The Design of Solar Cell-Based Street Lighting for School Area

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ABSTRACT

Currently, public street lighting using Solar-based Public Street Lighting has been widely used. Solar-based Public Street Lighting is an off-grid Solar Power Plant application for street lighting. This study aims to use Solar-based Public Street Lighting which has been designed for Inayah Islamic School according to the geographical features of the school. To design this Solar-based Public Street Lighting by considering the economic aspect. From the data obtained directly at the location, the road width is 4.5 meters and the total length is 330 meters. Road size is used to determine the need for lighting quality according to the Indonesian National Standard of 7391:2008. This Solar-based Public Street Lighting has been designed with a pole height of 5 meters and a 1.5-meter pole arm using a 20 Watt 2-in-1 LED lamp and a solar cell capacity of 50 Wp per pole. From the results of the design analysis, the component specifications used in the design have met the requirements according to SNI of 7391:2008, and the required poles for Solar-based Public Street Lighting are 22 points for the Inayah Islamic School Complex area

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1. INTRODUCTION

Inayah Islamic School plans to build Solar-based Public Street Lighting on the road of the school complex. Solar-based Public Street Lighting is an off-grid solar power generation application for street or regional lighting using batteries charged from sunlight as an energy source. Solar-based Public Street Lighting lamps are designed to stay on for 12 hours daily. The general rule of lighting is that too much light will not be better. Vision does not get better only with the amount or quantity of light but also with its quality, which is determined by the level of light reflection and the level of exposure ratio. This research examines the design of artificial lighting in terms of saving electricity on the Inayah Islamic School Complex Road. Street lighting must meet the SNI 7391:2008 [1] standard which discusses street lighting specifications because it aims to achieve uniformity in street lighting planning, especially street lighting in an area. With a road size that is not as big as a highway, economic calculations will be one of the references in this study. Thus, street lighting that can provide safety, comfort, and convenience for road users can be planned and provided.

This research is conducted on how to design street lighting that the solar power plant supplies. The type of road according to field data is a type of local road based on The National Standardization Agency SNI 7391:2008 which is related to the topic of Street Lighting Specifications in Urban Areas. This standard has provisions regarding lighting on various forms and sections of roads in urban areas that

have arterial, collector, and local road function classifications. The specifications referred to in this standard include function, type, size, installation, and placement/arrangement of street lighting as needed. Nurochim [2] in his writings related to Solar-based Public Street Lighting Planning for the Kendal sea road and its budget and in Pangkalpinang [3], in addition to using solar power in energy savings, and the cost of LED-type lights. Energy-efficient LED lamps are used in street lighting for better lumens per watt or efficacy. Thus, street lighting that uses LEDs requires less energy to illuminate an area. Therefore, this study will use the previous research as a reference in designing street lighting with energy and cost savings. The design of the lighting system on the road by taking a case study at the Inayah Islamic School Complex.

1.1. Lighting

Lighting is needed for humans to see an object, and inappropriate lighting will affect eye fatigue and nervous tension. To get the ideal lighting quality, the recommended lighting strength standard is set. The pole is part of Solar-based Public Street Lighting which is used to support the lights. Figure 1 is used to simplify calculations in the design and placement of lights for public road lighting so that the lighting angle can be calculated according to CIE 180:2007 [4,5] and SNI 7391:2008 [1] standards.
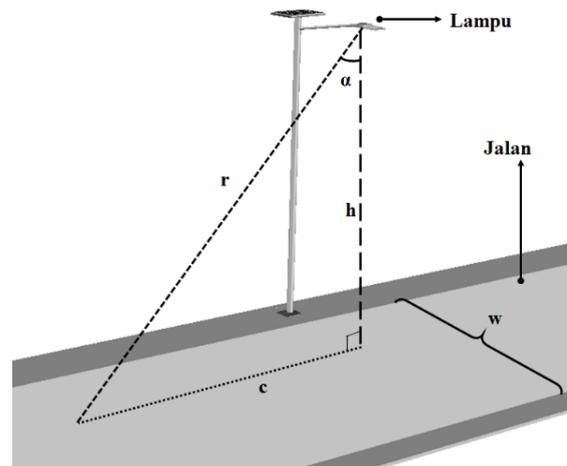

Figure 1. Determining lighting on the street size

Actual distance from the lamps to the middle of the road (r) can be obtained by Pythagoras theorem [6].

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

And to find out the angle α can be obtained with trigonometry ratios.

$$cos\ cos\ \alpha = \frac{h}{r} \tag{2}$$

Luminous flux is the amount of power of light emitted by a light source per second. Luminous flux is denoted by ϕ_v with units of lumens (lm). Luminance is the light intensity emitted or reflected on a surface area, symbolized by L_v with Candela per meter squared (Cd/m^2). Illumination (E_v) is the level of illumination on a surface expressed in lux or lm/m^2. The lighting level can be determined by CIE 115:2010 [9] and SNI 7391:2008 standards [1]. Table 1 shows the standard for lighting quality based on the type of road according to SNI 7391:2008 [1].

Table 1. Lighting level based on road type

Road Type or Classification	Average E_v (lux)
Local Street	2-5
Collector Street	3-7
Arterial Street	11-20

Source: SNI 7391 [1]

According to Lambert's law, Illumination (E_v) is related to the intensity of light (I_v) that is emitted in a direction with an angle of incidence (α) and is inversely proportional to the square of the distance traveled by the light (r) [7].

$$E_v \; = \; \frac{I_v}{r^2} \cos \cos \alpha \tag{3}$$

Efficacy (η_v) is the amount of flux produced by a lamp for every watt of electrical power used, with units of lumens per Watt (lm/W). Efficacy is closely related to the wavelength radiated by the lamp. LED efficacy continues to increase, and white LED sources have an efficacy approaching 100 lumens/Watt [4].

$$\eta_v \; = \; \frac{\phi_v}{P} \tag{4}$$

Light intensity (I_v) is the flux radiated in a certain direction in a space angle (Ω). The intensity of light in lumens per steradian is called candela (cd).

$$I_v \; = \; \frac{\phi_v}{\Omega} \tag{5}$$

Figure 2 shows the shape of the space angle (Ω). Steradian (sr) is the unit of space or solid angle from the midpoint of the ball between the radii, expressed by the surface area of the ball which is determined per the square of the radius [8].
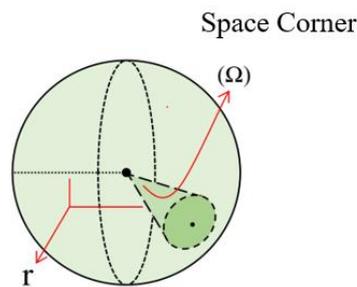

Figure 2. Space angle (Ω)

Space angle equation:

$$\Omega \; = \; 4 \, \pi \tag{6}$$

1.2. Solar-based Public Street Lighting

Solar-based Public Street Lighting is the application of a solar power generation system as a generator of electricity to supply lights that illuminate the street. Based on the origin of the source, a solar power generation system is divided into two types. They are On-Grid and Off-Grid. Grid solar power generation system is a Solar-based Public Street Lighting that not only uses solar cells as a source of electric power to supply loads, but this type of solar power generation system is also generally connected to a source from PLN and a Generator Set (GenSet) as another source of electric power. In contrast to the On-Grid type, Off Grid solar power generation system only uses solar cells as the sole source of electric power to supply loads. Components of Solar-based Public Street Lighting are divided into several parts: the generator system, load section, and supporting equipment. The generating system includes solar cells, solar charge controllers, and batteries. The loading tool is the lamp. The supporting tools include poles, conductor cables, and panel boxes. There are several types of lamps used in lighting systems, namely incandescent lamps, halogen lamps, fluorescent lamps, mercury lamps, sodium lamps, and Light-Emitting Diode (LED) lamps. LED is a type of semiconductor diode that can emit light energy when given an electric voltage. By consuming less electrical energy, LEDs can produce light that has 60-100 lm/W. The battery is one of the PLTS components whose function is to store electricity generated from solar cells during the day. To determine the battery capacity to be used, first know the amount of energy used by the load in a day.

$$Electric \; Power \; = \; P \; \times \; usage \; time \; (jam) per-day \tag{7}$$

Where P is the load power. Load reserves in Watt-hour units are converted to Ampere-hours (Ah) expressed in [10].

$$Ah = \frac{Electric\ Energy}{V} \tag{8}$$

Batteries have a maximum usage limit for battery capacity or Depth of Discharge (DoD). The day unit for storing and distributing energy to loads is generally determined as one day. Calculation of the required battery capacity is shown in the equation: [2].

$$Battery\ Capacity = \frac{Ah \times Day}{DoD} \tag{9}$$

or

$$Battery\ Capacity = \frac{Electric\ Energy \times Day}{V \times DoD} \tag{10}$$

Solar cells are devices that can convert sunlight into electricity. Solar cells generally take a maximum of about 5 hours to convert sunlight into electrical energy in a day. Electrical energy will be stored in batteries that are obtained from morning to evening so that electricity can be used whenever it is needed. The time equation needed for the module to get global light accurately is symbolized by t_{modul} as follows [6].

$$t_{modul} = \frac{GTI_{opta}}{G_{STC}} \tag{11}$$

Thus the size of the required solar panel module capacity (Wp) can be found by the equation:

$$Module\ Capacity = \frac{Energy\ Needed}{t_{modul}} \tag{12}$$

Solar panels, based on the type of material, are generally divided into three types: polycrystalline, monocrystalline, and thin film solar cells [11]. Solar Charge Controller (SCC) is an electronic device that is used as a charge regulator to limit the current and voltage flowing into the battery. SCC is used to prevent the battery from overcharging.

2. RESEARCH METHOD

This research method describes the initial stages carried out in research. In this research, a Solar-Based Public Lighting device is designed for Powered Public Street Lighting. At the research location, which is on the Inayah Islamic School complex, there was no street lighting, so the only data obtained were in the form of road size at the research location. Table 2 summarizes the measured road sizes at the study locations.

Table 2. Road size data

Part of the Street	Street Width	Street Length
Entrance	4.5 m	100 m
Inside Road	4.5 m	130 m
Exit Road	4.5 m	100 m

In designing Solar-Based Public Lighting, it uses an Off-Grid solar power plant system so that Solar-Based Public Lighting uses a DC electricity system and does not need to use an inverter. Street lighting is designed using Solar-Based Public Lighting type 2-in-1, this type has several advantages over the other two types of public lighting; unlike conventional Solar-Based Public Lighting which requires a panel box to store SCC and batteries, tilt solar cells can be adjusted freely without being affected by the tilt of the lamp, unlike the Solar-Based Public Lighting AIO. The specifications consist of a pole height of 5 m and a pole length of 1.5 m, a 2 in 1 20 W LED lamp, and a 50 Wp solar cell. The type of lamp to be used is a 2-in-1 LED lamp. The 2-in-1 LED lamp is integrated with the controller and battery

in the lamp housing. The lamp model proposed in the design with AutoCAD software, with power from a 20 Watt lamp with a battery capacity of 32 Ah and a battery voltage of 3.2 V as shown in Table 3.

Table 3. The specification of LED light 2-*in*-1

Explanation	Specification
Power	20 W
Battery Voltage	3.2 V
Battery Capacity	32 Ah

The type of solar cell that will be used in the design is a polycrystalline solar cell. This type is suitable for consumption needs that are not too large. Figure 4 shows the design of a polycrystalline solar panel using AutoCAD software. The image design was based on an online shop. The module power is 50 Wp with a maximum voltage of 18 V and a maximum current of 3 A. Table 4 summarizes the specifications of the solar panels used in the design of Solar-Based Public Lighting.

Table 4. Solar panel specifications

Explanation	Specification
Module Capacity	50 Wp
Peak Force (V_m)	18 V
Peak Current (I_m)	3 A

The lamp is directly connected to the solar cell because the battery and controller are already available in the lamp housing. The positive pin of the solar cell is connected to the positive SCC pin, and the negative pin of the solar cell is connected to the negative SCC pin as shown in the electrical system circuit in Figure 3.
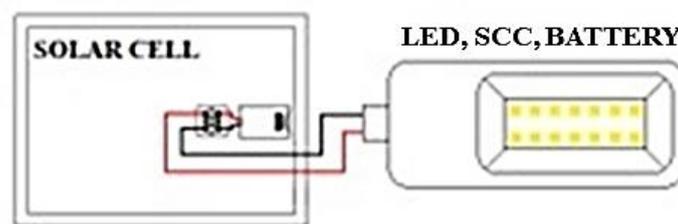

Figure 3. Electrical system circuit of solar cell-based street lighting 2-*in*-1

The work scheme for solar street lighting has two schemes. They are during the day and at night, the following is an explanation of how it works. When sunlight begins to shine on the solar cell, the solar cell begins to absorb sunlight and convert it into electrical energy. SCC regulates the electrical energy generated by solar cells to charge the battery and turn the lights off. When it is nighttime and the solar cells are no longer absorbing sunlight on the SCC, the SCC regulates the battery current to supply the LED lights and keeps the lights on. In making Solar Cell-Based Street Lighting sketches, a reference is needed to be used for component sizes. Due to the height of buses and trucks reaching 3.5 meters. To avoid collisions with vehicles, the pole height will use a measurement of 5 meters. The length of the lamppost arm is about 1.5 m and the pole is 0.5 meters away from the roadside. Figure 4 shows the initial design designed with AutoCAD software in centimeters. Solar Cell-Based Street Lighting is designed using a single arm.
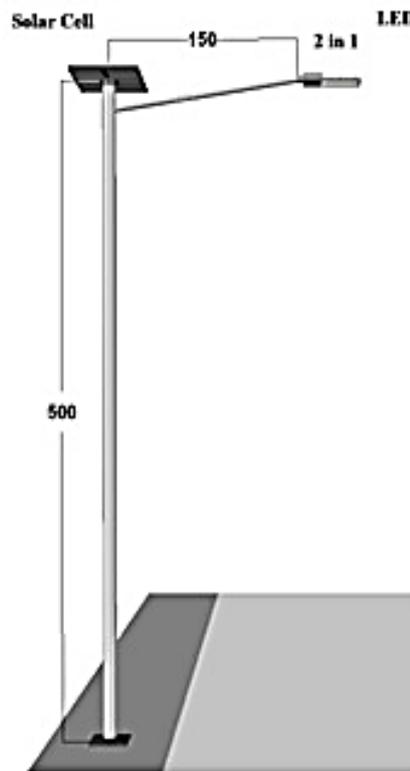
Figure 4. The design of solar cell-based street lighting for Inayah Islamic School

3. RESULTS AND DISCUSSION

Solar Cell-Based Street Lighting that has been designed will be reviewed and analyzed whether the design meets the applicable SNI. This chapter also explains how suitable the design of Solar Cell-Based Street Lighting is from the processed data and then economic calculations are carried out afterward. In the design, a 2-in-1 LED lamp with a power size of 20 watts is used, but it is not yet known whether the power size complies with SNI 7391:2008 or not. To calculate the distance and angle between the light rays on the end surface of the path. It is known that the height of the lamp is 4 m and the horizontal distance from the lamp to the middle of the road (c) is 1.5 m. The actual distance from the lamp to the end of the road (r) is obtained from equation (1) to be r = 5.154 meters, to calculate the angle β using equation (2) it is obtained $\alpha = 14,070°$. Calculating Light Intensity and Flux SNI 7391:2008 stipulates that the type of local road must have an illumination (E_v) of around 2 Lux to 5 Lux. And according to the parameters of CIE 115:2010, the research location is in class P4. In this calculation the illumination value used is 5 Lux, from equation (3) it can be found the required intensity $I_v = 136.920 \, cd$. To calculate the luminous flux obtained using equation (5) it is obtained $\phi_v = 1720.663 \, lm$. The light intensity required to comply with the provisions of SNI 7391:2008 is 136.920 candela and the luminous flux is 1720.663 lumens with an illumination of 5 Lux. Palaloi [12] in their scientific work said that LEDs generally have a light efficacy (η_v) of 65-100 lumens/watt and the average efficacy when used for a long time is 85.5 lumens/Watt [13]. So, by using equation (4), the power of the lights needed for the road of the Inayah Islamic School complex according to SNI is $P = 20.125 \, W$. The light power required on the road of the Inayah Islamic School complex from the technical analysis is 20.125 Watt. The power of the lamp used in the design is 20 watts, this size is close to even greater than the size of the power needed on the road of the Inayah Islamic School complex.

Solar Cell-Based Street Lighting lamps are designed to be on for approximately 12 hours at night a day. To find out how much electrical energy is needed for a 20 Watt lamp to burn for 12 hours a day, you can use equation (7) to become 240 Watt-Hour. Lithium battery DoD [14] reaches 100%, with equation (10) you can find how much battery capacity is needed to supply lights in one working day. The capacity of the battery needed to supply a 20 Watt lamp for 12 hours in one day is 75 Ah. To find

out the capacity of solar cells [15], a calculation is needed by considering how long the sun's peak time is to maximize energy absorption. From the statistical data on the Global Solar Atlas website, at the coordinates of the Inayah Islamic School, the GTI$_{opta}$ value was obtained which is 4.756 kWh/m2 per day. So the time needed for the module to get global light can be obtained by equation (11) is $t_{modul} = 4.756\ hours$. The required solar panel capacity can be found by using equation (12). The internal solar panel capacity required in the design is 50.463 Wp rounded up to 50 Wp. The number of Solar-based Street Lighting needed along the road of Inayah Islamic School Complex can be found by determining the distance between the pillars with the following steps. To determine the distance between poles, it is necessary to calculate the maximum lighting distance (midpoint between poles). The lamp power used is 20 W with an average efficacy of 85.5 lm/W at a height of 5 m, with equation (4) for the light flux is$\phi_v = 1710\ lm$, and with equation (5) for the light intensity $I_v = 136,077\ cd$. The actual distance from the lamp to the farthest distance of illumination with 1 lux illumination (1 lux from each lamp, in SNI 7391:2008 the lowest illumination on local roads is 2 lux) with equations (3) and (2). So with equation (1) the horizontal distance of the lamp to the farthest street point with the smallest illumination is c = 7.235 m. The farthest horizontal distance of illumination of a 20 W LED lamp at a height of 5 m is 7.235 m. The distance between the poles is twice the farthest horizontal distance of the lighting so that 14.470 m is obtained, rounded up to 15 m. All sections of the Inayah Islamic School Complex have the same road width, but different lengths. The entrance road is 100 meters long, the inner road is 130 meters long and the exit is 100 meters long. From the entrance to the exit, the total length of the road is added up. So that the number of light pole points obtained is 22 poles. The number of light points from the entrance gate to the exit gate is 22 poles with a distance of 15 meters between poles. Figure 5 shows the placement and distance between pole points which are useful for knowing the approximate location of the Solar Cell-Based Street Lighting pole points on the site plan.
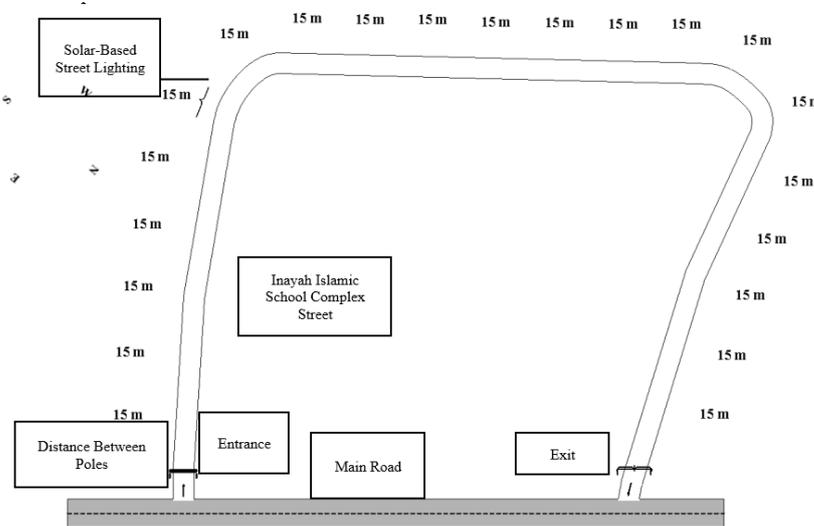

Figure 5. Estimation of point locations and distances between poles of solar cell-based street lighting

Figure 6 shows the placement and distance between the PJUTS pole points based on the original plan taken from a Google Map designed using AutoCAD software. This is useful for knowing the placement of poles in two-dimensional and three-dimensional views.
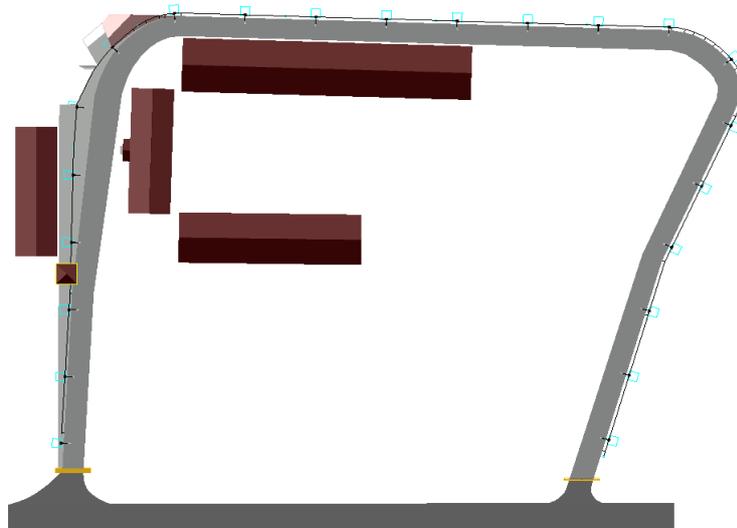
Figure 6. Pole points of solar cell-based street lighting on site plans with AutoCAD software

Three-dimensional design from the top view of the placement of the Solar Cell-Based Street Lighting pole points with AutoCAD software. The image is designed directly from a Google Map photo, the photo is coated with the specified colored line and then stores the three-dimensional version. The pole point in Figure 6 is symbolized by an empty cyan or light blue box and the school road in gray, while the red color shows the school roof.
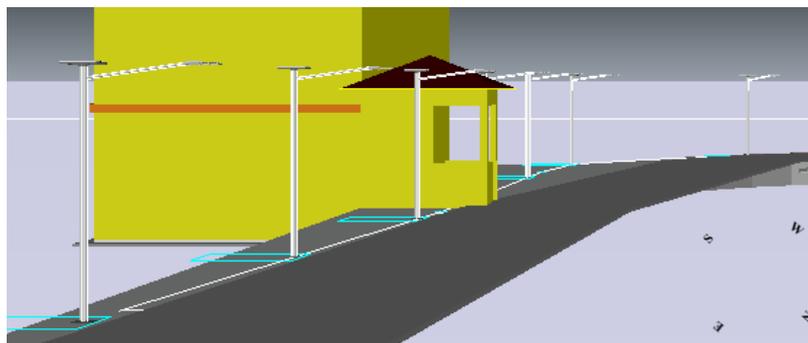

Figure 7. The display of solar cell-based street lighting at the entrance

Figure 7 shows a simulation in the AutoCAD software of the design of Solar Cell-Based Street Lighting at the entrance to the Inayah Islamic School Complex from the outside (entrance). It can be seen that Solar Cell-Based Street Lighting is placed on the left side of the road.
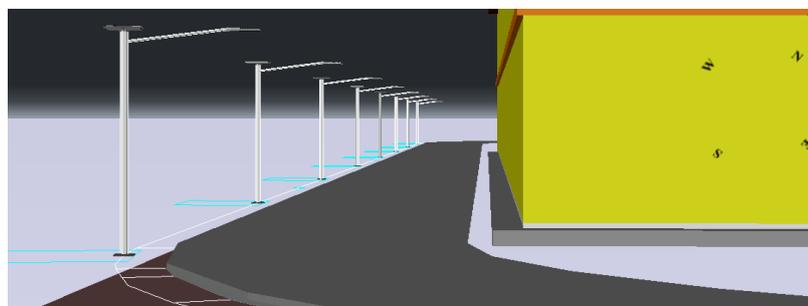

Figure 8. The display of solar cell-based street lighting the inside

Figure 8 shows a simulation in the AutoCAD software of the design of Solar Cell-Based Street Lighting on the inner road of the Inayah Islamic School Complex from the side of the entrance. Solar Cell-Based Street Lighting is placed on the left side of the road because there is no land on the right side of the road because it is adjacent to the school building.
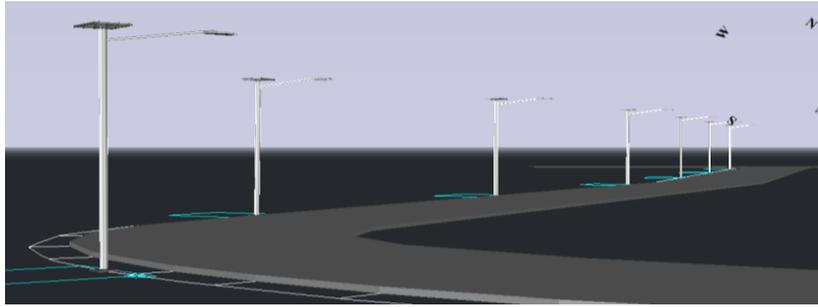
Figure 9. The display of solar cell-based street lighting in the exit

Figure 9 shows a simulation in the AutoCAD software of the design of Solar Cell-Based Street Lighting at the exit of the Inayah Islamic School Complex from the inside of the school. Solar Cell-Based Street Lighting is placed on the right side of the road from the outside because that side is the outer side of the Inayah Islamic School Complex. The table will show a comparison of the specifications of the components used with the components obtained from the calculations. Solar Cell-Based Street Lighting is placed on the right side of the road from the outside because that side is the outer side of the Inayah Islamic School Complex.

Table 5. Component specifications are designed with that into account

Component	Used	Estimation
LED	20 Watt	20.125 Watt
Battery	32 Ah	75 Ah
Solar Cell	50 Wp	50.463 Wp

From table 5, the capacity of the battery used and the one obtained from the calculation is quite different, the battery used has a capacity of 32 Ah and the battery obtained from the calculation has a capacity of 75 Ah. There are several reasons for still using a 2 in 1 LED lamp that is integrated with a 32 Ah battery, including a 2 in 1 LED lamp having a controller and the difficulty of finding suitable specifications on the market because it comes directly from the seller or factory. The two in one LED light controller is referred to as intelligent power control, when it adjusts the output power. The power used at the beginning is very small and over time will continue to increase until it reaches a maximum of one-third of the usage time and decreases again gradually from the last third of the usage time until the end of the usage time. Table 6 is the result of the first economic analysis, namely a comparison of the component prices for Solar Cell-Based Street Lighting and Conventional Street Lighting, showing the specifications and prices for the designed Solar Cell-Based Street Lighting. Meanwhile, the price and component specifications of conventional Street Lighting can be seen in Table 7. The specifications of conventional Street Lighting components follow the specifications of Solar Cell-Based Street Lighting.

Table 6. Estimated component prices of solar cell-based street lighting

Component	Type	Size	Price (Rp)
Pole	-	4 meters	2.000.000
Pole Arm	-	1.5 meters	250.000
Lamp	LED 2-*in*-1	20 Watt	990.000
Solar Cell	*Polycrystalline*	50 WP	650.000
Cable	NYY 2×1.5 mm^2	2 meters	30.000
Supporting Component	-	-	1.000.000
Total Cost per-pole			4.920.000
Total Cost of Solar Cell-Based Street Lighting (times poles)			108.240.000

Table 7. The estimated price of Conventional Street Lighting components

Component	Type	Size	Price (IDR)
Pole	-	4 meters	2.000.000
Pole Arm	-	1.5 meters	250.000
Lamp	LED	20 Watt	130.000
Component	**Type**	**Size**	**Price (IDR)**
Contact Cable	NYM 2×2.5 mm^2	4 meters	29.000
Connecting Cable for	NYFGBY 2×6 mm^2	32 meters	1.712.000
Supporting Components	-	-	500.000
Total cost per-pole			4.621.000
Total cost of all street lamps (times total poles)			101.662.000

Due to the energy source of conventional street lamps from State Electricity Company, there is a predetermined tariff fee. According to the State Electricity Company, schools are included in the social tariff category with a usage fee of IDR 455.00/kWh. The cost of using electricity for conventional street lamps as a whole in 1 year as a whole is 876,876 rupiah. The cost of using electricity for all conventional type street lamps in 1 year is IDR 1,392,120.95. The age of solar cells can reach 20 years. To find out the operational costs of conventional Street Lighting that uses State Electricity Company electricity, you can see the cost of electricity usage over the life of the solar cells. The operational cost of conventional street lamps for the next 20 years is IDR 17,537,520. In terms of investment costs, conventional street lamps are cheaper, but in terms of operational costs, Solar Cell-Based Street Lighting two-in-one is much more economical because Solar Cell-Based Street Lighting generates electrical energy from solar cells, so electricity usage rates are not charged.

4. CONCLUSION

Based on data analysis and calculation results on the design of street lighting at Inayah Islamic School Complex, it can be concluded that the design of street lighting at Inayah Islamic School Complex uses 2-in-1 LED lights with a power of 20 Watt, and the parameters of the poles with a road width of 4, 5 meters, namely the height of the pole is 5 meters, the distance between the poles is 15 meters and the Street Lightings point is 22 points, which is in accordance with SNI 7391:2008. By using 50 Wp solar cells, the design of Solar Cell-Based Street Lighting on the road of the Inayah Islamic School Complex requires a budget of around IDR 108,240,000.00 and conditional maintenance operational costs for the future. In terms of investment costs, conventional Street lighting is cheaper, but in terms of operational costs, 2-in-1 Solar Cell-Based Street Lighting is much more economical. This is because Solar Cell-Based Street Lighting generates electrical energy from solar cells, so electricity usage rates are not charged.

REFERENCES

[1] Indonesia, Standar Nasional. *Spesifikasi penerangan jalan di kawasan perkotaan*. Badan Standardisasi Nasional (BSN). 2008.

[2] A. Nurrohim, *Perencanaan Lampu Penerangan Jalan Umum*. Universitas Semarang. 2018.

[3] A. Febrianto, W. Sunanda, R. F. Gusa. "Penerangan Jalan Umum Tenaga Surya: Studi Kasus di Kota Pangkalpinang." *Jurnal Presipitasi*: *Media Komunikasi dan Pengembangan Teknik Lingkungan* vol. 16, no. 2, pp. 76-82. 2019.

[4] S. Almási, M. Bizjak, E. Burini, D. Coatham, D. Crawford, J. Hart, N. Hodson, D. Schreuder, R. Yates, J.S Yerrell, *CIE 180:2007 Road Transport Lighting for Developing Countries*. The International Commission on Illumination (CIE), 47, 2007.

[5]   IEC. International electrotechnical vocabulary (IEV) – Part 845: Lighting. In the International Electrotechnical Commission (2nd ed.). 2022

[6]   I. B. Ramahani, Buku Instalasi PLTS. Jakarta : Deutsche Gesellscjsft fur Internastionale Zusammenarbit (GIZ. 2018.

[7]   V.C Bender, F. B. Mendes, T.Maggi, M. A. D. Costa, T. B. Marchesan, "Design Methodology for Street Lighting Luminaires Based on a Photometrical Analysis". *IEEE*, pp. 1160–1165, 2013.

[8]   S. Rolaskhi, "Inovasi Perancangan dan Perencanaan Bisnis Paket Panel Surya (Solar Home System)" [Universitas Komputer Indonesia]. In *Universitas Komputer Indonesia*. https://elibrary.unikom.ac.id/id/eprint/2608/

[9]   T. Adams, A. Augdal, M. Bizjak, E. Bjeland, N. Bonne, C. Chain, M. Gillet, B. Hamel, B., P. Hautala, *CIE 115-2010 Lighting of Roads for Motor and Pedestrian Traffic*. The International Commission on Illumination (CIE), 35, 2010.

[10]   A.A. Zakri, N. Nurhalim, D.P.H. Simanullang, I. Tribowo. "Photovoltaic Modeling Methods Based on Matlab Simulink Implementation". *Sinergi*, vol. *22*, no. 1, pp. 1-6, 2018.

[11]   S. Rolaskhi, "Inovasi Perancangan dan Perencanaan Bisnis Paket Panel Surya (Solar Home System)" [Universitas Komputer Indonesia]. In *Universitas Komputer Indonesia*. https://elibrary.unikom.ac.id/id/eprint/2608/. 2019.

[12]   S. Palaloi, S. Nafis, S.Emo. "Kajian Tingkat Efikasi Lampu LED Swabalast Untuk Pencahayaan Umum". *Ketenagalistrikan dan Energi Terbarukan*. vol. 14, no. 1, pp. 1–14. 2015.

[13]   A.A. Zakri, R. Febriyursandi, A. Hamzah, *Teknik Pencahayaan Ruangan Via Dialux Evo*.2019.

[14]   A.A Zakri, *et al*. "Alat Otomatis Pengisi Baterai Bersumber Solar Sel Menggunakan Pengendali Arduino. *Seminar Nasional Terapan Riset Dan Inovatif*, pp. 128–139. 2019.

[15]   W. Sunanda, R. F. Gusa, Y. Tiandho, E.A Pratama, E. A. "Impact of shading net on photovoltaic cells performance". *Jurnal Teknik Elektro,* vol.11, no. 2, pp. 56-60. 2019.