A study of lighting technologies and controls

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Abstract

You can save energy and money by phasing out the old incandescent light bulbs and replacing them with LEDs. You will help the environment by minimizing the amount of waste generated and with a lower energy usage. A typical LED lamp will last about 25 times longer and use 1/6 of the energy compared to traditional incandescent light bulbs. Alternatives are Halogen lamps, most of which will be banned in the EU by 2016 and Fluorescent lamps, many of which contains the neurotoxin mercury. OLED is another fast-growing new technology with efficiency and lifespan comparable to that of fluorescent lamps. Although currently expensive, OLED prices are expected to rapidly decrease. Lighting controlling by dimming, motion sensors and photo sensors are ways to further increase the longevity of bulbs and reduce energy consumption.

Contents

I. Introduction

This paper is a study of lighting, from incandescent light bulbs to the ongoing development of OLED lamps. The main foci will be the different sub systems; technology, innovation, ethics, environment and sustainability. We will study each of these topics individually, and see how they are related to each other.

II. Research Questions

One of the largest environmental challenges in society these days is the overuse of fossil energy. We need to increase the use of renewable energy, whilst maintaining a minimum consumption level. This paper will present one way of doing so, which is both easy to apply and inexpensive; the light emitting diode. What can be done to reduce energy consumption in lighting? What has been done previously? How can we continue to reduce consumption in both present and future?

A. Technology

What kind of technology has been developed in the past, and how can new technology impact the future?

What is the connections between technology and; innovation, ethics, environment and sustainability, and how does these connections influence and impact each other?

B. Innovation

What kind of innovations has been done in the past, and how can innovation impact the future?

What is the connections between innovation and; technology, ethics, environment and sustainability, and how does these connections influence and impact each other?

C. Ethics

What are the ethical concerns when it comes to lighting?

Are there ways to change lighting related ethics, present and future?

What is the connection between ethics and; technology, innovation, environment and sustainability?

How does these connections influence and impact each other?

D. Environment and Sustainability

What kind of impact had this technology on environment and sustainability in the past?

What do we want the environment and sustainability to be present, and in the future?

What is the connections between environment and sustainability, and technology, innovation, ethics?

How does these connections influence and impact each other?

III. Technologies: Past, Present and Future

A. Incandescent Light Bulbs

An electric lamp which produces light with a tungsten filament wire heated to a high temperature by an electric current passing through it, until it glows. The bulb is filled with an inert gas (argon 97%, nitrogen 3%).

About 5 - 10 % of the energy is converted into visible light, the rest being converted to heat. Most of the energy is therefore wasted, and incandescent light bulbs are now illegal to sell or import in the EU. [2]

B. Halogen Lamps

A halogen lamp is an incandescent lamp that has a small amount of halogen added (iodine or bromine). Combined with the tungsten filament, this produces a halogen cycle chemical reaction which redeposits evaporated tungsten back to the filament, increasing its life. Because of this, a halogen lamp can be operated at a higher temperature than a standard lamp, producing light of a higher luminous efficacy[1] and color temperature. Most halogen lamps will be banned in the EU by 2016. Only a few of the most energy-efficient types will be allowed.

A typical halogen lamp is only 20 - 25 % more energy-efficient than traditional incandescent light bulbs and will be banned. The newer IRC (infrared reflective coating) technology are 40% more efficient than a typical halogen lamp and will be sold after 2016. [1]

C. Fluorescent Lamps

A fluorescent lamp is a low-pressure mercury-vapor gas-discharge lamp that uses fluorescent to produce visible light. An electric current in the gas produces short wave ultraviolet light that causes a phosphor coating on the inside of the bulb to fluoresce, producing visible light. Fluorescent lamps require a ballast to regulate the current. This makes them more costly than incandescent lamps. An energy-saving lamp is a compact fluorescent lamp (CFL). Fluorescent lamps are classified as hazardous waste because they contain mercury[2].[4]

D. LED Lamps

The LED lamp is a Light Emitting Diode (LED) product assembled into a lamp. The LED uses a semiconductor chip and electroluminescence to create light. LEDs have been used for over 50 years, but it is the recent development of white LEDs that made it an alternative lighting source. LED lamps uses less energy per lumen and has a longer lifespan than any other lighting source.[3]

E. OLED Lamps

The OLED (Organic Light Emitting Diode) is a LED where the electroluminescent layer is a film of organic material (carbon). R&D of white OLED devices for use in lamps is ongoing. The cost is at present high and produces less lumen per watt than a regular LED. OLED is a promising technology, but we need more research with new materials to find out how these lamps compare with established LED technology. OLED technology is still young, but lighting efficiency and lifespan is already on par with fluorescent lamps, and is expected to surpass them. Furthermore, OLEDs are completely mercury free, and produce neither UV nor IR radiation. OLEDs emit very little heat when used, which make them directly applicable to wooden surfaces without the use of bulky heat sinks. As they are produced on very thin and flexible carbon-film, new lighting designs can revolutionize the way we think of the common luminance today. In addition, OLEDs are infinitely dimmable.[3]

Table III.1
Comparison of emitted light

	Lamp life in hrs	Lumen[3] pr. Watt	Color [4] Temperature	CRI[5]
Incandescent	750-1000	8-24	2700-5000 K	100
Halogen	1700-2500	10-35	2800-3400K	100
CFL	10‘000-45‘000	46-105	5600K	74-90
LED	25‘000 100‘000	28-150	2540-10‘000K	70

F. Lighting Controls

Installing lighting controls is another way to save energy. The most common types include:

1) Dimmer Controls: Dimmers reduces wattage output, which save energy and increase the lamps service life. However, dimming reduces lumen output more than its wattage, making the lamp less efficient.

2) Motion Sensor Controls: Utility lights are only needed when its dark and people are present. A good way to control lighting is to combine the motion sensor with a photosensor.

3) Photosensor Controls: Photosensors will prevent outdoor lights from operating during daylight hours. Photosensors sense ambient light, making them useful for all types of outdoor lighting.

Many indoor LED nightlights have photosensors built in which makes them more efficient.[5]

IV. Discussion of Ethics, Environment and Sustainability

These three topics are intertwined and will be discussed together. We will focus on these important parts that has great impact on the environment and sustainability.

A. The lifetime of a lamp

The lifespan of a LED lamp is about 25 times than that of an incandescent light bulb, with fluorescent lamps trailing closely behind. This has huge impact on waste management and influences on the environment. Fluorescent lamps do however contain mercury, and must be treated as special waste.

B. Energy usage of lamps

LED lamps uses 1/6 of the energy (lumen/W) compared to the incandescent light bulb. The less energy used, the less energy needs to be produced. Which again leads to decreased production of fossil energy. Lighting controls decreases the usage of lighting. Which decreases energy usage, and increases the lamps lifetime.

These two important parts also effect the ethical questions.

C. Why is it important to waste fewer light bulbs?

Vast amounts of waste has negative impact on the environment. I.e. bigger landfills and CO_2 emission from transport.

D. Why is it important to reduce energy consumption?

A reduction in energy consumption, reduces the need to use fossil energy sources. These sources have a negative impact on the environment. it is important that the western countries takes responsibility, and sett a good example for countries with less knowledge and a struggling economy.

E. CFL-Mercury

A compact fluorescent lamp (CFL) contains about 5 milligrams of mercury, and the need for the element is unlikely to change anytime soon. This is an extremely small amount, and poses minimal risk. One CFL lamp contains a hundred times less mercury than is found in a single dental amalgam filling or glass thermometer, according to the U.S. Environmental Protection Agency (EPA).

"By using less electricity, CFL's help reduce mercury emissions from coal-burning power plants, which are the largest source of human caused mercury emissions" said agency press officer Ernest Jones to National Geography News $[October\ 28, 2010]$.

F. LED disadvantages

Semiconductors are sensitive to overheating. Most LED lamps employ large heat sinks to keep the lamp cool. These heat sinks are made of aluminum which is energy-intensive to mine, refine and process. This also creates byproducts like sulfuric acid that must be taken to a hazardous waste disposal facility.

Aluminum is easy to recycle and requires only 5 % of the energy that would be needed to make new aluminum[6]. Recycling will therefor make LEDs even more environmental friendly.

It is estimated that the prospective impacts of the improved LED lamp in 2017 wil be approximately 50 % lower than the 2012 LED lamp (table IV.1 and IV.2).

G. Life Cycle Assessment

It is important to compare the overall environmental impact of each lamp type to determine which have the smallest overall impact.

The following table presents the air and climate impacts for each of the lamp types[7]. The lighting service has been normalized to represent 20 Mlm-hr (megalumen-hour) of light output.

Table IV.1
ENVIRONMENTAL IMPACTS OF THE LAMPS FOR 20 MLM-HR OF LIGHTING SERVICE

Lamp Type	Global Warming Potential (GWP)	Acidification Potential (AP)	Human Toxicity Potential (HTP)
	kg CO_2-Eq	kg SO_2-Eq	kg 1,4-DCB-Eq
Incandescent	1031,640	7,90790	205,4860
CFL	304,879	2.27035	67,6920
LED-2012	251,025	1,75115	60,4102
LED-2017	122,772	0,85335	30,4625

The table below presents four resource-related environmental indicators[7]. The lighting service has been normalized to represent 20 Mlm-hr of light output.

Table IV.2
RESOURCE-RELATED ENVIRONMENTAL IMPACTS OF THE LAMPS FOR 20 MLM-HR OF LIGHTING SERVICE

Lamp Type	Abiotic Resource Depletion (ARD)	Non-Hazardous Waste Landfills (NHWL)	Radioactive Waste Landfills (RWL)	Hazardous Waste Landfills (HWL)
	kg antimony-Eq	kg waste	kg waste	kg waste
Incandescent	7,6389	35,9500	0,0426	0,0234
CFL	2,2279	13,2890	0,0125	0,0077
LED-2012	1,8502	12,3668	0,0106	0,0081
LED-2017	0,9048	7,4469	0,0052	0,0037

V. CONCLUSION

By phasing out incadescent light bulbs, halogen lamps and older CFLs and replacing them with LED lamps, you will save both energy and money. LED lamps use only a sixth of the energy compared to a regular incadescent light bulb. If lighting controls are installed, you can save even more. Less energy needs to be produced, and because LEDs lasts up to 25 times longer, less waste is generated.

The projected 2017 LED lamp which takes into account prospective improvements in manufacturing, performance and driver electronics will reduce the environmental impacts of LED by approximately 50 %.

OLED is a promising new technology, but we do not yet know if we will be able to use it for lighting purposes, and not just for aesthetics.

NOTES

[1]Efficacy is the ratio of produced light versus power consumed to produce it, usually measured in lumen per watt $[lm/W]$

[2]Mercury (Hg) is a potent neurotoxin and among the most dangerous environmental toxins. Volcanoes are responsible for approximately half of atmospheric emissions, the other half being human-generated.

[3]Lumen (lm) is a measure of the total "amount" of visible light emitted by a source.

[4]Color temperature is the temperature at which a black body would emit radiation of the same color as a given light source.

Color temperatures over 5'000K are cool colors (bluish white), while lower temperatures (2'700-3'000K) are warm colors (yellowish whit through red)

[5]CRI-color rendering index is a quantitative measure of the ability of a light source to reproduce the colors of various objects faithfully in comparison with an ideal or natural light source.

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