City College of New York

Energy Efficiency of an Incandescent Light Bulb vs. a CFL Bulb

 

Rebecca Rose Gindoff

English 21007

Professor Danielle Carr

25 March 2021

Table of Contents

Abstract ....………………...…………………………………………………………………….   2

Introduction  ....………………………………………………………………………………….   2

Materials  …………………..……….……………………………………....…………….…….   4

Procedure …………..………………..…………………………………………………….…...   4

Results …………..………………..…………………………………………………….……….  4

Discussion ……………………….………………………………………………………………  5

Conclusion ………………………………………………………………………………………  6

References ………....………………………………………………………………………….…  7

**Abstract**

This experiment compares the percent energy waste of a Compact Fluorescent Light (CFL) bulb versus an Incandescent bulb by measuring the amount of heat each bulb produces compared to the electrical input during a specific amount of time. The hypothesis that fluorescent light bulbs will have a lower temperature and therefore waste significantly less energy than incandescent light bulbs due to their use of mercury vapor as opposed to tungsten filaments was proven true by the experiment. These results have important implications when it comes to reducing energy consumption for both monetary and environmental reasons.

**Introduction**

During the pandemic, New York City has seen a substantial rise in consumption of electricity in the residential sector. During the 9-to-5 window, when most household members would usually be at work or school, there has been a 23% increase in average residential energy consumption. This additional daytime energy usage which would normally be the responsibility of the employers or institutions has been shifted to individuals (Meinrenken et al., 2020). For many New Yorkers already suffering financially due to the pandemic, understanding how to reduce energy consumption can help households lower their electric bills.

Light bulbs play a crucial role in our everyday lives. They make working past sundown easy, traveling at night safer, and gloomy days more bearable. Choosing energy efficient light bulbs is crucial as they account for approximately 20% of United States’ electricity consumption and 5% of worldwide greenhouse gas emissions. Lighting also accounts for about 10% of the average household’s electricity bill, so switching to energy efficient lighting is one of the easiest ways to combat global warming and fastest ways to lower electricity bills (*50 Surprising Facts,* 2020).

The efficiency of a light bulb is a measure of the light energy produced compared to the electricity (electrical energy) inputted. In the ideal world a light bulb would be 100% efficient, converting all the electricity to light and not producing any heat at all. According to the first Law of Energy, also known as the Law of Conservation of Energy, energy cannot be created or destroyed, only converted from one form of energy to another. Some of the energy created is “lost”, according to the Second Law of Energy, often having been dissipated in the form of heat which is unusable. In the case of the light bulb the heat is “lost” energy and light is our desired product. The less heat that is produced, the more “efficient” the light bulb is.

Although both light bulbs used in the experiment are 60 watt equivalent bulbs, the incandescent produces much more heat due to its design. When an incandescent bulb is hooked up to a power supply, the electric current passes through a tungsten filament, heating it until the filament is hot enough to glow. As the electrons move, they bump into the metal atoms of the filament. The energy of each collision vibrates the atoms and heats them up, eventually producing light (Steele, 2021).

In a fluorescent bulb, rather than passing through a filament, the light is created by high-energy dislodged electrons that are produced when electric current is applied to the mercury gas; heat is just a byproduct of the energetic electrons (Steele, 2021).

To calculate the percent efficiency of any energy transformation one can use the equation:

% Energy Efficiency = $\frac{useful energy output}{energy input}$ x 100

Alternatively, one can estimate the percent efficiency of an energy transformation by calculating the percent energy waste and subtracting that from the 100% efficiency using the equation:

% Energy Waste = $\frac{heat energy output}{energy input}$ x 100

In this equation, both the heat energy output and energy input are measured in calories. The light bulbs capacity to heat water can be used to find the heat energy output and can be calculated using:

Heat Energy Output (calories) = volume of water (mL) x temperature change (oC)

This equation is derived from the equation Q = mcΔT. Where Q is the energy transferred (calories), m is the mass of water (grams), c is the specific heat capacity of water (1.0 cal/goC) and ΔT is the change in temperature (oC).

To calculate the energy input, first measure the electricity used in watt-hours and then use the conversion factor of 860 calories/1 watt-hour to convert to calories, as follows:

Energy Input (calories) = power rating (watts) x time used (hours) x 860

**Materials**

 1- 60 Watt Incandescent Light Bulb

 1- 13 Watt Compact Fluorescent Light (CFL) Bulb (60 watt equivalent)

 1- Gooseneck Lamp

 1- Meat Thermometer

 1- Graduated Cylinder

 Timer

 120 mL Water

**Procedure**

Using a graduated cylinder, 60 mL of water was carefully measured out and its initial temperature was recorded to be 21.5oC. After screwing in the 13-watt CFL bulb into the gooseneck lamp, the lamp was positioned so that 3 cm of the light bulb was submerged in the water. After leaving the light on for 10 minutes, the final temperature of the water was measured to be 22.6oC and the change in temperature (ΔT) was calculated to be 1.1oC.

This procedure was then repeated for the 60-watt incandescent light bulb. The initial temperature of the 60 mL of water was measured to be 21.8oC and the final temperature 38.3oC. With this information ΔT was calculated to be 16.5oC.

**Results and Calculations**

|  |  |  |
| --- | --- | --- |
|  | **CFL** | **Incandescent** |
| Initial Temperature of Water | 21.5oC | 21.8oC |
| Final Temperature of Water | 22.6oC | 38.3oC |
| Change in Temperature (ΔT) | 1.1oC | 16.5oC |

Using the data in the table above and the equations explained in the introduction, the following calculations were performed.

Compact Fluorescent Light Bulb Energy Waste:

Heat Output = 60 mL x 1.1oC = 66 calories

Energy Input = 13 W x $\frac{10}{60}$ min x 860 = 1,863 calories

Percent Energy Waste = $\frac{66}{1863}$ x 100 = 3.5%

 Incandescent Light Bulb Energy Waste:

Heat Output = 60 mL x 16.5oC = 990 calories

Energy Input = 60 W x $\frac{10}{60}$ min x 860 = 8,600 calories

Percent Energy Waste = $\frac{990}{8,600}$ x 100 = 11.5%

The calculated percentages are only a small portion of the energy lost to heat. This is due to the fact that there are experimental errors, such as the entire light bulb not being submerged, leading to an inaccurate measurement of heat produced. Additionally, the lamp and the base of the light bulb became hot as well, another indication of heat production that was not measured in the experimental setup.

**Discussion**

In reality, the percent energy waste for each of the light bulbs would be significantly higher. With incandescent bulbs, only about 10% of the energy used is converted to light, the other 90% is lost as heat. About 85% of the energy used by a fluorescent bulb is converted to light, with only 15% being lost as heat (*Light Bulb Efficiency,* 2018). The small portion of data collected in this experiment demonstrates the drastic difference between the energy loss of incandescent bulbs and the CFL bulbs, with the incandescent having more than triple the percent energy waste of the CFL.

The difference in energy waste between the two kinds of light bulbs leads to drastically different costs of operation. Below is the approximate cost of purchasing and operating each type of light bulb for 1 year (3,600 hours) in New York State.

|  |  |  |
| --- | --- | --- |
|  | **CFL** | **Incandescent** |
| Approximate cost per bulb | $2 | $1 |
| Average lifespan | 8,000 hours | 1,200 hours |
| Watts used | 13W | 60W |
| No. of bulbs needed for 3,600 hours of use (1 year) | 1 | 3 |
| Total purchase price of bulbs over 1 year | $2 | $3 |
| Total cost of electricity used New York State (3,600 hours at $0.19 per kWh) | $8.90 | $41.04 |

The average U.S. household has 41 light bulbs with 20-30% accounting for 80-90% of the energy use ([Johnson,](http://large.stanford.edu/courses/2018/ph240/walter1/docs/johnson-jul18.pdf) 2004). By replacing 30%, or 9, of the most used incandescent light bulbs in a home with CFL bulbs, one could save upwards of $250 per year. Additionally, because CFL bulbs produce about 75% less heat, they are safer to operate and can cut energy costs of home cooling systems.

**Conclusion**

Through measurement and analysis of the relative temperature change of the water each light bulb was submerged in, this experiment gives a clear picture on the efficiency advantage that compact fluorescent bulbs have over incandescent light bulbs. In terms of energy waste, this experiment supports the claim that CFL bulbs waste 75% less energy, confirming that CFL bulbs use less energy, thereby helping the environment, and are in fact less expensive to operate. These results can help homeowners understand how to lower their energy consumption, both for monetary and environmental reasons, by simply changing a light bulb.

Through measurement and analysis of the relative light intensities and power inputs of 8 light

bulbs, this experiment gives a very clear picture on the efficiency advantage that fluorescents

have over incandescent light bulbs. In terms of power, this experiment confirms Guidice’s claim

that fluorescents are 6 times more efficient than incandescents [2]. Cost-wise, fluorescents of

similar light output can be up to 60% less expensive to operate than incandescents for one year.

This experiment supports that fluorescents are in fact more efficient in saving money as well as

valuable energy. Hopefully, as more individuals acknowledge this advantage and switch to the

use of fluorescent bulbs, we will advance a small step towards the ultimate goal of energy

conservation.

Through measurement and analysis of the relative light intensities and power inputs of 8 light

bulbs, this experiment gives a very clear picture on the efficiency advantage that fluorescents

have over incandescent light bulbs. In terms of power, this experiment confirms Guidice’s claim

that fluorescents are 6 times more efficient than incandescents [2]. Cost-wise, fluorescents of

similar light output can be up to 60% less expensive to operate than incandescents for one year.

This experiment supports that fluorescents are in fact more efficient in saving money as well as

valuable energy. Hopefully, as more individuals acknowledge this advantage and switch to the

use of fluorescent bulbs, we will advance a small step towards the ultimate goal of energy

conservation.

Through measurement and analysis of the relative light intensities and power inputs of 8 light

bulbs, this experiment gives a very clear picture on the efficiency advantage that fluorescents

have over incandescent light bulbs. In terms of power, this experiment confirms Guidice’s claim

that fluorescents are 6 times more efficient than incandescents [2]. Cost-wise, fluorescents of

similar light output can be up to 60% less expensive to operate than incandescents for one year.

This experiment supports that fluorescents are in fact more efficient in saving money as well as

valuable energy. Hopefully, as more individuals acknowledge this advantage and switch to the

use of fluorescent bulbs, we will advance a small step towards the ultimate goal of energy

conservation.

**References**

*50 Surprising Facts on Energy Consumption in the United States*. (2017). Electric Choice. www.electricchoice.com/blog/50-surprising-facts-on-energy-consumption/.

Steele, J. (2021). *Incandescent vs Compact Fluorescent Light Bulbs (CFL) – Energy Savings Worth the Cost.* Money Crashers. www.moneycrashers.com/incandescent-vs-compact-fluorescent-light-bulbs-cfl/.

Johnson K. (2004, July 18). *Residential Lighting Technologies in the United States: An Assessment of Programs, Policies, and Practices*. Intermountain Energy. http://large.stanford.edu/courses/2018/ph240/walter1/docs/johnson-jul18.pdf.

*Light Bulb Efficiency.* (2018). Center for Nanoscale Science. www.mrsec.psu.edu/content/light-bulb-efficiency.

Meinrenken, C., Modi V., McKeown K., & Culligan P. (2020, April 21). *New Data Suggest COVID-19 Is Shifting the Burden of Energy Costs to Households.* State of the Planet. blogs.ei.columbia.edu/2020/04/21/covid-19-energy-costs-households/.

**Audience Profile Sheet**

|  |  |
| --- | --- |
| Reader:  |  |
| Homeowners or tenants looking to lower their electricity bills or people concerned with their environmental footprint |
| Kind of Reader: | Primary\_\_\_X\_\_\_ Secondary\_\_\_\_\_\_ |
|  |
| Reader’s Level of Education: |  |
| High school (minimum education needed to properly understand physics concepts and mathematical calculations) |
| Reader’s Professional Experience: |  |
| Little to none |
| Reader’s Job Responsibilities: |  |
| N/A |
| Reader’s Personal Characteristics: |  |
| Concerned about how much money they spend on electricity and/or their impact on the environment  |
| Reader’s Cultural Background: |  |
| N/A |
| Reader’s Attitude Toward the Writer: |  |
| N/A |
| Reader’s Attitude Toward Information: |  |
| Interested because want to learn how they can make a difference in their day-to-day electricity use |
| Reader’s Expectations: |  |
| Learn about the difference between CFL and Incandescent light bulbs  |
| Reader’s Way of Reading the Document: |  |
| Read it well/in its entirety, may skip from abstract to the results/discussion |
| Reader’s Reading Skill: |  |
| Adequate |
| Reader's Physical Environment: |  |
| At home  |

**Reflection Essay**

The genre of this assignment is a lab report because it follows the structure and composition of a lab report. This includes an abstract, introduction, materials, procedure, results, discussion, conclusion, and sources for the information. Lab reports are used to document findings and communicate their significance and are one of the most used documents in engineering. I have chosen a digital medium to communicate the lab report on the comparison of the energy efficiency of an incandescent light bulb versus a CFL bulb, as I believe that with the current global pandemic, this is the most effective and safe way to reach my audiences.

The purpose of my lab report is to inform my audience, homeowners or tenants looking to lower their electricity bills or people concerned with their environmental footprint, about the energy efficiency of different light bulbs. By using CFL bulbs as opposed to incandescent bulbs one can lower the amount of electricity they use, cutting upwards of $200 from their electrical bill. As lighting accounts for approximately 15% of global energy use, switching to more energy efficient light bulbs can help to reduce our overall energy use and conserve resources. Although light bulbs are seemingly simple devices with little impact on the environment, my goal is to communicate to my audience the importance of making this quick switch to more eco-friendly, energy efficient lighting.

My targeted audience is anyone who is concerned with their energy usage, either from a homeowner’s perspective or for environmental footprint purposes. Although not strictly necessary, my audience would most likely have at minimum a high school education in order to understand the basic laws of energy and the mathematical calculations presented in the report.

The exigencies for my lab report were my experiences over lockdown during the pandemic and as a virtual student over the past year. When people were leaving for school or work, lights were turned off for most of the day, but with everyone in my family always being home, lights are constantly on in every room, increasing our electric bill. With this document I hope to educate my audience about the difference between incandescent light bulbs and CFL bulbs by demonstrating the drastic difference in energy waste of each light bulb. For this lab report I have a neutral stance, with the goal of communicating my results to my audience and persuading my audience of my comprehension of the concepts and methodology behind my findings.

With this assignment I have met multiple course learning outcomes. I was able to “develop and engage in the collaborative and social aspects of writing processes” through commenting on my classmates' topic choices and the class discussion regarding what makes a good lab report. I was also able to “formulate and articulate my stance through my writing”, which in this case was neutral, as well as negotiate “the conventions of genre, medium, and rhetorical situations” within my writing, and practice using various online resources to find information for my lab report. I hope that I communicated the background, experiment, and results regarding the energy efficiency of an incandescent bulb versus a CFL bulb clearly and critically and that this document will be a comprehensive guide for my audience.