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Public Street Lighting Planning (PJU) Using New and Renewable Energy in Tanjung Gusta Village, Hamlet III, Sunggal District

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ABSTRACT

Indonesia has great potential in renewable energy, especially solar energy, due to its geographical location in the tropics. This research aims to plan an efficient and sustainable Public Street Lighting (PJU) system in Tanjung Gusta Village, Sunggal District, by utilizing new and renewable energy (NRE). Tanjung Gusta Village has a need for adequate street lighting to improve the safety, mobility, and quality of life of the community. The research method includes field surveys to analyze conditions, calculation of lighting needs based on applicable standards, and PJU system design using NRE. The results of the study show that the PJU system with solar power is the most suitable solution for Tanjung Gusta Village, taking into account the availability of resources. The planning of this solar PJU system includes the selection of the type of lamp to be used, determining the capacity of the solar panel and battery, and calculating the optimal layout and height of the light pole.

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1. INTRODUCTION

Electricity is a useful form of energy, one of the uses of electrical energy that is widely used is as lighting, where lighting electrical installations have various types of needs, namely for households, industry and public street lighting. Public street lighting is a lighting installation that is general in nature and is usually installed in street media, bridges and certain places such as parks and other public places. A good public street lighting installation must use existing standards and regulations so that the public street lighting installation can work properly according to its function and have a long service life. The study location located in an area with high intensity of sunlight throughout the year has great potential for the implementation of Solar Public Street Lighting (PJU-TS). The use of solar energy as an alternative resource is considered to be the right and sustainable solution to overcome the problem of electricity availability. With Indonesia's geographical conditions located on the equator and an average solar radiation level of 4.8 kWh/m²/day, this region has great potential for the development of solar-based PJU systems. However, in various areas, including the location of this study, the existing condition of PJU installations is still not optimal. At some points, the street lights malfunctioned, the safety guards were damaged, and the conductor cables were damaged due to lack of maintenance. This problem is exacerbated by limited access to electricity in certain areas as well as disruptions in the reliability of electricity supply from PLN, especially at night when peak loads increase. This research offers novelty by examining the implementation of the PJU-TS system based on local potential technically and economically in areas that have not been used as the object of similar research. The main focus of this study is how to design an efficient and sustainable solar PJU system according to the characteristics of the study area. In public street lighting installations that have been operating but are rarely maintained, problems will arise in public street lighting, including damaged lighting, safety guards that no longer work, and damaged conductors. The way to overcome this problem is that in the implementation of PJU construction, good planning is needed, so that the installation of lights has high efficiency, strong enough lighting and low operational costs [1].

Public lighting using solar power is a cheap and economical alternative to be used as a source of electric lighting because it uses a free and unlimited energy source from nature, namely solar energy. Solar PJU is an alternative to an environmentally friendly and efficient lighting system. This system utilizes free and unlimited available solar energy to generate electricity, thereby reducing dependence on PLN's power grid, which mostly still uses fossil energy such as coal. In addition, solar PJU is particularly suitable for remote areas that are difficult to reach by conventional power grids. The implementation of this technology can also reduce operational costs in the long run and support government programs in the clean energy transition.

Solar PJUs work by using solar panels made up of photovoltaic cells. Photovoltaic cells function to convert solar radiation energy into electrical energy through the photovoltaic process. The electrical energy generated is stored in the battery and used to power the LED lights at night. These systems generally have a panel life of up to 25 years and are equipped with an automatic control system that turns the lights on and off according to the ambient light intensity. The selection of solar PJU technology at the study site was based on very favorable geographical conditions, as well as the need for an independent and reliable lighting system. In addition, limited access to electricity and supply disruptions from PLN are the main reasons for the need for alternative solutions. Solar Street Lights (PJU Solar Energy) can be applied in various places, including: public roads, park lights, campus areas, residential environments, gas station areas, factory areas, tourist area lighting, dock lights, parking area lights, remote highway lights, rural street lights, sports field lights, mountainous areas, beach areas, bus stops, etc. Overall, the system is designed for the provision of public lighting with renewable energy sources. With a quick and easy installation system, Solar LED PJU can be a quick solution in overcoming the needs of public street lighting. Solar Street Lights (PJU Solar) use Solar Modules/Panels with a lifespan of up to 25 years which function to receive sunlight which is then converted into electricity through a photovoltaic process. Photovoltaics is a technology that functions to convert or convert solar radiation into electrical energy directly [2]. Indonesia is one of the countries that gets a surplus of sunlight throughout the year because of its geographical location on the equator [3]. Indonesia has good sun irradiation all year round and is located in the equatorial region. The equator is the central region that divides the earth into north and south. This position means that all regions of Indonesia have sunlight available most of the year, except in the rainy season and when thick clouds block the sun. Based on the solar radiation map, Indonesia has a solar potential of 4.8 kW/m2/day [4]. This is certainly a great potential that can be used to meet the needs of electrical energy by utilizing solar energy into power plants or commonly known as solar power plants [5]. Solar energy is one of the renewable energies that is unlimited and never runs out of availability. Solar energy as an alternative energy, can be converted into electrical energy by using solar panels. Solar panels are devices that are able to convert solar radiation into electrical energy [6]. In addition, the use of solar energy as the main source of electrical energy will reduce the electricity dependence of PLN's coal-dependent network [7].Careful planning is to create a street lighting system that aims to achieve an ideal public street lighting system. In addition, careful planning can also create the right lighting system so that there is no waste of energy or wasted energy [8].

Based on the description above, this study aims to carry out Public Street Lighting Planning (PJU) Using New and Renewable Energy in Tanjung Gusta Village, Hamlet III, Sunggal District.

2. METHOD

2.1. Research Location

In this study, the location will be taken in Tanjung Gusta Village, Dusun III, Sunggal District, Deli Serdang Regency, which has a track length of 300 meters with a road width of 5 meters. Highway lighting on Jalan Desa Tanjung Gusta Dusun III, Sunggal District, Deli Serdang Regency still uses sources from PLN or conventional street lighting.

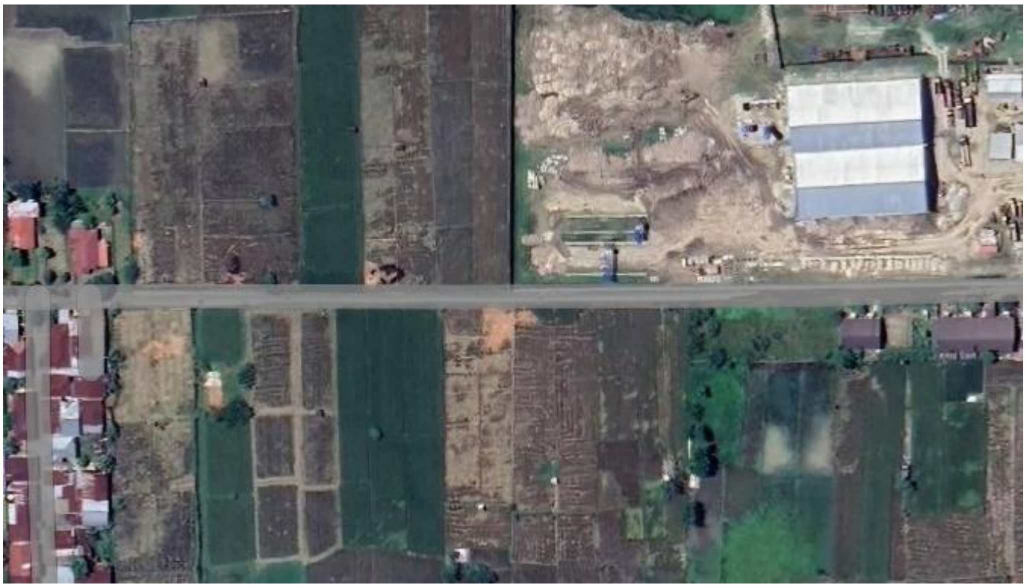

Figure 1 Research Location

Data Collection Techniques

1. Field Observations

Data collection with field observation aims to obtain accurate and in-depth information about the situation being studied.

2. Litelatur Studies

Data collection with literacy studies is used to collect data through pre-existing sources.

2.2. Data Analysis Techniques

This analysis technique is an observational analysis, with the calculation of existing formulas, and adjustments to the criteria of the applicable Indonesian National Standardization (SNI) listed in the PUIL (General Requirements for Electrical Installations).

2.3. Technical Data

The road used as a case study in the study was a road in Tanjung Gusta Village, Hamlet III, Sunggal District, Deli Serdang Regency. The condition of street lighting at night is not good due to uneven lighting.

Table 1 Road Technical Data

Information	Specifications
Street names	Tanjung Gusta Hamlet III. All Rights Reserved.
Length of the road	300m Road length
Width	5M
Number of columns	1 Lane
Road status	village
Road function	Collector
Street classes	Collector

2.4. Calculations to be discussed

The calculations to be discussed are the lighting system including light flux, lighting light intensity, determination of the angle of inclination of the pole arm on the lamp with the width of the road, solar shutter capacity, Battery Charge Regulator (BCR), battery and number of lighting points.

2.5. Calculation of the slope of the street lighting arm

Lighting lampposts are divided into three, namely single-arm light poles, double-arm light poles and armless light poles, light poles have different shapes, among which the commonly used ones are round in shape and octagonal.to determine the angle of inclination of the light pole arm so that the illumination point goes to the middle of the road, the formula used is:

$$t = \sqrt{h^2 + c^2} \tag{1}$$

so that:

$$\cos a = \frac{h}{t}$$

Where:
h = Pole Height
t = Light distance to the middle of the road
c = Horizontal distance of the lamp to the middle of the road
W1 = Pole to the end of the lamp
W2 = Horizontal distance of light to the end of the road

2.6. Light Flux (Φ)

Light flux is the total amount of light required per second of a light source.

$$\boldsymbol{\Phi = \omega . I} \tag{2}$$

Where:

$\boldsymbol{\Phi}$ $= Light\ Flux$

$\boldsymbol{\omega}$ $= Steradian\ Space\ Angle$

$\boldsymbol{I}$ $= light\ intensity$

2.7. Calculation of the number of light points

The number of light points can be known if we have determined the distance between the points of the lamppost. The formula used is.

$$T = \frac{L}{S} \tag{3}$$

T = Number of light points

L = Length of the road (m)

S = Distance from pole to pole (m)

2.8. Lighting Light Intensity

Light Intensity is the Flux of light per unit of the angle of space emitted in a certain direction.

$$I = \frac{\Phi}{\omega} . \omega = 4\pi \text{ With } K = \frac{\Phi}{p} . \Phi = KxP \tag{4}$$

So that:

$$I = \frac{k\ x\ p}{\omega}$$

Where:
Φ = Light Flux(lm)
W = Corner of Space (sr)
I = Light Intensity (cd)

3. RESULTS AND DISCUSSION

3.1. Determining what key components I will use

1. 60 Watt Lamp LED
2. Solar Cell 100 Wp 2 unit (Pollycrystalline)
3. Main pole (9 Meters high)
4. Flat Clamp
5. Armartur
6. BCR 5A
7. 2 units of 100Ah Battery

3.2. Calculation of the slope of the street light arm

PJU pole is an octagonal hot dip galvanized with base plate construction, where the ornaments used are single-armed. The foundation of the light pole is made of concrete construction. With an octagonal pole height of 9 meters (h), a decorative handlebar length of 2 meters and a horizontal distance of roadside lights (c) of 1.5 meters, the slope of the ornamental handlebar can be calculated with Pers.1 as follows:

$$t = \sqrt{h^2 + c^2}$$

$$t = \sqrt{9^2 + 1{,}5^2}$$

$$t = 9{,}124$$

After getting a t-value, to determine the slope of the ornamental handlebars use the following equation:

$$\cos\cos\theta = \frac{h}{t}$$

$$\cos\cos\theta = \frac{9}{9{,}124}$$

$$\theta = \cos^{-1}\frac{9}{9{,}124}$$

$$\theta = 9{,}60^{\circ}$$

3.3. Light Intensity Calculation

The magnitude of the light intensity on the candela (cd) with a 6000 Lumen LED lamp lumen is:

$$i = \frac{\varphi}{\omega}$$

$$i = \frac{6000}{4\pi}$$

$i = 477.70$ Cendela (cd)

3.4. Lighting Intensity Calculation

Light Intensity is the Flux of light per unit angle of space emitted in a specific direction. The luminous flux of the unit of the angular of the space emitted in a certain direction can be calculated using Pers.4 as follows:

$$E_{average} = \frac{\Phi . \eta . \mathrm{MF}}{w.s}$$

For the value $\eta = 0{,}35$ (SNI) and for its value MF = 0,7- 0,9 (SNI) middle value for value MF is 0.8 then obtained

$$E_{average} = \frac{\Phi . \eta . \mathrm{MF}}{w.s}$$

$$E_{average} = \frac{6000.0{,}35.0{,}8}{150}$$

$$E_{average} = 11{,}2\ Lux$$

To find out the illumination at the point/coordinate (P) equation is used:

$$E = \frac{1}{E^2} \cos\cos\phi$$

As a sample taken at the end of the road pavement with a value of h = 9m and W2 = 2m

$$r = \sqrt{h^2 + W^2}$$

$$r = \sqrt{9^2 + 2^2}$$

$$r = 9{,}21$$

Once the value of r is known, enter it into the equation to be

$$E = \frac{I}{r^2} \cos\cos\phi$$

$$E = \frac{477{,}70}{9{,}21^2}$$

$$E = 5{,}63\ Lux$$

So the illumination value at the point/coordinates of the road pavement is 5.27 Lux

3.5. Luminance Calculation

To calculate the illumination (L) on an LED lamp, an equation is used

$$L = \frac{I}{As}$$

With As = A cos θ, then to get the amount of illumination (L) on the LED lamp, i.e.

$$L = \frac{I}{As \cos\cos\theta}$$

$$L = \frac{477{,}70}{12^{\circ}}$$

$$L = 39{,}80$$

So the amount of illumination obtained for each LED light installed is 39.80 (cd/m2)

3.6. Efficacy *Calculation*

The light efficacy in lumens/watts in general street lighting designs can be calculated using the equation

$$K = \frac{\theta}{P}$$

$$K = \frac{6000}{60}$$

$$K = 100\ Lumen/watt$$

So that the light efficacy obtained in LED lights installed on each street lighting pole is 100 Lumens/watt

3.7. Calculate the number of light points to be installed

The distance between the light pole points used is 30 meters where the distance is used because the lighting of 60 Watt LED lamps is equivalent to the 120 Watt SON lamp in SNI 2008, so that the number of light pole points needed can be calculated with Pers.3 as follows:

$$T = \frac{L}{S}$$

Tanjung Gusta Village, Hamlet III, Sunggal District, Deliserdang Regency with a road length of 300m and a road width of 5m, with a distance between the poles of 30m, then

$$T = \frac{300}{30}$$

$$T = 10\ Titik$$

So that many light points are used in Tanjung Gusta Village, Dusun III, Sunggal District, Deliserdang Regency, namely as many as 10 light points.

Table 2 Lighting Calculation

Light Flux (Im)	Light Intensity (cd)	illumination (lux)	Lighting (cd/m2)
6000	477.70	11.2	1.16
10000	796.17	18.92	1.93
12000	955.41	22.70	2.32

From the results of the above calculations, it shows that the Light Intensity strength of 60 Watt LED Lamps is 477.70 and 60 Watt LED Lighting is 11.3 lux and 60 Watt LED Lamp Lighting is 1.16 Based (SNI 2008) for secondary street lighting power is 11-20 lux, therefore in this planning lighting lamps are used 60 Watt LED lamps as per SNI 2008.

3.8. Calculation of solar specifications

Calculation of energy needs In this study, the amount of power used is 60 Watts. The load in question is a light load that is usually used for 12 hours a day, but in anticipation in accordance with the regulations of the transportation office that reserves solar energy is for 3 days, meaning for 36 hours of use. then the energy needs are

$$E_T = P_L x\ t$$
$$E_T = 60x36 \lesssim Jam$$
$$E_T = 2{,}160\ Watt$$

3.9. Solar Module Capacity

The determination of the power capacity of the solar panel is taken based on the price of the lowest solar insulation. Based on solar insolation data, the lowest price of solar insolation is 4.31 kWh/m2/day. Then the capacity of the solar panel is

Panel Capacity = $\frac{E_T}{Isolasi}\ x\ 1{,}1$
Panel Capacity = $\frac{2{,}160}{4{,}31}\ x\ 1{,}1$
Total Capacity Panel = 551.2 wp

The solar module that will be used is a solar module with a capacity of 100Wp. Assuming 3 hours of solar irradiation, the energy generated by the solar panels is.

Emodule = Pmodule *x multiplier factor*

$Emodul$ = 100 $Wp\ x$ 3 h

Emodul = 300 Wh

3.10. Calculation of the Number of Solar Panels

With a module capacity of 100 Wp and an irradiation time of 3 hours, energy is generated by 300 Wh. The number of solar panels needed on one lighting pole is

$$\sum Modul = \frac{E_T}{E_{Module}}$$

$$\sum Modul = \frac{551{,}2wp}{300Wh}$$

$$\sum Modul = 1{,}83\ \approx 2\ \text{Unit}$$

So that many panels are used in Tanjung Gusta Village, Dusun III, Sunggal District, Deliserdang Regency, namely as many as 2 Solar Panel Units on each light pole.

3.11. Battery Calculation

The number of batteries and the capacity of the batteries used must be able to accommodate the total energy required. The unit of battery capacity is Ah, while the unit of energy is Wh, so determining the capacity of the battery must be divided by the system voltage

$$I_{Ah} = \frac{E_T}{V_S}$$
$$I_{Ah} = \frac{2{,}160}{12}$$
$$I_{Ah} = 180Ah$$

3.12. DOD calculations

Considering the DOD (depth of discharge) factor, the required battery capacity is

$$I_{Ah}Total = \frac{I_{Ah}}{DOD}$$
$$I_{Ah}Total = \frac{180}{80\%}$$
$$I_{Ah}Total = 144\ Ah$$

3.13. Calculation of the number of batteries

If you use a 180Ah, 12V capacity battery, then the number of batteries needed for one public street lighting pole is

$$\sum Battery = \frac{I_{Ah}Total}{Battery\ Capacity\ Pernit}$$
$$\sum Battry = \frac{180}{100}$$
$$\sum Battery = 1{,}8 \approx 2\ \text{Unit}$$

So that many batteries are used in Tanjung Gusta Village, Dusun III, Sunggal District, Deliserdang Regency, namely 2 units of batteries on each light pole with a capacity of 100Ah each.

3.14. BCR Calculation

The Battery Charge Regulator (BCR) serves as a central point that connects the load, solar panels, and batteries. Then the maximum current in the battery is

$$I_{BCR}Total = \frac{P_{Total}}{V_S}$$
$$I_{BCR}Total = \frac{60}{12}$$
$$I_{BCR}Total = 5A$$

The following are the results of the design and the Indonesian National Standard (SNI)

Table 3 Comparison of SNI Result Design

Parameter	Account	SNI
average E	6,72 lux	3-7 lux
E min	3,59 lux	3 lux
average L	1,95 cd/m2	1,00 cd/m2
Pemerataan	0,469	0,14
L maks	1,98 cd/m2	-
L min	0,96 cd/m2	-
VD	0,484	0,40
VI	0,50	0,50

4. CONCLUSION

This study shows that the solar-based street lighting system applied in Tanjung Gusta Dusun III Village, Sunggal District, Deliserdang Regency has been designed in accordance with the SNI standard for Public Street Lighting (PJU). With the use of two units of solar panels with a capacity of 100 Wp on each pole and two units of batteries with a capacity of 100 Ah, this lighting system is able to operate for 36 hours in three days with a duration of 12 hours per day.

The technical design of the system includes a lamp arm tilt angle of 9.60 degrees, a light intensity of 477.70 cd, a lighting intensity of 5.63 lux, and a luminance of 39.80 cd/m². Light efficacy reaches 100 lumens/watt, which indicates high efficiency in energy use.

With a total of 10 light points installed, the required solar power requirement reaches 2,160 watts. The number of solar panels used is in accordance with the calculation of energy needs, namely two units of panels on each pole, as well as two batteries with a capacity of 100 Ah per pole. In addition, the use of BCR of 5A ensures optimal system performance.

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