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Effectiveness of Solar Panel-Based Street Lights and Their Impact on Environmental Sustainability

Arisman Arisman[1, *], Iwan Iwan[2]

[1] *Department of Energy Systems Engineering, Institut Teknologi Yogyakarta, Yogyakarta, Indonesia*

[2] *Department of Management, STIE Widya Wiwaha, Yogyakarta, Indonesia*

[*] Corresponding author:

Email:

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Abstract

Unlike conventional energy sources, solar lights provide access to sustainable lighting in areas not yet covered by the electricity grid. However, it is also important to carry out a detailed analysis of the energy effectiveness of using streetlights. The aim of this research is to analyze the difference in energy effectiveness between the use of conventional streetlights and solar panel-based streetlights. The research method used in this research is a field research method with a comparative approach. Field research is an approach that involves collecting data directly from the location or place where the phenomenon under study occurs. This research uses a comparative approach, where in this case the researcher compares the energy effectiveness between the two types of streetlights used, namely conventional streetlights in Andongsili Village and solar panel-based streetlights in Bumerto Village, both are in Central Java. The results of this research prove that solar panel-based streetlights have extraordinary energy effectiveness, converting sunlight into a sufficient resource for lighting throughout the night. The use of solar panel-based streetlights has a positive impact on the environment by reducing greenhouse gas emissions and dependence on fossil fuels. Additionally, in the context of remote villages that have limited electricity supplies, solar panel-based streetlights bring significant benefits in providing sustainable lighting. The use of solar panel-based streetlights provides significant financial benefits in the long term compared to conventional streetlights.

Keywords

Effectiveness, Efficiency, Energy, Conventional, Solar Panels

1. Introduction

Public street lighting is an important component in urban and rural infrastructure that ensures safety, mobility, and community activities at night (Khan & Arsalan, 2016; Suwarno, 2022). Conventional streetlights, which have been widely used for many years, are the main technology for providing street lighting. However, the use of conventional streetlights has several aspects that need to be considered in the context of climate change, energy sustainability and environmental challenges (Østergaard et al., 2020; Sarkodie et al., 2020). Pramudiyanto & Suedy (2020) Solar-powered public street lighting has become increasingly popular in recent years. Unlike conventional energy sources, solar lights are more environmentally friendly and energy efficient. Apart from that, solar panel lights that do not depend on the PLN electricity network mean you can avoid monthly electricity bills. Solar streetlights are outdoor lighting devices that are powered by sunlight captured by solar panels (Ridwan et al., 2021; Sarkodie et al., 2020). To be able to light up at night, the lights are equipped with batteries that can be recharged with electricity produced by solar panels (Wiranata, 2017; Huang et al., 2023). Public streetlights usually use energy sources obtained from PLN electricity, but in recent years many roads have started to have solar panel lights installed (Khan & Arsalan, 2016). The choice of solar power as an energy source further confirms that solar-powered public street lighting (PJU TS) is superior to conventional lighting (Nadhiroh et al., 2022; Pradana, 2023).

Currently, renewable energy is increasingly becoming the main focus in efforts to overcome the challenges of climate change and increasing energy needs (Pramudiyanto & Suedy, 2020). Solar panels have become one of the most used renewable energy technologies in a variety of applications, including street lighting. Kinasti et al. (2019) solar panel-based streetlights have the potential to reduce dependence on fossil energy sources and reduce greenhouse gas emissions, as well as providing access to sustainable lighting in areas not yet covered by the electricity grid (Adhiem et al., 2021; Ridwan et al., 2021). However, despite the expected benefits of using solar panel-based streetlights, it is important to carry out a detailed analysis of the energy effectiveness of using such streetlights. Comparison with conventional streetlights without solar panels can provide valuable insights into energy efficiency, sustainability, and the feasibility of using this technology on a wider scale.

This research aims to analyze the difference in energy effectiveness between the use of conventional streetlights and solar panel-based streetlights in two villages, namely Andongsili Village and Bumerto Village. Andongsili Village uses conventional streetlights, while Bumerto Village uses streetlights that use solar panel energy. These two villages were chosen because they have different characteristics in terms of energy infrastructure and street lighting needs that may not be met. This research will identify and attempt to describe the methods that will be used, and outline the benefits expected from the research results. This research will be conducted through field studies that include comprehensive measurement and data collection, as well as careful comparative analysis. By gaining a better understanding of the energy effectiveness of using conventional streetlights and solar panel-based streetlights, this research is expected to provide important information for decision makers, local governments, and communities to increase the use of renewable energy and implement more sustainable lighting solutions.

2. Research Methods

The research method used in this research is a field research method with a comparative approach. Field research is an approach that involves collecting data directly from the location or place where the phenomenon under study occurs. In the context of this research, data was collected directly from the two villages that were the focus of the study, namely Andongsili Village and Bumerto Village. Andongsili Village consists of some hamlets such as Andongsili, Karangsari and Panggrungan. Meanwhile, Bumerto Village consists of 3 hamlets, namely Bumerto, Wonojoyo and Larangan. In the data collection process, researchers carried out direct observations, interviews with the community or related parties, and measurements related to street lighting using solar panel-based lights and conventional lights.

This research uses a comparative approach, where in this case the researcher compares the energy effectiveness between the two types of streetlights used, namely conventional streetlights in Andongsili Village and solar panel-based streetlights in Bumerto Village. By carrying out this comparison, the research aims to determine the advantages and disadvantages of each type of lamp and evaluate whether the use of solar panel-based lamps is more energy efficient when compared to conventional lamps. This field research method with a comparative approach will provide comprehensive data and in-depth information regarding the energy effectiveness of the two types of streetlights, as well as allowing researchers to draw stronger conclusions regarding the benefits of using solar panel-based lights in the context of public street lighting. Data obtained from field observations and interviews will be analyzed comprehensively. Researchers will compare the energy effectiveness between the two types of streetlights, calculating how much energy is saved by using solar panel-based lights compared to conventional lights.

3. Research Results

3.1 Conventional Street Lights

Conventional streetlights are an important component in the street lighting system which has long been used in various regions (Zubi et al., 2016; Shahsavari & Akbari, 2018). Conventional streetlights, which have been an important part of the public street lighting system for many years, have characteristics that are worth considering in terms of energy efficiency (Wiranata, 2017). The efficiency of conventional streetlights is a key parameter in assessing their performance. One aspect that needs to be considered is that conventional streetlights have quite high levels of energy consumption (Harpini et al., 2017; Romprasert & Jermsittiparsert, 2019). This means that in operation this lamp requires a significant amount of energy to produce adequate light. Shahsavari & Akbari (2018) in terms of reliability, conventional streetlights usually have a good level of reliability when properly maintained. However, the efficiency associated with this maintenance can be a challenge in poor settings. Therefore, it is important to understand that the efficiency of conventional streetlights can vary greatly depending on maintenance conditions and other factors (Gao et al., 2015; Ramirez et al., 2019).

Apart from high levels of energy consumption, conventional streetlights also have environmental impacts that need to be taken into account (Suwarno, 2022; Rumahorbo & Nursadi, 2023). The main energy sources for conventional streetlights are fossils such as coal and petroleum, which produce carbon dioxide emissions and other greenhouse gases that contribute

to global climate change (Pramudiyanto & Suedy, 2020). Sinaga et al. (2021) conventional streetlights also create light pollution with excess light which can disrupt the ecosystem and human health. Furthermore, the use of conventional streetlights also means greater dependence on fossil energy sources, prolonging dependence on non-renewable resources and negatively impacting the environment as a whole (Simanjutak & Artanto, 2022). Therefore, implementing more sustainable alternatives in street lighting such as renewable energy-based streetlights is becoming increasingly important in efforts to preserve the environment (Kinasti et al., 2019; Pradana, 2023).

Figure 1. Conventional lamps in Andongsili Village

In this research, energy consumption was measured from conventional streetlights spread across 3 (three) Padukuhan which are part of Andongsili Village. In Andongsili Village, there are as many as 50 units of conventional streetlights that are used to provide lighting on village roads. To operate and maintain these lights, costs are required that cover various aspects. The initial cost of installing 50 conventional streetlights is IDR 15,000,000. Meanwhile, over a period of 5 (five) years, the operational and maintenance costs required for conventional streetlights are IDR 8,000,000. The electricity costs used to pay for the electricity for 50 lamps over a 5-year period reached IDR 10,000,000. Thus, within a period of 5 years, the costs required to maintain and operate 50 conventional streetlights in Andongsili Village reached a total of IDR 33,000,000.

The measurement results show that the average daily energy consumption by conventional streetlights in Andongsili Village reaches around 150 kilowatt-hours (kWh). This data indicates that conventional streetlights in Andongsili Village have a significant level of energy consumption. In addition, it was also identified that the energy consumption of conventional streetlights fluctuates throughout the day. Peak energy consumption occurs during the night, when streetlights are fully active to provide adequate street lighting. Although these streetlights have automatic controls to regulate the light brightness during the night, energy consumption remains high during this period. This increase in energy consumption during the night shows that the use of conventional streetlights in Andongsili Village has a significant impact on PLN's electricity load.

3.2 Energy Effectiveness of Solar Panel Based Street Lights

Solar panel-based streetlights have been proven as a very effective solution in optimizing energy use (Hasibuan et al., 2020; Makkulau et al., 2020). The efficiency of solar panels is also reflected in the use of rechargeable batteries (Anjeli et al., 2023). The batteries used to store energy from solar panels have a long lifespan, and recharging is done automatically when sunlight is available. This results in more efficient energy use because streetlights can remain on without depending on the electricity supply from the PLN network (Simanjutak & Artanto, 2022; Nadhiroh et al., 2022). This solar panel energy consumption provides strong evidence that solar panel technology is a reliable and sustainable solution for providing street lighting. High efficiency in collecting solar energy and intelligent use of batteries make solar panels an excellent choice for optimizing energy consumption for sustainable street lighting (Harpini et al., 2017; Ipung & Thamrin, 2023).

Bumerto Village has adopted an environmentally friendly street lighting solution by using 62 units of solar panel-based streetlights. The initial installation cost for all solar panel street light units reaches IDR 20,420,000. Over the next 5 (five) years, Bumerto Village also allocated funds amounting to IDR 9,300,000 for the operation and maintenance of the solar panel-based lights. However, what is worth noting is that Bumerto Village does not need to think about additional electricity costs because these solar panel-based streetlights produce their own energy from sunlight, so there are no additional burdens related to electricity. From this data, it can be concluded that within a period of five years, the total costs required for the installation, operation, and maintenance of 62 solar panel-based streetlights in Bumerto Village reached a total of IDR 29,720,000. Over the longer term, these lights have the potential to provide more significant savings, given the higher initial investment for this more efficient and sustainable technology.

In addition, this research identified that solar panel-based streetlights in Bumerto Village have extraordinary energy effectiveness. Solar panels are able to convert sunlight into sufficient electrical energy to provide lighting throughout the night (Adhiem et al., 2021; Nadhiroh et al., 2022). The main advantage of these streetlights is their independence in generating electricity, which allows efficient and independent operation without dependence on PLN electricity supplies. Apart from energy efficiency, solar panel-based streetlights also make a positive contribution to environmental sustainability (Nadhiroh et al., 2022; Rumahorbo & Nursadi, 2023). By relying on renewable energy sources, these streetlights help reduce greenhouse gas emissions and dependence on fossil fuels (Pramudiyanto & Suedy, 2020). This is in line with global efforts to tackle climate change and maintain a cleaner environment (Wiranata, 2017; Sarkodie et al., 2020).

Figure 2. Solar Panel Street Lights (PLTS) in Bumerto Village

In the case of some villages, such as Bumerto Village, which has limited electricity supplies, solar panel-based streetlights bring significant benefits in providing sustainable lighting. With striking energy savings and positive impacts on the environment, the use of solar panel-based streetlights is increasingly becoming a wise and sustainable choice in facing future energy and environmental challenges (Sinaga et al., 2021; Ipung & Thamrin, 2023; Butt et al.., 2021). In this research, data on solar panel energy consumption in Bumerto Village is one of the important points that reveals the effectiveness of solar panel-based streetlights. The solar panel system used to light the roads in Bumerto Village has very efficient energy consumption. Data indicates that solar panels are able to meet the energy needs of streetlights well, even on dark nights. Apart from providing sustainable lighting, the use of solar panel-based streetlights also has a positive impact on the environment and village financial management, reducing dependence on conventional energy resources, and minimizing the impact of climate change (Butt et al., 2021; Huang et al., 2023).

4. Discussion

Conventional streetlights, although they have been used for a long time, have several significant disadvantages (Khan & Arsalan, 2016). One of them is the high level of energy consumption, especially during the night when streetlights must provide maximum illumination. Shahsavari & Akbari (2018) this high energy consumption results in a significant electricity burden on major electricity providers. Additionally, conventional lights rely on fossil energy sources such as coal and petroleum, which contribute to greenhouse gas emissions and other negative environmental impacts (Ramirez et al., 2019; Yu et al., 2022). Light pollution is also a problem, disrupting ecosystems and human health. Dependence on conventional energy sources also increases the risk of fuel price fluctuations (Romprasert & Jermsittiparsert, 2019; Svechkina et al., 2020).

Solar panel-based streetlights demonstrate extraordinary energy efficiency. Solar panel-based streetlights are able to produce electricity from sunlight, this technology reduces the main electricity load (Khan & Arsalan, 2016; Lucas et al., 2016). In addition, solar panel-based lights make a positive contribution to the environment by reducing greenhouse gas emissions and dependence on fossil energy sources. The use of clean and renewable solar energy reduces the impact of climate change and increases environmental sustainability (Shahsavari & Akbari, 2018). Another advantage is the energy independence provided by solar panel-based lights, reducing the risk of electricity supply interruptions. Although the initial investment is higher, in the long term, solar panel-based lights have the potential to save significant funds.

In the context of village economic management, the use of solar panel-based lights has a significant positive impact. Solar panel-based streetlights eliminate or completely reduce the electricity costs required to operate streetlights (Zubi et al., 2016; Yu et al., 2022). This means the village no longer has to pay monthly or annual electricity bills to light the streets. In the long term, these savings can be very significant and allow the allocation of village funds for other more urgent needs, such as infrastructure, education, or community welfare. Using solar panel-based lights also helps reduce the village's dependence on conventional energy sources such as coal or petroleum (Shahsavari & Akbari, 2018). This is an important step towards energy sustainability, considering that fossil resources are increasingly scarce and contribute to climate change (Johnsson et al., 2019). In this way, the village participates in global efforts to reduce greenhouse gas emissions and address the impacts of climate change.

Solar panel-based streetlights have the ability to produce electricity independently without depending on external electricity supplies. This provides operational stability, especially in areas that frequently experience power outages or have limited access to electricity. This energy independence also reduces the risk of fuel price fluctuations and energy supply uncertainty. Zubi et al. (2016) in supporting environmental sustainability, solar panel-based streetlights which use solar energy as a clean and renewable energy resource help reduce negative impacts on the environment. This includes reducing greenhouse gas emissions that contribute to climate change, as well as reducing air and land pollution often associated with conventional power plants (Lucas et al., 2016; Johnsson et al., 2019).

5. Conclusion

The results of this research prove that solar panel-based streetlights have extraordinary energy effectiveness, converting sunlight into a sufficient resource for lighting throughout the night. Its main advantage is its independence in generating electricity, which reduces dependence on PLN electricity supplies. The use of solar panel-based streetlights has a positive impact on the environment by reducing greenhouse gas emissions and dependence on fossil fuels. In the context of remote villages that have limited electricity supplies, solar panel-based streetlights bring significant benefits in providing sustainable lighting. In addition, the use of solar panel-based streetlights provides significant financial benefits in the long term. The higher initial costs are quickly offset by savings in operational and maintenance costs, as well as no electricity costs being charged. This supports more efficient and sustainable village economic management. This research also highlights that the energy efficiency of conventional streetlights, although they have been used for a long time, has high levels of energy consumption and fluctuations throughout the

day. This indicates a significant impact on PLN's electricity load, and the use of fossil energy sources which contribute to greenhouse gas emissions. Therefore, this research underlines the importance of seeking sustainable alternatives in street lighting that can reduce environmental impacts and dependence on conventional energy. Thus, it can be concluded that solar panel-based streetlights are a very efficient and sustainable solution in meeting public street lighting needs. By relying on renewable energy sources, this technology makes a real contribution to global efforts to overcome climate change, maintain a clean environment, and provide access to sustainable lighting, especially in areas not yet covered by conventional electricity networks. The implication of this research is that the use of solar panel-based streetlights is considered a wise alternative in facing energy and environmental challenges in the future.

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