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The Student Union Building Renewal – Light Bulb Sustainability

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Abstract

This report examines six different light sources to determine which is most effective at meeting the triple bottom line. The types of lighting considered are incandescent, fluorescent, halogen, low-pressure sodium, high intensity discharge, and LED. Each of the light sources were examined in eight categories, which are manufacturing, cost, installation, lifetime, light bulb characteristics, disposal, health impacts, and the impact on other processes. The light sources were then ranked for each of the categories to determine which is most suitable for the new student union building for the University of British Columbia. It was found that the LED lights were the best choice taking into consideration all the factors.

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List of Abbreviations

BC	British Columbia
HID	high intensity discharge
IR	infrared
LED	light emitting diodes
LPS	low-pressure sodium
SUB	student union building
UBC	University of British Columbia
UK	United Kingdom
US/USA	United States/United States of America
UV	ultra-violet

1.0 Introduction

The purpose of this report is to research a variety of different sources of light for the University of British Columbia's Student Union Building. Upon completing the research portion of the report, and decision matrix will be created to determine the best variation based on the triple bottom line assessment.

2.0 Light Bulb Variations

Six light bulb variations have been included to ensure that the scope was as complete as possible. The six variations, which are outlined in this report, are Incandescent Light Bulbs, Fluorescent Light Bulbs, Halogen Bulbs, Low-Pressure Sodium Lamps, High Intensity Discharge Lamps, and Light Emitting Diode Lamps.

The six variations were researched based on eight categories, which encompass the social, environmental and economic issues outlined in the triple bottom line assessment. The eight categories are manufacturing, cost, installation, lifetime, light bulb characteristics, disposal, health impacts, and impacts on other processes.

2.1 Incandescent Light Bulb

<u>Manufacturing:</u>

The incandescent light bulb is a type of bulb where electric current passes through a thin filament inside which heats the filament until it produces light. The bulb's envelope is made of hard glass or fused quartz and the thin filament inside is made of tungsten. The sealed glass bulb prevents oxidation of the tungsten which occurs spontaneously in contact with oxygen in air.

The materials used in the manufacture of incandescent light bulbs are quite safe, and there are no harmful or toxic materials inside.

The incandescent light bulbs available in Canada are mostly made in the U.S.

<u>Cost:</u>

The cost of Incandescent light bulbs is generally low, depending on the quality. For example, a 60 Watt incandescent light bulb costs $0.25. Since they are small and light-weight, the transportation cost is relatively low.

<u>Installation:</u>

The traditional incandescent light bulbs are easy to install. The fixtures are standard, and the bulbs can easily be screwed into the existing socket. No special technique or tools are required, resulting in low installation costs.

<u>Lifetime:</u>

Incandescent light bulbs last between a few hundred and 2000 hours. For example, a normal 60 Watt incandescent light bulb would last approximately 1000 hours.

<u>Light Bulb Characteristics:</u>

The color of light is more like amber rather than bright white. The quality of light is less diffused. The luminous efficiency differs from different voltages. For example, for a 110 volt, 60 Watt incandescent light bulb produces approximately 800 Lumens of light.

<u>Disposal:</u>

There is no way to recycle the incandescent light bulbs. However, some organizations like “Ecofriend” have suggested that to reuse the used bulbs as art and decoration is better than just disposing them.

<u>Health Impacts:</u>

Incandescent light bulbs are quite safe compared to the other types of bulbs. They do not contain any harmful materials inside. The incandescent bulbs can reach temperatures between 200 and 260 degrees Celsius. Skin burns may result if incandescent light bulbs are accidentally touched.

<u>Impact on Other Processes:</u>

Around ninety percent of the power consumed by an incandescent light bulb is emitted as heat. Therefore, the power used for air conditioning in the summer time may increase and the power used for heating system in the winter time will decrease.

2.2 Fluorescent Light Bulb

Manufacturing:

A fluorescent light bulb is a gas-discharge lamp that uses electricity to excite mercury vapor. The excited mercury atoms produce short-wave UV light and cause a phosphor to fluoresce which produces visible light.

It is made with ballast to regulate the flow of power through the bulb. A trace amount of mercury is used inside the tube. The glow starter consists of a small discharge tube, containing neon and fitted by a bi-metallic electrode.

The fluorescent light bulbs available in Canada are mostly made in US.

Cost:

The cost of Fluorescent light bulbs is relatively higher, depending on the quality of it. For example, a 13 Watt Fluorescent light bulb will typically cost $5. Again, since they are small and light, the transportation cost is low.

Installation:

The installation of fluorescent light bulbs is the same as traditional incandescent light bulbs. All one needs to do is screw them in. The installation cost remains low as there is no special technique is required.

Lifetime:

Fluorescent light bulbs last 10-20 times longer than the incandescent light bulbs. A normal 13 Watt fluorescent light bulb is expected to last approximately 8000 hours.

Light Bulb Characteristics:

The color of light is generally bright white. The quality of light is more diffused than an incandescent light bulb. The luminous efficiency differs from different voltages. For example, a 110 volt, 13 Watt Fluorescent light bulb in Canada produces approximately 800 Lumens of light. This type of bulb displays a much greater luminous density than incandescent bulbs, making it a more powerful light source.

Disposal:

Fluorescent light bulbs can be recycled. The recycling cost is quite high, and it costs several dollars to grind each light bulb and to extract the mercury for reuse in new bulbs. Some companies like Sylvania use recycled mercury for their fluorescent light bulbs. Moreover, disposal of fluorescent bulbs in household waste is illegal in many areas since they contain mercury, a highly toxic element.

Health Impacts:

Fluorescent light bulbs contain a trace amount of mercury. It may leak if not handled properly or if it breaks. This is an environmental risk to nature as well as humans as mercury can cause many illnesses and is very toxic. Fluorescent bulbs also emit a small amount of ultra-violet light that may cause skin problems for people.

Impact on Other Processes:

Different colour temperature for fluorescent light bulbs can be chosen from for different uses in different areas. It emits two thirds to three quarters less heat compared to an incandescent light bulb. Therefore, the cost, size, and energy consumption, both directly and secondarily on air conditioning, is lower.

2.3 Halogen Bulb

Manufacturing:

Halogen Lamps are a type of incandescent lamp, with "a tungsten filament [] sealed into a compact transparent envelope filled with an inert gas and a small amount of halogen such as iodine or bromine." The chemical reaction, called the halogen cycle, occurs inside the bulb between the halogen gas and the tungsten filament. As a result the bulb is brighter and lasts longer than a normal incandescent lamp.

The materials involved in the halogen lamp are not considered extremely toxic; tungsten is not a toxic metal and halogen (as either Iodine or Bromide) is considered toxic only if it is in excess, and has similar effects of iodine deficiency – which include the "abnormal growth of the thyroid gland and disorders in functioning and growth of the organism as a whole."

Halogen Lamps are mostly produced in China, and as a result would have to be shipped to distributers in Canada.

Cost:

The cost of one Halogen Bulb ranges from $4 to $12, and will last for around 10,000 hours.

Installation:

The installation of Halogen Bulbs is slightly more difficult and would require some instruction or training. One of the difficult aspects when installing a Halogen Bulb is that the oils in human skin damage the bulb. If a Halogen Bulb was installed with bare hands, the bulb could fail causing a significant hazard to anyone near the bulb. In addition some of the Halogen Bulbs are not the traditional "screw in bulbs" and may require a bit of instruction.

Lifetime:

Halogen Bulbs last approximately 10,000 hours on average, or twice that of a normal incandescent bulb.

Light Bulb Characteristics:

The chemical reaction between the halogen and tungsten filament requires a high temperature to occur, and as a result a Halogen Bulb will operate at a significantly higher temperature than a normal incandescent bulb. Due to this high temperature, the light is often brighter, and is a higher color temperature when compared to a normal incandescent bulb. Halogen Bulbs are smaller than most other bulbs and as a result require less space to install.

Disposal:

Halogen Bulbs can be recycled either with BC Hydro or with a private company near Vancouver.

Health Impacts:

The major health implications involved with an operating Halogen Bulb is the high temperature of the bulb. Extreme burns could result if a bulb was touched accidently. In addition, curtains or other flammable material near the bulb could catch fire, and thus safety precautions must be put in place to ensure nothing flammable is near the bulb. In addition, the bulb emits UV rays which in some extreme cases can cause sun burns.

Furthermore, oils in human skin can damage the bulb and cause it to fail by exploding, which poses as an extreme safety hazard.

Impact on Other Processes:

The high temperature of the Halogen bulb is much hotter than a normal incandescent bulb, and as a result a reduction in heating during the winter may be involved, and the implementation of air conditioning could be required if the temperature gets hot enough.

2.4 Low-Pressure Sodium (LPS) Lamp

Manufacturing

Most Low-Pressure Sodium (LPS) Lamps are manufactured in China, the UK, with some that created in the US. The materials in the bulb are sodium, lead and glass. Sodium and glass are not toxic, but lead can be toxic in some cases. Lead poisoning occurs as a result of overexposure to the metal through air, water, soil or food.

Cost:

The cost of a LPS Lamp is considered fairly expensive when compared to a normal incandescent bulb. Energy usage is usually lower than a normal incandescent bulb, but bulb prices are generally higher.

Installation:

The installation of LPS Lamps is very easy, similar to that of an incandescent bulb. The low operating temperatures of the bulb mean there is no risk of burning when removing the bulb, and plastic housing can be used without the risk of melting.

Lifetime:

The average lifetime of a LPS bulb is approximately 18,000 hours.

Light Bulb Characteristics:

LPS Lamps emit a very dim light that is an orange-yellow colour. LPS Lamps are considered monochromatic and thus do not provide much colour perception, to the extent that in extreme cases, colours cannot be identified. The main application of LPS Lamps is as outdoor street lighting. The lamps are also fairly large in size, which affects their ability to be adaptable.

Disposal:

LPS Lamps contain zero mercury, and can be easily disposed with no toxic waste entering the environment.

Health Impacts:

There are no health implications involved in any step of the lights life, except for the danger of being cut by a shard of broken glass.

Impact on Other Processes:

There are no considerable impacts on other processes, although the bulb does operate at a much lower temperature than a normal incandescent bulb, so heating and cooling may become an issue.

2.5 High Intensity Discharge (HID) Lamp

<u>Manufacturing:</u>

High intensity discharge (HID) lamps can be made in a variety of ways. The most common appear to be the metal halide and the mercury vapour lamps. The light is produced by generating an electric arc between two tungsten electrodes. The use of these materials increases the danger in the production stage as it involves toxins.

Many of the manufacturers are located in China or Taiwan.

<u>Cost:</u>

The initial costs of HID lamps are quite high. However, these costs are offset by the low operation costs. HID lamps currently offer the highest efficiency of commercially produced light bulbs. Therefore, they require less energy, which lowers the operation costs, which effectively addresses two of the three issues in the triple bottom line.

<u>Installation:</u>

Most HID lamps are designed to conform to industry standards, making them fairly simple to install. However, it is important to insure that the lights match the desired lamp.

<u>Lifetime:</u>

The lifetime of HID lamps is estimated at between 16 000 and 24 000 hours. This is one of the highest lifetimes of the light bulbs considered for this report. Like the low operating cost, the high lifetime is beneficial to both the economical and environmental aspects of the triple bottom line. The longer lifetime means that it does not need to be replaced, which reduces the amount of materials used.

<u>Light Bulb Characteristics:</u>

When first turned on, the light given off by HID lamps tends to be bluish due to the mercury vapour. The lamp requires several minutes to reach the full lumens output. The high levels of light make HID discharge more practical for outdoor applications, such as street lights. They are also becoming increasingly popular as headlights. However, these levels of light are less practical for indoor applications, which is the focus of this report.

Disposal:

HID lamps can be recycled, and are accepted by BC Hydro. The recycling process is able to recover up to 99% of the mercury. While that is an extremely high recovery rate, that still leaves the 1% of mercury released into the atmosphere that is not present with other lights that use no toxic material.

Health Impacts:

As mentioned previously, HID lamps often contain mercury. This increases the health risks in every area of its life cycle, from production to disposal. HID lamps also emit high levels of UV radiation during operation. Exposure to UV radiation increases the chances of skin cancer, causes premature aging, and can be damaging to eyes.

Impact on Other Processes:

HID lamps are not able to turn on immediately. This could create problems if the lights are turned off during daytime hours, or if they are needed immediately at the beginning of the day.

2.6 Light Emitting Diode (LED) Lamp

Manufacturing:

Light Emitting Diode (LED) lamps appear to be fairly safe in manufacturing. They do not contain mercury, which is the most common toxic element found in the types of lighting considered for this report. In addition, they are also manufactured without lead, heavy metals, or other toxins.

Many LED manufacturers are in China, but there are also manufacturers available in North America.

Cost:

The initial costs of LED lighting varies from around $12 to $100, depending on the lumens output. The efficiency of LED lights also appears to vary between light bulbs. Most appear to be close to 30 lumens/watt, but can be as high as 100 lumens/watt. The higher efficiency means that a LED light using 2 Watts produces the same amount of light as an incandescent light bulb requiring around 15 Watts, which reduces energy costs.

Installation:

Many LED light bulbs are created to fit standard fixtures. In addition to simplifying the installation and replacement process, this allows for the possibility of changing to a different type of lighting without requiring new fixtures.

Lifetime:

The lifetime of LED lighting is estimated at 20 000 to 60 000 hours. This offers the highest lifetime of all the lighting examined in this report. However, this is also the highest range for the lifetime. This makes it difficult to anticipate when the lights will require replacement. In addition, this also means that the lights may need to be replaced individually, as opposed to replacing multiple lights at once, which could save on maintenance costs.

Light Bulb Characteristics:

LED lights are able to turn on instantaneously, as opposed to other lights which can take longer to reach their full output. With LED lights there are no filaments or tubes as there are with other types of lighting. This increases the durability of the lights as the filaments and tubes tend to be the most fragile parts of the bulb.

Disposal:

As with most of the lights in this report, LED light bulbs are recyclable.

Health Impacts:

LED lights have little to no impact on ones health. Unlike some of the other light bulbs in this report, LED lights have no UV radiation. There is also no IR radiation, and, as mentioned previously, the lights contain no toxins.

Impact on Other Processes:

LED lighting produces very little to no heat. This means that the costs for heating during the winter may be increased. However, it also may decrease the need for air conditioning during the warmer months.

3.0 Decision Matrix

The Decision Matrix was created to ensure that all of the six variations could be compared and ranked in an easy and clear manner. Another important aspect of the Decision Matrix is the ability to use the weights corresponding to each category to ensure that the category that we perceive as being the most important, has the largest impact on the final ranking of the variations.

3.1 Categories

Below is a description of the eight categories involved in the decision matrix.

Manufacturing:

This part involves the manufacturing process of both the light bulb itself and the associated parts. The places that where each type of light bulb made in, what kind of materials it is made of, any dangerous/harmful materials is used, the quantity of the material used, how it is made, and the energy involved in the creation are all included in this category.

Cost:

The purchasing cost, transportation cost, and energy spent on transporting of each type of light bulb are mentioned in this part.

Installation:

This section examines the installation cost of each type of light bulbs including the time and energy involved in installation as well level of difficulty involved.

Lifetime:

This section compares the lifetime, in hours, of each type of lighting.

Light Bulb Characteristics:

The characteristics of each type of light bulb in terms of quality of light, color of the light, the luminous efficiency, or even area lit by the light in some case.

Disposal:

This section considers whether each type of light bulbs can be recycled or not. If yes, the cost of recycling is taken into consideration. If no, the feasibility of disposal is discussed. Also, we will mention the materials which may cause environmental impacts for each type of bulbs.

<u>Health Impacts:</u>

This is related to the health implications of each type of bulbs to people during each stage of the life cycle. The hazards to people from the bulbs at any stage in the process will be discussed if there is any.

<u>Impact on Other Processes:</u>

This is the impacts on the other processes by the uses each type of bulbs involved in the SUB. For example, like the air conditioning and heating system in the summer and winter time respectively. The heating and cooling effects involved in this case.

3.2 Ranking the Categories/Assigning Weights

The triple bottom line was the key factor in determining the ranking for each of the categories. They were ranked from one to eight, where one corresponds to a weighting of 100%, and the weighting decrements by 10% for each rating.

The ranking of each of the categories is outlined below.

<u>Manufacturing</u>

Manufacturing was given a ranking of four. As there are three categories tied given a rating of one, manufacturing was given a weighting of 90%.

<u>Cost</u>

The cost was determined to be the category that best exemplifies the economic aspect of the triple bottom line. Therefore, cost was given a ranking of one, which corresponds to 100%.

<u>Installation</u>

While installation was considered important enough to include in the report, it was determined to have the least effect on the triple bottom line. Therefore, installation was given a ranking of eight and a weighting of 60%.

<u>Lifetime</u>

The lifetime of the light bulb was determined to affect both the economic and the environmental aspects of the triple bottom line. It was given a ranking of five, and weighting of 80%.

Light Bulb Characteristics

The light bulb characteristics category was tied with lifetime with a ranking of five, and weighting of 80%. It was determined to complete the triple bottom line as it accounts for the social aspect.

Disposal

Disposal of the light bulb was determined to have the greatest impact on the environment, and was given a ranking of one, with a weighting of 100%.

Health Impacts

Health Impacts were determined to be the most important category for the social aspect of the triple bottom line. Therefore, this category was given a ranking of one, and a weighting of 100%.

Impact on Other Processes

The impact on other processes was determined to affect all aspects of the triple bottom line. However, it was difficult to determine how to accurately measure, and was given a ranking of seven, which translates into a weighting of 70%.

3.3 Ranking the Variations

The variations were ranked within each category from one to six, with one being the **least ideal** and six being the **most ideal** variation for that category.

Below the rankings of each variation within each category will be explained briefly.

Manufacturing

For the manufacturing category, each variation was ranked based on the materials involved in the manufacturing process of the bulb as well as the location of manufacturing plant. In addition, the energy involved in creating the finished bulb was taken into consideration.

The most ideal bulb was determined to be the Halogen bulb as it contained no toxins.

Costs

Variations were ranked for the costs category based on the price of a bulb with similar lighting capacity and the cost to transport the bulb from where it is manufactured to UBC.

Installation

The different variations were ranked for installation based on the cost to install and the time and energy spent installing the bulbs.

All of the variations were considered to have the same level of ease and energy spent installing them except for the Halogen bulb which had a higher degree of instruction to install.

Lifetime

The different bulbs were ranked according to the approximate number of hours the bulb will continue to produce an acceptable amount of light.

Light Bulb Characteristics

The variations were ranked within the light bulb characteristic category according to the quality and colour of the light as well as the area light by a standard bulb. The standard incandescent light bulb was ranked the highest in this category as it is what most people are accustomed to, and it produces a very good colour and quality of light.

Disposal

The ranking within the disposal category is based on the variations ease of disposal, whether harmful chemicals are released when the bulb is disposed, and whether it is economical to dispose the bulbs. While some of the variations contained harmful chemicals, which made disposal challenging, Halogen Bulbs and Low-Pressure Sodium Lamps contained no, or little chemicals that would severely impact the environment.

Health Impacts

Variations were ranked within the health impacts category based on their impacts on humans during the manufacturing, lifetime and disposal of the bulbs. Incandescent and LED bulbs were considered the most ideal, as, though they contained some harmful chemicals, they were extremely safe during their operating hours, which some other variations were not.

Impacts on Other Processes

The variations were ranked within the impacts on other processes category based on the impact of the bulb, operating under normal conditions, on other things operating within the Student Union Building such as heating and cooling.

Incandescent bulbs were considered to have the least impact on other processes, as they do not operate at a significantly high or low temperature, making them fairly neutral.

3.4 Final Matrix

Within the Decision Matrix, the eight Categories are ranked from one through eight, with one being considered the most important category in the comparison and eight being the least important. Corresponding to their rank, each category was assigned a weight, which was used to represent each categories importance.

Categories	Rank (1 being most important, 8 being least)	Weight	Incandescent Light Bulbs	Fluorescent Light Bulbs	Halogen Bulbs	Low-Pressure Sodium Lamps	High Intensity Discharge Lamps	LED Bulb
Manufacturing	4	90%	5	2	6	5	2	5
Costs	1	100%	6	5	4	3	1	2
Installation	8	60%	6	6	1	6	6	6
Lifetime	5	80%	1	2	3	5	5	6
Light Bulb Characteristics	5	80%	6	3	4	2	2	5
Disposal	1	100%	1	3	6	6	3	6
Health Impacts	1	100%	6	3	1	4	2	6
Impacts on Other Processes	7	70%	6	5	1	4	4	4
Total Unranked			37	29	26	35	25	40
Rank			***2***	***4***	***5***	***3***	***6***	***1***
Total Ranked			30.9	23.9	23.3	29.5	19.8	33.7
Rank			***2***	***4***	***5***	***3***	***6***	***1***

Figure 1 – Decision Matrix

4.0 Recommendation

After analyzing the six lighting alternatives using a matrix that compares the options in eight categories that are weighted based on their level of importance, the most ideal options became apparent. Using both the unranked and ranked totals for each alternative, LED was clearly the best option. The standard incandescent light bulb was considered to be the next best option, and low-pressure sodium lamps were considered the third best option for both the unranked and ranked totals.

The eight weighted categories reflect the triple bottom line assessment method in ensuring the alternative is the most ideal in terms of economics, environmental impacts, and societal impacts. The main reasons why the LED alternative was considered the most ideal was the fact that it was extremely safe to operate, manufacture, and dispose of, it had excellent light bulb characteristics, and the average life of a bulb was extremely long.

The outcome of the decision matrix was a bit of a surprise to our group as we did not know a lot about some of the alternatives, and the process involved in our report helped us learn a lot about the different alternatives that exist.

While our recommendation is for the Student Union Building to use LED lights in the SUB, our focus was on indoor, large space lighting. LED lights might not be the most ideal light sources for outside and more specific applications.

The main source of error in terms of how we arrived at our conclusion is how we weighted the categories. The categories weights were based purely on our own personal opinions, and may vary from others. While even though the LED was considered the most ideal in the unranked total, it is possible that if the weights were assigned differently, a different alternative could have been considered more ideal.

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