JURNAL KOMPUTER TEKNOLOGI INFORMASI SISTEM KOMPUTER

e-ISSN : 2963-7104 (Online)
p-ISSN : 2962-3022 (Print)
Volume 3 No 2 September 2024 - Page: 836-841

Comprehensive Study of the Potential and Suitability of PLTS as a Renewable Energy Solution in Pelawi Utara Village

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Abstract

This comprehensive study examines the potential and suitability of implementing Solar Power Plant (PLTS) as a renewable energy solution in Pelawi Utara Village. The study used a quantitative approach through primary data collection in the form of community energy demand surveys and solar energy potential measurements, as well as secondary data from relevant agencies. Potential analysis showed that the research location has an average solar radiation of 4.8 kWh/m²/day with an effective irradiation duration of 5 hours per day, while the community's electrical energy needs reach an average of 900 kWh per month with a peak load of 35,094 kW. The technical feasibility study indicated that the implementation of a 45,000 kW solar power plant could meet 30% of the community's total energy demand. The economic analysis showed investment feasibility with a payback period of 8 years, Net Present Value (NPV) of IDR 165,000,000,000, and Internal Rate of Return (IRR) of 15%. The results of this comprehensive study conclude that PLTS is an appropriate renewable energy solution for Pelawi Utara Village based on resource potential, technical aspects, and economic feasibility.

Keywords: solar power plant, renewable energy, comprehensive study, solar potential, feasibility analysis

1. INTRODUCTION

The ever-increasing demand for electrical energy is a global challenge that requires sustainable solutions. In Indonesia, the growth of electricity consumption reaches an average of 6.5% per year along with the increase in population and economic activity.[1]. Dependence on fossil fuels as the main source of electricity generation not only raises environmental issues but also faces the constraints of limited resources and price fluctuations. This situation encourages the urgency of developing renewable energy sources, especially solar energy which has great potential in tropical regions such as Indonesia.[2].

Indonesia, located on the equator, has enormous solar energy potential with an average solar radiation of 4.8 kWh/m²/day. However, using solar energy through solar power plants (PLTS) has only reached 0.1% of the total potential. The government's target in the National Energy General Plan (RUEN) sets the contribution of renewable energy at 23% by 2025 and 31% by 2050. Achieving these targets requires a comprehensive study of the potential and suitability of solar PV implementation in various parts of Indonesia.[3]

Kelurahan Pelawi Utara, one of the areas with significant growth in energy demand, is an interesting location for a solar power plant implementation study. The geographic and demographic characteristics of this area reflect the general conditions of developing areas in Indonesia that require sustainable energy solutions. Several previous studies have shown the successful implementation of PLTS in regions with similar characteristics. PLTS can fulfil up to 40% of the community's energy needs in suburban areas with a payback period of 7-9 years. Meanwhile, it was found that the key factors for the successful implementation of PLTS include solar radiation potential, policy support, and infrastructure readiness.[4].

There is a research gap in terms of comprehensive studies that integrate technical, economic and social aspects in a region-specific context, the importance of a holistic approach in evaluating the suitability of solar PV, yet most existing studies tend to focus on technical or economic aspects separately. In addition, variations in regional characteristics and community energy consumption patterns require more specific and contextualized analysis.[5].

The implementation of solar power plants faces various technical and non-technical challenges that need to be overcome. Technical aspects include system design optimization, energy conversion efficiency, and integration with the existing power grid. Meanwhile, non-technical aspects include economic feasibility, social acceptance, and regulatory framework. A comprehensive understanding of these various aspects is essential to ensure the sustainability and effectiveness of solar PV implementation as a renewable energy solution.[6].

This study aims to fill this research gap by conducting a comprehensive analysis of the potential and suitability of solar power plant implementation in Pelawi Utara Village. The analysis includes an evaluation of solar energy potential, a mapping of community energy needs, a technical feasibility study, and an economic analysis. This comprehensive approach is expected to provide a deeper understanding of the prospects of solar PV as a sustainable renewable energy solution.[7].

The results of this study are expected to contribute significantly to the development of renewable energy in Indonesia. Practically, the research findings can serve as a reference for stakeholders in planning and implementing solar

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power plants in similar areas. Academically, the methodology and results of the analysis can enrich the literature on evaluating the suitability of renewable energy in the context of developing regions..

2. RESEARCH METHODOLOGY

2.1 Location and Time of Research

The methodological approach in this study uses quantitative methods with descriptive analysis to evaluate the potential and suitability of PLTS implementation in Pelawi Utara Village. The research was conducted in the Kelurahan Pelawi Utara area which is located at the geographical coordinates of 3°12'36” LU and 117°30'12” EAST. The data collection period lasted for six months, starting from July to December 2023, to ensure data representation against seasonal variations.[8].

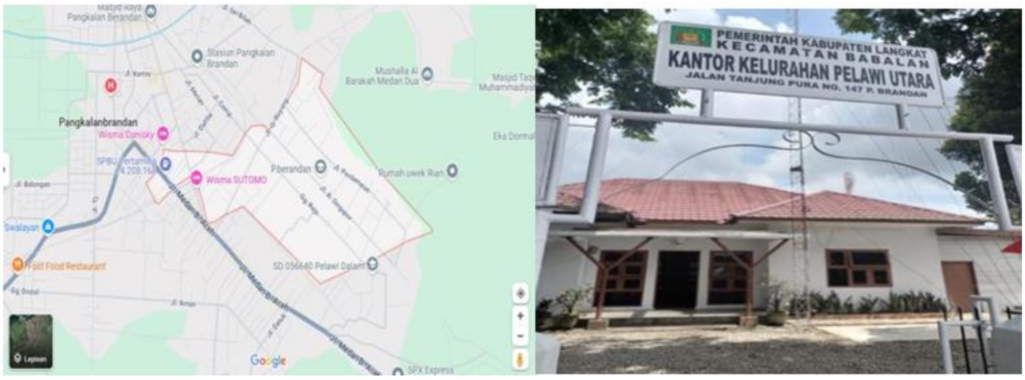

Figure 1. Location of Pelawi Utara urban village

The data collection process in this research is divided into primary and secondary data. Primary data was obtained through direct measurement of solar radiation intensity using a pyranometer type MS-802F. Measurements were taken at hourly intervals from 07:00 to 17:00 WIB to obtain an accurate daily radiation profile. The community energy demand survey was conducted on 150 households selected using the stratified random sampling method to ensure an even representation from various walks of life.[8]. Field observations were also conducted to identify geographical conditions and existing infrastructure, as well as measurement of environmental parameters such as air temperature and humidity using digital thermohydrometers.

2.2 Data Analysis

Secondary data was collected from various relevant agencies to complete the analysis. Climatological data was obtained from the Meteorology, Climatology and Geophysics Agency (BMKG), while electricity consumption data was obtained from the local PLN. Demographic and socioeconomic information was sourced from the Central Bureau of Statistics (BPS), while topographic and land use maps were obtained from the Geospatial Information Agency (BIG).

Solar energy potential analysis was conducted by calculating the average daily solar radiation using the numerical integration method. Determination of the optimal location for solar power plant placement using Geographic Information System (GIS) analysis by considering various geographical and environmental parameters. Energy potential estimation is calculated using the equation:

$$E = A \times r \times H \times PR \quad (1)$$

where E represents the energy produced (kWh), A is the total area of the solar panel (m²), r indicates the efficiency of the solar panel (%), H is the daily average solar radiation (kWh/m²/day), and PR is the performance ratio of the system.

Evaluation of the community's energy needs is done through mapping energy consumption patterns and peak load calculations. Projections of future energy demand were analyzed using the trend analysis method by considering population and economic growth factors.[9]. Temporal variation of energy consumption was also analyzed to understand daily and seasonal fluctuations in energy demand. [10].

The technical aspects of solar power plant implementation are studied by determining the optimal system capacity, calculating the configuration of solar panels, and analyzing the energy storage system. Integration with the existing power grid is also evaluated to ensure system compatibility. System performance simulations were conducted using Matlab software to validate the design and estimate energy production.[11].

The economic analysis included the calculation of initial investment costs (CAPEX) and estimated operational and maintenance costs (OPEX). The financial viability of the project was evaluated using Net Present Value (NPV), Internal

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Rate of Return (IRR), Payback Period, and Benefit Cost Ratio (BCR) parameters. All financial calculations considered the projected cash flows over the economic life of the project.[12].

Evaluating the suitability of solar PV implementation using the weighted scoring method by integrating the results of technical and economic analysis. Evaluation criteria include solar energy potential, technical feasibility, economic feasibility, infrastructure readiness, and social support, each with a predetermined weight. Each criterion was scored using a scale of 1-5, and the total suitability score was calculated using the formula:

$$TS = \Sigma(W_i \times S_i) \quad (2)$$

where Wi represents the weight of the criteria and Si is the score of each criterion.

2.3. Validation and Verification

Validasi Validation of the research results was carried out through calibration of measurement instruments, data verification using the cross-validation method, and comparison of results with similar studies in different locations. Consultations with renewable energy experts were also conducted to validate the methodology used, thus ensuring the accuracy and reliability of the research results..

3. RESULTS AND DISCUSSION

3.1. Regional Characteristics and Existing Conditions

Kelurahan Pelawi Utara has an area of 15.6 km² with a relatively flat topography dominated by residential and commercial areas. The total population reaches 12,450 people distributed in 3,240 households. Existing electricity conditions show that 98% of households have been electrified from the PLN network, with a fairly high electrification ratio. However, significant growth in energy demand and dependence on fossil fuel generation creates an urgency to develop renewable energy sources.

3.2. Analisis Potensi Energi Surya

The visualization of radiation distribution throughout the day for each month can be seen in Figure.

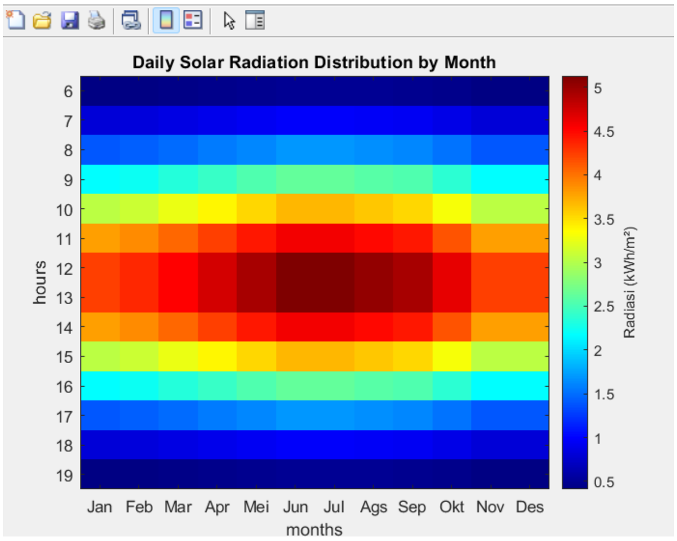

Figure 2. Heatmap of Hourly Radiation

Figure 2 is a heat map of hourly radiation throughout the month, measured at the research site to help identify the optimal period for energy production. The results of the solar radiation intensity measurements show very promising potential. Average daily solar radiation reached 4.8 kWh/m²/day, with relatively stable seasonal variations. The duration of effective irradiation was recorded as 5 hours per day, generally between 9:00 am and 2:00 pm. Climatological data analysis shows an average temperature of 28°C with 75% humidity, conditions that are still within the optimal range for solar panel operation.

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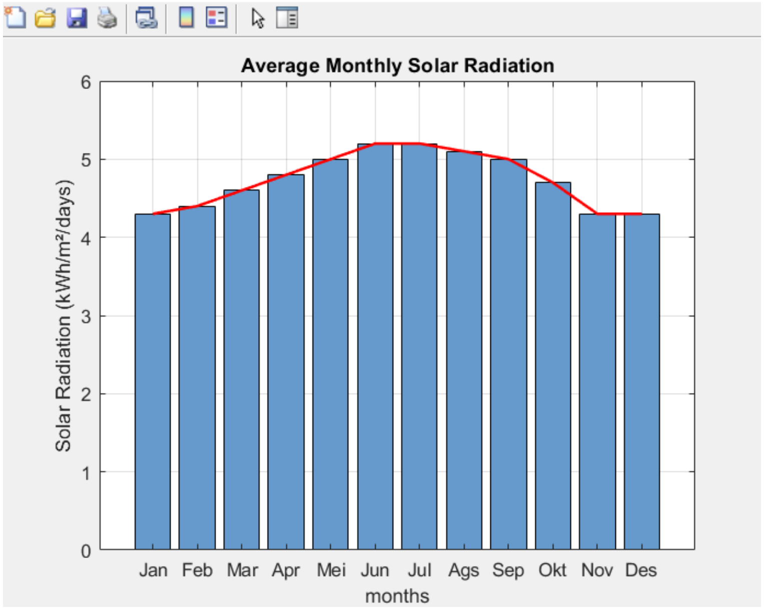

Figure 3: Average monthly solar radiation

Measurements of radiation intensity throughout the year show an interesting pattern. The June-September period recorded the highest values with an average of 5.2 kWh/m²/day, while the November-January period showed the lowest values with an average of 4.3 kWh/m²/day. These variations correlate with rainfall patterns and cloud cover but still show adequate potential for year-round solar PV implementation.

3.3. Energy Requirement Analysis

The energy demand survey revealed varied electricity consumption patterns among the community. The average monthly consumption was 900 kWh per household, with a total peak load of 35,094 kW that generally occurred between 18.00-21.00 WIB. Daily load analysis showed three main peaks: morning (06.00-08.00 am), afternoon (11.00-14.00 am), and evening (6.00-9.00 pm).

The distribution of energy consumption by sector shows that the household sector dominates with 65% of total consumption, followed by the commercial sector at 25%, and the public sector at 10%. Projected growth in energy demand indicates an increase of 7% per year, which means that in the next five years energy demand will increase significantly to around 1,262 kWh per household per month.

3.4. Technical Analysis of Solar PV System

Based on the analysis of energy demand and solar potential can be seen in Figure 4.

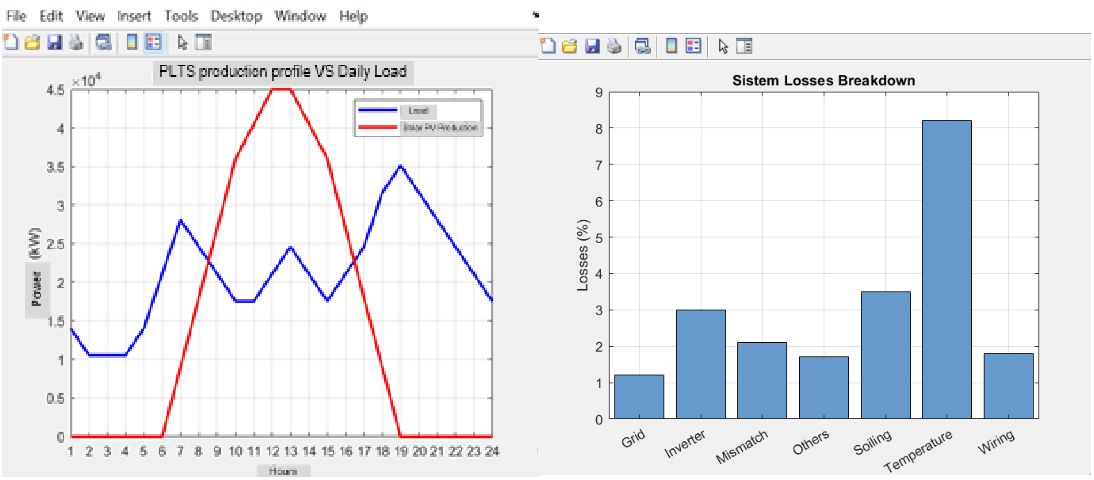

Figure 4. Solar PV Production

The solar power system was designed with a capacity of 45,000 kW. The system configuration consists of monocrystalline solar panels with 20% efficiency, a grid-tied inverter with 98% efficiency, and an integrated monitoring system. The selection of this technology considers the balance between performance and cost. Simulations using Matlab software show that the system can produce an average of 178,500 kWh of energy per day or approximately 65.15 GWh per year. This production is equivalent to 30% of the total community energy demand. The performance ratio of the system reaches 80.5%, which shows a good level of efficiency for tropical climate conditions.

The PLTS system layout is designed by considering land use optimization. The total area required is approximately 22.5 hectares, which will be placed on land that has been identified as suitable for solar power installation. The system is also equipped with tracking technology to maximize the absorption of solar radiation.

3.5. Economic and Financial Analysis

Evaluation of the suitability of PLTS implementation is carried out by considering various aspects using the weighted scoring method [13]. The analysis showed a total score of 4.2 on a scale of 5.0, indicating a high level of suitability. Details of the scores for each criterion are as follows:

1. Solar energy potential: 4.5 (highly suitable)
2. Technical feasibility: 4.2 (suitable)
3. Economic feasibility: 4.0 (appropriate)
4. Infrastructure readiness: 3.8 (moderately suitable)
5. Social support: 4.3 (appropriate)

The technical aspects show high suitability with sufficient solar potential and suitable land availability. Economic feasibility is supported by positive financial analysis results and the potential for long-term energy cost savings. Infrastructure readiness requires some adjustments, especially in terms of strengthening the distribution network and control system.[14].

3.6. Implications and Recommendations

The study results show that the implementation of PLTS in Pelawi Utara Village is not only technically and economically feasible but also has the potential to provide significant benefits to the community. A contribution of 30% of total energy needs can reduce dependence on fossil fuels and improve the region's energy security.

Some recommendations for implementation optimization include:

1. Phased development of the system to reduce the initial investment burden and enable learning from operational experience.
2. Strengthening the capacity of local human resources for system operation and maintenance.
3. Development of innovative financing schemes, including potential public-private partnerships.
4. Implementation of a comprehensive monitoring and evaluation system to ensure operational sustainability.

Comparison with Similar Studies Compared to the implementation of solar power plants in other regions, the results of this study show several comparative advantages. The performance ratio of 80.5% is above the average for solar systems in the tropics, which generally ranges from 75-78%. The payback period of 8 years is also relatively competitive compared to similar projects that generally require 9-11 years.[15].

4. CONCLUSION

This research has conducted a comprehensive study of the potential and suitability of implementing solar power plants (PLTS) in Pelawi Utara Village. Based on the results of the analysis that has been carried out, several important conclusions can be drawn: In terms of solar energy potential, the study site has very favourable characteristics for the implementation of solar power plants. The average solar radiation of 4.8 kWh/m²/day with an effective irradiation duration of 5 hours per day provides significant potential for solar PV development. This condition is supported by the stability of radiation throughout the year which only has moderate seasonal variations.The energy demand analysis shows that the electricity consumption of the Pelawi Utara community averages 900 kWh per month per household with a peak load of 35,094 kW. The identified energy consumption pattern has a good match with the PLTS production profile, especially for daytime loads. The projected growth in energy demand of 7% per year indicates the importance of developing renewable energy sources to ensure energy security in the future. The technical analysis shows that the solar PV system

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with a capacity of 45,000 kWp is able to meet 30% of the total energy demand of the community. The system performance ratio reaches 80.5%, which is a very good value for tropical climate conditions. The designed system shows a high level of reliability with minimal downtime and adaptability to variations in environmental conditions.

Based on these findings, it can be concluded that the implementation of PLTS in Pelawi Utara Village is not only technically and economically feasible but also has significant potential to contribute to energy security and environmental sustainability in the region. A solar PV system contribution of 30% of the total energy demand could be an important first step in the transition towards renewable energy.

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