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URBAN LIGHTING TECHNOLOGY ADVANCEMENT IN ELECTRICITY ENERGY EFFICIENCY, EVIDENCE: BANDUNG MUNICIPALITY STREET LIGHTS

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ABSTRACT

Street lighting (PJU) is one of the critical facilities that have a vital function, it has a very strategic feature. Besides provide night vision for road users, PJU also has a city artistic value that can add to the attractiveness, harmony, beautification as well. Considering to improve PJU services as the aim for the city's splendor, safety, security for its residents around public roads, also provide significant savings on energy consumption, Bandung Municipality using effective, efficient, and sustainable resources, intends through Light Emitted Diode (LED) as an advancement of PJU technology. To find out how far the reduction in energy consumption and electricity costs charged by PJU, this research measuring through comparison approach both Non-LED PJU and LED PJU electricity payment, in addition, electricity consumption. This research depicts both lamps' evaluation descriptively as well. LED lighting is a combination of solid-state light sources, control gears for LED lighting operations, and optics for light distribution. The parts would influence the performance of LED lighting in terms of energy efficiency, color quality, life, and lumen maintenance. These components affect the quality of the LED lighting itself. With lower electricity power, LED PJU lights are not inferior to conventional PJU lamps' lighting quality, thus, LED PJU conducts high saving energy demand. Moreover, detracts electricity cost at the same time. The expenditure from changing the PJU lamp from Non-LED to LED PJU able to contribute efficiency of both electrical energy and electricity payment slightly above 30% in Bandung municipality.

Keywords: PJU (Street Lights), Light Emitted Diode (LED), Electricity Consumption, Electricity Costs.

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1 Introduction

The end of the cold war, which was marked by the collapse of the Soviet Union in the late 80s and the early 90s, also changed the constellation of the international world order characterized by the shifting of geo-politics into geo-economy. This also raises new strategic issues, one of which is the environment. The thing that is meant about the atmosphere here is how we protect the ecosystems and habitats of living things by protecting the environment. This issue becomes a strategic issue. Governments should be achieved by running a sustainable development program with the indicators development concern, focus, and pro on environmental sustainability.

Environment-based development has a significant impact on a country for developing its cities as citizen's residences. As mentioned in the IEEE ICC 2017 Green Communication System and Network Symposium by Giuseppe Cacciatore, who analyze the cost of smart lighting solution for smart cities, Sustainable development plays, therefore, a crucial role in city development. While urban environments occupy nearly 2% of the world's surface, cities contribute to 80% of global gas emission, 75% of global energy consumption, and 60% of residential water use.

Besides, environmental issues are also one of them is the problem of climate change. One of the global energy demand is ht used of electrical energy, as it's revealed in the Europe 2020 strategy, defines three targets for climate change and energy: (i) 20% reduction of greenhouse gas emission, (ii) 20% increase in energy production from renewable sources, and (iii) at least 20% increase of the energy efficiency.

Street lighting attributes nearly 19% of the worldwide use of electrical energy and entails 6% of global emissions of greenhouse gases. A decrease of 40% of the energy spent on lighting purposes is equivalent to eliminating half of the emissions from the production of electricity and heat generation in the US. In this context, public street lighting, which is an essential community service, plays an important role, as it impacts around 40% of the cities' energy budget. Consequently, in preparation of the EU commitments, optimizing the lighting service is a primary objective for the municipalities according to The Cost Analysis of Smart Lighting Solutions For Smart Cities by Giuseppe Cacciatore, Claudio Fiandino, DzmitryKliazovich, FabrizioGranelli, Pascal Bouvr in IEEE ICC 2017 Green Communication System And Network Symposium (Cacciatore, Fiandrino, Kliazovich, Granelli, & Bouvry, 2017).

Indonesia is a developing country consisting of 34 provinces. As the country that has the fourth largest population after China, India, and America. Indonesia is a vast archipelagic country

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that consists of diverse tribes and races. One of the most critical regions in Indonesia is West Java Province, which is the most important economic center in Indonesia after the capital city of Jakarta and has various advantages in all crucial aspects compared to other regions.

Geographically, West Java Province is located directly adjacent to Jakarta, which means the West Java Province has an essential role as a province that supports the capital. In terms of urban infrastructure and in helping other development sectors, such as supporting National Government Policies in reducing greenhouse emissions and providing high energy saving.

West Java province has its capital in the city of Bandung, which is also the center of government and the economy of West Java. Notably, besides as the capital of the Province of West Java, Bandung City is a storefront city of West Java and the city of West Java community pride, well-known as the place where the majority Sundanese people live, also as a benchmark for urban development in Indonesia.

To create a beautiful and comfortable city of Bandung, it is necessary to arrange the city, especially concerning the aspects of street lighting (PJU). Public street lighting (PJU) is one of the critical facilities that have a vital function. PJU has a very strategic feature, especially for road users at night. Besides that, PJU also has a city artistic value that can add to the attractiveness, harmony, and beauty of the City's arrangement to support the City of Bandung's vision as a Service City.

Ouerhani, Pazos, Aeberli, and Muller (2016) said that street lighting is an essential infrastructure for cities to ensure citizens' security and goods. This infrastructure has, however, a high economic and ecological cost. Moreover, similar to Nabil Ouerhani, Street lighting is an essential community service. Still, current implementations are not energy efficient and require municipalities to spend up to 40% of their allocated budget as mentioned in The Cost Analysis of Smart Lighting Solutions for Smart Cities by Giuseppe Cacciatore, Claudio Fiandino, DzmitryKliazovich, FabrizioGranelli, Pascal Bouvr in IEEE ICC 2017 Green Communication System and Network Symposium (Cacciatore et al., 2017).

One effort to solve these problems and implement an environmentally friendly development program is the development of street lights technology that has been widely circulated in the market about street lights that are environmentally friendly or what we are familiar with LEDs. With the advancement of modern technology, new street lamps have gradually become one of the hot topics discussed in the industry in recent years. (Research and design of environmental monitoring and road lighting system based on the Internet of things YangXu, Shuai Liu, YingPeng) (Xu, Liu, & Peng, 2018).

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The statement is also supported in Modes of Governance for Municipal Energy Efficiency Services-The Case of LED Street Lighting in Germany by FriedemannPolzin, Paschen von Flotow, Colin Nolden that LED streetlights to provide an excellent example for the analysis of governance options of municipal energy efficiency procurement and retrofitting, the diffusion of municipal LED street lighting as a replacement for conventional lighting serves as an example. Thus, significant initial investments are necessary to retrofit existing street lighting stock and to tap into long-term energy efficiency benefits and savings associated with new technologies such as LED.

The street light is one of the city's necessary public facilities, which is widely distributed in cities. In the future, light street utility not only serves to illuminate the environment but also has advancement multi-function as mentioned by Shichao Chen, Gang Xiong, JiaXu, Shuangshuang Han, Fei-Yue Wang, Kun Wang in The Smart Street Lighting System Based on NB-IoT that street light, as one of the tools of the smart city, is a solution for the urban development problems such as urban traffic congestion, excessive city consumption, urban environmental pollution, which is new concepts and models for the sustainable urban development.

Technically, Dr. Ronald Gibbons and Christopher Edwards' research from Virginia Tech Transportation Institute (VTTI) in 2010 described the application of streetlights in the City of San Jose, United States of America. It can be seen from the research conclusion that streetlights that use broad-spectrum light sources such as Light Emitting Diode (LED) and Induction Lamp can reduce energy consumption by up to 40%, improve night vision, and the quality of the lighting on a city street.

In terms of an average lifetime, maintenance, electrical performances, and energy savings LED technology appears to be the most convenient solution as it's said by Giuseppe Cacciatore, Claudio Fiandino, DzmitryKliazovich, FabrizioGranelli, Pascal Bouvr in The Cost Analysis of Smart Lighting Solutions for Smart Cities, IEEE ICC 2017 Green Communication system and network symposium.

LED lights are semiconductor lights that produce solid phase semiconductor devices that convert electrical energy directly into view with the wavelength right when the current is applied. The LED light source is arranged in an arrangement of 10 to 200+ individual light sources, each of which has a lens attached to control the distribution of light from the lamp. Because each lamp consists of several small light sources, there is the potential for the lamp container to be designed to distribute light uniformly and efficiently in certain areas and to avoid lighting outside the desired area. The advantages of LED lights, in general, can be seen from the study of Soni and Devendra

(2008), which is cited in Bandung Municipality Public Works Agency Strategic Planning Document, provides an overview of the superiority of LED lights in the form of energy savings and high costs compared to the use of conventional lamps.

Remains according to Soni and Devandra as cited in Bandung Municipality Public Works Agency Strategic Planning Document, The advantages of LED lights are as follows:

1. Because of the high efficiency of LED, it makes this lamp very useful by using a battery or energy-saving device;
2. The resulting light is more cooling and pleasant;
3. LED lights can remove the desired light without using a color filter as required by conventional lights so far;
4. This LED light can be designed to focus on the light without using a mirror.

The light emitted from each LED can vary by varying the power level applied. Unlike conventional High-Intensity Discharge, the emitted light level has a linear relation with the applied power level, reducing the power level to the LED by 50% will roughly reduce the light level to 40%. In contrast, for HID sources the level of light will decrease to a much higher degree. Besides, dimming LED lights will tend to extend their life and also increase lumen efficacy. At the same time, HID lamps will experience a decrease in effectiveness and change in the color temperature of the lamp when it is not operating at its optimal level. Furthermore, the quality and level of light from LED are generally not degraded (lumen shrinkage) from time to time in the same way as conventional lamps, so there is no need to 'over-ignite' during the initial years of installation to meet the level of lighting required at the end of the lamp clothes as in the HID lamp.

FriedemannPolzin, Paschen von Flotow, Colin Nolden said in Modes of Governance For Municipal Energy Efficiency Services-The Case of LED Street Lighting in Germany, LED lighting provides a technological advantage over conventional lighting: higher energy efficiency (Polzin, von Flotow, & Nolden, 2016). The use of LEDs is gradually gaining popularity due to its photometric characteristics, such as low weighted energy consumption (kW/ 1000hrs), high luminous efficacy (lm / W), high mechanical strength, long lifespan and reduction of light pollution. This solution is expected to be highly efficient (Cacciatore et al., 2017).

The following are other characteristics of LED lighting that make LED lights ideal for Public Street Lighting compared to other existing technologies:

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1. Low energy consumption due to high efficacy, one-way light emission, high optical efficiency, and high driver efficiency, namely the ability to convert electricity into light in a specific direction;
2. Low maintenance costs due to a long life of up to 50,000 hours;
3. Resilience: LED lights are impact resistant and vibration resistant making them the best choice for places such as roads, bridges, and environments with high wind intensity;
4. It is environmentally friendly because it is free of harmful substances such as mercury, lead, or other hazardous chemicals and gases. Unused LED lights can be disposed of without special handling because they can be recycled and have a lower environmental impact when discarded;
5. Desired lighting level: directly obtained without the need for the required heating period;
6. Low light depreciation - loss of brightness or reduction of lumen on LED lights run slower than sodium lamps or other types of lights. LED not only have a longer lifetime than conventional lamps, but they also last longer brighter than other lights, thereby reducing the need to replace the lights as they often do;
7. There is no production of infrared or ultraviolet light (which attracts insects);
8. Low light pollution because directional light is carefully distributed precisely to the intended location. Therefore, there is no or only a small amount of light wasted by illuminating the night sky. Lighting that is not in place and towards the sky is minimal;
9. Controlled lighting output, allowing dimming or adaptive management;
10. A high color rendition index of 70-90 allowing different color recognition (both for Closed-Circuit Television (CCTV));
11. Better operating characteristics. The LED lights operate at lower temperatures, are not sensitive to low temperatures, and do not affect the dead flame cycle, making these lights safer and more efficient in cold environments.

As mentioned before that LED Street Lights, as the new street lighting technology improvement, in the future, not only functioned to illuminate. Along with the development of new street lighting technologies, a multitude of solutions was developed to offer a safe and, at the same time, a healthy, ornamental, and enjoyable environment. Intelligent street lighting systems were developed to improve the luminous efficiency, to reduce energy consumption and light pollution (Events based Advanced Control Strategy for Urban Street Lighting Adina Astilean, CameliaAvram, Ramona Bolboaca, ValentinSita, Mihai Pop Automation Department Technical University of Cluj-Napoca Cluj-Napoca, Romania).

LED-based on the light that emitted by a diode, LED can light up/ dim the light intensity, while High-Pressure Sodium (HPS) cannot. As a result, LED combined with sensing of presence can be used to dim the light intensity when people are passing in the lampposts' vicinity. On the other hand, HPS-based lampposts can only turn on or off the lamp. This makes each smart lighting solution to bring in different level of energy saving. (Cacciatore et al., 2017).

This type of mercury lamp has a general characteristic white light color (color temperature around 3000-3300 K). Lumen efficacy between 50-70 lm/ W. The color rendering is more than 60 Ra. The rate of conversion of electrical energy into visible light is called the luminous effect and is a significant driver of energy consumption by PJU. Street lighting generally uses sodium or mercury lamps with high intensity over the past few decades. However, lighting technology has developed rapidly over the years, which leads to increased energy efficiency.

The following table presents the advantages and limitations of several types of lamps used in PJU currently in the city of Bandung.

Table 1
Performance Comparison of the Conventional and Energy-Saving Lamps

No.	Lamps Type	Efficiency Average (Lumen/ Watt)	Lifetime Average in Hour	Light Quality	Advantages and Limitations
1	High pressure lamps (HPL)	110	12.000 - 20.000	Bad	High efficiency, long life, small lamp size, efficient light distribution but poor light quality.
2	Low Pressure tube lamps *fluorescent*	60 - 70	8.000 - 10.000	Normal	Short age. Used is limited to small roads.
3	Gas lamp sodium	100 - 200	16.000 - 24.000	Very Bad	High efficiency, long life time.
4	Low pressure lamps (SON Type)				Low control of light distribution and light quality is very poor.
5	High pressure mercury gas lamps	50 - 55	8000 - 12.000	Normal	Low efficiency, short life time, small size.
6	Light Emited Diode	70 - 160	50.000	Good	High efficiency, long life, small lamp size, high light quality, dimming feature.

http://bestLEDtreetlights.com/uploads/WHY_BE_OFF_THE_GRID.com__LED_STREET_LIGHTING.pdf

According to the table above, LED lights, which were used in the past four years, have their advantages in terms of efficiency, age, and light quality, and have become the technology of choice for PJU. The results highlight that LED technology, combined with the dimming of light intensity, provides higher energy savings than other evaluated solutions. In Luxembourg city center, replacing all existing lamps with LED is beneficial financially already after the first year of deployment, while in other countries like China and USA economic returns will come after the second year of installation. (Cacciatore et al., 2017).

According to Shichao Chen, Gang Xiong, JiaXu, Shuangshuang Han, Fei-Yue Wang, Kun Wang in The Smart Street Lighting System Based on NB-IoT, the developed smart street lighting system is a typical application of the smart city. The intelligent operation and management of the street light are an effective means to realize a smart city. The single control and creative adjustment strategy of the street light by IoT technology can recognize the refined, intelligent, and visual management of the street light, which can achieve a good result in energy saving, efficient operation, and diversified services (Xu et al., 2018).

LED lights have three key benefits, namely: they can be controlled with high precision, dimmed rapidly, and adjusted continuously to create the visibility level and safety feeling required. Moreover, LED lights to provide high-quality light, less environmental damage, and lower long-term costs as its mentioned by Dolores MaríaLlidóEscrivá, Rafael Berlanga-Llavori and Joaquín Torres-Sospedra in Smart Outdoor Light Desktop Central Management System, Department of Software and Computer Systems and Institute of New Imaging Technologie, UniversitatJaume I, Castellón de la Plana, España.

The replacement of conventional lamps into LED on Public Street Lighting (PJU) in cities today is one of the efforts to save the cost of electricity usage of PJU. Akola City in India, with a population of around 400 thousand invested around US$ 120 thousand with a decrease in energy of approximately 2.1 million Kwh or a savings of about 56% a year or around US$ 133 thousand (Energy Sector Management Assistance Program (ESMAP), 2014)(Ingleby, 2012). From the report, the investment project only requires less than one year for the repayment period. Therefore, projects like this will be implemented in Maharashtra Province and Madya Pradesh. This success provides an option to explore carbon funding sources from the World Bank and the Government of India through the CDM (Clean Development Mechanism). Even though the project is an investment in public street lighting using only T5 lights and not yet LED lights that are more economical than the T5, it was cheaper than conventional lamps.

In the city of Ann Arbor, Michigan has also begun a pilot project for energy-efficient LED street lighting which was one of the first in the US, to be installed by the city center by cutting US$1.39 million to half its budget by replacing LED PJU lights. Meanwhile, in the city of San Antonio, Texas, the City Council has agreed to pay around US$ 14 million for the replacement of new LED PJU lamps and explained that this would save an equivalent of 5.1 megawatts over 15 years.

There are about 9.5 million public street lights installed in Germany where there are more than 11,000 cities, which consumes about 4 TWh of electricity per year. Street lighting costs around € 750 million per year, representing nearly one-third of the city's total energy costs. Pricing used varies from regular tariffs to reduced tariffs for lighting and per street lamp payments, depending on each city's governance structure. Cities in Germany usually impose strict budgetary constraints as this relates to the total city debt that reached € 133.6 billion in 2013 (Bennich, 2014). In Germany, potential savings when switching to energy-efficient lighting systems (mainly LED) are around € 400 million per year (Colhoun, 2018).In his employment contract, these ESCOs include offering control systems and energy information, energy audits, installation, operation and maintenance of equipment, competitive financing, and electricity and fuel usage (Sorrell, 2007).

The process of renewal in the use of new LED technology is often hampered by technological, institutional, competency, and economic factors. The following table shows these factors in more detail.

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Table 2

Factors That Influence The Government To Switch To LED Technology

No.	Factors Affecting Uptake of LED		Choice of Governance Model		Transaction Costs (TC)
a	Technological Factors	1	Measurement and verification of savings	1	Technical asset specificity and task complexity
		2	Lack of standardisation	2	Technical asset specificity and task complexity
		3	Short warranties	3	Technical asset specificity and task complexity
b	Competency and Capacity Factors	1	Cost transparency and neutral tenders	1	Human capital specificity and task complexity
		2	Open-book accounting	2	Human capital specificity
		3	Expert facilitators	3	Human capital specificity
c	Institutional Factors	1	Lock-in contracts with existing suppliers	1	Human capital specificity
		2	Risk transferral	2	Human capital specificity
		3	Transparency and flexibility of outsourcing procedure and contracts	3	Human capital specificity and task complexity
		4	Administrative approval procedure	4	Dedicated resources
		5	Low energy service market competitiveness	5	Competitiveness of the market
d	Economic/ Investment Factors	1	Volatile energy prices and uncertain technological development trajectories	1	Human capital specificity and task complexity
		2	Experience of current lighting system and providing maintenance	2	Dedicated resources
		3	EUCOs and MUCOs potentially selling and saving energy	3	Competitiveness of the market
		4	Financing environment	4	Competitiveness of the market

(Polzin et al., 2016)

For this transition process to take place better, the government needs facilitators, such as energy agents and consultants. This facilitator is required because they can accompany this process by giving constructive suggestions. On the other hand, the regulatory body oversees the city's finances and can even (not) approve the budget, especially when a city already has a substantial debt burden. Capital providers consist mainly of (state-owned) banks, such as the German KfW bank, which can finance as well as MUCO, EUCO, and ESCO.

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Germany has 4 EUCOs and around 900 MUCOs which supply energy (Hockenos, 2013). ESCO solutions get good acceptance from customers even though the market only reaches 10% of its potential. Polzin et al. (Polzin et al., 2016) identified ten companies offering ESCO lighting services to the city, which included subsidiaries from EUCO or infrastructure providers.

The case study of governance modes for LED street lighting for the public sector provides an excellent example because of the potential for high savings (LED modules are ten times more efficient than halogens for the same light output although overall system efficiency is lower due to losses incurred due to LED drivers and lamp configurations) and the capacity of the municipality to invest in the use of LED is limited (Bennich, 2014).

The benefits to the city government from not using an in-house approach for a more market-based solution include reducing energy costs, transferring risks, and avoiding more or fewer fluctuations in energy prices, which allows the city government to focus more on other core cities management activities. But the negative side is that with more market-based governance modes, it will reduce the city's ability to control and flexibility.

For savings, the initial budget is not more than € 300,000.00. Consists of 10 lighting subsystems, each of which can use 316 units of lighting. As an outcome of the decision design phase, several activities were identified: first replacing 150watt HPS (high-pressure sodium) lamps, second replacing 250w HPS lamps, and third installing energy-saving lamps.

Different ways of street lighting governance have arisen. Policymakers face four sources of choice, namely innovative solutions directly from home, procurement via relational contracts, long-term contracts, or performance contracts (Freeman & Williamson, 1987).In Germany, street lighting is provided from home by just 27 percent of cities. As much as 10 percent is entrusted (partially outsourced) by management to MUCOs (Municipal Utility Companies) through relational contracts, 35 percent is handed over to EUCOs (Energy Utility Company) through long-term contracts. Another 25 percent is handed over through outsourcing performance contracts, while 3 percent of the other municipalities in Germany use energy efficiency co-contracts (Colhoun, 2018).

In general, the use of LED lights has not been desirable to markets, especially among households, because the price is relatively high. However, the companies have used many types of LED lights because of the top savings and long-lasting so that it is widely used in factories, and current sales of LED type lights grow almost five times each year. If we can say that the municipal government as the same as companies/ factories, thus LED provides a particularly useful case study for applying TCE due to the nature of the underlying technology (its 'isolation,' economies of scale, and substantial

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energy savings). The case study of governance modes for public sector LED street lighting provides an excellent example as potential savings are high (LED modules are ten times more efficient than halogen for the same light output although the overall system efficiency is lower as losses occur due LED drivers and configuration of the lamp) (Modes of governance for municipal energy efficiency services-The case of LED street lighting in Germany, FriedemannPolzin, Paschen von Flotow, Colin Nolden).

It must be mentioned a different orientation of a small part of recent research studies that propose adaptive control light systems taking into account both the reduction of energy consumption and the associated impact of such schemes on the usefulness of the streetlight. The application of the proposed control strategy leads to significantly less power consumption (energy savings of more than 50%) (Events based Advanced Control Strategy for Urban Street Lighting Adina Astilean, CameliaAvram, Ramona Bolboaca, ValentinSita, Mihai Pop Automation Department Technical University of Cluj-Napoca Cluj-Napoca, Romania). Thus, this research goal is to measure the calculate and compare the extent of demand for electrical energy for PJU and electricity payment as well before and after being replaced with LED. Furthermore, the city revenue allocated initially to pay for electricity, due to the savings in electricity bills, then the budget can be assigned to finance other development. The indirect effect is the quality of people's lives can improve.

Giuseppe Cacciatore, Claudio Fiandino, DzmitryKliazovich, FabrizioGranelli, Pascal Bouvr, in Cost Analysis of Smart Lighting Solutions For Smart Cities IEEE ICC 2017 Green Communication System and Network Symposium mentioned that the replacement of conventional lamps to LED conduct multi-benefit to the municipal government, in addition to reducing energy consumption, it can also save electricity payments which are a burden on the government. Other than that. Replacing all existing lamps with LED and dimming light intensity in the absence of users in the vicinity of the lampposts is convenient and provides an economic return already after the first year of deployment. Moreover, intending to improve citizens' quality of life, significant research efforts are undertaken to give the citizens innovative and sustainable solutions for public services such as healthcare and well-being, safety, and smart transportation.

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2. Research Method

To find out the electricity consumption and to calculate which PJU provide high saving energy, this research uses a quantitative method with a formula from the National Electricity Company (PLN) as follows :

$$\mathbf{Ec = (w:pf) . (oh . dm)}$$

explanation :

- Ec = Electricity Consumption;
- W = Lamp Wattage;
- pf = Power Factor (12% or 0,8);
- oh = Operating Hours;
- dm = Number of Days in a Month.

Besides, research methods for evaluation can be divided into two categories: descriptive and causative. The evaluation analysis approach used in this study is a causal method, which is an approach that is more focused on analysis into impact assessment. This research aims to analyze whether the main program causes the primary outcomes or whether it is the leading cause of the effects.

The basis for this research methodology is an evaluation-based approach, called "Before-after Comparison," which means that this methodology refers only to one object and is the same as evaluating the object's condition before and after treatment. The method of study employed is mixed-quantitative. Work on mixed methods is a process that focuses on data collection and interpretation and the incorporation of qualitative and quantitative data. Based on this, this mixed method of research aims to find more mixed results.

There are many factors to be considered when developing procedures for mixed research methods, including time, weight, mixing and theorization, the effects of consideration of these aspects, the techniques used in diverse research methods are sequential explaining techniques as mentioned in the figure below.

The Sequential analytical technique is a technique that involves the collection and analysis of quantitative data in the first stage. The collection and analysis of qualitative data in the second stage (based on the early stage) followed. Priority weights appear to be in the first step, and the mixing phase between the two approaches happens when quantitative data collection is related to qualitative data gathering. Sequential methods of description are based

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upon such theoretical perspectives. Interpretation of all analyzes is achieved using an assessment approach to implementation.

Merriam (Troudi & Nunan, 1995) describes a qualitative case study as an intense, systematic definition and examination of a single individual, event, or social unit. Case studies are unusual, concise, and heuristic and rely heavily on inductive reasoning to manage multiple sources of data.

One reason the study employs a case study as the method is actually due to its strength. "The most common form of case study requires a detailed overview and examination of a particular topic from which the database is generated by observations, interviews, and histories" (Troudi & Nunan, 1995).

On the other hand, research methods for evaluation can be divided into two types, namely descriptive purposes and causative means. The evaluation research method used in this study is causal, a method that is more focused on research into impact assessment. This study tries to examine whether the main program causes the primary outcomes or whether the main program is the leading cause of the impact. The basis for this research approach is an evaluation-based approach, namely "Before vs. After Comparison," meaning that this approach applies only to one object which is the same as comparing the object's condition before and after the treatment.

A review of secondary analysis which uses qualitative and quantitative methods. According to Bryman(Bryman, 2012) "secondary analysis is the study of data by researchers who were not interested in the collection of such data for reasons which might not have been envisaged by those responsible for the collection of data" (p. 309). In other words, to address the research questions, this analysis was based on existing data and examined both qualitatively and quantitatively.

Other good reasons why this study considered both qualitative and quantitative methods relevant to the principles of "complementarity, completeness, growth, extension, corroboration/confirmation, compensation, and diversity" (Venkatesh, Brown, & Bala, 2013). Furthermore, quoted in Pluye, Gagnon, Griffiths, and Johnson-Lafleur(Pluye, Gagnon, Griffiths, & Johnson-Lafleur, 2009), affirms that using both quantitative and qualitative approaches has the "specific aim" of "gaining scope and depth of understanding, in particular, research studies" (p. 2), and hence such an approach is supposed to lead to detailed study results.

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However, in a research study, some argue against using both methods. Newby (2010), for example, views it merely as "an attempt by positivists to undermine the purity of qualitative research" (p. 126). Debates on integrating qualitative and quantitative approaches are often focused on fundamentally different paradigmatic theories (Venkatesh et al., 2013). Hence, there are two points of 'purist' views involved in combining two approaches in a research study. Nonetheless, purists are concerned not to combine the two methods as a sort of "threat to the advancement of science" (Onwuegbuzie & Leech, 2005).

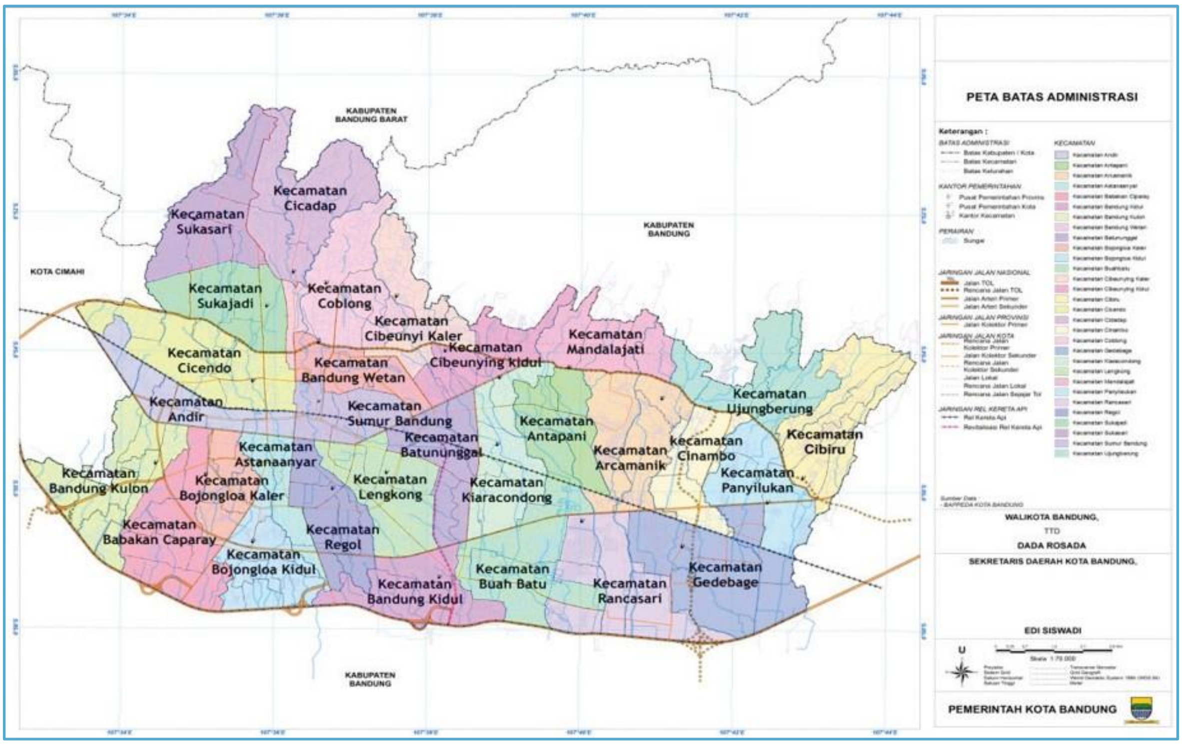
Therefore, as long as the proposed research design applies to the research application and in compliance with the data preparation, collection, and analysis, in addition to the research results, these debates may be overestimated as to which approach is better. It would be better if they focus on using both methods were to enhance a research study's quality rather than a further debate on which methods are the best paradigms in social research. This view is also consistent with the reasons this research used qualitative and quantitative data analysis.

3. Result and Discussions

a. The Study Area General Description

Administratively, Bandung City as the capital of West Java Province is bordered by several other regencies/ cities, in the north it is bordered by Bandung Regency and West Bandung Regency, in the west it is bordered by West Bandung Regency and Cimahi City, in the east it is bordered by Bandung Regency and in the south bordering Bandung Regency.

Figure 1
Maps of Bandung



Source : Regional Regulation of Bandung Municipality Number 6 Year 2006 Concerning The Provision and Establishment of District and Sub-district Areas in Bandung Municipality.

The area of the City of Bandung is based on the Regulations of the Regional Level II Bandung Region Number 10 of 1989 concerning Changes to the Regional Levels of the Bandung Level II Region which is a follow-up to the issuance of Government Regulation Number 16 of 1987 concerning the Amendment of the Regional Levels of the Level II Region of Bandung with the District Level II Region Bandung, is 16.729,65 Ha. This area is the latest change from the previous area, namely:

1. 1.922 Ha (Year 1906–1917);
2. 2.871 Ha (Year 1917–1942);
3. 5.413 Ha (Year1942–1949);

4. 8.098 Ha (Year 1949–1987).

Bandung City Region is divided into several administrative regions, consisting of:

1. 30Districts, headed by a chief called camat;
2. 151 Sub-district, headed by a chief called Lurah;
3. 1.584 Citizens Association (RW), headed by Neighborhood Chief;
4. 9.872NeighborhoodAssociation(RT), headed by Neighborhood Chairman.

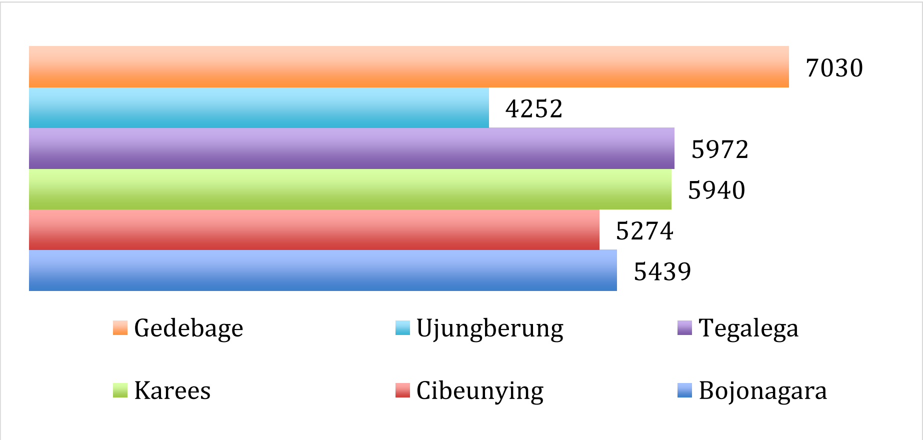
Topographically, the landscape of the city of Bandung is a basin surrounded by hills in the north and plains in the south, which lie at an altitude between 675 m-1.050 m above sea level (asl), where the highest point is in the northern area with an altitude of 1.050 m above sea level and the lowest point to the south with an altitude of 675 m asl

The population of Bandung City during the 2013-2017 period experienced a significant increase. In the year 2013, the population of Bandung City was 2.458.503 people, in 2017 it increased to 2.499.809 people, or an increase of 1.68% compared to 2013. In this case, the average population growth rate of Bandung City in 2013-2017 reached 0.42%.

b. PJU General Conditions in Bandung

A survey carried out in 2019 depicted that 33.907 PJU were installed in The City of Bandung spread over the 6 SWK namely Bojonagara, Cibeunying, Karees, Tegalega, Ujungberung, and Gedebage.

Figure 2
The Number of PJU in Bandung City 6 Sub-region Areas

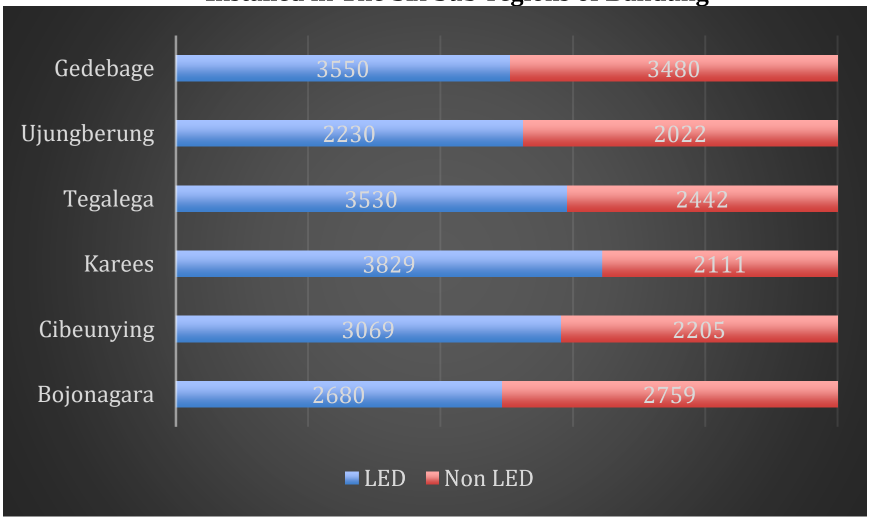


Source : Author’s computation based on *Bandung Municipality Public Works Agency Data 2019*

It can be seen from the chart *that Gedebage has the most PJU, which is 7.030 PJU, because Gedebage area is the residential area that has more road networks than the rest. While Ujungberung is the area with the fewest PJU lamps including as many as 4.252 lamps. Although Ujungberung, due to a lot of vacant land in the area, includes the residential area category and fewer roads compared to other regions.*

Some of these PJU's used LED lights, while others continue to use non-LED lights. The number of PJUs depending on the form of lamp and wattage in each area will appear in the figure below.

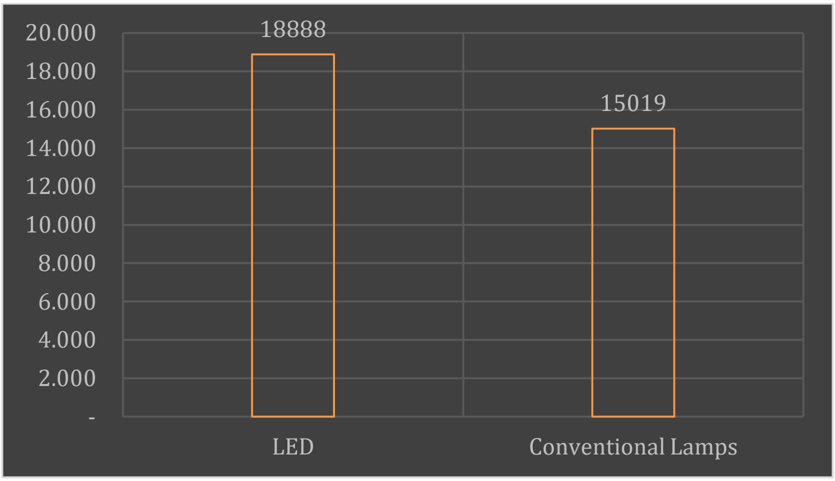
Figure 3
The Total Number of LED and Non-LED PJU Lamps Installed in The Six Sub-regions of Bandung



Source : Author's computation based on *Bandung Municipality Public Works Agency Data 2019*

According to the figure 3, the area with most installed PJU LED is Karees approximately 3,829 lamps, followed by Gedebage approximately 3,550 lamps, while Ujungberung is the smallest area with approximately 2,230 lamps and also the region with the fewest number of PJUs installed with LED PJU lamps slightly above 2,022 lamps as shown in the bar chart below. In comparison, the region with the most non-LED-installed PJU is Gedebage slightly below 3,500 lamps.

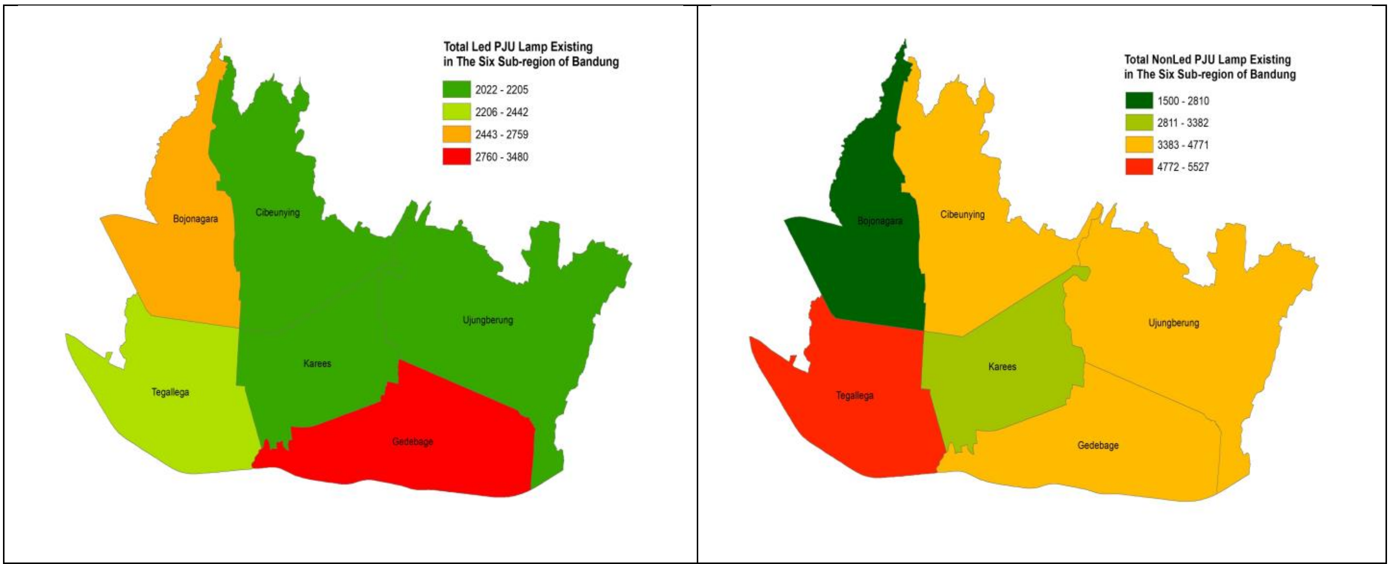
Figure 4
Comparison of the Number of LED PJU Lampswith Conventional PJU Lamps



Source : Author's computation based on *Bandung Municipality Public Works Agency Data 2019*

All in all, the total PJU LED that was installed is 18,888 lamps according to the pie chart above. It is 50 percent higher than conventional PJU lamps, whereas conventional PJU lamps are as high as 15,019. The distribution of lamps in each area and the estimation of electricity costs and energy usage per month as well as the scenario of saving the conversion of traditional lamps to LED will be further explained as below.

Figure 5
Maps of Existing LED PJU and Non LED PJU



LED PJU Existing in The Six Bandung Sub-region	Non-LED PJU Existing in The Six Bandung Sub-region

Source: Author's computation based on *Bandung Municipality Public Works Agency Data 2019.*

c. Recapitulation of Electrical Energy Consumption Comparisons Before and After The Replacement of The LED PJU

The following table summarizes the comparison of electrical energy consumption before and after conventional PJU lamps are replaced with LED PJU lamps in each SWK.

Table 3
Comparison of Electric Energy Consumption in Six SWK Bandung City

No.	Sub Region Area	Monthly Electricity Consumption			%
		Without LED (Kwh)	With LED (Kwh)	Subtraction (Kwh)	
1.	Bojonagara	232.253,55	142.438,80	89.814,75	38,67
2.	Cibeunying	232.354,92	151.853,71	80.501,21	34,65
3.	Karees	224.533,62	148.737,17	75.796,45	33,76
4.	Tegalega	256.973,88	168.380,43	88.593,45	34,48
5.	Ujungberung	197.457,60	125.372,27	72.085,33	36,51
6.	Gedebage	228.498,21	203.109,52	25.388,69	11,11
	Total	**1.372.071,78**	**939.891,89**	**432.179,89**	**31,50**
Total in a Year		**16.464.861,36**	**11.278.702,72**	**5.186.158,64**	**31,50**

Source:analysis results

Based on the table above, before all conventional lamps were replaced with LED, the most significant electricity consumption of PJU lamps was found in the Tegalega Region, which was 256.973,88 Kwh, while the lowest electricity consumption of PJU lamps was found in Ujungberung Region which was 197.457,60 Kwh. However, after the conventional PJU lamps were replaced into LED PJU lamps, the highest electricity cost was 203.109,52 Kwh found in the Gedebage Region, while Ujungberung was the region with the lowest PJU lamp electricity cost with electricity consumption of 125.372,27 Kwh.

The cost savings in electricity costs affect the consumption of electrical energy used by PJU lamps, and it can be seen in the table above that the consumption of electrical energy used for PJU lamps is lost by 31,50%. The following line chart shows which regions save the most significant electricity consumption and which saves the least electricity consumption.

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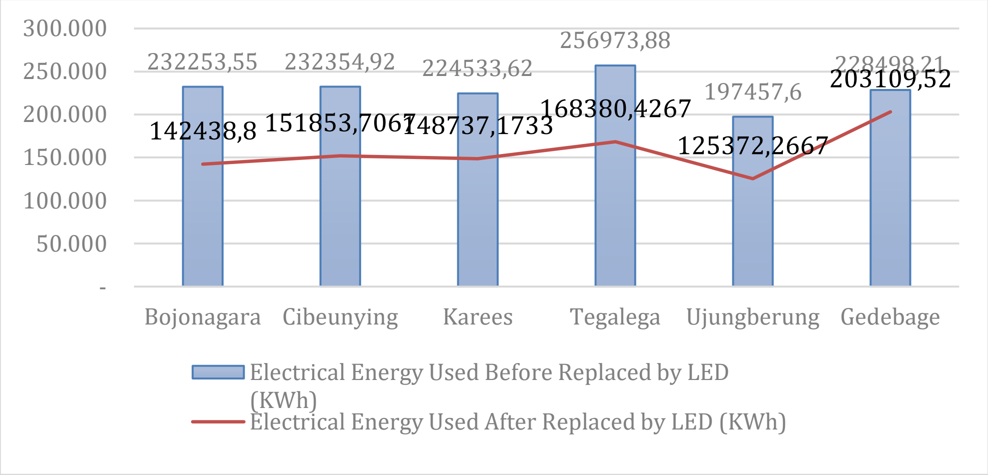
Figure 6
Comparison of Electricity Costs in Six SWK Bandung

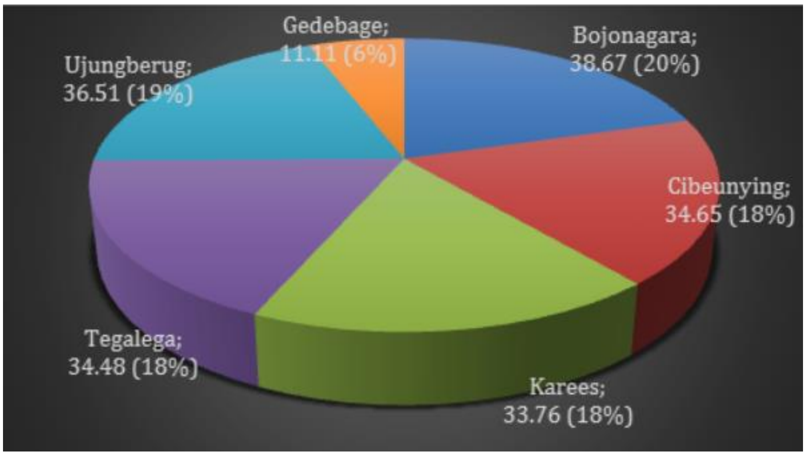


Source: analysis result.

Just as electricity cost savings decreased, the trend was also followed by the consumption of electricity used for PJU lamps. The highest decrease in electricity consumption was found in the Bojonegara Region, which dropped by 89.814,75 Kwh. While Gedebage is the region with the smallest reduction in electricity consumption, which is 25.388,69 Kwh. The following pie chart shows the proportion of reduction in electricity consumption for PJU lamps in six SWK.

Figure 7

Percentage of Comparison of Electric Energy Consumption in Six SWK Bandung City



Source: analysis result.

d. Recapitulation of Electricity Cost Comparisons Before and After The Replacement of The LED PJU.

A summary of the comparison of electricity costs before and after conventional PJU lamps are replaced with LED PJU lamps in each SWK can be seen in the table below.

Table 4

Comparison of Electricity Costs in Six SWK Bandung

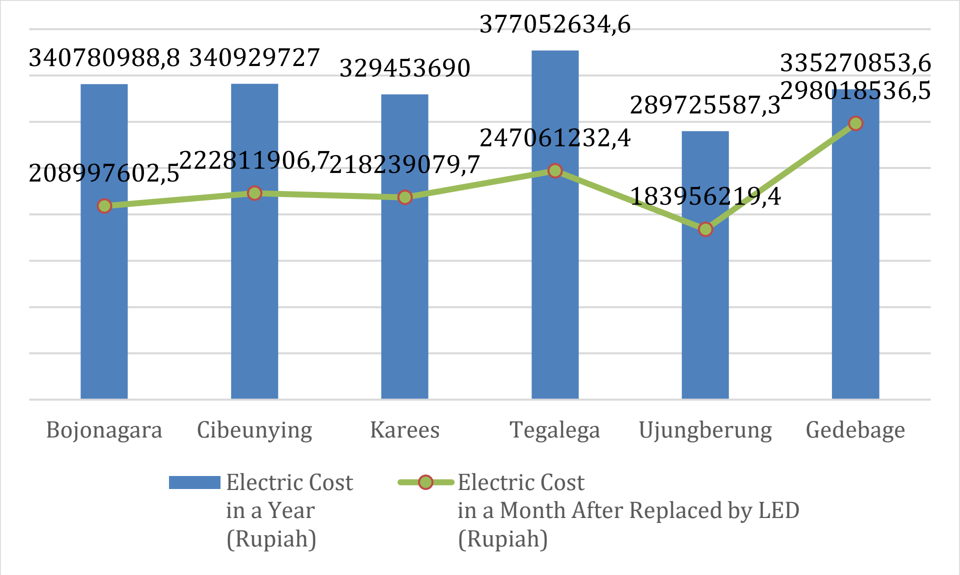
No.	Sub Region Area	Monthly Electricity Cost			%
		Without LED (Rupiah)	With LED (Rupiah)	Subtraction (Rupiah)	
1.	Bojonagara	340.780.988,84	208.997.602,46	131.783.386,38	38,67
2.	Cibeunying	340.929.727,02	222.811.906,72	118.117.820,30	34,65
3.	Karees	329.453.689,95	218.239.079,69	111.214.610,27	33,76
4.	Tegalega	377.052.634,65	247.061.232,44	129.991.402,21	34,48
5.	Ujungberung	289.725.587,33	183.956.219,43	105.769.367,89	36,51
6.	Gedebage	335.270.853,57	298.018.536,51	37.252.317,06	11,11
	Total	**2.013.213.481,36**	**1.379.084.577,25**	**634.128.904,11**	**31,50**
Total in a Year		**24.158.561.776,30**	**16.549.014.927,00**	**7.609.546.849,30**	**31,50**

Source : analysis results

As shown in the table above, before all conventional lamps were replaced with LED lights, the largest electricity cost for PJU lamps was found in the Tegalega Region, which is Rp. 377.052.634,65. While the lowest cost of electricity PJU lamps found in the Ujungberung Region is Rp. 183.956.219,43. However, after the conventional PJU lights were replaced into LED PJU lights, the highest electricity cost was in the Gedebage Region, which was Rp. 298.018.536,51. Conversely, the lowest electricity costs are Rp. 183.956.219,43 is the Ujungberung Region.

The savings in electricity costs, if conventional PJU lights are replaced with LED PJU lights in six SWKs in Bandung, is 31,50%. The line chart for the comparison of the electricity cost can be seen in the figure below.

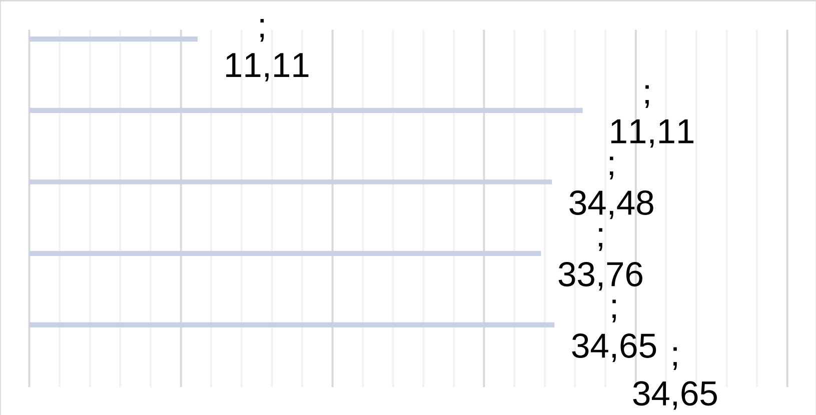
Figure 8
Comparison of Electricity Costs in Six SWK Bandung



Source: analysis result.

According to the line chart above, the largest electricity cost savings is in the Bojonegara Region by 38,67%. On the other hand, the lowest electricity cost savings of 11,11% is in the Gedebage Region. Comparison of the reduction in electricity costs in each region is shown in the figure below.

Figure 9
Comparison of Electricity Costs in Six SWK Bandung



Source: analysis result.

4. Conclusion

Bandung committed to participate in carrying out environmental development, and to contribute to the success of national programs and to reduce greenhouse gas emissions, through the implementation of energy-efficient PJU with LED lights, as well as the replacement of conventional lamps with LED lights. The effort of the City of Bandung to save PJU electricity costs and, at the same time, to reduce PJU electricity consumption can be through replacing conventional gas-based lamps with LED lights.

In calculation and comparison, the electricity consumption of LED PJU lamps is much lower than that of conventional PJU lamps. On the other hand, with the installation of LED PJU, it can also save electricity consumption. Since LED PJU has further technology such as dimming systems, electricity consumption able to be saved lower. The dimming system can be used at certain hours when traffic has decreased in density, and it can be categorized in the city of Bandung at 23:00 Western Indonesian Time to 05.00 Western Indonesian Time.

LED lighting is a combination of solid-state light sources, control gears for LED lighting operations, and optics for light distribution. The parts will influence the performance of LED lighting in terms of energy efficiency, color quality, life, and lumen maintenance. This affects the quality of the LED lighting itself. With lower electricity power, LED PJU lights are not inferior to conventional PJU lamps' lighting quality. For example, a traditional 150 Watt lamp can be replaced with a 70 Watt LED lamp which lighting quality is almost equal, even much better, so the replacement of conventional PJU lights to PJU LED lights does not reduce the function of the PJU itself as a means of safety, security and for the beauty of the city. In terms of performance, the durability of LED PJU lamps is more extended than conventional PJU lights, Bandung City Government, as the responsible PJU can also reduce maintenance costs.

Like the conventional PJU lamps, LED PJU lamps in this study require an Alternate Current (AC). Therefore, it is necessary to conduct a study comparing the performance and savings of AC-powered PJU lamps with Direct Current (DC) powered PJU lamps. The need for further research in other areas with the same method with the aim that the quality of PJU services is better, at the same time it provides saving electricity costs and reduce electricity consumption PJU in the area as well.

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