G-Tech : Jurnal Teknologi Terapan
Vol. 8, No. 4, October 2024, pp. 2597-2602
E-ISSN: 2623-064X | P-ISSN: 2580-8737

Optimization of Electricity Supply in East Nusa Tenggara Through Communal Solar Power Plants: A Case Study of Kupang City Using PVSyst

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Article Information

Article History

Received : August 23, 2024
Revised : September 07, 2024
Accepted : September 20, 2024

***Keywords*:**

Electricity; Solar power plant; PVSyst; Inverter; CO_2 emission.

Kata Kunci:

Listrik; Pembangkit listrik tenaga surya; PVSyst; Inverter; emisi CO_2.

ABSTRACT

Certain regions in Indonesia face challenges related to inadequate electricity supply. To address this, it is essential to model and simulate potential solutions before implementation. This study focuses on optimizing electricity provision to resolve a 4 MW deficit in Kupang, East Nusa Tenggara, particularly at night, through the development of a communal Solar Power Plant. PVsyst software is used for analysis to determine the most economical and optimal solar system configuration. The Oelnasi site, selected for its solar radiation levels, land availability, and proximity to the grid, will house 17,411 solar panels covering 28,360 m², with 196 inverters. The system will generate 4.005 kWp of PV power, with a maximum DC power of 3.583 kWDC, and an AC power of 2.940 kWAC. Simulation results indicate that the Oelnasi Solar Power Plant can supply stable nighttime electricity and reduce CO_2 emissions by approximately 7,200 tons annually.

ABSTRAK

Beberapa wilayah di Indonesia menghadapi tantangan terkait kurangnya pasokan listrik. Untuk mengatasi masalah ini, penting untuk melakukan pemodelan dan simulasi sebelum implementasi. Penelitian ini berfokus pada optimalisasi penyediaan listrik untuk mengatasi defisit 4 MW di Kupang, Nusa Tenggara Timur, khususnya pada malam hari, melalui pembangunan Pembangkit Listrik Tenaga Surya (PLTS) komunal. Analisis dilakukan menggunakan perangkat lunak PVsyst untuk menentukan konfigurasi PLTS yang paling ekonomis dan optimal. Lokasi Oelnasi dipilih berdasarkan tingkat radiasi matahari, ketersediaan lahan, dan jarak ke jaringan listrik. Sistem ini akan memiliki 17.411 panel surya dengan luas area 28.360 m² dan 196 inverter. PLTS ini akan menghasilkan daya PV sebesar 4.005 kWp, daya DC maksimum 3.583 kWDC, dan daya AC sebesar 2.940 kWAC. Hasil simulasi menunjukkan bahwa PLTS Oelnasi dapat menyediakan listrik yang stabil pada malam hari dan mengurangi emisi CO_2 sekitar 7.200 ton per tahun.

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INTRODUCTION

Indonesia, as a developing nation, faces significant challenges in meeting its energy needs, particularly in rural and remote regions. Rapid population growth, increasing industrial activities, and urbanization have led to a rising demand for electricity, often outpacing supply capabilities (Pranata & Saputri, 2024). This has resulted in frequent electricity shortages, especially during peak demand periods, affecting various sectors of the economy and the quality of life for many communities. One such region severely impacted by this issue is East Nusa Tenggara, specifically the Kupang area. Province of East Nusa Tenggara, particularly the Kupang area, is currently facing challenges in electricity supply. One of the most pressing issues is the electricity shortage, which occurs primarily at night and affects the community's daily life and economic activities in Kupang. The limitations of the current power generation capacity and the increase in electricity demand, which is not matched by a corresponding increase in supply, are some of the causes of this electricity deficit. Kupang, the capital of East Nusa Tenggara, is one of the regions in Indonesia experiencing a 4 MW electricity shortfall, especially at night (Likadja et al., 2022). This indicates that the current electricity supply is insufficient to meet the growing demand during peak loads in the evening (Artiningrum & Havianto, 2019; Ferial, 2015).

Utilizing renewable energy is one of the primary solutions to address the electricity deficit, as awareness of the importance of sustainability and reducing carbon emissions has increased (Dwisari et al., 2023; Lorent et al., 2024; Nakmofa et al., 2018). The high solar radiation potential throughout the year in NTT makes it an ideal location for the development of solar power plants. One of the solutions to address the electricity deficit in Kupang is the construction of communal solar power plants (Zaenal et al., 2024) . This solution offers several advantages, such as harnessing abundant local solar energy, reducing operational costs compared to fossil fuel power plants, and scalability, which allows solar power plants to be gradually developed to meet the growing energy demand (Hidayat & Sutrisno, 2021; Nurjaman & Purnama, 2022; Rizal, 2017).

PVsyst software is used to design and optimize photovoltaic systems (Lee & Saputri, 2024). By using this software, we can simulate and determine the most efficient and economical photovoltaic system configuration (Qasimi et al., 2023; Windarta et al., 2021). This analysis optimizes various parameters, including panel orientation, the number of panels, energy storage capacity, and other factors to achieve the best performance levels (Hermawan et al., 2024; Prabowo, Y. A., Triwiyatno, A., & Sumardi, 2013).

The purpose of this study is to optimize the communal solar power plants system in Kupang using PVsyst software. With this optimization, the planned solar power plants are expected to meet the 4 MW energy demand at night, preventing electricity shortages in the area. This optimization also aims to reduce investment and operational costs, increase efficiency, and enhance the sustainability of the solar power plants system. Through the implementation of the optimized solar power plants, it is expected that Kupang can achieve a more stable and sustainable electricity condition, supporting economic growth and the well-being of the local community.

RESEARCH METHODS

This research utilized several steps. First, primary and secondary data on Kupang's electricity conditions were collected through website surveys, and literature research. This data includes potential solar radiation, electricity demand, and technical data related to solar power plants. Secondly, simulation and optimization of the solar PV system was conducted using PVsyst software. At this stage, various system configurations were tested to determine the most efficient and economical design, including the orientation and number of solar panels, energy storage capacity, and other factors. Then, the simulation results are analyzed to evaluate the performance of the system through indicators such as energy production capacity, investment and operational costs, as well as the economic feasibility test is conducted to ensure that the proposed solution is not only technically feasible but also economically viable for the community and the local government of Kupang City. Finally, the objective of this research is to provide useful and

applicable recommendations for implementing communal solar PV in Kupang to address the current electricity deficit.

RESULTS AND DISCUSSION

The first step in this research is the selection of the study site. The site selection was aided by data from Google Maps, and the area chosen for the construction of the solar power plant is Oelnasi Village, with a land area of 26,513 m², as shown in Figure 1. This location was selected because it is situated along a major road, facilitating the distribution of electricity to the Oelpuah solar power plant (Kristyadi & Arfianto, 2021). The distance from the selected site in Oelnasi Village to the Oelpuah solar power plant is 8.4 km, which influences the cost calculations for installing the distribution lines from the new solar power plant to Oelpuah.

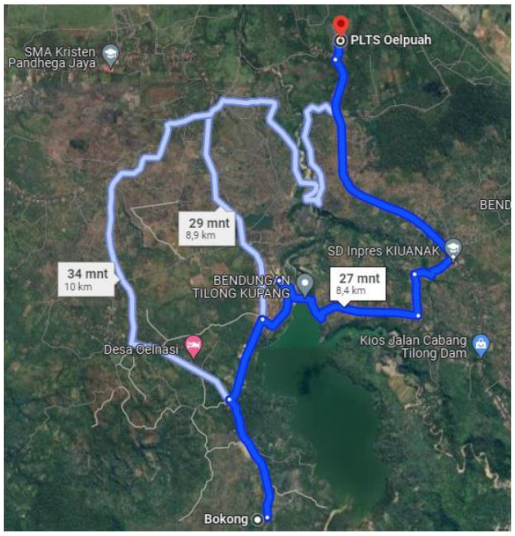

Figure 1. Distance from the construction site of Oelnasi Solar Power Plant to Oelpuah Solar Power Plant

The chosen site is also near the Tilong Dam, allowing the operational use of water resources from the dam. The land area used in Oelnasi is smaller compared to the 59,311 m² of the Oelpuah solar power plant. The area surrounding the Oelnasi solar power plant is largely undeveloped, providing opportunities for future expansion or development to meet the local community's energy needs. The Oelnasi solar power plants will require 32,798 m² less land than the Oelpuah solar power plants, resulting in lower land acquisition costs. The site is located at Latitude -10.1872626283166905 and Longitude 123.73914434574544, with an azimuth angle of 104 degrees.

Determining the coordinates of the selected site will facilitate the design process using PVsyst software. The average duration of sunlight in Oelnasi Village is 17 hours per day, making it highly suitable for a solar power plant. The average irradiation is 6.20 kWh/m²/day, indicating a high solar energy potential with an average temperature of 27 degrees Celsius.

According to the Central Bureau of Statistics of East Nusa Tenggara Province, the population of Kupang City in 2022 was 458,253 people. However, the number of households is not known, making it difficult to determine the total electricity needs for the entire city of Kupang and, consequently, the extent of the 4 MW electricity shortfall that affects the distribution of electricity to each household.

The design and simulation of the solar power plant were carried out using PVsyst software, adjusting parameters for system orientation, solar power plants design, and economic evaluation. The project was simulated using geographical and weather data specific to the Oelnasi solar power plant area (Hermawan et al., 2024; Prabowo, Y. A., Triwiyatno, A., & Sumardi, 2013). The design

and simulation of the solar power plant were carried out using PVsyst software, with parameters set for system orientation, solar power plant design, and economic evaluation. The project was simulated using geographical and weather data corresponding to the Oelnasi solar power plant area.

System Design Overview

The system is designed with solar panels tilted at an azimuth of 104 degrees and an inclination angle of 5 degrees. The annual losses, relative to the optimum, are calculated at -3.3%, and the Global on Collector Plane value is 2,256 kWh/m². The system is designed to meet a requirement of 4,000 kWp, with the specified orientation and tilt angle.

Solar Panels and Inverters

The system uses solar panels manufactured by Sun Earth Solar Power, with specifications of 230 Wp, 25V monocrystalline, Vmpp (at 60 degrees Celsius) of 24.7V, and Voc (at -10 degrees Celsius) of 42.1V. The system employs inverters from Sunways, with a specification of 15kW, 160-1000V, and a maximum input voltage of 1100V. A total of 196 inverters are used.

System Configuration

The system consists of 17,411 solar panels, arranged in 23 series and 757 parallel connections. This configuration requires a land area of 28,360 m². The setup is expected to generate 4,005 kWp, with operating voltages of Vmpp (at 60 degrees Celsius) = 567 V, Vmpp (at 20 degrees Celsius) = 703 V, Voc (at -10 degrees Celsius) = 967 V, and standard condition currents of Impp (STC) = 5,857 A, Isc (STC) = 6,245 A. The maximum power output under 1000 W/m² irradiance and 50 degrees Celsius is 3,524 kW.

System Performance and Financials

The flow diagram of the Oelnasi solar power plant system is shown in Figure 2. The entire Oelnasi solar power plant system uses 17,411 solar panels and requires a land area of 28,360 m². The system will produce 4,005 kWp of PV power, a maximum DC power of 3,583 kWDC, an AC power output of 2,940 kWAC, and a Pnom ratio of 1.362.

Global system summary

Nb. of modules	17411
Module area	28360 m²
Nb. of inverters	196
Nominal PV Power	4005 kWp
Maximum PV Power	3852 kWDC
Nominal AC Power	2940 kWAC
Pnom ratio	1.362

Figure 2. Global Simulation Results by PVSyst

As shown in Figure 3, the system is projected to generate 6,877 MWh/year, contributing significantly to revenue. The total installation cost of the system is estimated at IDR 244,801,743,000.00, with annual maintenance costs of IDR 13,074,754,796.00. The initial investment is expected to pay off in 10.2 years, with a Return on Investment (ROI) of 90.5%.

System summary

Project:	Kupang PLTS	
PV Array, Pnom =	4005 kWp	Grid-Connected System
Produced Energy	**6877** MWh/year	

Financial summary

Installation costs	**244.801.743.000.00**	IDR
Total yearly cost	**13.074.754.796.26**	IDR/year
LCOE	**1.922.9561**	IDR/kWh
Payback period	**10.2**	years

Figure 3. Financial summary of the Oelnasi solar PV system

Furthermore, as shown in Figure 4, the Oelnasi solar power plant system is expected to reduce CO_2 emissions by 123,591.966 tons. The reduction in carbon emissions from using solar

energy will have a positive impact on environmental health and support the transition to renewable energy.

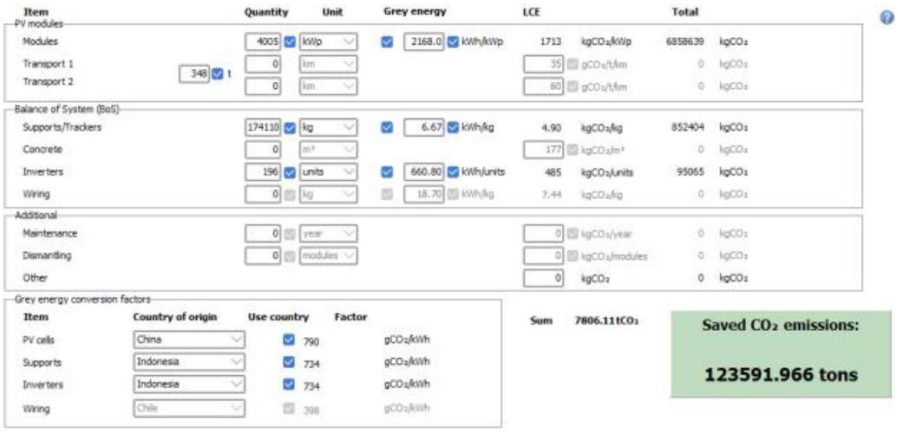

Figure 4. Saved CO_2 Emissions Prediction

CONCLUSION

This research successfully optimized the design of a communal solar power plant in Oelnasi Village, Kupang City, using PVsyst software, with results showing that the designed system is capable of generating 4,005 kWp of power and reducing CO2 emissions by 123,591.966 tons per year. With a total installation cost of Rp.244.8 billion and an annual maintenance cost of Rp.13.07 billion, the project is expected to break even in 10.2 years, with an ROI of 90.5%. The results of this study show that the Oelnasi solar power plant can be an effective and sustainable solution to Kupang's electricity deficit, while having a positive impact on the environment and the welfare of the local community.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to Universitas Multimedia Nusantara for providing support and resources for this research.

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