

## COMPARISON OF LIGHTING EFFICIENCY (LED-CFL) BASED ON ENVIRONMENTALLY FRIENDLY TECHNOLOGY

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### ABSTRACT

Light bulb waste is categorized as non-organic waste which cannot be decomposed in nature and has the potential to damage the environment. Currently the production of light bulb waste reaches 4.50% of the total waste production per day. These conditions require a solution to reduce the amount of waste produced by light bulbs. This paper aims to discuss the recycling technology used for light bulb waste, so that the waste can be reused as recycled and environmentally friendly lighting lamps. The method used in this study refers to an environmentally friendly concept, namely, designing lighting lamps using waste light bulbs that are no longer used. The design product is designed exactly the same as the previous product from the manufacturer, then proceed with testing in the laboratory to determine the electrical parameters and the amount of lumens produced. From the results of the research conducted, it can be seen that the results of the design of recycled lighting lamps have a decrease in lumens value for CFL types by 7%, LED by 8%, the durability and lifespan of light bulbs are reduced by CFL types by 32%, LED types by 30%, the results of the design recycled lighting lamps can be reused as factory lighting, and can reduce non-organic waste.

**Keywords:** Recycle, Green technology, Conservation, Environmentally Friendly Lighting Lamps

### 1. Introduction

According to Law No. 18 of 2008 the definition of waste is the residue of daily human activities and/or natural processes in solid form. Meanwhile, in PP No. 18/1999 jo PP No. 85/1999 concerning the management of hazardous and toxic waste, waste is generally defined as residual material in an activity and/or production process.

The level of waste productivity is increasing along with the increase in population and economic growth throughout the world, especially for cities and tourism areas. The generated municipal waste is dominated by organic waste types (Chuenwong et al., 2022) (Awasthi et al., 2021). The economical use of municipal solid waste is an effective method for anticipating the negative impacts of solid waste on the environment (Wimansa Neelawathura et al., 2022). Based on data from the Sanitation and Landscaping Service of Medan City in 2017, the composition of waste at the Falls TPA consists of non-organic waste and 71.5% organic waste; Paper 2 %; plastics 10.1%; wood 2 %; cloth 2.5% rubber 2.5%; metal 0.6%; glass 0.8 %; 1 % chunks; pampers / pads 3.1% and others 3.8% (Anisah et al., 2020).

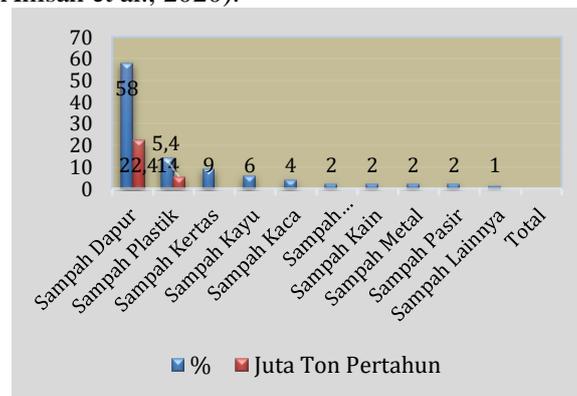


Fig. 1. Waste Production Statistical Data

Based on the picture above, it can be seen that the production of kitchen waste is the highest amount among other waste (Cenci et al., 2021). Apart from the amount of waste production, it can also be categorized by type, namely organic, non-organic and B3 waste. The amount of waste production by category can be seen in the following figure:

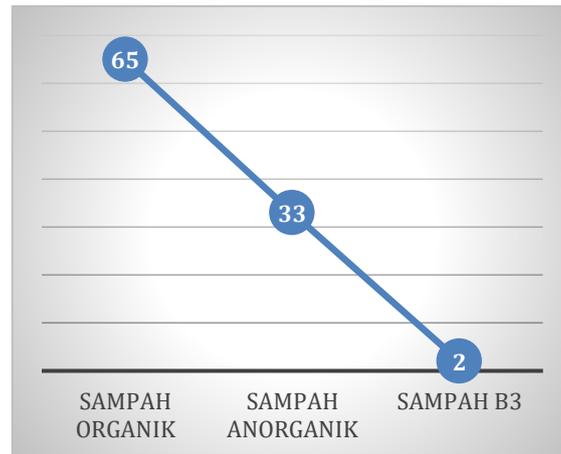


Fig. 2. Waste Composition Data (Anisah et al., 2022).

Based on the picture above, the amount of organic waste production reaches 65%, non-organic 33% and B3 waste as much as 2%. Of the three categories of waste, the hazardous waste is an organic waste and B3 waste because it cannot be decomposed in nature.

The lighting system is a primary need in a room, especially residential lighting. To get lighting, it cannot be separated from the light bulbs produced by the manufacturer (Balocco & Volante, 2018). Light bulbs are one of the contributors to waste. The use of artificial lighting devices in the form of light bulbs can have an impact on environmental pollution caused by damaged light bulb waste.

Light bulb waste is categorized into non-organic waste that cannot be decomposed in free space. Currently the production of light bulb waste reaches 4.50% of the total waste production per day (Masrida, 2017). Light bulb tube which has a glass base material. Other components that are the main content of light bulbs are displays, printed circuit boards (PCB) and metal, such as those contained in Light-Emitting Diode (LED) and Compact Fluorescent Lamp (CFL) bulbs (Rahman et al., 2021) (İşildar et al., 2018) (Nikulski et al., 2021). Components contained in the bulb Light-Emitting Diode (LED) waste contains some metal gallium which cannot be decomposed which has an impact on environmental pollution and damage to soil composition (de Oliveira et al., 2021; Rahayu & Sumarni, 2021).

LED type lighting lamps are made of semiconductor materials with the concept that electric current flows in one direction and not in the other direction. LED chips generally have a long life and break down relatively rarely (Nikulski et al., 2021). The characteristics of LED chips in general are the same as those of diodes which only require a certain voltage to operate. The LED will be damaged if the voltage is too large. The components of an LED lighting lamp consist of resistors, capacitors and diodes. LED lighting lamps also have a higher lighting level compared to other types of lighting lamps (Balocco & Volante, 2019). LED lamps are also known as energy saving lamps (Machacek et al., 2015).

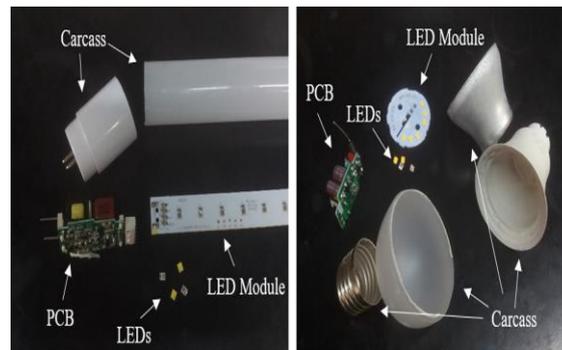


Fig. 3. LED Waste Components(Cenci et al., 2020).

CFL (Compact Fluorescent Lamp) lamps are lamps that use an alternative voltage current (Vac) of 220 Volts. The components of a CFL lamp are a glass discharge tube, tube reflection clip, mounting plate, electronic ballast components, polycarbonate housing, excision screw base, discharge path, phosphor coating, electrodes, bridge, base pins, suppression capacitor and starter. Lamp life The use of CFL lighting lamps has the potential to produce 710.90 million tons of CO<sub>2</sub>-eq which has an impact on emissions(S. Chen et al., 2017)

The age of the lighting lamps produced by the manufacturer differs from one type to another. Damaged light bulbs will be discarded. There is no waste treatment technology from the light bulb. The life of a typical LED lamp is 50,000 hours, a typical CFL is 12,000 hours(Martins et al., 2020). The lifetime of CFL lamps is four times shorter and has a lower efficiency value than LEDs(Machacek et al., 2015).

Electronic equipment waste including lighting lamps has become an international topic and issue(de Oliveira et al., 2021). Various efforts have been made to minimize the amount of waste, especially for non-organic waste. One of the efforts made is through the concept of recycling and waste management. Regulation of the Minister of Environment of the Republic of Indonesia Number 13 of 2012 concerning Guidelines for Implementing Reduce, and Reuse and Recycle through waste banks. Policies regarding energy efficiency are also regulated in the Law of the Republic of Indonesia Number 30 of 2007 concerning Energy with supporting policies covering: Energy conservation and diversification, Environment and safety, prices, energy subsidies and incentives, Infrastructure, public access and the energy industry, Research and energy and institutional development and funding. The development of science and technology, various technologies in the electricity sector, especially to save energy,(Wimansa Neelawathura et al., 2022).

Environmentally friendly technology is a zero waste technology to reduce the amount of waste(Cenci et al., 2021) (J. Chen et al., 2022). The concept of zero waste requires that there is a reserve activity for sources of waste production(Awasthi et al., 2021). The characteristics of environmentally friendly technology with the following categories: a). This includes all transitional technologies that will become environmentally sound technologies. b). All material, energy and water life cycle flows in production and consumption systems. c). Covering the whole spectrum, starting from the basic technology of production and consumption systems to the whole integrated technology where environmental technology is a production and consumption technology for itself. d). Including closed system technology where the target is zero waste and a significant reduction in resource use and environmental technology that produces few emissions, considering technological developments in an ecological and social context.(Principi & Fioretti, 2014) (Dong et al., 2022).

This paper is an article based on the results of research that aims to design lighting products with the main raw material being waste light bulbs that are no longer used. The results of the design are expected to be reused as lighting lamps for recycled products that are environmentally friendly.

## 2. Literature Review

Previous research on testing the effect of the age of CFL and LED manufacturer lighting. This study shows that the life of CFL and LED lamps is longer than other types of lighting lamps. The use of these lights can reduce emissions by 50% (Allione et al., 2011). Another research conducted as an effort to reduce lighting lamp waste is through recycling with the 10R method and strategy (Rahman et al., 2021). Based on the results of research that has been carried out using the pyrolysis method, the content of electronic waste bulbs contains metals which can damage the soil structure so that special treatment is needed in dealing with this problem. (de Oliveira et al., 2021). The recycling system carried out by previous researchers was carried out through the destruction of metals found in lamp waste (Cenci et al., 2021) (İşıldar et al., 2018). Another research conducted to reduce waste production is by controlling the use of artificial light from lighting (Gentile, 2022)

Another research that has been done is that recycling waste lighting lamps can increase economic value with a nominal value of 639.82 dollars per ton in terms of environmentally friendly aspects. (Martins et al., 2020). The results of previous studies that have examined the comparison of the use of LED, CFL and Neon type lighting state that the greatest level of efficiency and energy saving is found in LED type lighting. (Anisah et al., 2020).

The differences between the research to be carried out and the previous studies are: a) in this study the design method was used by disassembling and repairing damaged light bulb components; b) the bulbs used are LED and CFL bulb types.

## 3. Research Method

The purpose of this research is to produce recycled lighting products that are environmentally friendly types of LEDs and CFLs with the basic material being waste light bulbs. The implementation of this research was carried out in the following stages:

### a. Collection of data, references and materials:

This activity is carried out to collect literature, references, journals and related scientific works as a reference in collecting theories that support research activities. collection of materials or raw materials is carried out to meet the needs of materials that become raw materials in the implementation of this research. The raw materials used are LED and CFL type lighting lamp waste.

The equipment needed in the implementation of this research are:

Table 1 - Materials and Tools

No	Tool's name
1	LED bulb
2	LED light
3	CFL bulb
3	PCB board
4	Kid's Electronic Components
5	Measuring instrument
6	Cable
7	PCB Solvent Liquid
8	Adequate Cable

### b. Environmentally friendly lighting product design. The working mechanism and design in this study were carried out as follows:

- 1) Opening waste bulbs of LED and CFL lighting lamps.
- 2) Check each part of the electrical component of the lamp with a multi meter / multi tester to find out which part of the lamp is damaged.

- 3) Mark the damaged part for easy repair.
- 4) Then remove the micro LED, then unite the positive and negative sides using solder
- 5) In jelly LED lights, if one of the micro LEDs is damaged, then all the electrical components will not work.
- 6) Make a lighting installation design that will be designed on a PCB board, in this study the PCB design was carried out through a proteus simulation program, then the PCB board was cut and adjusted to the diameter of the lighting fittings,
- 7) Replace and repair damaged parts on lighting lamps.
- 8) Re-measurement to ensure that all components are active,
- 9) After repairs Place the external parts and assembly back into the lamp body.
- 10) Connect the light fitting with the switch, the light will turn on again.
- 11) Checking the total load current on the led lamp
- 12) Checking the voltage source of the switching power supply at direct or DC voltage
- 13) Measurements on the voltage of each led lamp



Fig. 4. CFL and LED Light Bulb Waste

The line diagram and design installation scheme can be seen in the following figure

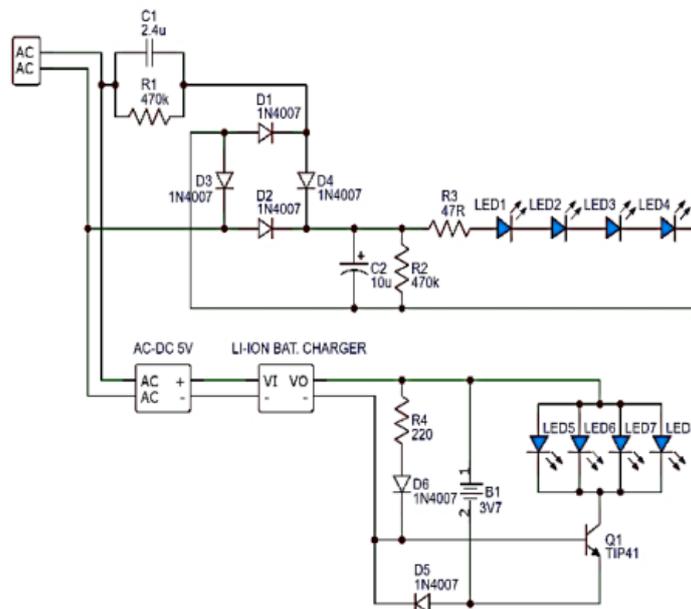


Fig. 5. Design Line Diagram

After the design is carried out, the product of the design results is tested in the laboratory. The tests carried out on lighting products are:

- 1) Testing the electrical parameters in the form of voltage, current and electric power.
- 2) Testing lumens or lighting on recycled lighting lamps
- 3) Testing the life of the designed lighting lamps

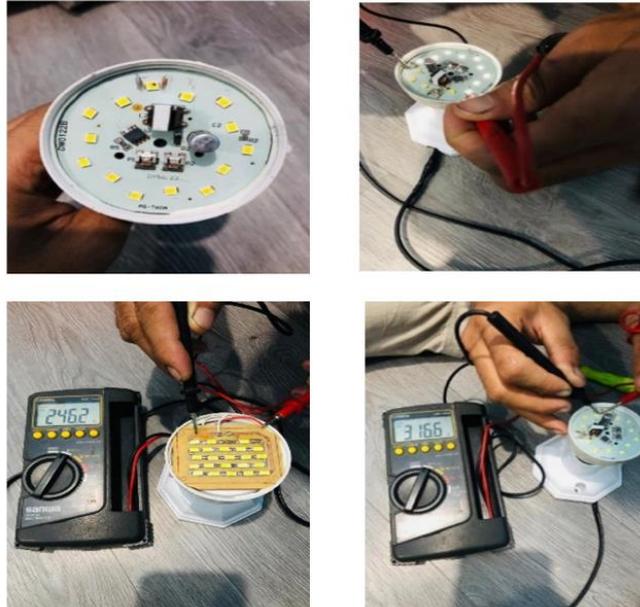


Fig. 6. Product Testing

#### 4. RESULTS AND DISCUSSION

##### a. Power Analysis on Recycled LED Type Lighting:

The results of the design in the form of lighting can be seen in the following figure:



Fig. 7. Recycled CFL Lamp



Fig. 8. Recycled LED Lamp

Based on the results of the design it can be analyzed

- 1) The circuit on this lamp is arranged in series, with a total power written on the packaging of 12W.
- 2) The number of lamps is 14 pcs, there are 2 pcs which are damaged, it can be seen from the blackened physical LEDs, so the number of LEDs = 12 pcs.
- 3) The total current measurement ( $I_{tot}$ ) uses a multimeter at the following points: (pictured) the measured value is 0.085A (83.8mA).
- 4) Voltage measurement using a multimeter on one of the LEDs ( $V_{led}$ ) shows a value of 8.71V.

Based on the data above, it can be analyzed

- 1) What is the total power value ( $P_{tot}$ ) with the number of LEDs that are still good at this time (12pcs)?
- 2) What is the rated power of each LED ( $P_{LED}$ )?
- 3) What is the total power value ( $P_{tot}$ ) if none of the LEDs are damaged?
- 4) How much is the energy consumption (kWh) of the LED lamp that has been repaired per month (30 days) if it is assumed that the lamp is on for 8 hours a day?
- 5) How much is the fee to be paid for a month (30 days) from the calculation results in point 'd'?

Answer:

$$\begin{aligned} P_{tot} &= (V_{LED} \times \text{Number of good LEDs}) \times I_{tot} \\ &= (8.71 \text{ V} \times 12 \text{ pcs}) \cdot 0.085 \text{ mA} \\ &= (104.52\text{V}) \times 0.085\text{mA} \\ &= 8.88\text{W} \end{aligned}$$

The remaining power with a good number of LEDs (12pcs) is 8.88W

$$\begin{aligned} P_{LEDs} &= P_{tot} / \text{Number of LEDs is good} \\ &= 8.88\text{W} / 12\text{pcs} \\ &= 0.74 \text{ W} \end{aligned}$$

The power of each LED is 0.74W

Number of LEDs 14pcs

$$\begin{aligned} P_{tot} &= P_{LEDs} \times 14\text{pcs} \\ &= 0.74\text{W} \times 14\text{pcs} \\ &= 10.36\text{W} \end{aligned}$$

The calculated LED power is 10.36W

Number of days a month = 30 days, daily use 8 hours, number of LEDs 12pcs

Lamp operating hours for a month (t) = 8 hours x 30 days = 240 hours (h)

$$\begin{aligned} W &= P_{LEDs} \times t \\ &= 0.00888 \text{ kW} \times 240 \text{ h} \\ &= 2.13 \text{ kWh/month} \end{aligned}$$

In the above analysis, the energy consumption for a month is 2.13kWh. If we assume that the house's power is 900VA, then the basic electricity tariff (TDL) for PLN is IDR 1,352. Then the costs to be incurred can be calculated as follows:

$$\begin{aligned} \text{Cost} &= \text{TDL} \times W \\ &= \text{IDR } 1,352 \times 2.13 \text{ kWh} \\ &= \text{IDR } 2,879.76 \end{aligned}$$

#### **b. Power Analysis on CFL Type Recycled Lighting:**

Based on the results of the design it can be analyzed

Test result :

- 1) In testing, it was found that the DC output voltage value from the lamp power supply was 246.2V when the power supply was not connected to the load.

- 2) Then after the DC power supply is connected to the PCB, the measured power supply voltage value changes to 65.7 V. From this measurement it can be calculated that the voltage is:

$$\begin{aligned} \text{VLOADS} &= \text{Voltage without load} - \text{Voltage with load} \\ &= 246.2 \text{ V} - 65.7 \text{ V} \\ &= 180.5 \text{ V DC} \end{aligned}$$

- 3) From the results of test number 2, we can find out what the value of each component is. It is known that on the PCB board there are 22 pcs. Then the calculation is:

$$\begin{aligned} \text{VLED} &= \text{VLOAD} / \text{Number of lights} \\ &= 180.5\text{V} / 22\text{pcs} \\ &= 8.2 \text{ VDC} \end{aligned}$$

- 4) At this point we will measure the total current of the series circuit with a total of 22pcs. The current value obtained is 112mA (0.112A).  
5) After the total voltage (VLOAD) and total current (ILOAD) are obtained, then we can then find the power value of our LED circuit through the following formula:

$$\begin{aligned} \text{PLOAD} &= \text{V}_{\text{LOAD}} \times \text{I}_{\text{LOADS}} \\ &= 180.5\text{V} \times 0.112\text{A} \\ &= 20.22 \text{ W} \end{aligned}$$

### c. Lumens Analysis – Illumination of Illumination Lamps

Lumens value analysis on LED and CFL lamps refers to the manufacturer's lumens value. The results of the analysis carried out on several lighting products designed by using a light intensity meter type LX1330 Ks3910. Analysis was carried out by comparing the lumen values that were carried out for 1 year. The measurement results can be seen in the following table:

Table 2 - Measurement Comparison Results

Lamp Power	Lumens Lamp Design Results		Lumens of Manufactured Lamps		Condition
	LEDs	CFLs	LEDs	CFLs	
	12W	1215	590	1320	
14W	1415	720	1550	870	Life
18W	1690	1260	1700	1300	Life

The data in the table above is the data taken during the initial measurements. Based on the results of measurements carried out in the laboratory, it is known that the value of lumens or lighting in lighting lamps has decreased by an average of 10.8% compared to lighting in new lighting produced by the manufacturer, this is due to the influence of the waste bulb used which is dirty and experience darkening due to age.

Measurements and analysis of lumens are also carried out every week by measuring changes in lumens that occur every week with the measurement results showing that the lumens of lighting have decreased by an average of 2% per week.

### d. Analysis of the Age of Use of Lighting Design Results

Analysis was carried out on the duration of use of the resulting lighting lamps, the methods used in this measurement and analysis were carried out using 2 methods.

6) The first method is by turning on the lighting continuously for 24 hours.

7) The second method is to turn on the lighting for 12 hours.

These two methods and treatments were given to LED and CFL type lighting lamps with a power capacity of 12 W, 14 W and 18 W. but there is a decrease in lighting. This is due to the additional age of the bulb used.

## 5. Conclusion

From the research that has been done it can be concluded that: The waste generated by electrical materials, especially lighting waste, can be recycled again through environmentally friendly technology and the zero waste concept. Environmentally friendly lighting is a research product that can be reused as a substitute for manufactured lighting. Based on the results of electrical power testing, lumens/lighting testing, and usage age, LED type eco-friendly lighting products are more efficient than CFL types.

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