Lights Out!

A Research Summary of Lighting Waste

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0.0 Abstract

We were tasked with assessing lighting waste on campus in the evenings, because of reports that it looked like a lot of lights were on. Counting the number of accessible rooms in academic buildings that were on and empty, off, or occupied. From there on, counting the number of lit light bulbs in the 'on' rooms was how data was assessed and calculated to cost Western $344 a month in lighting waste. This waste and cost looks at seven particular buildings, as well as for a period of time of six hours daily. Therefore the cost of lighting waste for Western is actually higher than this.

1.0 Introduction

1.1 Statement of Need

Western has received reports from evening walkers who are concerned about the lights that they see on. Western Washington University, and Bellingham, are communities that take pride in being environmentally friendly. Seeing so many lights on, and knowing that it is a waste of energy, contradicts the ideals of Bellingham and Western in promoting sustainability. It is outlined in Western's *Climate Action Plan* to eliminate wasteful practices and make responsible choices to the best of our ability; this would include cutting down on lighting waste.

1.2 Our Response

Our assignment in the Campus Sustainability Planning Studio was to collect data, first to find if there is a real problem of lighting waste, and second to propose possible actions to react to the problem.

2.0 Investigative Process

2.1 Assess the Situation

To start, we reviewed the rumors of dog walkers and other late night walkers with Seth Vidana, they had been noticing that Western's campus has too many lights on. We did this to get an idea of what the issue was and how to proceed. We concluded that after classes were over in the evening there might be many lights on that were not being used, and that we should investigate.

2.2 Research Collection

After considering the nature of a college campus, we supposed that the buildings that would be most prominent to our project were the academic buildings on campus. The residential buildings were not chosen for data collection because only the people living in a building have access to get inside, and, students spend most of their evening time in the dorms. Occupied spaces do not constitute lighting waste, and the dorms are occupied with approximately 4,000 students in the evenings (University Residences).

The academic buildings were defined in our study as any building containing classrooms or student lounges that are accessible to anyone on campus. We surveyed all of the academic buildings between 7 and 9PM, and found that some buildings were locked at this time. Those buildings were not included in the study. During these hours of 7-9PM we chronicled whether a room's lights were off, the lights were on but the room was empty, or whether it was occupied. Utilized rooms or rooms with the lights off did not count as lighting waste. The rooms that were empty but had the lights on were the sector that was most relevant to our study. We counted the number of light bulbs on,

categorized them by size, and counted how many switches were needed to turn off those lights. We counted the number of switches to see if the number of switches correlated with the amount of lights left on.

It took three rounds to survey all of the buildings that were unlocked between 7-9PM, after which we narrowed our sample size to buildings containing fifteen or more accessible rooms. This left us with a list of seven buildings from the original fourteen.

Surveying at the later time of 10PM-12AM was done to see if the data differed as the night got later and less people were on campus. We had noticed that a few classes were still in session, clubs had meetings, and there was frequent student activity between 7-9PM.

Of the seven buildings with fifteen accessible rooms, one building was locked at the later survey time of 10PM-12AM. We did not collect data for that building from the 10PM-12AM time slot. It was while recording data from this later time frame that we noticed that the custodial night staff was still working, and our data might be imprecise due to their presence and activity.

Consultation with Don Bakkensen, Academic Custodial Services Manager, gave us a schedule of custodial shifts, which said some custodians are done at 11PM. Two staff members of Custodial Services stated that the night staff is done by 11:30PM and the morning staff started at 5AM. A new survey time of 11PM-5AM was planned to ensure that we were recording data when the custodians were done with their shift, because if the lights were still on after the custodians left then they would presumably stay on throughout the entire night. The six hour time period given by this break in building activity is what we based our calculations on. We were told that custodians are not asked to turn off the lights. Some of the buildings have automated lights, which turn off after 40 minutes without activity in a room, and those lights are left on so that they will turn on automatically in the mornings when classrooms are used again. When asked about the rooms without automated lights, we were told that custodians aren't asked to turn those off either, but that asking night staff to do so in future would be easy and uncontested.

In order to collect data starting at 11PM, we needed the buildings to be unlocked for us because all of the buildings we were surveying lock by 11PM. Access to the buildings was granted by the Green Coats, who unlocked buildings individually as we needed them.

We collected data for our seven buildings three times, which took place from 11PM to approximately 2:30AM. Data was collected three times because that is the minimum number of times necessary to achieve reliable data; we did not collect data any additional times because we were running out of time for our project and the data we had collected was very similar, making us think that more data would not change the outcome of our interpretations. We followed our established format of recording whether a room's lights were off, on, or occupied. Many less rooms were occupied at these late times, and more lights were off as well. This told us that the custodians were turning off lights that would have been on at 7PM. In addition, we twice met a professor whose office is in Parks Hall, who told us that he usually leaves at around 1AM and he goes through the entire building to turn off all of the lights. Because we had run into each other before he was going to turn off the remaining lights, we know that our data was unaltered by him.

However, his testimony asserts that he commonly finds some lights on after the custodians leave and the building is locked.

A problem that was noticed during our observations was that more rooms were locked by this time of night. We narrowed down our data collection to the buildings containing fifteen or more accessible rooms, but by 11PM the Fine Arts building had less than fifteen accessible rooms. We kept the building in our data collection anyways.

2.3 Research Interpretation

Our sampling took place between October 7th and November 14th, 2015. During our first few rounds of data collection we went out at 7PM and went through each of the accessible buildings. The following table condenses our data to show the number of rooms in a building that were empty with the lights on, the amount of occupied rooms, and those with the lights off.

Time Slot	Building	Accessible Rooms	On & Empty	Occupied	Off
7-9PM	AW	18	4	12	2
7-9PM	AH	19	3	6	10
7-9PM	CF	32	6	16	10
7-9PM	PH	18	5	6	7
7-9PM	FI	17	4	8	5
7-9PM	BH	25	6	9	10
7-9PM	MH	25	8	4	13

The following table shows the data collected for the 10PM-12AM time slot.

Time Slot	Building	Accessible Rooms	On & Empty	Occupied	Off
10PM-12AM	AW	17	5	8	4
10PM-12AM	AH	15	7	1	7
10PM-12AM	CF	34	7	14	13
10PM-12AM	PH	20	3	2	15
10PM-12AM	FI	10	2	5	3
10PM-12AM	BH	26	7	3	16
10PM-12AM	MH	Locked	Locked	Locked	Locked

The following table shows the data collected for the 11PM-3AM time slot. Unlike the other time periods, this data was collected multiple times, and the table shows the averages of the data collected on three separate evenings.

Time Slot	Building	Accessible Rooms	On & Empty	Occupied	Off
11PM-3AM	AW	~17	~7	~2	~7
11PM-3AM	AH	19	~6	0	~14

11PM-3AM	CF	~30	~10	~4	~17
11PM-3AM	PH	~21	~2	0	19
11PM-3AM	FI	11	~5	2	~4
11PM-3AM	BH	~24	~4	3	22
11PM-3AM	MH	24	~5	1	18

Once we had gathered our data from multiple surveys from 11:00PM onwards, we calculated how much energy it costs to keep the average number of lights on during the six hours a night that the buildings are not being used. We used the average of how many lights were on, taken from our surveillance, and contacted Scott Dorough, the Energy Manager of WWU, to find the light bulbs most commonly used on campus that matched our descriptions. We had categorized by size the light bulbs we found into three categories, but noticed that light bulbs differed slightly by room or building, or were too difficult to see clearly due to their lighting fixture. By using the most commonly used light bulbs, we were able to simplify our data while maintaining relevant accuracy.

Western pays $0.075/kWh, and two types of bulbs we saw uses 30 watts each, and the remaining type uses between 22 to over 30 watts. To be sure, we used 22 watts in our calculations, because that would be the minimum but guaranteed amount used.

3.0 Future Savings

By having the custodians turn off all of the lights when they leave a building, WWU would save $12.42 a night, or $344.35 a month.

These savings were calculated by taking the quantity of bulbs at 30 watts each (28 watts for the bulb, plus 2 watts for ballast losses) and multiplying it by $0.075/kWh, for 6 hours a night. The other type of bulbs commonly used on campus use between 22 watts and over 30 watts each, so we used 22 watts for our calculations as a guaranteed, though maybe low, estimate. We used the website *Rapid Tables* to do the calculations using their electricity bill calculator, and *michaelbluejay.com* to verify that the calculations were correct.

The buildings that cost more than $50 a month in lighting waste were Fine Arts ($50.23 a month), Communications Facility ($69.29 a month), and Arntzen Hall ($84.57 a month). The lowest costing building by comparison was Parks Hall, which costs $2.82 a month in lighting waste.

4.0 Consultations

4.1 Scott Dorough

Questions and discussion with Scott Dorough on October 6th, 2015, by Jenna Whitney and Mary Ryan. Because the interview was not recorded audibly, this has been transcribed from notes and paraphrased into sentence form.

Question 1: What are some of the current efforts to reduce energy waste related to lighting?

Answer: There are occupancy sensors in many lecture halls, which are tied into the HVAC system and lights. The problem is that too short of a delay turns lights on/off frequently, which shortens the life of the bulb. Our occupancy sensors range from about 5-20 minutes duration, and is done case-by-case. It's ideal for fluorescent lights to have a

3-hour minimum that they are on to increase their life and efficiency. We are making steps to increase the efficiency of lighting itself by switching to LED bulbs.

Question 2: What sort of data is important in moving forward, what's important to you?
Answer: We're moving toward better-automated control of the buildings, such as "smart buildings". Smart buildings sense what's needed based on the occupancy and natural light available, focusing on HVAC and lighting needs. Smart buildings requires extensive technology that is not currently available across campus, but WWU will be moving towards it more and more in coming years. As WWU develops its Sustainable Action Plan for campus, it is trying to go 'state of the art'. Currently there are lighting sensors for a daylight harvesting strategy somewhere on campus, but the location is unknown.

Question 3: What are the current automated systems in buildings now?
Answer: Occupancy sensors turn off the lights after a scheduled length of time without movement, and movement will turn the lights back on.

Question 4: What are innovative lighting solutions you've seen?
Answer: Solar Hybrid Fibrotic Light is a method using a collector on the roof to channel light through tubes, directing it into interior spaces through fibrotic transmission. The downside is that our climate has diffused lighting, so it is not as effective here. Another solution is Dark Sky Client Complaint Movement, which would involve replacing the giant bulbs that are our outdoor lighting because they are light diluters and spread light all around weakly. Focusing lenses that direct the light downward would be better, and we are moving towards this. Each new lamp costs about $1200 apiece. This movement helps with our circadian rhythm, so it has health benefits as well.

Question 5: what can we do to make sure we're not skewing data?
Answer: Go at different times and go through campus multiple times.

Question 6: What are the best times to go, or not to go, survey lights? (Not same time/or same day each week/same people would be there)
Answer: After dusk, so our timing of 7-9ish would be fine, but we should return at an unreasonable hour for lights to be on (such as 2am) to see if lights are still on.

Question 7: Did he (Scott) think this was a problem before we approached him?
Answer: It's an issue, and visibly evident, but not considered a priority. In the bigger picture about energy management, it will be taken care of once smart buildings are built. The HVAC systems are his current problem, because it is very problematic, with lots of overcompensation that wastes energy. Staff is probably not educated on daylight harvesting or encouraged to turn out the lights.

Question 8: The hallway lights are always left on, as far as we can tell. What does he know of that?
Answer: Some lights are left on for custodians, but he agrees not all lights need to be left on while cleaning. Night staff is probably not trained to turn off the lights, and hallway

lights are probably controlled through circuit breakers which means night staff wouldn't have access. This system is no longer up to code, but it was when those buildings were being built. Scott gave advice to talk to maintenance supervisor Lloyd Hungate for more information about how extraneous light fixtures are controlled.

Question 9: What can be done for older buildings on campus?
Answer: A complete investigation and renovation would be required to fix the problem in our buildings. However, it is interesting to note that Wilson Library, which is very old, uses the least energy because it has a thick exterior wall and not very many appliances. The Chemistry and Biology buildings are energy hogs, because they have so many appliances, tools, technology, ventilation, etc. that are using energy, and its building envelope is inferior. The residence halls use a lot of energy (but they are not studied in this project, which focuses on classrooms, lounges, and other spaces that anyone has access to). One of the problems for corridor lighting is that we must comply with codes for egress safety, so stairwells must always be lit. It would be helpful if we could dim the lights when spaces are not occupied, but that is very expensive to implement.

Questions and discussion with Scott Dorough between October 28th and November 4th, 2015, by emails between Scott Dorough and Jenna Whitney. The responses were injected into the original email, and are noted as 'reply'.

"Hi Scott, we met earlier this quarter to discuss a project the Campus Sustainability Planning Studio my partner and I are doing under Seth Vidana's guidance. In our calculations of how much money we could save by turning off the lights in classrooms, we need to know the wattage of the light bulbs. We'd like to simplify things by using the most commonly used bulbs on campus (we've noticed that classrooms differ from one another).

So our questions for you are:
1. What is the bulb that is a skinny tube about 4 feet long?
Reply: F32T8. Our campus standard for this type of fixture is to use the newer reduced wattage "T8" which is 28 watts (W) each. Thus, in a two lamp fixture, the wattage would be 2 X 28W = 56W. Then add another 4 watts for ballast losses and a two lamp fixture consumes approximately 60W.
2. What is the bulb that is about 2 feet long and shaped like a U? (it looks just like the 4 foot bar, but bent in half).
Reply: F32T8U. Same wattage as above for each U-lamp.
3. What is the bulb that looks like a traditional round orb?
Reply: If these are as you are describing, I hope we don't have too many of these left. What I think you're describing is an older "Circline" lamp. Depending on their size, they can range from 22 to over 30W.

Again, we need the wattage for calculations, so if you could tell us the bulbs most commonly used and their wattage per hour that would be perfect for helping us make accurate calculations.

Thank you,
Jenna Whitney"

"Sorry Scott, one more thing...what is our electricity rate, how much do we pay for c/kWh?
Reply: Our campus rate for electric energy, not including any other charges such as demand, credits, surcharges, taxes, etc, is $0.06/kWh. However, the melded cost of energy when these charges are included is $0.075/kWh. My suggestion is to use this latter value because it's a more straightforward recognition for the total cost to deliver a kWh to campus. Hope this helps. SD"

Our initial interview with Mr. Dorough helped guide us to collecting data on lighting, and foregoing the arduous process of trying to include hallway lighting in our data collection. Since we were told that Mr. Dorough has a plan for automating the academic buildings on campus, we decided that our project needed to focus on data collection only, which could hopefully prove useful to Mr. Dorough.

4.2 Don Bakkensen

We reached Don Bakkensen by phone, but were told to send questions by email instead so he could provide an answer he knew was accurate. However, our email was not answered and Seth Vidana stepped in to ask Mr. Bakkensen our questions. Through Seth, we found that the custodial schedules have two shifts. Our interest was in the shift ending in late evening, which was confirmed by scheduling charts given by Don Bakkensen to Seth Vidana that the evening shift ends at 11PM or 11:30PM, depending on the building. Based on this information, we modified our data collection time to start at 11PM in a building that was done being cleaned so that we would not be present at the same time as the custodial staff.

In trying to reach Mr. Bakkensen at his office, we met some of his coworkers who offered to answer our questions. They thought the custodial shifts were done at about 12AM, and said that custodians are not asked to turn off the lights, so if they do they are doing so by personal choice. Hearing this, we thought that if our data said that lights were being left on, then reaching out to the custodial staff would be a potential response in trying to decrease the lights being left on.

4.3 John McLaughlin

Important to note is our understanding of statistical significance and how it relates to our project. Before sitting down with John McLaughlin we had the impression that statistical significance is something that we needed for our project in order to make our data reliable. In order for our data to hold more weight we had the impression that ensuring a reasonable level of statistical significance would be a good route to go. However, after the interview we found ourselves with a deeper understanding of how this term is not applicable to every data collection and that for our collecting of data, one not based on a specific hypothesis, that considering statistical significance is not necessary. That being said meeting with John was helpful in that he gave us advice for how to organize study design on presenting information, as well as confirmed that three trials, though low, is acceptable to presenting data on a location. During the interview he talked

about standard deviation and what a reasonable level was, with more trials the lower the standard deviation. Therefore indicating more trials makes for data with a higher level of reliability.

Questions and discussion with John McLaughlin between October 26th and November 2nd, 2015, by emails between John McLaughlin and Mary Ryan.The following emails encompass our initial contact with John, inquiring about statistical significance and study design.

“Hi John,

We’re with Seth Vidana’s Campus Sustainability Planning Studio class and are collecting information on lights being left on. For our research we would greatly appreciate information on making our data statistically significant. In trials, how many times does data need to be collected to have statistical significance (or be on the track towards this)? The number 3 rings in our heads (3 trials) but we're not sure if this is all we need.

Your help is greatly appreciated,

Lights Out Team - Jenna & Mary”

“Dear Jenna and Mary,

Unfortunately, I cannot give a simple, correct answer to your question with the information given. (Neither can anyone else.) Statistical significance depends on several factors besides sample size. I could advise you about sample size or replication needed to yield significance with high probability, given information (or estimates, even guesses) of those other factors. It sounds like this really is a matter of study design. It might be most effective to discuss or develop a design that would be most effective -- otherwise, you risk wasting much time and effort.

Best,

John”

We then inquired

“Hi Mary,

To answer your question, I (or anyone else) would need to know what prediction(s) or hypothesis(es) you plan to test. Estimating sample size required for a given significance level (i.e., determining "statistical power") also requires an estimate of the magnitude of the effect or difference you are trying to measure. Sorry that there are no simple answers,

although an informed answer might not be difficult to obtain. I would be happy to meet with you to discuss this.

Best,

John"

Discussion with John McLaughlin on November 4th, 2015, by Jenna Whitney and Mary Ryan. Because the interview was not recorded audibly, this has been transcribed from brief notes and paraphrased into sentence form.

We went into the interview with John primarily concerned about statistical significance and how we might alter our study design in order to achieve the most significant data. However John enlightened us upon a few points.

We explained our project, and how we had gone to all accessible buildings on campus to collect light waste data. Asking about statistical significance was a main point we went in with, and John's response was inquiring what our hypothesis was. We explained that our project was more simple data collection, and that we did not have a hypothesis. This being said, John informed us that statistical significance is basically irrelevant when a testable question is not being asked. He also reiterated to us that what we are doing is sampling.

We inquired about the number of trials and how it affects results, and John informed us that the more trials reduces the standard error. By sampling more times we can shrink standard error. With only a few weeks left in the quarter we assessed our availability and concurred that three late night runs were what we were able to perform.

5.0 Conclusion

With the data that was collected, it is apparent that lighting waste is a problem on WWU's campus. Scott Dorough stated that WWU's buildings will be upgraded in the next twenty years to be 'smart buildings', which are buildings with technological advancements such as automated lights, motion sensors, adaptive lights, and other methods of reducing electrical waste. While 'smart buildings' will improve upon or solve the lighting waste analyzed in this study, twenty years is a long time to wait. Until the implementation of smart buildings, we suggest that coordination with the custodial staff be done to turn off the lights during the night hours when buildings are closed and vacant. By doing so, WWU would save about $344 a month. It is important to realize that while the energy budget for campus exceeds $1million, it is worth our efforts to eliminate waste in our attempts to be sustainable and environmentally responsible.

During our research we discovered that from an exterior view, academic buildings look well lit. However, once inside, it is obvious that the lights on and visible from outside are the hallway lights. Hallway lights for the most part are not able to be turned off by custodians because there are not switches accessible to them, and concerns about safety. Though the energy waste from hallway light was not assessed, we are confident that it would far surpass the waste from classrooms and lounges. In making improvements to campus through 'smart buildings' or other methods, attention should be

paid to hallways as a target for improvement. Dimming the lights, using motion sensors, or other practices would greatly improve the image we present as a sustainable campus.

6.0 Sources

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