UBC Social, Ecological Economic Development Studies (SEEDS) Student Reports

An Investigation into Light Bulb Sustainability

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ABSTRACT

The lighting for the Student Union Building (SUB) will induce a large cost and a large environmental impact. Providing a sustainable environment when there is little or no natural light available can pose quite a challenge. In the following report, the options available for the lighting of the SUB are discussed. For simplicity and applicability, the lighting options are kept to Incandescent, High Intensity Discharge (HID), Fluorescent, and Light Emitting Diode (LED).

With the ban on incandescent light bulbs starting in 2012, it is clear that the new SUB will not be using incandescent lighting; however, these bulbs provide a good base point for comparisons. Aside from the approaching legal issues, due to the low efficiency and the short life span, incandescent light bulbs are a poor choice for the a building, regardless of the cheap installation price.

HID lamps provide a higher efficacy and a longer life than incandescent lighing. In situations where durability and a large level of light over a large area is required, HID lamps are the superior choice. The HID lamps could be argued as the superior choice for outside lighting; for example, street lights and parking lot lighting. The durability and high output of HID lamps makes them superior to fluorescent lighting and LED bulbs in an outdoor environment.

Fluorescent lighting is by far the cheapest, most effective large-scale lighting option. Fluorescent tubes provide a large amount of light per area, which means few light fixtures will be needed; as well, fluorescent tubes have a long lifespan relative to their cost. The use of mercury in the fluorescent bulbs is an environmental concern; however, the mercury inside a fluorescent tube can be recycled rather easily at a low cost. Since the mercury can be re-used, the costs are so low, and the output is so high, fluorescent tubes are the best option for large areas where large amounts of evenly spread light is desirable.

LED light bulbs are very compact and are extremely efficient. The light emitted by LED bulbs requires up to 50% less energy than incandescent bulbs, and up to 35% less energy than fluorescent bulbs; however, the light is extremely directional, which could make the use for a large room extremely costly, or unachievable. LED bulbs are recommended for small rooms, and any small area where directional light is acceptable.

The new SUB should include various types of lighting in order to take advantage of the many diverse lighting options available. Outside of the SUB building (i.e. parking lots, outdoor building lighting, etc.), HID lamps are recommended. This will ensure a long life, minimal challenging light bulb replacements, and a durable source of high-level light over a large area. Fluorescent tubes are recommended for large indoor areas, as the inexpensive costs and minimal fixtures required cut both costs and the use of materials. In instances where directional light is acceptable indoors, LED bulbs are the most operationally cost effective and the best overall choice.

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GLOSSARY

Ballast – The ballast is a device that maintains the current through a fluorescent or mercury lamp at the desired constant value, sometimes also providing the necessary starting voltage and current.

Compact Fluorescent Light – compact fluorescent lamp (CFL), also known as a compact fluorescent light is an energy saving light. Many CFLs are designed to replace an incandescent lamp and can fit into most existing light fixtures formerly used for incandescent lighting.

Efficacy – the capacity for producing a desired result or effect; effectiveness: *a remedy of great efficacy.*

Fluorescent Lamp – A fluorescent lamp or fluorescent tube is a gas-discharge lamp that uses electricity toexcite mercury vapor. The excited mercury atoms produce short-wave ultraviolet light that then causes a phosphor to fluoresce, producing visible light

High Intensity Discharge Lamp (HID) – HID stands for high-intensity discharge, a technical term for the electric arc that produces the light. The high intensity of the arc comes from metallic salts that are vapourised within the arc chamber. These lamps are formally known as gas-discharge burners, and produce more light for a given level of power consumption than ordinary tungsten and tungsten-halogen bulbs

Incandescent Bulb – The incandescent light bulb, incandescent lamp or incandescent light globe is a source of electric light that works by incandescence (a general term for heat-driven light emissions which includes the simple case of black body radiation). An electric current passes through a thin filament, heating it until it produces light. The enclosing glass bulb prevents the oxygen in air from reaching the hot filament, which otherwise would be destroyed rapidly by oxidation

Light Emitting Diode Bulb (LED) – A Light Emitting Diode lamp is a solid state lamp (SSL) that uses light-emitting diodes (LEDs) as the source of light. Since the light output of individual light-emitting diodes is small compared to incandescent and compact fluorescent lamps, multiple diodes are used together.

Light Fixture – something securely, and usually permanently, attached or appended, as to a house or apartment building.

Ultraviolet (UV) – light is electromagnetic radiation with a wavelength shorter than that of visable light, but longer than x-rays, in the range 10 nm to 400 nm, and energies from 3 eVto 124 eV. It is so named because the spectrum consists of electromagnetic waves with frequencies higher than those that humans identify as the color violet.

LIST OF ABBREVIATIONS

A-19 – standard household base bulb (equal to a 60 W incandescent bulb)

CFL – Compact Fluorescent

HID – High Intensity Discharge

HPS – High Pressure Sodium

kW – *Unit of measurement: Kilowatt*

kWh – *Unit of measurement*: Kilowatt Hour

LED – Light Emitting Diode

lm – *Unit of measurement*: Lumens

lm/W – *Unit of measurement:* Lumens per Watt

LR6 – LED downlight (ceiling light) by Cree™

LRP-38 – LED narrow bean spotlight by Cree™

m – *Unit of measurement:* Meter

mm – *Unit of measurement:* Millimeter

SUB – Student Union Building

T8 – Type of Fluorescent tube

UV – Ultra Violet

W – *Unit of measurement*: Watts

1 INTRODUCTION

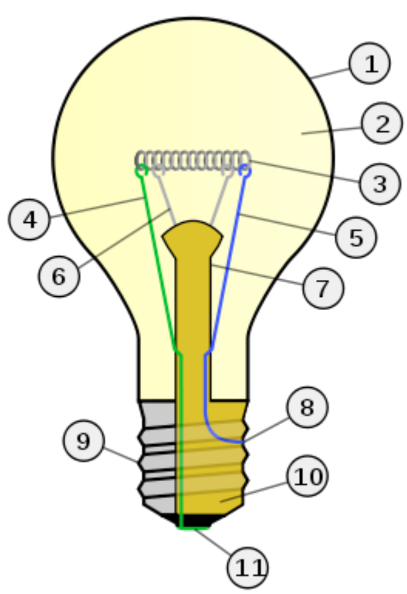
The University of British Columbia will be constructing one of many possible sustainable buildings in the near future. This first sustainable building will serve as the new Student Union Building. This report discusses the light requirements for the new building when light cannot be provided naturally. Many factors such as the environmental, economic, and social advantages and disadvantages of several lighting options are discussed. In a building that will "strive to promote sustainability," (UBC, 2009) it is important to choose the lighting option that best encapsulates decreased environmental and social impacts, while conserving the economics of the project. The main idea of this report is to aid in designing a sustainable building that has an extremely conservative ecological footprint.

The lighting options discussed for consideration for the new SUB are: Incandescent, HID, Fluorescent, and LED. Since the use of inefficient light bulbs will be banned in Canada in 2012, they will be discussed merely as a reference point for many comparisons.

2 INCANDESCENT LIGHTING

2.1 OVERVIEW

Incandescent light bulbs are the standard bulbs that most people are familiar with. These bulbs work by using electricity to heat a tungsten filament in the bulb until it glows. Most of the energy consumed by the bulb is given off as heat, causing its Lumens per Watt (lm/W) performance to be low. Because of the filament's high temperature, the tungsten tends to evaporate and collect on the sides of the bulb. Incandescent bulbs do not require external regulating equipment and they have a low manufacturing cost. As a result of the low cost of incandescent lamps and the easy applicability, this lighting option is widely used residentially and industrially. Incandescent bulbs produce a steady warm, light that is good for most household applications. A standard incandescent bulb can last for 700-1000 hours, and can be used with a dimmer. In cold weather the heat shed by incandescent lamps contributes to building heating; however, in hot climates, incandescent lamp heat losses increase the energy used by air conditioning systems. The materials that are used for this kind of light bulb usually consist of: glass, tungsten filament, and nickel-iron wire, see Figure 1 below.



1. Outline of Glass bulb
2. Low pressure inert gas (argon, neon, nitrogen)
3. Tungsten filament
4. Contact wire (goes out of stem)
5. Contact wire (goes into stem)
6. Support wires
7. Stem (glass mount)
8. Contact wire (goes out of stem)
9. Cap (sleeve)
10. Insulation (vitrite)
11. Electrical contact

Figure 1 - Incandescent Light Bulb (http://en.wikipedia.org/wiki/Incandescent_light_bulb)

2.2 ENVIRONMENTAL

Incandescent bulbs are not usually recycled because they do not contain any toxic material. The bulbs are being replaced by other kinds of light bulbs in many applications because approximately 90% of the power consumed by an incandescent light bulb is emitted as heat, rather than as visible light. For this reason, in 2012 the Canadian government will be banning these types of inefficient light bulbs from sale.

The environmental footprint left by incandescent light bulbs is well-known. This being the case, the inefficient traditional bulbs will not be discussed in detail.

2.3 ECONOMIC AND SOCIAL IMPLICATIONS

The incandescent light bulb is an extremely cheap lighting option. The cost of the bulb itself is extremely low; however the energy consumption and society's trend toward more sustainable means of technology tends to be the underlying issue. Detailed analyses of incandescent lighting will be omitted from this section due to the impracticality of usage post 2012, due to the previously mentioned ban.

The cost of installing an incandescent bulb is about	$5
hours of light per year	6570
0.1 Kilowatts incandescent bulb	0.1
Average cost **per kWh**: $0.08	$0.08
total cost of bulbs per year (based on lifespan of the bulb)	3.96
Total cost	$61.52

Figure 2 - Incandescent Light Costs per Unit

3 HIGH INTENSITY DISCHARGE LIGHTING

3.1 OVERVIEW

High Pressure Sodium, Metal Halide, Mercury Vapour and Self-Ballasted Mercury bulbs are all examples of High Intensity Discharge bulbs (HID). With the exception of self-ballasted bulbs, auxiliary equipment such as ballasts and starters must be provided for proper starting and operation of each type of bulb. Compared to incandescent bulbs, HID lamps produce a large quantity of light from a relatively small bulb. High-Pressure Sodium bulbs that produce a whiter light are now available, but efficiency is somewhat sacrificed. Metal Halide bulbs are less efficient but produce a whiter, more natural light than High Pressure Sodium lamps. HID bulbs are typically used, not only when energy efficiency and/or long life are desired, but also when high levels of light are required over large areas. Such areas include outdoor activity areas, roadways, pathways, and parking lots. Lately, metal halide is successfully being used in residential environments. High-intensity discharge (HID) lamps provide the highest efficacy and longest service life of any lighting type. They can save 75%–90% of lighting energy when they replace incandescent lamps (Ministry of sports and recreation of western Australia, 1998) . Negatively, the HID bulbs do contain mercury, so they have to be recycled. It is economically more beneficial to recycle the HID bulbs instead of disposing of them: it takes $^{\$}$0.27 to recycle one HID bulb, compared to $^{\$}$0.38 to dispose of one HID bulb. (US Army Corps, 2003).

3.2 ENVIRONMENTAL

HID bulbs are another option for lighting in the new building. Based on light bulbs Inc, the average HPS (an HID light bulb) has efficiency is about 65-130 lm/W depending on the watts (light bulbs direct,2009) Also, they are manufactured from much more expensive material and using a more advanced technology; therefore, it is fair to assume that the energy consumption to manufacture them is twice as much as an ordinary bulb which makes them roughly about 0.58 kWh. In addition, we have to account for energy consumed for the recycling which is equal to energy of manufacturing. Therefore, HID light bulbs have 1.16 kWh energy consumption for manufacturing and recycling. They can save

75%–90% of lighting energy when they replace incandescent lamps. They have a life span of 24000 hours typically, which is 24 times more than an incandescent light bulb. Thus, the energy that we preserve from using them is much more than the energy consumed for manufacturing and recycling. Based on this information, they are the most environmentally friendly light bulbs there is.

3.3 ECONOMICS

HID lamps are an example of a lighting option with a moderate initial cost and a moderate operating cost over the life of the bulb. See **Error! Reference source not found.** for a cost breakdown. As the economics are not a major selling point of HID lighting, the section is rather brief and to the point. We will see later on that with the disadvantage of the upfront costs, there are unique advantages and applications for HID lamps.

The cost of installing a HID bulb is about	$20
hours of light per year	6570
0.1 Kilowatts HID bulb	0.1
Average cost **per kWh**: $0.08	$0.08
total cost of bulbs per year (based on lifespan of the bulb)	$14.99
Recycling cost	$3.71
Total cost	$91.25

Figure 3 - HID Costs per Unit

These calculations are per unit watt consumption. Furthermore, if we want to produce the amount of lumens that one HID lamp is producing; we need about nine incandescent light bulbs. Thus, HID will in turn use fewer bulbs than the comparable incandescent light bulbs.

3.4 SOCIAL IMPLICATIONS

Some of the HID light bulbs have to be recycled because they contain mercury. With that in mind, the UBC staff for maintaining the New SUB building facility should know how to recycle them properly. Furthermore, it would beneficial to use a Canadian based company for purchasing the HID bulbs to reduce the likelihood of poor environmental practices occurring in the life cycle of this product, while supporting Canadian jobs. A Canadian made product also allows us to reduce the carbon emissions incurred during transport.

4 FLUORESCENT LIGHTING

4.1 OVERVIEW

With the introduction of compact fluorescent lights (CFLs) the residential industry has been trending toward the replacement of incandescent lighting with CFL technology. Since the introduction of this technology in the residential sector, changes have followed in industrial applications. This section will investigate the potential use of CFLs and relatively new, energy efficient, T8 fluorescent tubes in the new Student Union Building.

Fluorescent lamp tubes are most often straight and range from 100 mm to 2.43 m. The tubes are constructed with a low pressure mercery vapor and xenon (or argon, neon, krypton) consealed in a fused quartz envelope. Fluorescent lighting is quite efficient (about 65%) and very sensitive to temperature (Wikipedia).

4.2 ENVIRONMENTAL

Producing a more advanced lighting system requires an increase in the use of raw materials and labour. For that reason, it is important for us to investigate the life cycle of fluorescent lighting to better understand the environmental impact that it has. Figure 4**Error! Reference source not found.** outlines the different materials used in each technology, as well as the energy consumption during production that corresponds to each technology.

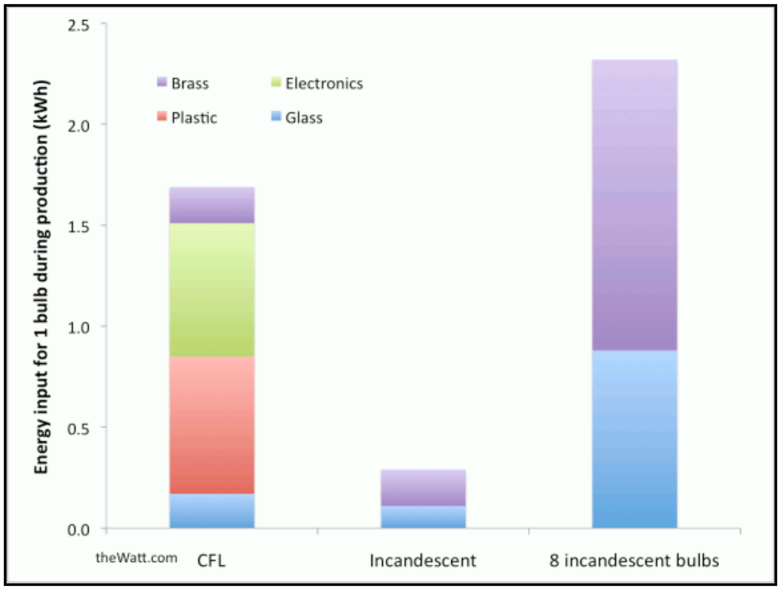


Figure 4 - Materials Used for Energy Consumption (The Watt)

The results of a study by Gydesen and Maimann (1991) show that the material and energy content in one CFL sums to approximately 1.7 kWh, while the material and energy consumption for one incandescent light sums to approximately 0.29 kWh. These statistics were based on energy values for materials that were measured in 1979 and in the past 30 years, manufacturing processes have improved in terms of efficiency, and these values are likely to be lower (Gydesen and Maimann, 1991). When we compare the manufacturing energy to the energy consumed during use, we find that for a CFL the manufacturing energy is less than 1% of the total energy that will be used to power the bulb in its lifetime (Gydesen and Maimann, 1991). As a comparison, it would require the lifetime of 8 incandescent bulbs to equate to the lifetime of one CFL (The Watt, 2009). This assumes that each CFL will last 8000 hours, and each incandescent light will last 1000 hours (the Watt, 2009). However, modern CFL lamps have a rated life of, on average, 10000 hours (BuyLighting). This data can be used to approximate the energy required to produce a T8 fluorescent tube as well.

Although a similar study has not been included for T8 fluorescent tubes, we can assume certain factors based on the different manufacturing processes. Firstly, fluorescent tubes use external ballast rather than an internal ballast to provide the voltage needed for operation (Wikipedia). This means that the electronic materials required will only be needed initially, and during occasional maintenance. They will not need to be replaced with each bulb failure. This will remove the majority of the production energy required for the electronics, as the upfront energy used can be averaged over the lifetime of the ballasts, and not over each individual bulb. The same can be said about the majority of the plastic used as well. Most of this plastic is present in the enclosure and not the bulb itself (Wikipedia). There will be an increase in glass used, as well as Mercury; this is based on purely size. Regardless, the life of T8 fluorescent tubes is much higher, roughly 35000 hours. This increase in lifespan will more than offset any additional manufacturing energy required, and when combined with the more efficient light distribution of the long tubes, gives fluorescent lighting, particularly the energy efficient T8 fluorescent bulbs with low mercury content, a definite advantage over the traditional incandescent bulbs in terms of energy costs vs. lifetime output.

Although no data was readily available, it is relatively safe to assume that the energy required to recycle fluorescent bulbs is approximately equal to the energy used in production. When compared to the energy saved during operation, this will still result in a large energy savings relative to the energy consumed in the lifetime of a traditional incandescent bulb.

One of the biggest concerns regarding fluorescent lighting is the use of mercury; however, when recycled properly this mercury poses little threat to the environment, certainly not as large a threat as the increased pollution that would arise from the increased electrical demands of incandescent lighting. There is a company (Nu-Life Industries) serving the lower mainland that will recycle these tubular T8 fluorescent bulbs for $0.12/foot (Nu-Life Industries).

For the reasons stated above, unless small-scale lighting is required for private offices and other small rooms, if fluorescent lighting is chosen, the new SUB building should make use of T8 fluorescent lighting rather than CFLs. This will reduce the overall cost per lumen of light when replacing lights for maintenance. To minimize transportation requirements, and therefore minimize carbon pollution, the new SUB should make use of a product manufactured in Canada. Canlyte is one such company, and has distributers of their fixtures located in Vancouver.

4.3 ECONOMICS

The largest cost when installing T8 fluorescent lighting will be the initial startup expenses. The cost of installing a 2x4 foot, 4-lamp Canlyte T8 fixture is approximately $70 to $100 (Nedco). The cost of a four-lamp ballast is approximate $30 (Nedco). However, the cost per bulb is less than $3 for an efficient 32W T8 lamp (Nedco ProductInfo). This bulb in manufactured by Sylvania, presumably in their Quebec plant (Sylvania). Each one of these bulbs will last a rated 36000 hours, and produce 3000 lm of output. The bulbs are simple enough to change that this system can be maintained, for the most part, by existing SUB staff. In the rare event that a ballast fails, an electrician can service the unit for roughly one hour of labour, plus the cost of the ballast (Conco Electrical). Fixtures/Ballasts have an average rated lifespan of 25 years (NRC), and it would be an adequate to estimate a 5% premature failure rate. Each four-foot bulb can be recycled for a cost of $0.48 ($0.12x4) at the end of its useful life cycle.

If we assume that the equipment above is used in the new SUB for 18 hours per day, and that repairs will be charged at a rate of $80/hour, the following approximate costs per fixture, over the 25-year lifespan, will result: Also see Figure 6.

Cost = [$70+30(1.05)+80(0.05)+4(3+0.48)(18*365*25/36000)]/25

= $6.76/12000 lm annually (or $6.76/fixture annually)

= $0.0005/lm annually

	Conventional T8 Fluorescent Tube
Wattage (W)	32 W
Life Span	36,000 hours
Ballast Cost	$30
Fixture Cost	$70
Bulb Cost	$3
Recycling Cost	$0.12 (4 tubes = $0.48)
Maintenance Fees	Assume 5% over 25 years @ $80/hour
Radiation	Contains Mercury Vapor
Lumens (lm)	3000
Cost/lm per year	**$0.0005**

Figure 6 - Fluorescent Cost Analysis Table

4.4 SOCIAL IMPLICATIONS

The most discerning aspect of fluorescent lighting is the use of heavy metals, primarily mercury. However, as long as proper care is taken in the transport and disposal of fluorescent lighting, this concern can be easily offset by the resulting energy savings. Furthermore, by utilizing Canadian made goods, we can reduce the likelihood of poor environmental practices occurring in the life cycle of this product, while also guaranteeing Canadian jobs. A Canadian made product also allows us to reduce the carbon emissions incurred during transport.

5 LIGHT EMITTING DIODE LIGHTING

5.1 OVERVIEW

A Light Emitting Diode (LED) is a solid state light source that is an efficient and long-lasting replacement for fluorescent or for incandescent light, it is also better for the environment. LEDs are compact and do not contain glass tubes, which makes them very desirable for a multitude of heavy-duty applications. LEDs come in a variety of colors, so they do not require the use of efficiency compromising filters to achieve a desired color. Another advantage is that, unlike fluorescent lighting, LEDs can be dimmed, and this can further increase the efficiency and life expectancy of the light. Even with the small nature of LED lighting provides more light per watt than incandescent or HID bulbs. If it wasn't for the high initial cost, and the fact that due to the directional light provided you would require many LED light bulbs, LED's are an excellent light source for any situation.

5.2 ENVIRONMENTAL

Generally LEDs only provide "directional light" rather than a 360-degree glow, meaning that they are better suited to instances where small stature and/or directional light is appropriate. For example, study rooms, downward facing streetlights, and automotive lighting, rather than settings where much spread light is required (Rosenthal and Barringer, 2009). The light in a room produced by a single incandescent light bulb would be hard to replicate with a single LED light bulb. This makes LED lights for home and office use costly. However, in Japan this year the consumer price for LED lights "dropped by half". (Fukuoka, 2009) This is an indication that affordable LED lights may be available in as few as five years. The high cost comes from early production LEDs that required growing on sapphire which has a similar cooling rate as Galium nitride, and prevents cracking during cooling. New production techniques use aluminum gallium nitride layers. These layers shrink at a slower speed during cooling and so LEDs can be grown on silicon without cracking. The outcome is cleaner, more efficient bulbs that last up to ten times longer than compact fluorescents and cost significantly less than the old LEDs. More important than cost are the environmental benefits. LEDs do not contain mercury and do not have any health risks. (Barras and Colin,2009) In fact, because humans are photobiotic, the absence of UV rays and full spectrum of light provided by LEDs make for happier, healthier and more productive consumers. (Marshall, 2009) Because new LEDs are using aluminum layers, they can be fully recycled.

5.3 ECONOMICS

The Cree LR6 LEDs is a $130 light that has a 12 W input with an output equivalent to a 65 W incandescent bulb, and an efficacy of 54 lm/W. The lights can be shipped from North Carolina, where they are manufactured. The estimated lifetime of the LR6 is 50000 hours. Comparing it to a $5.40 65 W incandescent bulb, the initial cost will be paid back in energy bill savings after 17 months. The total savings over the lifetime of the light add to $425. Using LR6s for 20 years would result in an approximate savings of $1250. These lights are capable of dimming to 20% output; connecting them to a system that monitors available light from outside, and/or monitors human activity, savings could be immensely increased. The lights have integrated thermal management that conducts heat away from the source and prevents damaging the light. This reduces costs and basically eliminates maintenance. The LR6 has health benefits too. It does not contain any hazardous materials, nor does it emit ultraviolet light or harmful infrared light. It is evident that the savings in a small scale, single bulb, setting LED bulbs are quite efficient and therefor cost effective.

For large scale situations, In order to compare the cost analysis of LED lighting technology to fluorescent T8 tubes, we will look at the comparable 2x4 foot LED fluorescent tube. The LED tubes require no ballast, they produce 1800 lm from a 20 W lamp, the bulbs cost $75 each and last 50000 hours.

If we assume that the equipment above is used in the new SUB for 18 hours per day, an assume a lifespan of the fixture is 25 years, the following is a cost analysis, see Figure 7 for detailed inputs:

Cost = [$70+4(75)(18*365*25/50000)]/25

= $42.22/7200 lm annually (or $6.76/fixture annually)

= $0.006/lm annually

	LED T8 Fluorescent Tube
Wattage (W)	20 W
Life Span	50,000 hours
Ballast Cost	None
Fixture Cost	$70
Tube Cost	$75
Recycling Fees	$0
Maintenance Fees	None
Radiation	No Mercury
Lumens (lm)	1800
Cost/lm per Year	**$0.006**

Figure 7 - LED Cost Analysis Table

5.4 SOCIAL IMPLICATIONS

Because LEDs are more efficient than the alternative, more bulbs are used at the same energy usage to produce the desired light needed for the new SUB. The initial cost of LEDs may be more than CFLs or incandescent but the social and environmental advantages outweigh the other light technologies. The initial cost of the bulbs will be offset by cheaper electricity bills. Ronn Moore, the Franchise Representative of Marco's Pizza says, "the quality enhancement is noticeable, and the 50% energy savings is valuable", about the renovation of a pizza shop with all new LED lighting (LEDs Magazine, 2009). The opportunity for economical savings and reduction of one's carbon footprint is massive. Market-leading innovator of lighting-class LEDs, Cree, has recently introduced a light with the "highest lumen output and efficacy reported in the industry". The A-19 LED lamp has an output of 969 lm with an efficacy of 102 lm/W. Using only 9.5 W the light output is equivalent to that produced by a 65 W incandescent bulb. (LEDs Magazine, 2009)

Even Walmart, the largest cost-cutting company in the world, is recognizing the benefits of LED lighting. Walmart has selected Cree to replace the existing ceramic metal halide bulbs with their LRP-38 LED light bulbs in 650 stores. The new bulbs will last 50000 hours and consume 82 percent less energy than the 70 W bulbs they are replacing. Neal Hunter, President of Cree LED lighting says that the bulbs will " enhance the customer's experience" (LEDs Magazine, 2009). Another company has switched to LED; Marvel Food and Deli, of Auburn, WA., became the first US commercial building to use 100% LED lighting. This move brought the project in well below Washington State's 27 kW energy code at under 9 kW (LEDs Magazine, 2009).

6 CONCLUSION AND RECOMMENDATIONS

The artificial lighting choice for the new Student Union Building has the opportunity to be energy efficient and cost effective; however, having the absolute best of both worlds is impossible. After much research, the options yielded various results for a number of reasons.

LED lighting is our recommendation for small areas where directional, small scale, lighting is acceptable. The costs of the few light bulbs are acceptable in areas where extremely bright, well-spread light, is not needed. The cost of the light bulbs is outweighed by the energy savings is these areas. As shown by cost analyses, the cost of LED lights for large areas (LED T8 replacement tubes) is up to 12 times greater than the cost of the conventional T8 fluorescent tubes. This cost will not be able to be made up by the possible 18 W per tube energy savings. Also, in order for the LED tubes to provide the same light as fluorescent tubes, 5/3 more LED fixtures will need to be installed. These added installations mean more manufacturing costs and environmental impacts, more materials, and more labour. See Figure 8 for a good cost comparison between the LED large-scale indoor lighting and the conventional T8 fluorescent tube lighting.

	LED T8 Fluorescent Tube	**Conventional T8 Fluorescent Tube**
Wattage (W)	20 W	32 W
Life Span	50,000 hours	36,000 hours
Ballast Cost	None	$30
Fixture Cost	$70	$70
Tube Cost	$75	$3
Recycling Fees	$0	$0.12
Maintenance Fees	None	Assume 5% over 25 years @ $80/hr
Radiation	No Mercury	Contains Mercury Vapor
Lumens (lm)	1800	3000
Cost/lm per Year	**$0.006**	**$0.0005**

Figure 8 - Cost Comparison, LED vs Fluorescent Tube

The exterior of the building should be using HID lamps. These lamps are extremely durable, and they provide great amounts of light for large areas such as parking lots, walkways, etc. Along with the startup cost savings of HID lamps instead of LED lighting, the applicable scale of LED light again comes into question. HID lamps have "tried and true" outdoor lighting capabilities, whereas outdoor LED lighting is better known for extremely small track lighting on walkways, and other small-scale applications.

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