Utilization of Electronic Waste for Energy-saving Lamp Circuits

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Abstract. Indonesia is one of the largest electronic consumer countries in the world. The negative impact unless the increase in the use of electrical energy, there is also an increase in electronic waste or e-waste. If electronic waste (e-waste) is not managed properly, it will cause its own problems, especially environmental health problems. One alternative to overcome these problems is the use of e-waste as a raw material for a series of Waste-Based Energy Saving Lamps, abbreviated as SLHE BBL. This study aims to develop SLHE BBL prototypes based on electric and electronics waste, and test the performance of SLHE BBL prototypes. The SLHE BBL method developed by research and development adapted from Borg & Gall with the following stages: First, needs analysis and product planning; Second: Initial product development, validation and initial product revision. Third: Product development, testing, product revision. Fourth: Finalization dan Dissemination. The research instrument consisted of an observation sheet, luxmeter, voltmeter, ammeter, multimeter, watt meter. The collected data was then analyzed quantitatively and descriptively. The results of the research are as follows: 1) waste that can be recycled into raw materials for SLHE BBL include: resistors, capacitors, LED lights on computer mice or electronic component indicators, used goods casings, adapters, diodes, cables, TV's control remote; 2) Electrical and mechanical design of SLHE BBL can be assembled into prototype of SLHE BBL; 3) The performance of the SLHE BBL prototype is that the lamp can be adjusted in colour and light intensity; the measured electrical parameters are within the range in accordance with the provisions of electrical standards such as Perasyaratan Umum Instalasi Lstrik (PUIL), International Electrical Commisionin (IEC), or National Electrical Code (NEC)

1. Introduction
The volume of electronic waste generated worldwide in 2019 was roughly 54 million metric tons. Several factors such as increased spending power and the availability of electronics have fuelled e-waste generation in recent decades, making it the fastest growing waste stream worldwide. This trend is expected to continue, with projections showing that by 2030, annual e-waste generation worldwide will have increased by approximately 30% as shown in Figure 1 [1]. According to [2], On March 6, 2021, an article from Suara.com stated that it was estimated that Citation is not good Indonesia would produce 2 million tons of e-waste in 2021, and this is the most in Southeast Asia. Annual e-waste production in Indonesia is projected to increase to 3.2 million tons in 20 years. Based on the Material Flow Analysis (MFA) method [3], the accumulation of electronic waste generated from households in Indonesia in 2025 can reach 622,000 tons. Based on the MFA model, the total e-
waste generated (2015-2025) is estimated at 3.75–4.98 million tons. The negative impact unless the increase in the use of electrical energy, there is also an increase in electronic waste or e-waste. If e-waste is not managed properly, it will cause its own problems, especially environmental health problems. One alternative to overcome these problems is the use of e-waste as a raw material for a series of Waste-Based Energy Saving Lamps, abbreviated as SLHE BBL.

The waste used in this research is electrical and electronic waste. Electrical and electronics waste, for example, used tubes lamp, other electrical components that are not used, electronic waste, which components can still be utilized. The Energy Saving Lamp Circuit Made from Waste with remote control (here in after abbreviated as SLHE BBL) developed in this study was inspired by the working principle of the remote control on a TV set. The analogy is that if the remote control is used on a TV set to adjust the sound volume, in this study it is used to adjust the intensity or dimness of the light. Furthermore, the function to change the TV channel, in this study is used to change the colour of the lamp.

Energy saving which is meant in this study is saving in electricity consumption, meaning that compared to other lamps with the same electrical power, the intensity of light produced by SLHE BBL is greater. Another savings found in the SLHE BBL is the use of a remote control as a regulator of the intensity and colour of the lamp that can be adjusted according to needs. In other words, the SLHE BBL lamp can be dimmed or brightened, and the colour of the light can be changed as needed, for example, for studying, the bright white colour is selected and the electrical power is set to 10 watts, for sleep, blue or green is selected and the power is reduced to 5 watts.

The SLHE BBL prototype is different from similar lamp products that have ever existed [4]. For example, PT Philip Indonesia produces a lamp called "Tornado Easy Scene" which is equipped with a remote control, but the remote control on the lamp only functions as a substitute for a switch and light intensity regulator, not yet equipped with a lamp colour setting and only one colour is available (usually milky white colour).

SLHE BBL is also different from similar studies that have been carried out by previous authors, for example the study conducted by [5], [6], [7], and [8]. The study entitled "Design of a light intensity regulator with remote control for incandescent lamps” [5], has limitations on the type of lamp that is controlled not the type of energy-saving lamp, namely incandescent lamps that can cause global warming. Another weakness is that the remote control device is only able to replace the function of the switch and light intensity regulator, the control sensor used (infrared) has a limited range. The weakness of Zulfahmianuddin's study is also found in the study of [6] entitled "Home lighting control system with Remote Control based on the ATMega8535 Microcontroller utilizing radio waves", and [7] entitled "SiMBeR as a load regulator for household electrical appliances automatically based on
ATMEGA16”. The advantage of the study compared to other studies is the use of radio waves whose control is able to penetrate walls, so that lights can be controlled from outside the building (walls) [8].

The AS unit of luminous intensity is the candle-power, abbreviated cp (cd), and normally represented by the letter “I”. An ordinary wax candle has a luminous intensity horizontally of approximately one candlepower. The candela and candlepower have the same magnitude [9]. This is consistent with Mullin & Smith (2002) which state that the luminous intensity of a source, when expressed in candelas, is the candlepower (cp) rating of the source.

According to [10], lumen (lm) is the amount of light received in a unit of time on a unit area at a unit distance from point source of one candela. If the units are in SI, then the unit area is one square meter, and the unit distance is one meter, thus a one-candela source produce one lumen on each square meter (one lux) for a total of 12.57lumen. Referring to [6], one lumen of luminous flux, produce an illumination of one foot candle (fc). Illumination is normally represented by the letter “E”. Illumination is the density of luminous power, expressed in terms of lumen per unit area, stated mathematically:

\[
E = \frac{\Phi}{F}
\]

Where:
- \( E \) = illumination (lux)
- \( \Phi \) = quantity of light (lumen)
- \( F \) = square meters of area (m²)

The unit of electric power is watt (W). In AC circuit impedance is compressed of resistance and reactance (AC resistance of inductance and capacitance) and causes a phase difference between voltage and current. This phase difference is represented by and angle, the cosine of which is called cos \( \theta \) or power factor, abbreviated “pf”. The AC power equation is:

\[
W = V \cdot I \cdot \cos \theta
\]

Where:
- \( W \) = electric power (watt)
- \( V \) = voltage (volt)
- \( I \) = current (ampere)
- \( \cos \theta \) = power factor

2. Method
The method used is R & D developed by [11] with various modifications as shown in Figure 2.

![Figure 2 Design Method](image)

The instruments used to measure the electrical parameters of the BBL SLHE are: a multi meter to measure current, voltage, and e-waste connections; wattmeter to measure lamp power; lux meter to measure lamp illumination as shown in Table 1.
Table 1: Measurements instrument

| Instruments   | To measure:                      |
|--------------|---------------------------------|
| Multi meter  | Electric current                |
|              | Voltage                          |
|              | E-waste connection               |
| Watt meter   | Lamp power                       |
| Lux meter    | lamp illumination                |

3. Results and Discussion

Based on laboratory tests, observations and testing of e-waste components, it can be identified several components that can still be recycled into basic materials or components of SLHE BBL, as follows: resistor, capacitor, LED lamps, for example the one on a computer mouse, casing of used goods, such as syrup bottles, packaged drinks, perfumes, broken incandescent lamps, used adapters for example from radio, TV and other equipment, diode, cable, remote control casing, e.g. TV remote control.

Furthermore, based on the identification of e-waste, the required circuit can be determined, namely:

1) a power supply circuit that requires components of transformers, diodes, resistors, and capacitors;
2) The system circuit, which consists of resistors, connectors, and connectors;
3) Rectifier, which requires a diode, power supply, resistor, capacitor, and cable;
4) LED circuit.

Figure 3 show the remote control circuit uses an infrared receiver with a working frequency of 38 kHz. The shape of the pulse issued by the sensor is the opposite of the pulse received from the remote (inverting pulse). The sensor output pulses are directly forwarded to the microcontroller.

Figure 4 adopting Hartono [12], this circuit consists of several sets of colours, namely white, red, green and blue. Performance that is measured from the LED circuit is the illumination, power, voltage,
and current. The microcontroller in this study serves to translate the pulses sent via the remote into numerical data by reading the length of each wave. The value of the translated number is then used to change the PWM value of the microcontroller output. Changes in the PWM value result in changes in the intensity of the LED lights as shown in Figure 5.

![Microcontroller circuits](image)

**Figure 5** Microcontroller circuits

The output of the microcontroller is limited to a voltage of 5 volts and a maximum current of 40mA, while the LED used requires a voltage of 32 volts. Therefore we need a device that can control a voltage of 32 volts with a microcontroller output voltage of only 5 volts. The control device used is a transistor. The PWM connection of the microcontroller output is connected to the base of the transistor, so that it can adjust the on-off transistor. The on-off transistor will produce an average voltage that varies according to the ratio of the on and off time as shown in Figure 6.

![LED control circuits](image)

**Figure 6** LED control circuits

Table 2 shows the reference parameters based on catalog and analysis for Performance Testing of SLHE BBL.
Table 2. Reference parameters

| Parameters       | Standard size | Parameters       | Standard size |
|------------------|---------------|------------------|---------------|
| Illumination (E) | 80 lux        | Voltage (V)      | 220 volt      |
| Lamp power (W)   | 40 watt       | Cos θ            | 0.56          |
| Current (I)      | 323 Ma        | Temperature      | 10° – 40° C   |

The performance of this study was tested through measurements of illumination, electric power, current, voltage, wiring system testing, and mechanical testing. Figure 7, 8, 9 and 10 show the results of testing the performance of SLHE BBL.

The lighting system on the LED is quite good because it is gradual and does not get hot easily. At a voltage of 220V, the light intensity on the LED does not decrease. It is still consistent, for white lights, the higher the voltage, the intensity light is higher. Likewise, the higher the current and the higher the electric power, the stronger the lighting of a lamp. As for coloured lights (red, green, and blue), the higher the power, current, and voltage, the stronger the lighting will be. This is according to the character of the colour, the redder, the greener, and the bluer, the darker or stronger the light is, the smaller it is.

![Figure 7: Illumination of lamp color in lux](image)

Figure 7 show that the blue light produces the largest illumination of 59 lux, while the red light has the lowest illumination. Referring to Table 1, the ideal lamp illumination is 80 lux. Based on the observation data, the blue light illumination is lower than the ideal illumination. This is due to the depreciation factor. This is in accordance with formula 1.
Based on Figure 8, the largest lamp power is the green lamp and the smallest is the blue and white lamp. This is identical to the illumination produced by the two lamps. If compared with Table 1, the lamp power from the observation is lower than the lamp power from the analysis. This is in accordance with formula 2.

Based on Figure 9, the largest electric current is the green lamp and the smallest is the blue and white lamp. This is identical to the illumination produced by the two lamps. If compared with Table 1, the lamp power from the observation is lower than the lamp power from the analysis. This is in accordance with formula 2.
Figure 10 Electric voltage of lamp color in volt

Based on Figure 10, the largest voltage is the red, green, and blue lamp and the smallest is the white lamp. If compared with Table 1, the lamp voltage from the observation is higher than the lamp power from the analysis. This is in accordance with formula 2.

Observational data shows that all test units have provided indicators that they can work according to design. Several points tested for the electrical system were at the input of the power supply, at the input of the microcontroller, at the output of the microcontroller, at the input LED, and at the output LED. The results of this test also give the result that electrically, all the wiring is good.

Furthermore, the mechanical test showed that all test points had met the requirements, except for the finger test and the isolation test. In the finger test, the SLHE BBL circuit does not meet the requirements because the circuit is still open, has not been packaged or included in the casing, so there is still the possibility that the electric current circuit is still open or can endanger safety because if it is touched the human body can electrocute.

4. Conclusion
The design and prototype of the SLHE BBL has been electrically and mechanically tested and the result is that the lamp circuit can be completed as planned.

It is necessary to make improvements to the design of the circuit, assembly or manufacturing circuit, as well as to continue with testing the temperature or heat generated by the SLHE BBL, whether it is still within reasonable limits or still causing excessive heat; The lamp casing is adjusted to the size of the LED lamp to withstand the heat or temperature caused by the high power LED lamp.

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