UBC Social Ecological Economic Development Studies (SEEDS) Student Report

# An Investigation in Sustainable Lighting Lighting at Koerner's Pub

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# AN INVESTIGATION INTO SUSTAINABLE LIGHTING AT KOERNER'S PUB

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# ABSTRACT

The following report investigates how Koerner's Pub, one of UBC's most famous pubs situated right in the heart of campus, can become more energy sustainable through the type of lighting used in the common area. The Pub already uses the very common incandescent light bulbs as their main lighting source in the common area, but this report will delve into whether the Pub should switch to the more sustainable, yet less common CFL or LED lighting. The analysis and comparison of the three technologies in question, namely incandescent, CFL, and LED lighting, will take the form of a triple bottom line assessment.

This triple bottom line assessment will measure the social, environmental, and economic impact of each of the three lighting methods. The primary research for the investigation was gathered through a personal tour of Koerner's Pub and its energy utilities provided by our stakeholder Mr. Tim Yu. On the other hand, all secondary research was obtained through various websites, peer-reviewed papers, and books. The cumulative social appraisal conducted shows that in terms of social sustainability, LED lighting is the best out of the three options. The environmental assessment prefers the use of LEDs due to their lack of any environmentally hazardous elements and their decreased amount of waste produced in the long term. The last area of study in this triple bottom line assessment, the economical assessment, concludes that LEDs are the most cost -efficient form of lighting that can be utilized by Koerner's Pub.

In conclusion, the study shows that LEDs are indeed the most sustainable form of lighting and would be the most advantageous lighting option for Koerner's Pub.

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# GLOSSARY

| | |
|---|---|
| *current* | the flow of electric charge, often carried through a wire |
| *electron holes* | the conceptual opposite of an electron, attracts electrons |
| *Hamilton Rating Scale for Depression* | a multiple item questionnaire used to provide an indication of depression |
| *lumens* | the SI unit of luminous flux, equal to the amount of light emitted per second |
| *photons* | a particle representing a quantum of light with zero mass |
| *tungsten* | the chemical element used to make electric light filament |
| *ultraviolet light* | a form of radiated energy not visible by the human eye |
| *wattage* | a measure of electrical power, calculated as energy per second |

# 1.0 INTRODUCTION

On the September of 1962, Rachel Carson's *Silent Spring* hit the shelves of bookstores around the United States. With that, the wheels of the modern environmental movement were set into motion. Since that September in 1962 and up till today, scientists, researchers, and engineers from all around the world have contributed to this movement and some have even dedicated their careers to making the world a more sustainable place. In more recent years, the University of British Columbia has proved to be a leader in the sustainability movement with its many ongoing and future projects.

This investigation report will be looking into Koerner's Pub: Energy, one of the ongoing sustainability projects taking place on UBC campus. The issue at hand was to find a way to make energy usage in the pub more efficient while abiding by the sustainability initiative at UBC. Thus, the purpose of this project was to come up with a rather simple and cost efficient solution that will solve this issue by either coming up with new technologies or more sustainable alternatives to already existing technologies. With some background information about the functionalities and workspace regulations at Koerner's Pub and a personal tour of the place, both provided by our stakeholder Mr. Tim Yu, and some initial research into energy usage we decided to tackle the lighting aspect of energy usage in Koerner's Pub.

The proposed solution that will be the focus of this investigation paper is to replace the currently employed incandescent light bulbs in the main customer area with the compact fluorescent lamps (CFL) or Light Emitting Diode (LED) bulbs. The three technologies in question here will be compared using the triple bottom line (TBL) assessment methodology. This assessment includes investigating the social, environmental, and economic aspects each technology, whilst focusing more on the environmental and economic aspects. Through weighing the different indicators of every TBL category a detailed analysis of every proposed solution will be produced and then compared in order to produce a viable solution that is in accordance with UBC's sustainability initiative.

## 2.0 METHODOLOGY

In order to accurately assess and draw conclusions regarding the lighting situation at Koerner's Pub, our group consulted various forms of resources. These resources aided in the analysis of the social, environmental, and economic impacts of the proposed lighting solutions. Our resources are separated into two distinctions: primary and secondary resources.

Primary Source

On October 2nd, 2014, our group visited Koerner's Pub. The stakeholder, Mr. Tim Yu led a group of UBC students on a tour of the facility. On the tour, useful information was accrued about the type of lighting used, rough number of lighting fixtures that will be changed, size of the facility, and hours of operation. This information was used primarily in the analysis of the economic assessment.

Secondary Sources

The bulk of information utilised for this investigation was acquired using the UBC library and other online sources such as Google Scholar and Elsevier Engineering Village. The investigation process exploited various scholarly journals, reports, encyclopedias, and manufacturer datasheets. Together, the secondary sources provided a strong base of knowledge to be used for analysis. To further describe the use of sources in each section, refer to the list below:

| | | |
|---|---|---|
| Social | - | scholarly journals, reports |
| Environmental | - | scholarly journals, encyclopedias, manufacturer datasheets |
| Economic | - | reports, encyclopedias, manufacturer datasheets |

Indicators

Our group used triple bottom line indicators to dissect the both the primary and secondary resources. The indicators describe the method of analysis for each triple bottom line section. A non-exhaustive list of indicators used can be found below:

| | |
|---|---|
| Social | ❖ Health benefits and hazards<br>❖ Decoration capability |
| Environmental | ❖ Energy consumption<br>❖ Material composition<br>❖ Product lifespan / Recyclability |
| Economic | ❖ Price of the product<br>❖ Maintenance costs<br>❖ Power consumption |

# 3.0 ENVIRONMENTAL ANALYSIS

The scope of this analysis will consist of the initial purchase of the light bulb up until the recycling or disposal of the bulb. The impact of any process outside of this scope, such as production, will not be considered. Each light bulb, as per the triple bottom line analysis, will be analysed using the following categories: energy consumption, material composition and product lifespan and recyclability. In regards to energy consumption, incandescent, CFL, and LED light bulbs with roughly the same light output will be examined.

## 3.1 Incandescent Light Bulb

Incandescent light bulbs are typically found in the 60-watt variety; this will be used as a reference for light output. These lights have the highest *wattage* per *lumen*. This is because incandescent bulb technology is very inefficient as most of the energy is lost due to heat across the filament.

Incandescent light bulbs contain a *tungsten* filament; however, the bulb is considered completely non-toxic to humans. While the effects of tungsten on the environment are not well defined, some studies show that "the presence of tungsten in soil results in the death of certain bacteria, red worms and plants" (Strigul, 2005). Despite this, incandescent bulbs contain the lowest presence of hazardous materials when compared to CFLs and LEDs.

The average incandescent light bulb lasts for about 1000 hours, which is far lower than CFLs and LEDs (Lim, 2013). Additionally, there is no longer a recycling program for incandescent bulbs, so dead bulbs are thrown away in the trash. The relatively short lifespan of the incandescent light bulb will result in greater waste accumulation in the landfill.

### 3.2 Compact Fluorescent Lamp

A 13-16 watt CFL can produce the same amount of light as a 60-watt incandescent bulb (BC Hydro, n.d.). That is, the CFL is approximately 75 per cent more efficient than the incandescent light. As a result of this improved technology, far less heat is emitted from the bulb. This can have negative effect on energy savings in cold environments, as more energy is used to compensate for lack of heating ("Efficient lighting equals higher heat bills," 2009). Conversely, these lights may have a positive effect in warm environments, as the lights will not emit much heat and as a result, put less strain on the cooling system.

CFL lights contain 2-4 milligrams of mercury per bulb (BC Hydro, n.d.). This can be damaging to the environment if the concentrated mercury comes in contact with plants and animals via air or water pollution. This can even affect humans indirectly; for example, consumption of fish occupying water polluted by mercury (NRDC, n.d.).

The average CFL lasts for 10000 hours, before needing replacement (Lim, 2013). This is a great improvement over incandescent lights, as the CFL will only require replacement once for every ten incandescent bulbs. Furthermore, the CFL also has mandatory recycling programs. This translates into far less waste, since fewer bulbs will be used and most of the materials will be recycled.

### 3.3 Light Emitting Diodes

A 9-12 watt LED light bulb can produce as much light as a 60-watt incandescent bulb. This bulb is significantly more efficient than the incandescent light and slightly more efficient than the CFL. As the most energy efficient light bulb, the LED results in the greatest decrease in energy consumption, which leads to a great decrease in carbon dioxide emissions.

LEDs contain some potentially toxic elements; however, they are generally present in concentrations below federally regulated levels (U.S. Department of Energy, n.d.). LED lights fall between incandescent lights and CFLs in terms of potential environmental impacts. Nonetheless, these bulbs have a mandatory recycling program to ensure these hazardous metals do not pollute the environment.

The average LED lasts for 50,000 hours before requiring replacement (Lim, 2013). This is far longer than the incandescent light and CFL. Similarly to the CFL, fewer bulbs will be used and most of the light bulb materials will be recycled.

## 3.4 Cumulative Analysis

In terms of energy consumption, LED light bulbs are the most efficient. Since electricity generation is not entirely clean, any reduction in energy used will reduce carbon dioxide emissions. Regarding the material composition, the LED was outperformed by the incandescent light bulb, as LEDs contain low concentrations of environmentally hazardous elements. The various recycling programs, such as the ones managed by BC Hydro, ensure that LEDs have minimal impact on the environment upon disposal. Lastly, the LED has incredibly long lifetime and as a result produces less waste than incandescent and CFL lights. The cumulative environmental analysis has led us to choose LED light bulbs as the most environmentally friendly and sustainable of our three lighting options.

## 4.0 SOCIAL ANALYSIS

The social analysis, as per our triple bottom line analysis, will be looking at health and safety risks and theme/style of the bulbs. Light bulbs may not seem to have an impact on social interactions, however they have significant impact on people's health through bulb radiation, internal materials and indirectly through its decoration capability; these factors can improve people's emotion and behaviour. The presentation of the light bulbs and how they fit into the theme of Koerner's Pub is also very important. Koerner's offers a unique atmosphere, and it is very important that new and returning customers feel comfortable.

### 4.1 Incandescent Light Bulb

As mentioned earlier, incandescent light bulbs carry tungsten filaments inside. These tungsten filaments can be health hazards to humans with direct exposure. Memory and sensory deficits, and increased mortality due to lung cancer have resulted from the use of high tensile strength tungsten (Witten, M. L., Sheppard, P. R., & Witten, B. L., 2012); however, incandescent light bulbs have benefits as well. Light generated from incandescent light bulbs was able to achieve a final score on the *Hamilton Rating Scale for Depression* (HRSD) of 50% which means it no longer meets the criteria for major depressive disorder (Yerevanian, Anderson, Grota & Bray, 1986). Another advantage of the incandescent light bulb is that they have a traditional design that brings the vintage theme to its surrounding environment. During our 3x3 presentation, Mr. Tim Yu stated that he prefers a traditional incandescent light bulb design due to their ability add to the vintage style of the Koerner's Pub.

### 4.2 Compact Fluorescent Lamp

Compact fluorescent lamps are known to be more efficient, producing around the same luminance as incandescent, and using less power. Compact fluorescent lamps contain very small amount of mercury, but when humans are exposed, it can cause potential harm. Mercury has harmful effects on the immune system and is also associated with forgetfulness, depression, drowsiness, headache, loss of energy and other various symptoms (Nabi, S., 2014). CFLs also produce ultraviolet rays, the same radiation produced from the sun, which can harm CFL users who might have skin problems. And these UV rays are the result of mercury present in the CFLs. Measurements of UV emissions from these bulbs found significant levels mercury, which appeared to come from cracks in the coatings of the bulbs (Mironava, T., Hadjiargyrou, M., Simon, M., Rafailovich, M.H., 2012). The social analysis is where CFL falls off when comparing to the incandescents and the LEDs. They contain very hazardous materials in them and using them could potentially harm people that require intensive skin care. There seems to be hardly any health benefits when in use. Also, CFLs don't have the design Mr. Tim Yu preferred, as it is always comes in a form of curly light bulb, so its design capability falls short when comparing to other light bulbs.

### 4.3 Light Emitting Diode

Exposure to LEDs has been found to offer some health benefits and other social gains. Precise ***wavelength*** light emitted from LEDs allows them to be a valuable resource for everyday medical applications. (Knisley, J., 2012) Due to their capability to produce ***wavelengths*** that can affect people's brain activity directly, LEDs can serve as an aid to one's sleep. (Knisley, J.,

2012) An experimental study has shown that adults, specifically senior adults, suffer from sleep disorders that may be caused by absorbing an abnormal amount of artificial light throughout the day. LED light, as the study discovered, can provide the optimum amount of light and wavelengths to help resolve such sleep disorders. (Knisley, J., 2012) This means a healthier and more positive effect on customers of the pub.

Although it may be known for many reasons, Koerner's Pub is best known for offering its customers a vintage feel and atmosphere. Incandescent bulbs help in providing this atmosphere, and so, prove valuable to the pub. Despite that, LEDs have the ability to mimic such incandescent light bulb design, offering the same quality of atmosphere for a potentially healthier form of light. For example, Feit Electric G19 Series (Lowes, n.d.), is a LED light bulb designed to look and feel like the tradition light bulb, which can very well be the perfect LED substitute to incandescent light bulbs and satisfy Koerner's Pub's decorative needs at the same time.

### 4.4 Cumulative Analysis

In terms of social impact, LEDs are the best option for Koerner's Pub. It does not contain any hazardous material unlike incandescent light bulbs, and CFLs, both of which contain tungsten and mercury respectively. In addition, LEDs can be a contributor to people's health by providing them a very precise wavelength of light and an optimal amount of light upon exposure. LED light bulbs also have the potential to offer the same atmosphere as incandescents which is important to maintain the pub's atmosphere. Thus, the social analysis concludes that LEDs are the best option out of the three based on the social indicators chosen and used for the analysis.

# 5.0 ECONOMIC ANALYSIS

The final component of the triple bottom line investigation is the economic analysis. For a business, the monetary running costs are vital to its success. As a result, this study will investigate the initial, ongoing, and cumulative costs associated with each potential solution, including the present incandescent light bulbs used at Koerner's Pub. There will be examinations upon the production of light and associated efficiencies, product costs, and expected product lifespan.

## 5.1 Incandescent Light Bulb

The most common light bulb in use today is the traditional incandescent light bulb (UNEP, 2010). Incandescents function by using an electric *current* to heat up a tungsten filament. Once the filament reaches a specific temperature, light is produced. To maintain light, the incandescent bulb must maintain the tungsten at a high temperature; as a result, there are large heat losses that make the bulb inefficient as compared to other technologies (Lunau, 2013). Due to the relatively high wattage of 60W required by an incandescent, energy costs over the long term can be overwhelming; however, since incandescents use simple technologies, they are extremely cheap per unit when compared to LEDs. It is not uncommon to see incandescent bulbs for less than $1. After about 1200 hours, an incandescent will burn out the tungsten filament, and no longer be capable to provide light ("Lighting lifespan by the numbers," 2012). Finally, it is worth noting that the bulbs produce 650-900 lumens.

## 5.2 Compact Fluorescent Lamp

Compact fluorescent lamp, also known as the CFL or energy saver bulb, is the first alternative under investigation. To produce light, CFLs use current to excite mercury electrons to a higher energy state. As these electrons return to their original energy state, they release *ultraviolet light*. The ultraviolet light is converted to visible light when it passes through the fluorescent coating on the bulb

("Compact fluorescent lamps (CFLs)," 2011). Generally CFLs are almost six times more efficient than incandescents. In order to produce the same luminance as an incandescent, CFLs require roughly 14 watts. In terms of cost, CFLs are slightly more expensive than incandescents, often ranging between $2-$4. Unlike incandescent light bulbs, CFL light bulbs have hundreds of electrical components, resulting in a greater possibilities for failure; however, a consumer can expect 10000 hours of working functionality before any breakdown ("Lighting lifespan by the numbers," 2012).

### 5.3 Light Emitting Diode

Light emitting diodes, or LEDs, are often considered the most efficient lighting solution in market today. Over the last 5 years, LEDs have seen a price decrease of 85% due to technological advances in the industry (BC Hydro, n.d.). Light emitting diodes use *electron holes* to attract electrons; upon contact, there is a release of lighting emitting *photons*. By changing the distances between the electrons and the corresponding holes, a different colour or intensity can be produced (Holonak, 2000). This allows for greater customization for manufacturers. To further entice consumers, LEDs have the lowest wattage, ranging from 6-10W - these wattages will produce the same number of lumens as a 60W incandescent. To further supplement the savings, LEDs can have life spans in excess of 50000 hours ("Lighting lifespan by the numbers," 2012). Unfortunately, integrating all these features into a light bulb come as a cost. In terms of market value, LEDs are the most expensive option initially with their cheapest variety found at roughly $15.

### 5.4 Cumulative Analysis

In order to compare incandescents, CFLs, and LEDs, there needs to be a cumulative analysis of the initial cost, as well as the ongoing maintenance costs. Moreover, the economical calculations are done in the ‘Specifications’ section of the table. These calculations are computed for 50000 hours, approximately 11 years at 12 hours of use a day.

To further describe the data formulated in the table, please inspect ‘Supplementary Table Information’ found on page 15.

NOTE: The values described in the table below are approximate and accurate as of November 2014.

**Table 1 :** Economic Analysis of Lighting

| | Incandescent | CFL | LED |
|---|---|---|---|
| **Features:** | | | |
| **Break protection** | none | none | outer casing |
| **Environmental concerns** | none | contains mercury | none |
| **Dimmable** | yes | yes - limited | yes - limited |
| **Temperature sensitive** | yes | yes | no |
| **Turning on speed** | instant | several seconds | instant |
| **Specifications:** | | | |
| **Wattage** | 60 | 12-16 | 6-10 |
| **Lumens/Watt*** | 13 | 57 | 100 |
| **Lifespan (hr)** | 1200 | 10000 | 50000 |
| **# of bulbs for 50k hrs*** | 42 | 5 | 1 |

| | | | |
|---|---|---|---|
| **Energy consumed (50k hrs)*** | 3000 kWh | 700 kWh | 400 kWh |
| **Energy cost*** | $6000 | $1400 | $800 |
| **Cost per bulb** | $0.60 | $2.00 | $20.00 |
| **Net cost for 50k hrs*** | $6500 | $1600 | $1200 |

Table 1 - Economical Analysis of Lighting, displayed above, shows the features and various costs associated with the potential lighting options at Koerner's Pub.

**Figure 1 :** Cost of Lighting up to 50k Hours

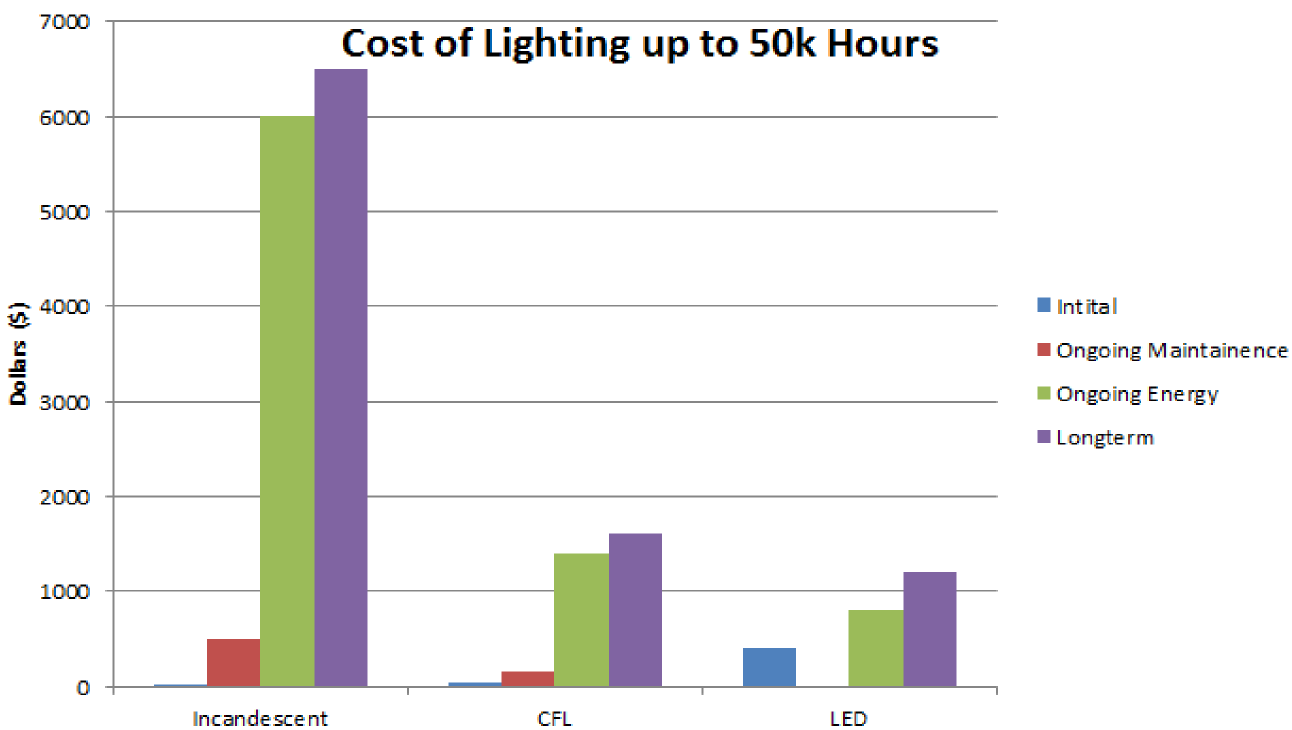


Figure 1 - Cost of Lighting up to 50k Hours, displayed above, shows costs associated at each time interval, eventually summing to 50k hours of use.

- *Initial* is the cost considers the price for 20 bulbs.
- *Ongoing Maintenance* is the product cost associated to maintain 20 light fixtures over 50k hours.
- *Ongoing Energy* is the energy cost associated to maintain 20 light fixtures over 50k hours.
- *Long Term* is the total cost over 50k hours.

Supplementary Table Information

| | | |
|---|---|---|
| Lumens/Watt | : | A common base of 800 lumens was used.<br>Common Lumens / Mean Wattage = Lumens/Watt |
| # of bulbs for 50k hrs | : | A common base of 50000 hours was used.<br>Common Hours / Lifespan = # of bulbs for 50k hrs |
| Energy consumed (50k hrs) | : | A common base of 50000 hours was used.<br>Common Hours * Mean Wattage = Energy consumed (50k hrs) |
| Energy cost | : | A common base of 20 bulbs was used.<br>A common base of $0.10 kWh was used.<br>Common Bulbs * Energy Consumed * Common kWh = Energy cost |
| Net cost for 50k hrs | : | A common base of 20 bulbs was used.<br>(# of bulbs for 50k hrs * Common Bulbs) + Energy cost = Net cost for 50k hrs |

## 6.0 CONCLUSION

Our stakeholder, Mr. Tim Yu informed us at the beginning stages of our investigation that rent for Koerner's Pub includes utilities so there was no financial incentive. So, we set out to find a low cost, yet effective solution to the task at hand. After careful analysis and comparison of CFLs, LED bulbs, and incandescent light bulbs, a conclusion has been reached.

In regards to the social aspect, LED light bulbs have been found to not contain any biologically hazardous materials and on exposure, might have some beneficial effects to one's sleep and mentality in the long run. As for the environmental aspect, LEDs produce less overall waste than CFLs and incandescents in the long run. Last but not least, economically, LEDs have a cheaper net cost for fifty thousand hours of use than its two counterparts. Hence the conclusion that this investigation report has led us to believe is that LED lighting is more socially, economically, and environmentally sustainable than CFL and incandescent lighting and can therefore be presented as the best viable lighting option that can be implemented at Koerner's Pub.

## LIST OF REFERENCES


Aucott, M., McLinden, M., & Winka, M. (2003). Release of mercury from broken fluorescent bulbs. Journal of the Air & Waste Management Association (1995), 53(2), 143.

BC Hydro. (n.d.). CFL Fact Sheet. Retrieved November 22, 2014, from https://www.bchydro.com/content/dam/hydro/medialib/internet/documents/Power_Smart_FACT_sheets/fact_sheet-cfl.pdf

BC Hydro. (n.d.). Lighting. Retrieved November 22, 2014, from https://www.bchydro.com/powersmart/

U.S. Department Of Energy (n.d.). Life-cycle assessment of LED lighting products. Retrieved November 24, 2014 from http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lca_factsheet_apr2013.pdf

Chow, J., Lee, T. (., Risi, S., & Wang, X. Z. (. (2009). Investigation into sustainable light bulbs Compact fluorescent light bulbs (CFLs) (2011). Sage Publications.

Lowes. Lighting. Feit Electric G19 Series, Retrieved November 19, 2014 from http://www.lowes.ca/led-light-bulbs/feit-electric-75-watt-40-w-a19-soft-white-3000k-indoor-led-light-bulbs-3-pack_g1536189.html?ProductSlot=9

Holonyak, N. (2000). Is the light emitting diode (LED) an ultimate lamp? American Journal of Physics, 68(9), 864.

Humble, M. B., Medicinska och farmaceutiska vetenskapsområdet, Uppsala universitet, Medicinska fakulteten, Institutionen för neurovetenskap, & Psykiatri, A. s. (2010). Vitamin D, light and mental health. Journal of Photochemistry & Photobiology, B: Biology, 101(2), 142-149.

Khan, N., & Abas, N. (2011). Comparative study of energy saving light sources. Renewable and Sustainable Energy Reviews, 15(1), 296-309.2

Knisley, J. (2012). The health benefits of LED lighting. EC & M

Lighting lifespan by the numbers. (2012). In Hotel Management (Vol. 227, p. 66). Duluth, Minnesota: Questex Media Group LLC Delaware.

Lim, S., Kang, D., Ogunseitan, O., & Schoenung, J. (2012). Potential Environmental Impacts from the Metals in Incandescent, Compact Fluorescent Lamp (CFL), and Light-Emitting Diode (LED) Bulbs. Environmental Science & Technology, 1040-1047.

Lunau, K. (2013, Dec 30). The incandescent light bulb. Maclean's, 126, 122

Mironava, T., Hadjiargyrou, M., Simon, M., & Rafailovich, M. H. (2012). The effects of UV emission from compact fluorescent light exposure on human dermal fibroblasts and keratinocytes in vitro. Photochemistry and Photobiology, 88(6), 1497-1506.

Moseley, H., & Ferguson, J. (2011). The risk to normal and photosensitive individuals from exposure to light from compact fluorescent lamps. Photodermatology, Photoimmunology & Photomedicine, 27, 131-137.

Nabi, S., SpringerLink (Online service), & SpringerLINK ebooks - Biomedical and Life Sciences. (2014). Toxic effects of mercury. Dordrecht: Springer India.

Ng, J.Efficiency of incandescent and fluorescent light bulbs: A comparative analysis on cost and power usage

NRDC. (n.d.). Mercury contamination. Retrieved November 25, 2014, from http://www.nrdc.org/health/effects/mercury/

Phillips, A. (2006). "Greening" the light bulb. Summit, 9(7), 17.

Principi, P., & Fioretti, R. (2014). A comparative life cycle assessment of luminaires for general lighting for the office - compact fluorescent (CFL) vs Light Emitting Diode (LED) - a case study.

Smolders, K. C. H. J., & de Kort, Y. A. W. (2014). Bright light and mental fatigue: Effects on alertness, vitality, performance and physiological arousal. Journal of Environmental Psychology, 39, 77.

Strigul, N., Koutsospyros, A., Arienti, P., Christodoulatos, C., Dermatas, D., & Braida, W. (2005).

Effects of tungsten on environmental systems. Chemosphere, 61(2), 248-258.

United Nations Environment Programme (UNEP). (2010, December 1). Press Releases November 2010

Winters, J. (2005). MORE LIGHT FROM LED. New York: American Society of Mechanical Engineers.

Witten, M. L., Sheppard, P. R., & Witten, B. L. (2012; 2011). Tungsten toxicity. Chemico-Biological Interactions, 196(3), 87.

Yerevanian, B. I., Anderson, J. L., Grota, L. J., & Bray, M. (1986). Effects of bright incandescent light on seasonal and nonseasonal major depressive disorder. Psychiatry Research, 18(4), 355-364.