alumni crescent almost in a straight line and that's why they ended up paving over some of that grass and putting down hardscaping because no one stuck to the road, they just cut across, it became a mud pit. So we would want to pull people in that direction and we would use lighting in an attempt to do that, to bring them down towards the main entry point of Sheriff. So, if you go there after dark, you'll walk and you'll see that the lighting tends to lead you past the daycare, around the corner towards the front of the building. The pathway that leads to the Ocean Sciences, is similarly lit, but if you're going to go to the back door of Sheriff after hours, with the card to get in, or a key to get in, we may not want to light that as strongly. We wouldn't want that to be a natural point of pedestrian travel because there's very poor aspects for visual surveillance. So you're between two large buildings; ocean science is generally unoccupied, a large building. Sheriff hall blocking out the ambient light from the streetlight and it's kind of a dark space to go into. We want to move people to areas where there's a lot of… just from a safety point of view, to have people travelling in areas where other people are travelling. We believe it enhances the sense of security, safety before we are going to then install any type of electronic surveillance cameras, we want to move people to go to the light. It's interesting when we talk to safety advocacy groups, they would like to see everything look like the front of LeMarchant place, that is, a prison yard type of effect. It's very, very bright. But what we want to do is create the lighting that when you move through the campus the way that people naturally move through campus, we light that pathway almost to create like a herd-type piece. Because it is safer to travel in groups after hours. It's also much easier if we direct people through a similar path when we get to this time of year, like, maybe a night like tonight, we have to start clearing snow and salting and prepping the walkway so that we can direct people. We know where to go plow and clear first, you know, to prevent the slip and falls. But if the whole campus is lit up like a baseball park, it's a lot more difficult, there's a lot more square footage to get to and it's the age old story, if you do everything at once, you do nothing well. It's trying to direct people between the buildings in that way. You see the main entrances lit up quite a bit more than some of the individual entrances. Because they have poor points of natural surveillance, they are not heavily used. People who are familiar with the area, who have car access may go that way, but if you were new to campus and you were going to the LSC, we don't want to light up a door that you can't get in. Because you're going to be like a moth to the flame, you're going to be drawn to it, it won't open, now you're there, now you have to come back through. So that's one of the considerations and it's where we can get the most safety per kilowatt hour out of it. And if we are going to put the lighting in that way and we know we're going to drive people there, then we can expand the walkways. You'll notice around campus, a lot of walkways are very, very narrow. They were built when I went here in the early 1970s, at Dal when there were like 7,200 students and so if you can create a lighted pathway that people will use then you can focus your hardscaping dollar on creating a wider pathway which keeps folks out of the way of bicycles, vehicular traffic, and heavy equipment. The lighting tends to draw people around but everything is a piece of the same puzzle. If we're putting in lighting, knowing what the desired outcome is, is helpful. There is lighting that we are using for just general illumination so that you can say "oh, there's a door" or "oh, there's a monument" or whatever. But then there's a lot of directional lighting that if you want the lighting projected down on the ground, if you were to go over into the Dunn parking lot, look at those old halogen heads, old Nova Scotia power lamps, they burn yellow shortly after they're installed and they light up the area around the lamp. Well, since the lamp is like, 30 feet in the air, that creates shadow on the ground. A lot of what has been replaced has been the use of directional, halogen lighting. And believe it or not, that sounds crazy but the ability to direct the lighting at the surface people are travelling on. You're supposed to look straight ahead when walking, but in a lot of cases a lot of us look at our feet or at our devices when we're walking, so it's to light up the area around you. You think of safety in terms of getting mugged or robbed, but safety is also "don't step in a hole, don't step on a crack, don't step off the curb". There's a whole physical safety piece, so what type of lighting can you use in order to achieve the effect that you want. If it's pedestrian travel and moving about, you want the lighting to be directed from the head down and to basically have a good flood, or good spread. In a high volume area, you want your lights on timers.

Q. Do you know anything about how the timers are controlled on campus?

The timers are basically controlled by the electrical shop. So there's a building automation system that runs the vast majority of campus, a company called, I believe, there's a couple, one is Johnson Controls, so everything from HFAC, to lighting, to water temperature. For a lot of people, it's imperceptible but at certain times of the day, the buildings are programmed that the lighting is turned down. A lot of the newer ones, the Mona Campbell, if you're not in a room for a pre-determined period of time, there's no movement and no body temperature, the lights turn off automatically. On campus they basically program in the seasonal patterns, how dark, how light it is, it gets a little off sometimes if it's really foggy, but the parkades, the various lights come on at different times of the day. When the time changes, that shifts as well. The one I never quite get is Wickwire field. That tends to be on quite a bit. Even from the view of Wickwire, it has a huge impact on the local amount of ambient light that reflects into the quad on that pathway from the library to Sheriff and then over into the Dalplex and that is a very dark corridor going across South Street. With those lights on you get that kind of spillover and then there's a balance between the spillover to light the crosswalk but not so much spillover that the people that live on South Street feel like they are living on the freeway. The light pollution can get quite intense there. That's the exterior. Interior buildings, you'll see we've been doing a retrofit for a while now and I don't know if they've got anything but if you were to go into the basement of the McCain building later in the afternoon or earlier in the morning, as you walk it's like an airport runway, as you walk the lights turn on. They are queuing off you. As you walk by you'll hear "click", light will come on, "click" light will come on and then as you go by, if you were to turn around and look back, they're probably on a delay and turning off as you move through. That's another technique. Basically on demand lighting, lighting when you need it. You see it in washrooms now in newer buildings they're building. That's kind of really odd, when the timing's not quite right and people go into the washroom, shut the door and it will be pitch dark and they can't find their way out. You'll see a lot of washrooms like that, being wired that way now because that's just a waste of energy. There's no one in the washroom so why have a light now, right? That's kind of what runs through our head when we're looking at different types, you don't want to over light it but then you want to make sure that you've got adequate lighting so that people can move safely around campus.

Q. So, who is it that makes the decisions about lighting? Do different departments work together?

Yeah, there's a couple of major players in here. There's Facilities Management. Within Facilities Management, that's the group of folks who work in the building that's the thermal plant, when they are in the design of a building or a project, there's university planners. One of the planners always involved in this type of thing would be the Electrical Planner. The Electrical Planner looks at exactly what I'm talking about: the square footage, where the lighting can be placed, what the intended use of the space is, what the requirements are. Actually it's kinda interesting, one of the guys working here actually worked with a major lighting construction firm that designed highway lighting. We were driving back from Truro one night and he was explaining that every light, because he'd worked on a project about how lights were based on the speed that a vehicle's travelling or what the speed limit is, the lights are positioned a certain way so you can see so far ahead. So, it would go to planning, and then from there, the plan becomes a project. There would be a couple of engineers who would be electrical project managers that would work with the university. That happens in a lot of the cases. In some of the larger projects, the planners may subcontract that out to an external engineering construction firm. You know something like Black & McDonald, and all that. But in all of these new buildings that are being built and major renovations, there's a whole architectural design around it. Where do the pot lamps go on the outside, where does the shrubbery go, what does the side of the building look like? The current design is not like this design standard (of the LSC), I understand that this is 1969 vintage. The university grew in the late 1960s/early 1970s. This building, the Killam library were all built at the same time. They call this "brutalism". All of this concrete. You see now the design around campus is more in line with the Wallace McCain. There's a lot that can be gained from that if you have the lighting on the inside designed in such a way, you can get the spillover to the pathway outside. To get an idea from that, if you walk up Robie Street and past the Goldberg, the Rowe and then the SUB, you can see when the lights are on in the buildings, you'll get quite a bit of lighting on the sidewalk. Now what's interesting, you'll see how these standards have changed over time, if you were to go out tonight around 8 o'clock and it would be particularly cloudy tonight because it's going to snow, stand down towards Nova Scotia Archives and look at what the lighting looks like in front of the Goldberg Computer Science Building. Not a lot of thought went into safety or travel on campus during that period, that would have been the 1980s and there's very little lighting. It's basically dependent on the lighting that's on the boulevard from the Nova Scotia Power utility poles. Unfortunately, we've had some very big trees that have grown over time, when they get overgrown they kind of cloud out the lighting effect. Go up one set of buildings and look at what it looks like in front of the Rowe. The Rowe has a lot of surface lighting on it that kind of illuminates the walkway much better and then you get in front of the SUB which has just been renovated. It's got the glass façade, the lights are on the inside. It's even a little more brilliant.

Q. Do you think that indoor lighting then has quite a lot of influence on lighting the street?

It can. But the electrical bill for this university is in the scope of millions of dollars here. Everything is on a control system and it's timed. So when a building closes, the lights start either getting turned down or turned off automatically and there are substantial savings. They also turn down the heat, and they also turn down any of the ventilation systems that are going. If a building is unoccupied, they don't have to have the lights on and the heat turned up for the mice, right? ***Laughs*** But you can see that there is a spillover impact in relation to that but most of our facilities close at 10pm, the library's at midnight. So all that is reliant on street lighting. The university has a design standard for street lighting. Anything that's not a wooden pole would belong to the city of Halifax, but a lot of those ornamental, those steel lights with the fancy gas light fixture on top, they are all the property of the university.

Q. Do you think that those would use more energy than the ones that are owned by Halifax?

Well, no. They've gone through… I know that the Office of Sustainability has gone through and they've done a whole lot of work in replacing those lights out from the incandescent type of light. A vast majority of those have now been converted to LED which in my understanding is pennies on the dollar.

Interviewer: We are actually working with the Office of Sustainability at the moment with this project.

Oh yeah? You should talk to Rochelle Owen, Rochelle was the manager responsible for all this lighting conversion around campus: interior and exterior. There may be one of her grad students that you can talk to about some of that but Rochelle would know to the nickel about what it costs to light the place. Everything is metred so they know what is costly, what isn't. There's way much more science behind it than I would be able to share with you but Rochelle would know for sure.

Q. Are there any other current concerns regarding lighting that need to be addressed?

It depends who you talk to. If you talk to safety advocates, they would like to see every area lit up to the maximum. That any dark space is a dangerous space.

Interviewer: So there is kind of a conflict between safety and then the economic side of lighting?

Well there's safety and the environment, safety and economics. There's always that trade-off. You can have safety or you can have convenience. You can have some degree of both. A lot of times it's sussing out what you are going to be using a space or a device for. How much safety are you going to invest into keeping me from getting radiated by this LCD watch? ***Laughs*** But, when the risk is minimal. The other piece too is that they could say "it's dark in this corner" and we would say "well we don't want to direct people to that pathway at that time of night". An example: if you were to be coming up from the Killam library and you wanted to get to the bus stop on Coburg Road, one terrible walkway that's terribly lit is if you were to walk up past the MacDonald building and on your right there is kind of a blind walkway that goes down behind the Chase building. People often say "you should light that up, you should absolutely light that up brighter and brighter and brighter". We would rather people didn't use it at all at night. We would rather, because we've lit the plaza on the Killam, and we have camera surveillance across the Killam, and we have the Dunlop well lit, and they just had a project where they're redeveloping the steps that lead back up to the bus stop on the city street. So we would say, yes we are not going to disregard the fact that that is not as well lit as it should be, but we probably would prefer that we didn't make is so quasi-attractive that people would use it because we've invested in the bigger area that can move more people safely across campus and because with that particular access point, we are going towards the back of Howe, the after-hours entrance, we're going to fountain, we're going towards the bus stop areas towards Coburg Road and we're taking people off campus. It's similar if you were going to Sheriff, you would want to move people across the alumni crescent walkway which is natural but maybe don't light up so much that you cut up in front of the U-Club and then turn left and come down that little alleyway where all the construction trucks are. But people like shortcuts. They would argue that everything should be lit up to the maximum. The reality is, it's expensive. And other than the government, students are the only other source of revenue. To think that the light bill doesn't have an impact on your tuition, it does. This is a business, or think of it as a large community, it's got a light bill, it's got a water bill, it's got a gas bill, you've got roofing repairs, you've got all of that right? And that's all on the bottom line, just to keep it up and running.

Interviewer: Is that what the Facilities Renewal fee covers, the one that students pay?

No, I think that's applied to either the SUB or the building of the fitness centre and those facilities, yep.

Interviewer: Great, we've got a lot of information from that. Do you have any questions for us?

You're writing a paper? Could you send me a copy when you're done? I'd like to read it.

Interviewer: Yeah, absolutely! Our report's looking at the wastage of overnight light usage within buildings specifically. Because, we found walking around campus that there's a lot of buildings that have random fourth floor offices which leave their lights on. So we just want to see the impact of that and if we can possibly try to change it and make savings for us as students. That was one of the biggest things we wanted to look at.

Yeah, that is a concern, right? People will leave the lights on, it seems that the newer buildings that allow for building automation, that is getting built in. The university strives, with the newer buildings, to achieve LEED certification. I think for anything that they do along that line, they get LEED points. So those would be from the low-flush toilets to the water recovery systems in the roof, to automated lighting and HFAC systems. In a dinosaur, like this (the LSC), there's not much you can do. This was built back in the days when the internet was used for research only. And the laptop hadn't arrived yet, and the best that you could have would be a Texas Instrument scientific calculator. So, of course most of these systems now, some are wired but everything new is IP- controlled. So the newer buildings, yes. Some of the older ones, especially the Hicks, I think you're talking the 1940s. And every time they drill a hole there, it gets expensive because anything built in that time period, has asbestos so you have the remediation piece. And no one likes to bring on that cost but nothing was wired. It was wired to plug in a kettle and a typewriter, so I know that there is a program to at least if not control the lighting, is to move to LED illumination which has got to save something, a certain cost. Of course, and the other thing too to factor in, incandescent creates heat. Heat has to be cooled in the summer and there's an expense associated with that and the heat that gets driven off of every PC that runs in these buildings somehow has to be dumped to the outside. Anything you can do to reduce the overall level of heat in a building in the summer, cuts back on the energy bill as well. But someone in Sustainability could talk to you for days about that. The other thing too, not a lot of people stay on campus after midnight. But there are people on campus after midnight, some grad students never go home. I'm sure there's some students that wouldn't if we let them stay in the libraries. So there's a bit of traffic around campus, not a lot but a bit after hours so you still have to have lighting in the main hallways to some degree to keep it quasi-navigable and safe. I have staff in here 24 hours a day that are going through the buildings looking for whatever right? So that's always a concern as well.

Appendix C

Interview coding scheme

A priori codes

- Lighting practices
    - Type of lights
    - Position of lights
    - Direction of lights
    - Timing of lights
- Lighting decisions
    - People who make decisions
    - Reasons behind decisions
    - Consultation
    - How decisions are made
- Social impacts
    - Safety
    - Health
    - Access
    - People impacted
- Economic impacts
    - Electricity
    - Energy
    - Maintenance/Upgrades
    - Budget
    - People impacted
- Environmental impacts
    - Animals
    - Electricity
    - Energy
    - Materials
    - LEED

Emergent codes

- Lighting practices
    - Age of buildings
    - Type of bulb
    - Spillover
    - Responsible lighting
    - Lighting corridors
    - Size of buildings
    - Landscaping
- Lighting decisions
    - External contracts
    - Planning
    - Projects
    - Change in decision-making
- Social impacts
    - People on campus at night
    - Social responsibility
    - Impact on neighbours
    - Transport
- Economic impacts
    - Student fees
    - Savings
- Environmental impacts
    - Heat
    - Pollution
    - Other environmental development

Appendix D

Building Audit Data (Day Collection)

Table D1 Raw data collected from indoor lighting audit by students in ENVS/SUST 3502 during the daytime throughout March 19 - 23, 2018 of academic buildings on Studley campus at Dalhousie University. (L) indicates the number of large fixtures containing 2 x 32 watt T8 Tube Lights and (S) indicates the number of small fixtures containing 1 x 14 watt CFL bulbs.

Building Name	Stairwell (1 floor)	Classroom	Hallway	Lecture Hall	Office	Common Area	# Floors	LEED (Y/N)
Central Services	2L		2L 6S		4L		5	N
Chase Building	1L	4L	10S		6S	4L 8S	4	N
Chemistry Building	3L	30L	18S 4L	60L	8L	110L	5	N
Dalhousie Arts	2L		15S 14L		4L	11L 70S	4	N
Dalplex	4L	28L	24L		8L	49L	4	N
GoldBerg CS	2L	12L	13S	30L 21S	2L	40S	5	N
Grad House (s)		6L	4S		2L		2	N
Henry Hicks	6S	50L 4S	6S 14L	20L 4S	8L	21S	4	N
Rowe Management	3S	80S	81S	52L 120S	16L	6L 72S	5	N
Killam Library	3L 1S	15L	22L	25L 18S	8L	160L 38S	5	N
Kings Library	4S		6S		2L	164L 36S	2	N
Kings Other	2S 2L	12L 5S	12S	20L 105S	2L	6L 72S	5	N
LSC	4L	15L	29S	12L	2L	26L	8	N
MacDonald	2L	35L	15L 3S	24L	6L	16L	4	N
McCain ASS	2L	9S	3L 30S	95S	1L	35S	4	N
McCain LC		4S	4L 58S	74S	8S	40S	1	Y
Mona Campbell	2L	15L	8S	10L	4L	50S	4	Y
Sir James Dunn	2L	24L	27L	30L	6L	18S	4	N
Stairs House		4L	5S		2L		2	N
Steele Oceans	2L	12L	20S	10L 18S	2L 2S	12L 30S	3	Y
SUB Main	6L		6L		2L	22S	4	N
Studley Gym	2L	3L	1L 1S		3S	84L	3	N
Sub Extension						89L 77S	1	N
University Club	13S		4S		1L	3L 9S	3	N
Weldon Law	4L	22L	16S	41L 24S	4L	40L	4	N

Appendix E

Building Audit Data (Night Collection)

Table E1 Raw data collected from exterior lighting audit by students in ENVS/SUST 3502 overnight on March 27, 2018 between 10:00 pm and 1:00 am. Includes the number of visible areas with lights on in the academic buildings on Studley campus at Dalhousie University.

Building Name	Stairwell (1 floor)	Classroom	Hallway	Lecture Hall	Office	Common Area	# Floors Lights On
Dalhousie Arts Centre	3	0	4	0	3	2	2
Central Services	0	0	0	0	1	0	1
Chase Building	3	0	1	0	2	1	3
Chemistry Building	0	3	2	0	4	0	2
Dalplex	0	0	1	0	0	0	1
GoldBerg Com. Sci.	4	2	8	0	4	6	5
Grad House (s)	0	2	3	0	1	0	2
Henry Hicks	5	0	5	0	7	1	4
Rowe Management	0	0	2	0	4	3	3
Killam Library	0	0	12	0	0	3	4
Kings Library	0	0	0	0	0	0	0
Kings Other buildings	0	1	1	1	1	1	2
Life Science Centre	24	2	18	0	7	3	8
MacDonald Building	0	1	3	0	0	0	1
McCain ASS	8	0	2	0	0	1	3
McCain LC	0	0	1	1	0	1	1
Mona Campbell	0	0	3	0	1	3	1
Sir James Dunn	19	2	1	0	19	1	4
Stairs House	0	0	1	0	0	0	1
Steele Ocean Sciences	8	1	0	0	2	1	4
SUB Main	0	0	5	0	4	3	4
Studley Gym	0	1	1	0	0	0	2
SUB Extension	0	0	0	0	0	2	1
University Club	1	0	0	0	3	1	3
Weldon Law Building	0	0	3	0	8	5	5

Appendix F

Photographs taken in various locations throughout campus

Figure F1 The Goldberg Computer Science building at night on March 27, 2018 at Dalhousie University's Studley campus.

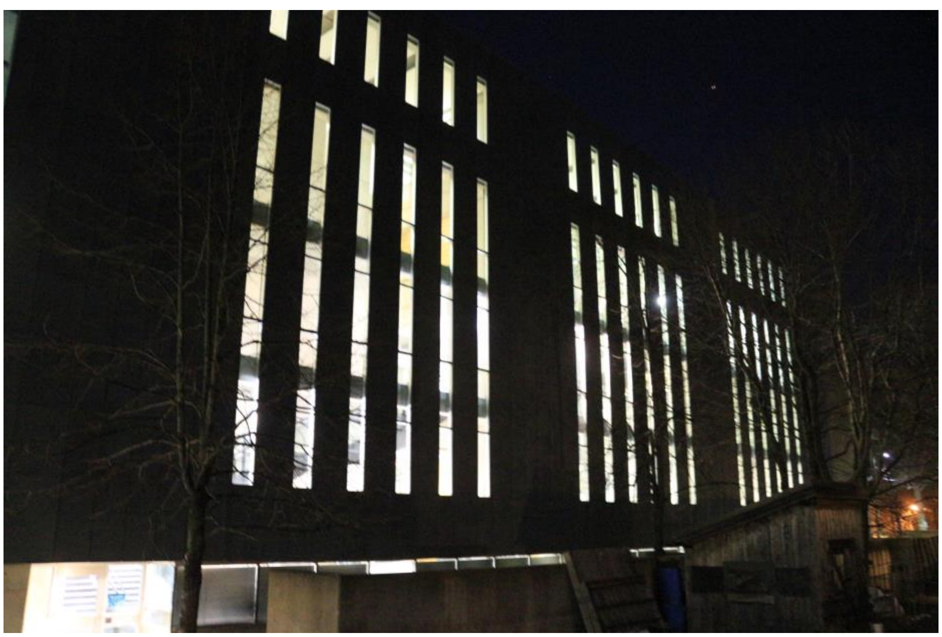

Figure F2 The Goldberg Computer Science building at night on March 27, 2018 at Dalhousie University's Studley campus.

Figure F3 The Student Union Building extension at night on March 27, 2018 at Dalhousie University's Studley campus.

Figure F4 Wickwire Field at night on March 27, 2018 at Dalhousie University's Studley campus.

Figure F5 The Studley Quad at night on March 27, 2018 at Dalhousie University's Studley campus.