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Sustainable Low Carbon Urban Lighting Analysis: A Case Study of Bandung City

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Abstract. Nowadays, lighting technology is in the transition period from conventional lighting to LED, which more environmentally friendly due to free of harmful substances such as mercury, lead, or other hazardous chemicals and gases. This low light pollution because directional light is carefully distributed precisely to the intended location. Performance of the lights also brighter than other lights. This research measuring the reduction of CO_2 gas emissions before and after PJU (street lights) in Bandung is changed from the conventional to the LED, also mapping the CO_2 gas emissions in six Development Areas (SWK). The basis for this research approach is a case study with before and after comparison, meaning that this approach only applies to one object that is the same as comparing the condition of the object before and after the treatment. In this study, the evaluation research method used is a causal method, which is a method that is more directed at impact evaluation research. Scientifically and objectively, PJU LED provides low CO_2 emissions gas by up to 26 % in Bandung city.

Keywords: CO_2 emission, the light emitted diode (LED), street lights.

1 Introduction

Sustainable development in Indonesia is still not well implemented, even though it has become a development policy formulated and implemented by the government. It is evident from the environmental conditions in various regions in Indonesia not to improve, even worse. To pursue economic growth, it is often carried out by exploiting natural resources on a large scale and paying little attention to environmental impacts. Natural resources are still the main capital that is expected to be able to balance development needs in various sectors. However, the impact of such exploitation is the destruction of the environment and natural resources in Indonesia, further damage to the social life order as an effect of development that is not oriented towards sustainable development such as the increase of the poverty percentage, increasing unemployment and for the worst is low public health conditions. This condition is caused by the human perspective on its position in the ecosystem, which is derived from anthropocentric ethics, which rests on Cartesian logic.

One example of the sustainability indicators used in sustainable city development is presented in the table below. Norwich City Council first adopted this sustainability indicator in England in the 90s. The indicators used are the same as the various indicators built to evaluate the implementation of sustainable city development. The indicator is divided into three aspects, namely environmental protection, economic development, and social development.

Before the mid-18th century, the use of natural light such as the moon and the sun as the lighting was so dominating that it could almost be said of people living in darkness. The condition has changed since artificial lights began to be used in the mid-18th century. Since then, the supply of artificial lights has continued to revolution with the innovation of various equipment, fuel, infrastructure, and institutions that can meet the demand for more economical artificial lighting (Fouquet and Pearson, 2006).

At present, conventional lighting technologies (such as incandescent, fluorescent, and halogen) are beginning to be replaced by LED lighting (De Almeida, Santos, Bertoldi, and Quicheron, 2014; McKinsey, 2012). Energy efficiency and cost savings needed are the main causes of this shift. Everything is inseparable from the issue of global climate change and the implications of the depletion of fuel reserves in the world so that the price is increasing. Therefore, energy management becomes a very vital factor for the sustainability of the development and management of urban areas (Adamo, Cavone, Di Nisio, Lanzolla, and Spadavecchia, 2013).

Table 1 – Sustainability indicators of Norwich city, England

No.		Indicator		Benchmarks
a.	Environmental protection			
	1	Clean air	1	Number of days with good air quality
	2	Decreasing the amount of domestic waste	2	The amount of waste produced by each family head; the amount of recycled waste
	3	Save water	3	The number of cubic meters of water consumed by all users per year
	4	Energy saving	4	Energy (gas and electricity) consumed by households and industries per year
	5	Clean river	5	River water quality
	6	Increasing wild animal	6	Number of wild animals (birds)
	7	Protection of green open spaces	7	Increased green open space
	8	Neat road	8	The amount of garbage on the road
	9	Traffic mobility density	9	Number of private vehicle use, public transportation, bicycle and walking
	10	Road safety	10	The length of the road for pedestrians and bicycles
b.	Economy development			
	1	Decreasing the number of unemployed	1	Increased employment
	2	Increased skilled workers	2	Percentage of population in achieving training and education according to national targets
	3	Opening of jobs	3	Net increase in the number of jobs
	4	Regional capital for business	4	The number of large and medium-sized companies both regionally and nationally has a head office the this city
	5	Increased income from the tourism sector	5	Number of days of stay by visitors at the hotel

Continuation of Table 1

c.	Social development			
	1	Decreased poor population	1	Percentage of population living on the line or below the poverty line
	2	Reduced housing problems	2	The number of people who do not have a home, the number of people who need certain accommodations, people who live in crowded accommodation
	3	Increased community service	3	The number of residents who live close to the service center
	4	Increased community involvement in the democratic-process	4	Percentage of population that has elections right at the local level
	5	Increased sports facilities	5	Increased sports facilities
	6	The realization of a safe city	6	The level of criminal acts such as domestic violence, theft/robbery, violence outside the household
	7	Increased art and cultural facilities	7	The number of places to watch such as theaters
	8	Maintenance of heritage	8	The number of registered buildings, the number of open public museum.

Rosada, Dada. Implementation of Bandung City Development Policy: Perspective of Sustainable Development, Unpad, 2012(Rosada, 2012).

The use of LED for street lighting is one application that has begun to be widely used in several cities to meet the needs of better and more efficient public lighting systems. The main goal of street lighting is to provide comfortable, safe lighting services for motorists and pedestrians at night. However, in addition to providing economic benefits, the use of street lighting can also contribute to large CO_2 emissions (Radulovic, Skok, and Kirincic, 2011). Therefore, the technicians and urban planners continue to strive to get the right formula in building more efficient and energy-efficient street lighting systems, both in terms of energy savings, high-quality design, and in terms of maintenance (Sedziwy and Kotulski, 2016).

LED PJU lamp has low carbon gas when compared to conventional or gas-based PJU lamps (mercury and sodium). Thus, by replacing the gas-based PJU lights into LED PJU lights, the Bandung City Government also applies an environmentally friendly policy, so that the use of these LED lights also naturally supports the steps of the Bandung City Government as a Green Government. Which in turn, will be followed by other regions and make green government a new trend that should be developed in the area of West Java province and even throughout the country.

2 Literature Review

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

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. 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 depreciation 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, 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.

Table 2 – Description of each type of the lamps

No.	Lamp Type		Description
a.	High-pressure mercury vapor lamp	1	One of the most common types of lamp used in Europe
		2	Contains mercury and gives out white light
		3	Inexpensive to install and has a life span of 3 years
		4	Extremely energy in-efficient.
b.	Low-pressure sodium	1	Used in older street lighting systems in Northern Ireland
		2	Commonly used in the UK.
		3	Contains no mercury
		4	Life span of 3 years
		5	Energy efficient
		6	Unable to direct the lamps light, therefore energy wasted
		7	Light is not immediate – must be switched on earlier than needed
		8	Provides orange light which lowers the quality of light for the road user
c.	High-pressure sodium	1	Used in new lighting installations in Northern Ireland
		2	Very energy efficient
		3	Lifespan of 4 years
		4	Optically efficient but the light is not immediate
		5	Provide golden/pink light
		6	Provide reasonable color/rendering identification
d.	Metal Halide	1	Based on the latest technology in street lighting
		2	Very energy efficient
		3	Low mercury levels
		4	Longer lifespan so cost advantages achieved
		5	Provides high-quality white light
		6	Significant environmental achievements
e.	LED	1	Relatively new technology
		2	Extremely energy efficient
		3	Longer lifespan of about ten years
		4	Relatively high cost to implement
		5	Cost savings achieved through reduced labor and maintenance costs
		6	Able to direct light which reduces the energy needed and limits light pollution
		7	Instantaneous light
		8	Dimming capabilities
		9	Can produce a specific color

Research and Library Services Northern Ireland Assembly, (2009). Research Paper 30/09 12 March 2009(*Research and Library Services Northern Ireland Assembly*, 2009).

In terms of CO_2 emissions, a comparison between LED lights, incandescent lamps, and compact energy-saving lamps (CFL) can be seen in the table as presented below.

Table 3 – Comparison of the environmental impact of conventional and energy-saving lamps

Environmentally Effect	LED	Incandescent Lamps	CFL
Mercury contains	–	–	+
CO_2 emission (30 pieces in a year), pounds/year	451	4500	1051

Comparison Chart: LED Lights vs Incandescent Light Bulb vs CFL (1 pound = 0.45 kg).

The table depicts that LED lights emit the lowest CO_2 emissions between incandescent lights and CFL lights, which is only about 10 % of incandescent CO_2 emissions or 42 % of CFL lamp emissions. So it appears that CO_2 emissions from LED are the lowest. Likewise, if the ratio uses a level of 1.000 lumens, then the energy needed for LED lights is only 4 watts, while for incandescent lamps is 60 watts, and each emits CO_2 emissions of 2 kg per kW·h for LED lights and 60kg per kW·h.

In the year 2007, Yuan-Jaan Lee dan Ching Ming Huang researched Taipei, Taiwan, in the frame of Sustainable Index for Taipei City(Lee and Huang, 2007), while in 2008, C. Y. Jin dan Wendi Y. Chen Assessing The Ecosystem Service of Air Pollution Removal by Urban Trees in Guangzhou, China(Jim and Chen, 2008). Besides, in 2007 located in Shenzhen, China, Zhang Yan, and Yang Zhifeng did a case study about the eco-efficiency of urban material metabolism(Zhang and Yang, 2007). Furthermore, Government Intervention in City Development in China: A Tool of Land Supply was written by Li Tian and Wen-Jun Ma in the year 2008(Tian and Ma, 2009).

Moreover, in the same year, Kampeng Lei and Zhishi Wang wrote Municipal Waste and Their Solar Transformities: An Energy Synthesis for Macao(Kampeng Lei., 2008). In the year 2008, Charles Choguill studied about Developing Sustainable Neighborhoods, on the other hand, Hiroaki Furumai was writing Rainwater and Reclaimed Wastewater for Sustainable Urban Water Use in 2008(Choguill, L, 2008). Study about Risk, Resilience, and Environmentally Sustainable Cities was written by Jou Coaffe around 2008(Coaffe, 2008). Amin Ibrahim studied the Development Approach that is Comprehensively Supported by the National Model of Food Security in the Context of Enhancing Regional Resilience: Case Study Bekasi, West Java Province, Indonesia in the year 2002(Ibrahim, 2002).

Whereas the city of Los Angeles in the US with a population of 3.8 million invested 56.9 million USD with a reduction in energy per year and 1–5, it was estimated that 68.6 thousand kW·h (40 %) (Energy Sector Management Assistance Program (ESMAP) Annual Report, 2011). Based on the report, the Project began in 2009 to 2014 by replacing 140 thousand lamps from more than 209 thousand conventional public street lighting lamps with LED lights that strengthened the quality of public street lighting, reduced pollution, improved road safety, saved energy and finance (Energy Sector Management Assistance Program (ESMAP) Annual Report, 2011). The project funds consisted of a city loan of 40 million USD, 3.6 million USD from SMALF and US $ 13.2 million from LA Department of Water and Power rebates (Energy Sector Management Assistance Program (ESMAP) Annual Report, 2011).

In the city of Rotterdam, The Netherland also launched the use of energy-efficient LED PJU in the summer of 2007 and is expected to reduce CO_2 emissions by 50 % compared to 1990 levels with level 2025 (Infrasite Commercial News, 2012).

(Carli, Dotoli, and Cianci, 2017) have made a decision support system that can be used by public policymakers in selecting and determining changes in optimum energy use in street lighting systems in the city of Bari, South Italy. Regarding the general urban area street lighting system, which has several lighting units, an electric power distribution system, and a command and control system. Geographically, the lighting units are distributed to all urban areas, which are divided into ten lighting subsystems. Each of these subsystems covers a particular lighting zone, which is responsible for street lighting in each neighboring zone.

Most of the studies that have been done are more focused on optimizing the design of street lighting systems, which include looking for the best combination of various lighting parameters such as the height of the lighting unit, how many inclinations are, and the distance between lighting points (Rabaza et al., 2014).

Some studies have focused more on-road lighting management conducted at both the operational and strategic levels. Following are examples of studies that focus on the operational level, such as (Wu, Shi, Zhang, and Yang, 2010) who propose how the methods of time control, optical control, and the combination of control between time and optics when used simultaneously using a multi-sensor arrays system. (Pizzuti, Annunziato, and Moretti, 2013) offer a new approach to adapting street lighting control based on forecasts of energy needs and traffic flows.

In another case with (Ramadhani, Bakar, and Shafer, 2013), he and his colleagues suggested a combination of dynamic lighting control and road management for street lighting systems that have multiple renewable energy sources. Other studies that focus more on the strategic level, such as (Huang, 2012), directed his research on the benefits of using LED in street lighting. The results of a study conducted in Taiwan found that the use of LED instead of mercury lamps for street lighting resulted in savings of 50 % electricity and 80 % acceptance by the public.

In Seville (Southern Spain), (Burgos-Payan, M., Correa-Moreno, F., Riquelme-Santos, J., 2012) analyzed the potential savings benefits from outside lighting installations. They offer a more economical solution to correct installation inefficiencies by utilizing the combined services of the Energy Service Company. And the results show the potential for cost savings and simultaneously reducing CO_2 emissions. Similar research was conducted by (Radulovic et al., 2011) in the city of Rijeka, Croatia. He gets better results in terms of reducing CO_2 emissions, lighting pollution, and electricity consumption. The activities that support the proposed energy management decision-making process are ideally divided into two macro phases, namely: the first part is the acquisition of street lighting status or the identification of corrective measures, and the second phase is the actualization of decision making that results in the identification and the selection of optimal actions that are possible.

In summary, different from previous studies, this study calculates carbon gas produced from conventional PJU. Then, after conventional PJU is replaced with LED lights, the carbon gas is calculated. Thus the comparison can be known before, and after the installation of LED PJU, also figure out how low the carbon gas decreases. This research also displays visually to map out which areas have the highest carbon gas and which has the lowest carbon ga to compare carbon gas that appears in each area before and after conventional PJU is replaced into LED.

3 Research Methodology

To measure how much PJU lamps produce the carbon, this research uses a quantitative method with formula from Energy Sector GHG Emission Data Inventory of The Ministry of Energy and Mineral Resources of The Republic of Indonesia Data and Information Technology Centre (http://gatrik.esdm.go.id) (*Ministry of Energy and Mineral Resources of The Republic of Indonesia Data and Information Technology Centre*, n.d.) as follows :

$$ECO2 = ef.ep.ln.oh$$

where ECO2 – CO_2 emissions; ef – emission factor (Java-Madura-Bali is 0,891 kg $CO_2/(kW{\cdot}h)$); ep – electrical power; ln – number of lights; oh – Operating Hours (12 hours a day in one year).

Furthermore, evaluation research methods can be divided into two types, namely descriptive methods and causal methods. In this study, the evaluation research method used is a causal method, which is a method that is more directed at impact evaluation research. This study attempts to examine whether the main program causes the main outcomes or whether the main program is the main cause of the impact.

The basis for this research approach is an evaluation based approach, namely "Before vs. After Comparison", meaning that this approach only applies to one object that is the same as comparing the condition of the object before and after the treatment. The research method used is a mixed-quantitative method. Mixed method research is a method that focuses on collecting and analyzing data and integrating qualitative and quantitative data. Based on this, the purpose of this mixed research method is to find more integrated research results.

Several aspects need to be considered in designing procedures for mixed methods research, including time, weight, mixing and theorization, the results of consideration of these aspects, the techniques used in mixed research methods are sequential explanatory techniques as described in the figure below this.

The sequential explanatory technique is a technique that involves collecting and analyzing quantitative data in the first stage, then followed by the collection and analysis of qualitative data in the second stage based on the results of the first stage. Weight/ priority is more likely to be in the first stage, and the mixing process between the two methods occurs when quantitative data analysis is associated with qualitative data collection. Sequential explanatory techniques are implemented based on certain theoretical perspectives. Therefore, the interpretation of the whole analysis is carried out using an implementation evaluation approach.

A case study to be exact will employ a qualitative method (Merriam, 1988). Nunan (1992) defines a qualitative case study as an intensive, holistic description and analysis of a single entity, phenomenon, or social unit. Case studies are particularistic, descriptive, and heuristic and rely heavily on inductive reasoning in handling multiple data sources.

One reason why the study employs a case study as the method is because of its strength in reality. “The most common type of Case Study involves the detailed description and analysis of an individual subject, from whom observations, interviews, and histories provide the database” (Dobson et al. cited in Nunan, 1992).

On the other hand, evaluation research methods can be divided into two types, namely descriptive methods and causal methods. In this study, the evaluation research method used is a causal method, which is a method that is more directed at impact evaluation research. This study attempts to examine whether the main program causes the main outcomes or whether the main program is the main cause of the impact. The basis for this research approach is an evaluation based approach, namely “Before vs. After Comparison”, meaning that this approach only applies to one object that is the same as comparing the condition of the object before and after the treatment.

However, a secondary analysis study utilizing qualitative and quantitative methods. According to (Bryman, 2016), “secondary analysis is the analysis of data by researchers who have not been involved in the collection of those data, for purposes that may not have been envisaged by those responsible for the data collection” (p. 309). In other words, this study focused on existing data and analyzed it both qualitatively and quantitatively to answer the research questions.

One reason why this study employed secondary analysis utilizing both quantitative and qualitative methods was that the study proposed “questions that cannot be answered using a single method” (Bell, S. and

Morse, 2008). Other good reasons why both qualitative and quantitative methods were considered in this study related to the principals of “complementariness, completeness, development, expansion, corroboration/ confirmation, compensation, and diversity” (Venkatesh, Brown, and Bala, 2013). Moreover, John et al. (2007), cited in (Pluye, Gagnon, Griffiths, and Johnson-Lafleur, 2009) assert that using both quantitative and qualitative methods has the “broad purpose” of “gaining breadth and depth of understanding in particular research studies”. Such an approach is, therefore, expected to result in comprehensive research findings.

However, some argue against using both methods in a research study. For example, (Newby, 2010) sees it merely as “an attempt by positivists to undermine the purity of qualitative research” (p. 126). Debates concerning the combination of both qualitative and quantitative methods are often based on radically different paradigmatic assumptions (Venkatesh et al., 2013). Hence, it can be seen that, in combining two approaches in a research study, there are two points of ‘purist’ views involved. Nevertheless, the “purists’” concern not to ‘merge’ both approaches can be considered as a kind of “threat to the advancement of science” (Onwuegbuzie and Leech, 2005).

Thus, as long as the proposed research design is relevant to the research application and under the planning, collecting, and analysis of data, in addition to the research findings, such debates regarding which method is best may be overstated. In other words, it would be better if they focus on the use of both methods was on the enhancement of the quality of a research study rather than a further debate about which methods are the best paradigms in social research. This view is also in line with the considerations of why this study utilized both qualitative and quantitative data analysis.

4 Results and Discussion

4.1 The study area general description

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 that consists of diverse tribes and races. One of the most important regions in Indonesia is West Java Province, which is the biggest economic center in Indonesia after the capital city of Jakarta and has various advantages in all important aspects compared to other regions. Geographically, West Java Province is located directly adjacent to Jakarta, which means the West Java Province has an important role as a province that supports the capital. Not only in terms of urban infrastructure but also in supporting other development sectors such as supporting National Government Policies in reducing greenhouse emissions. West Java province has its capital in the city of Bandung, which is also the center of government and the economy of West Jawa. Especially, besides as the capital of the Province of West Jawa, Bandung City is a storefront city of West Java and the city of West Java community pride also as a benchmark for urban development in Indonesia.

Bandung City consists of two City Service Center, namely Alun-Alun and Gedebage. Alun-Alun has City Sub-region Areas, which are Cibeunying, Karees, Bojonegara, dan Tegalega. Meanwhile, the City Sub-region Areas of Gedebageare Arcamanik, Derwati, Kordon, dan Ujungberung.

Table 4 – Special functions of sub-region areas

No.	Sub-region Area	Special Functions
1	Bojonagara	Government, Education
2	Cibeunying	Education, Industry, Housing
3	Tegallega	Industry and Warehousing
4	Karees	Trading
5	Arcamanik	Housing
6	Ujungberung	Housing
7	Kordon	Housing
8	Gedebage	Housing

Source: Regional Spatial Planning of Bandung City 2011-2031(Bandung Municipal Government, 2012).

Due to the purposes of infrastructure development, which is the responsibility of The Bandung Municipality Public Works Agency, six sub-regions are remaining used, consisting of Cibeunying, Karees, Bojonegara, Tegalega, Ujungberung, and Gedebage. Also, Bandung city divided into 30 sub-district and also 151 Kelurahan (Urban Villages).

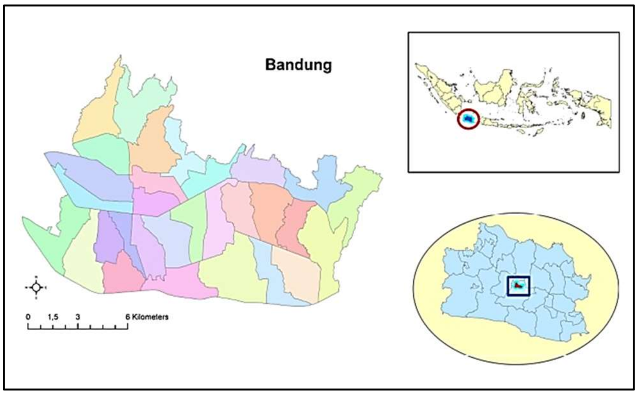


Figure 1 – Map of Bandung city: 6 sub-region areas

4.2 PJU general conditions in Bandung

Based on the results of a survey conducted in 2019, there have been 33.907 PJU built in The City of Bandung spread in the 6 SWK, namely Bojonagara, Cibeunying, Karees, Tegalega, Ujungberung, and Gedebage.

The bar chart above shows Gedebage has the most PJU, which is 7.030 PJU, due toGedebage area is the residential area which has more road networks than the other area and it followed by Tegalega and Karees in 5.972 PJU and 5.940 PJU, While Ujungberung is the area that has the fewest PJU lamps namely as many as 4.252lamps. Although Ujungberung include the residential area category, due to a lot of vacant land in the area, and fewer roads compared to other regions.

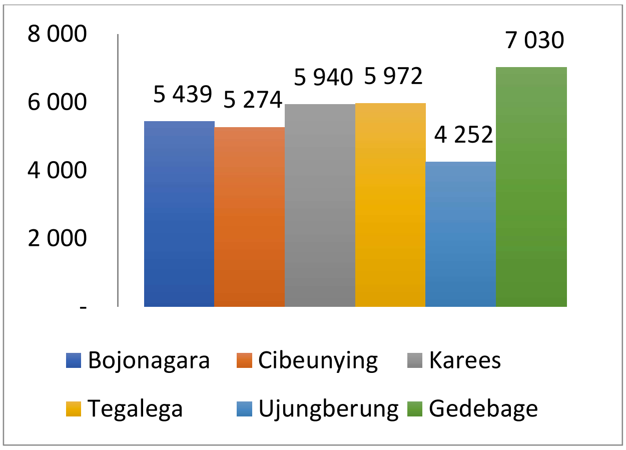


Figure 2 – The number of PJU in Bandung city:
6 Sub-region Areas

Some of these PJU have used LED lights, and some others still use non-LED lights. The number of PJU based on the type of lamp and wattage in each region will be displayed in the following figure.

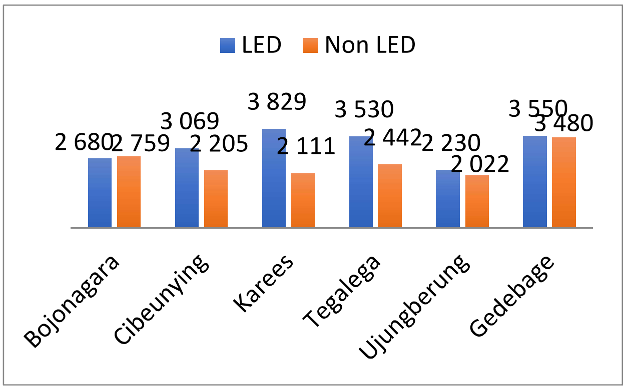


Figure 3 – PJU total number of LED and non-LED
in 6 sub-regions of Bandung

According to the bar chart, the area with the most PJU LED installed Karees approximately 3.829 lamps, followed by Gedebage around 3.550 lamps, while Ujungberung is the fewest area with about 2.230 lamps and also the area with the fewest number of PJUs installed with LED PJU lamps slightly above 2.022 lamps as it showed in the bar chart below. Furthermore, the area with the most PJU installed with non-LED is Gedebage, slightly below 3.500 lamps.

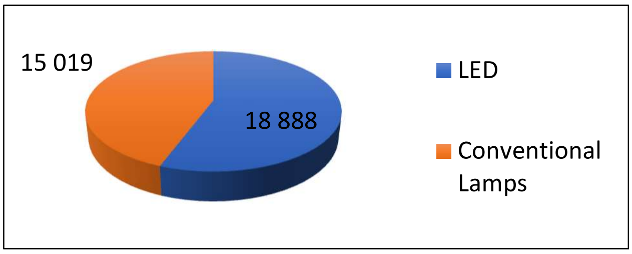
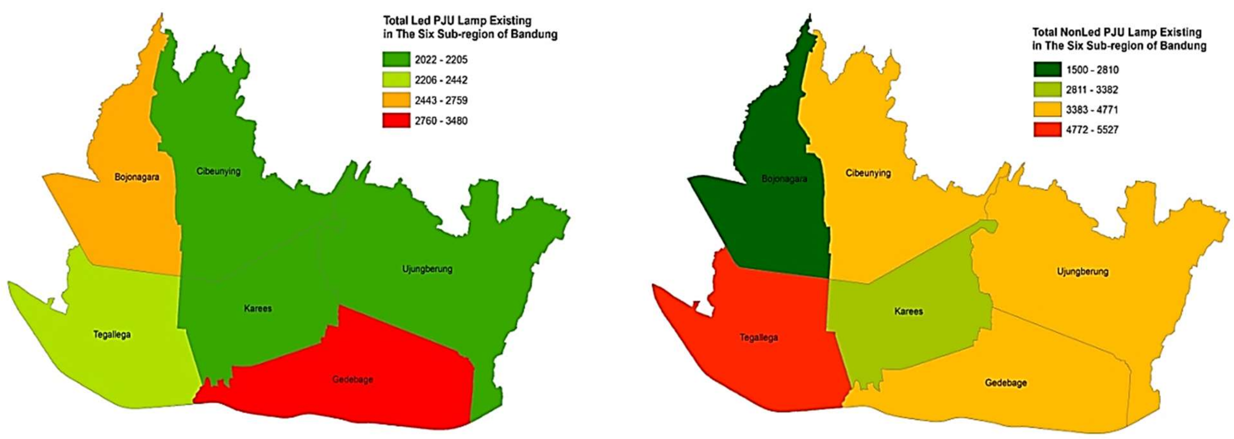


Figure 4 – Comparison of the number of LED PJU lamps
with conventional PJU lamps

Overall, according to the pie chart above, the total PJU LED that has been installed is18.888 lamps. It is 50 % more than conventional PJU lamps, while conventional PJU lamps as many as 15.019 lamps. The distribution of lamps in each region and the calculation of the electricity costs and energy consumption every month and the scenario of saving the conversion of conventional lamps to LED will be explained further as follows.



a b

Figure 5 – Maps of existing LED (a) and non-LED (b) PJU

4.3 Recapitulation of CO_2 emission comparisons before and after the replacement of the LED PJU

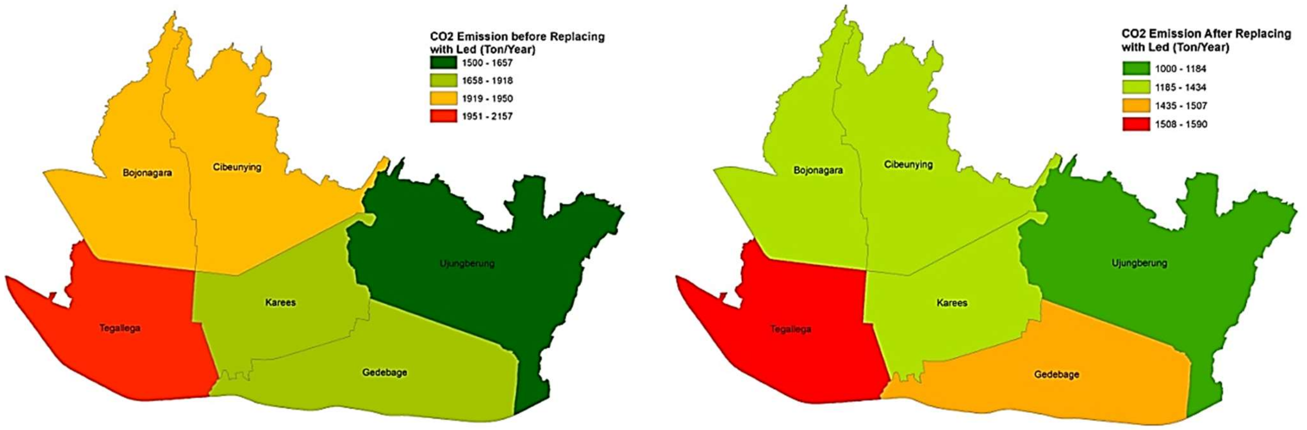
The following table contains the recapitulation of PJU lights that have been converted from conventional PJU lights to LED PJU lights in 6 SWK Bandung City.

Table 5 – Comparison of CO_2 gas emissions in 6 SWK Bandung city

No.	Sub-region area	CO_2 emission, ton/year			Percen-tage
		Without LED	With LED	Sub-traction	
1	Bojonagara	1.949	1.345	0.604	31.0
2	Cibeunying	1.950	1.434	0.516	26.5
3	Karees	1.884	1.404	0.480	25.5
4	Tegalega	2.157	1.590	0.567	26.3
5	Ujungberung	1.657	1.184	0.473	28.6
6	Gedebage	1.918	1.507	0.411	21.4
Total		11.515	8.463	3.052	26.5

Overall, in one year, CO_2 gas emissions of conventional PJU lamps before being replaced into LED PJU lamps were 11.51 tons. After conventional PJU lamps are converted into LED PJU lamps, the reduction in CO_2 emissions is 3.05 tons in one year, or a percentage of 26.5 %, so that the CO_2 gas emissions after conversion are 8.46 tons per year. The comparison of the decline in the six SWKs in Bandung is shown in the line chart as follows.

Based on the line chart above, before conventional PJU lamps were changed to LED PJU lights, the Tegalega Region was the region with the highest CO_2 gas emissions with CO_2 gas emissions of 2.157 tons in a year. It was followed by Cibeunying and Bojonagara region that reach 1.95 and 1.94 tons. At the same time, the region that has the lowest CO_2 gas emissions is the Ujungberung Region, with 1.657 tons in one year.



a b

Figure 6 – Maps of CO_2 gas emissions in 6 SWK Bandung city after (a) and before (b) LED CO_2 Emission

After the conventional PJU lights were converted to LED PJU lights, the Tegalega Region with 1.590 tons/year is still the highest area of its CO_2 gas emissions, in line with the Ujungberung Region which still has the lowest CO_2 gas emissions of 1.185 tons in one year. However, for each region in the city of Bandung has a reduction in gas emissions by more than 20 %. The region with the largest reduction in Co2 gas emissions is the Bojonegara Region by 31 %, which is the center of government and education in the city of Bandung because the government governs most of the management of lights. Followed by Ujung Berung, Cibeunying, and Tegalega. Meanwhile, as much as 21.4 % reduction in CO_2 gas emissions occurred in the Gedebage Region, which is the region with the lowest CO_2 gas emission reduction, as shown in the pie chart as follows.

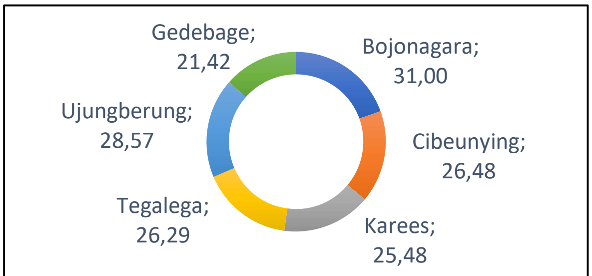


Figure 7 – Percentage of CO_2 gas emission reductions in 6 SWKs in Bandung

5 Conclusions

In this article, authors count PJU lights that have been installed in 6 SWK Bandung, both conventional PJU and LED PJU. After obtaining CO_2 emissions from the installed PJU, the author then perform the calculation by replacing all conventional PJU with PJU LED. Thus CO_2 emissions from all PJU LEDs are obtained, and then the results of these calculations are compared to be able to find out the extent of reducing PJU CO_2 emissions.

The calculation results depict that the PJU before and after being replaced with LED, CO_2 emissions decreased slightly above 26.5 % or approximately 3 tons in a year. Moreover, the author mapping the calculation into 6 SWK to find out which SWK has the highest and lowest CO_2 emissions. From the analysis of these calculations, the city of Bandung is committed to participating in carrying out environmental development and to contributing to the success of national programs and to reducing greenhouse gas emissions through the implementation of the replacement of conventional lamps with LED lights.

The scope of this article does not include the calculation of the energy consumption of PJU. Theoretically, due to the output of the low-power LED PJU is almost the same as conventional power PJU lamps with medium power, as well as the light output of medium-power LED PJU is almost the same as conventional high-power PJU as well, do not need to use the PJU with high power. By using PJU with low power, it will be consuming low electrical energy as well, and certainly will not reduce the quality of lighting at the same time.

Besides, the LED PJU able to provide the high saving electrical energy which can save the demand of energy for PJU, its need to conduct as a further study to measure how efficient the electricity consumption of PJU lamps is by comparing the LED PJU with conventional PJU. Same as the conventional PJU that LED PJU in this study requires 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 can save the calculation of electricity bill costs and can reduce electricity consumption PJU in the area. However, the authors hope this paper may be able to represent the general condition of Sustainable Low Carbon Urban Lighting Analysis in Bandung municipality; more work on this case is strongly recommended.

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