ECONOMIC ANALYSIS OF THE PROJECT DEVELOPMENT OF FLOATING SOLAR POWER PLANTS IN MRICA DAM, BANJARNEGARA

[1]**Mayan Wisnu Surya Pambudi**,[2]**Muhammad Mufti Azis**,[3]**Suhanan**

[1,3]System Engineering, Faculty of Engineering, Universitas Gadjah Mada, Indonesia
[2]Chemical Engineering, Faculty of Engineering, Universitas Gadjah Mada, Indonesia

Author's email:
[1]mayanwisnusuryapambudi1997@mail.ugm.ac.id; [2]muhammad.azis@ugm.ac.id; [3]suhanan@ugm.ac.id

Corresponding author: muhammad.azis@ugm.ac.id

Abstract. *Solar Power Plants (PLTS) represent one of the systems that utilize renewable energy sources (RES) to generate electricity. The implementation of floating solar power plants (PLTS Terapung) in Indonesia remains relatively limited. To minimize investment losses due to the significant initial capital required for PLTS projects, a feasibility analysis, referred to as techno-economic analysis, is essential. The objective of this study was to evaluate the economic feasibility of investing in the construction of a Floating Solar Power Plant with a capacity of 56.6 MWp located within the operational area of PT PLN Indonesia Power UBP Mrica.The research employed a predictive quantitative method by collecting annual energy yield data during the 30-year operational period to estimate the energy output over the project's lifespan, assuming a solar panel capacity degradation rate of 0.4% per year. The parameters used in the analysis included Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI), and Payback Period (PP). The reference interest rate and inflation rate were based on data from Bank Indonesia, with an interest rate of 6% and inflation rate of 2.3%. The analysis results showed that the PLTS achieved an efficiency of 19.29%, a Capacity Factor of 19.84%, a Performance Ratio of 83.65%, and an annual energy yield during operation of 92.94 GWh. The economic indicators revealed an NPV of $10,837,499.35, an IRR of 8% (which exceeds the Minimum Attractive Rate of Return, MARR), a PI of 1.23, and a Payback Period achieved in the 12th year. These findings indicate that the investment in the Floating Solar Power Plant is feasible*

Keywords: *Capacity Factor, Economic Analysis, Floating Solar PV, Performance Ratio*

1. INTRODUCTION

Renewable energy is one of the critical measures to mitigate ongoing climate change caused by the excessive use of fossil-based raw materials, which contribute to air pollution and global warming. Hazardous emissions from fossil fuel utilization as an energy source include carbon dioxide (CO_2), nitrogen oxide (N_2O), methane (CH_4), and many others that significantly damage the ozone layer in the atmosphere. Human activities over the past 50 to 100 years have resulted in a global temperature increase, with more than 95% of this rise attributed to industrialization—serving as the foundation of global economic development since the 18th century (Tim KIC, 2022)

The power plants owned and managed directly by PLN Indonesia in 2023 still reached 90.68% of the electricity produced on fossil fuels, while only 9.32% utilizes renewable energy, with a total installed capacity of 45,095.19 MW (PLN, 2023). This indicates that electricity generation is still dependent on fossil fuel-based power plants. In response, the National Energy Policy has set targets for renewable energy contributions of at least 23% by 2025 and 31% by 2050. These targets are integrated into the National Electricity General Plan for 2019–2038 (PLN, 2021). One approach to achieving these renewable energy targets involves developing and operating power plants utilizing sustainable and renewable energy sources, such as solar energy. Solar energy is converted into electricity through solar panels or photovoltaic (PV) technology.

Photovoltaic modules are commonly installed in open areas (ground-mounted) and on rooftops. However, these installations often face challenges, such as land use constraints and shading from buildings, which reduce the efficiency of energy production. To overcome these limitations, an innovative approach has been introduced: utilizing water bodies as platforms for solar power generation. This solution reduces the need for land acquisition costs, making it a viable option for Solar Power Plants (PLTS).

The utilization of water surfaces can support PLN’s efforts to meet renewable energy targets by leveraging water bodies such as reservoirs, dams, lakes, and irrigation areas. For instance, PLN operates a hydroelectric power plant with a reservoir area of 1,288 hectares, located in Mrica, Banjarnegara, Central Java. This area has significant potential to serve as the site for a Floating Photovoltaic powerplant. Implementing a Floating Photovoltaic powerplant would contribute to achieving PLN's 23% renewable energy target. The development of Floating Photovoltaic powerplant installations on water bodies must comply with regulations outlined by the Ministry of Public Works and Housing (PUPR) of the Republic of Indonesia in Regulation No. 7 of 2023. Article 105B(6) that the utilization of reservoir areas for floating solar power generation is limited to 20% of the surface area. Any exceedance requires a technical study and recommendations from the Reservoir Safety Commission.

Implementing a Floating PLTS in the PLN Indonesia Power UBP Mrica area would increase the installed capacity for future electricity generation. This is particularly relevant given that the existing hydropowerplant (PB Soedirman) cannot operate optimally due to reduced water volume caused by high sedimentation rates in the Serayu River upstream. This sedimentation is a result of agricultural and plantation activities in the Dieng region, which lack sustainable practices. Farmers prioritize high yields by encroaching on forest areas meant to serve as water catchments, can risks such as landslides during heavy rainfall. The goal of the projected investment in a Floating Photovoltaic becomes increasingly relevant to support additional energy production and achieve renewable energy targets.

2. LITERATURE REVIEW

2,1 Floating Photovoltaic Powerplant

Floating Photovoltaic Powerplant is power generation systems that utilize solar energy as their primary source, converting it into electricity using floating platforms installed on water surfaces. These systems can leverage water surfaces such as lakes, reservoirs, dams, irrigation channels, wastewater treatment areas, or offshore locations. Floating Solar Power Plants have been increasingly utilized in large-scale projects globally. However, their development entails specific challenges compared to land-based solar power plants. In Indonesia, the history of FPV development remains limited. Key concerns include cost uncertainties and a lack of clarity regarding environmental impacts, which may influence the required initial investment. Additionally, the design, construction, and operation of Floating Solar Power Plants are more complex than their land-based counterparts, particularly regarding electrical network security, as well as anchoring and mooring systems(Kementrian ESDM, 2021). Despite these challenges, Floating Solar Power Plants offer several advantages. They do not require land acquisition, simplifying installation, management, construction, and decommissioning compared to other power plants. Moreover, they help maintain water quality and supply and utilize water as a cost- effective and straightforward cooling system for solar panels (Rosa-Clot & Tina, 2018).

2.2 Components of FPV

The design of a Floating Solar Power Plant (PLTS Terapung) installation differs slightly from that of a ground-mounted PLTS. The primary distinction lies in the foundational structure for supporting the solar panel modules, as the water-based location necessitates the use of floaters, anchoring, and mooring systems. The main components utilized in a Floating Solar Power Plant include solar panel modules, a DC combiner box, an inverter, floaters, cables, and anchoring and mooring systems. (Kementrian ESDM, 2021).

2.3 Performance Analysis

System performance is evaluated based on energy output, Capacity Factor (CF), Performance Ratio (PR), and efficiency values. Energy is defined as the product of power and the active time period during which it is generated. The energy output can be calculated using the following equation.

$$\text{Eplts} = \text{Pplts x Time}$$

$$\text{Pplts} = \text{n x Ppv x } \frac{GTI}{1000} \text{ x nfrd}$$

Eplts: total energy produced (Wh) Pplts: total Power (Wp)
Ppv: power PV module (Wp) n: number of PV modules(unit)
GTI: Global Tilted Irradiance (W/m2) ηfrd: Efficiency power loss (%)

The performance of a solar powerplant is also assessed through CF, efficiency, and PR, which can be calculated using specific equations.

$$\text{CF} = \frac{Et}{Emax} \text{ x 100\%}$$

$$\text{nplts} = \text{npv x nFRD}$$

$$\text{PR} = \frac{Et}{Eideal} \text{ x 100\%}$$

CF: Capacity Factor (%)
Emax: Annual energy at peak power (GWh) ηPlts: Efficiency PLTS (%)
PR: Performance Ratio (%) Et: Annual Energy (GWh)
Eideal: Annual ideal energy produced (GWh) ηPv: Efficiency PV module (%)
ηFRD: Efficiency power loss (%)

CF (Capacity Factor) is the ratio of the energy generated by the PLTS to the maximum possible energy output during its operation at peak power over a given period. The CF value is directly proportional to the performance of the PLTS, with typical values ranging between 14% and 35% (Amal, 2022). Furthermore, the efficiency of a PLTS refers to the ratio between the power output of the PV module and its surface area. Efficiency depends on the amount of power generated and decreases due to various power loss factors that affect the energy production of the PV module. Currently, PLTS efficiency reaches a maximum of 21% (CFSS, 2024). The Performance Ratio (PR) represents the relationship between the energy generated by the PLTS and its theoretical ideal energy output. PR indicates the effectiveness of the PV modules in producing energy. For a PLTS system to be considered feasible, the PR value typically ranges between 70% and 90%(Hariyati et al., 2019).

2.4 Economy Analysis

Economic Analysis refers to the economic evaluation of a technical investment aimed at assessing the feasibility of developing a proposed technical project by analyzing its potential benefits compared to the costs incurred (Hidayat et al., 2024). Conducting a economic analysis can predicting or determining better decision-making regarding whether a project should proceed or not . Several aspects are typically considered in this analysis, including initial costs, operational costs, revenue, and investment evaluation indicators. Economic calculations can thus be employed to determine the economic feasibility of the Floating Solar Power Plant (PLTS Apung) system to be developed. Commonly used indicators include Net Present Value (NPV), Profitability Index (PI), Internal Rate of Return (IRR), Levelized Cost of Energy (LCOE), and Payback Period (PP).

- Net Present Value

Net Present Value (NPV) represents the difference between the total net revenue at the end of an investment and the initial total investment. It reflects the value of cash inflows and outflows over a specified period (Hidayat et al., 2024) . A positive NPV indicates that the project's earnings exceed its costs, making it financially viable. The calculation of NPV can be performed using a equation:

$$NPV = \sum_{t=1}^{t=n} \left(\frac{NCF}{(1+i)}\right) - S$$

NPV = Net Present Value
NCF = Net Cash Flow
i = Interest rate (%)
n = Total investment
S = Initial investment

- Benefit-Cost Ratio

Benefit-Cost Ratio (BCR) pr Profitability Index is the ratio between total net cash flows and the initial investment value (Hidayat et al., 2024). This ratio compares benefits (revenue) to costs at the same point in time. BCR is also referred to as the Profitability Index (PI). The result of the PI value calculation is >1, this shows that the benefits of the investment generated are greater than the costs used, so that the investment can be accepted or is worth implementing. The value of PI or BCR can be determined using equation.

$$PI = \sum_{t=1}^{t=n} \left(\frac{NCF \times (1+i)}{S}\right)$$

PI = Profitability Index
NCF = Net Cash Flow
i = Interest rate (%)
n = Total investment
S = Initial investment

- Internal Rate of Return (IRR)

Internal Rate of Return (IRR) is the rate of return on an investment when the Net Present Value (NPV) equals zero. This method calculates the interest rate by equating the value of cash inflows to cash outflows. The IRR value can be determined using equation.

$$IRR = i_2 + \left(\frac{NPV_1}{NPV_1 - NPV_2}\right) \times (i_2 - i_1)$$

IRR = Internal Rate of Return
NPV = Net Present Value
I = Discount rate

- Payback Period

Payback Period represents the minimum time required to recover the initial capital investment in a project through generated revenue. The PP value can be said to be feasible if the value is less than the project age (PP value < age) (Ifa & Nurdjannah, 2017).

$$Payback\ Period = \frac{Initial\ Investment}{Income\ Annual}$$

- Levelized Cost of Energy (LCOE)

Levelized Cost of Energy (LCOE) is a term commonly used to describe the costs associated with energy production and distribution. LCOE assesses the average unit cost of energy generated over the project lifecycle. The lifecycle is defined by the operational lifespan of the energy generation system. LCOE encompasses the total costs incurred, including investment, operational and maintenance (O&M) expenses, raw material costs, and equipment replacement costs, adjusted for future values within the system's operational cycle. The LCOE value can be calculated using its respective formula.

$$LCOE = \frac{\sum_{t=1}^{t=n} \frac{It + Mt + Ft}{(1+r)^t}}{\sum_{t=1}^{t=n} \frac{Et}{(1+r)}}$$

LCOE	= Levelized Cost of Energy Lt= investment in year (t)
Mt	= Operational and maintenance costs in year (t)
Ft	= Fuel cost in year (t)
Et	= Total electrical energy produced in year (t)
r	= Discount rate
n	= Operational lifetime

3. RESEARCH METHODS

Figure 1. Research Stages Diagram

This research was conducted at the Hydropower Plant located in the Mrica Business Unit of PT. PLN INDONESIA POWER on Banyumas Highway 8 Km, Banjarnegara Regency, Central Java Province. The analysis used a quantitative method by collecting data relevant to the calculations and analysis. Literature studies and field observations were planned to take over two months, included environmental observations, data collection, and preliminary analysist. This duration was chosen to ensure comprehensive data collection under literature data, expert interview and to directly assess site environmental conditions, as well as to align with project planning timelines.

The data used in this research included:

- Reservoir area data: To understand the enviroment characteristics of the resevoir.
- Solar radiation data: Sourced from the NSRDB (National Solar Radiation Database) for the years 2016–2020, obtained through measurements used the Himawari Physical Solar Model Version 3 (PSM v3) satellite.
- Components data: Based on the specifications of the components used in the Floating Photovoltaics.
- Financial data: used from the Solar Energy Research Institute of Singapore's solar market reports, previous studies, and expert opinions.
- This study used a combination of software tools (e.g., System Advisor Model and Microsoft Excel) and literature reviews for data and modeling system:
- System Advisor Model (SAM): used to generate solar irradiatiion data from Himawari Physical Solar Model Version 3 (PSM v3) satellite.
- Microsoft Excel: used to model system performance, energy output and
- calculated for economic analysis.

Based on the research diagram, this study had some stages as follows:

- Located analysis: A location analysis is used to find out more details about the environmental conditions in the research area. This location data covers the entire area of the reservoir to be studied. The location data consists of solar radiation data, wind speed, reservoir area temperature, and reservoir area. This will be used in determining the components in the construction.
- System Modelling FPV: the selection of components such as PV modules, Inverters and others that are suitable for the conditions in the Mrica reservoir and got the amount of energy output.
- Economic Analysis: Calculated NPV, PI ,IRR, PBP and LCOE. Conclution: Interprated the result about the Floating Photovoltaic.

4. RESULTS AND DISCUSSION

4.1 Location and Potential Energy

The total zoned area of the Mrica Reservoir is 1,288 hectares, with the water body covering 52.95% of the area, equivalent to 682 hectares from report of PLN Indonesia power. . The development of Floating Photovoltaic powerplant installations on water bodies must comply with regulations outlined by the Ministry of Public Works and Housing (PUPR) of the Republic of Indonesia in Regulation No. 7 of 2023. Article 105B(6) that the utilization of reservoir areas for floating solar power generation is limited to 20% of the surface area. The surface area available for a floating photovoltaic at the mrica reservoir is approximately ±136,4 hectar.

Table 1. Weather Data

Month	Global Horizontal irradiation (W/m^2)	Temperature (ºC)	Wind Velocity (m/s)
January	202,4	26,29	1,6
February	208	26,1	1,5
March	210,3	26,27	1,4
April	205,9	26,62	1,3
May	203	26,37	1,7
June	199,7	25,46	1,8
July	204,9	24,66	2,1
August	221,9	24,75	2,3
September	231,0	25,81	2,4

Oktober	222,3	26,52	2,3
November	198,9	26,57	1,9
December	197,5	26,07	1,8
Year	208,8	25,96	1,8

(Source: NSRDB (2016-2020)

Table 2. Global Horizontal Irradiation a Day in Hour

Hour	**Global Horizontal irradiation (W/m2)**	**Temperature (°C)**
6	133,337	24,3
7	210,345	25,6
8	392,980	26,8
9	574,3	28
10	715,257	28,8
11	779,017	29,4
12	764,488	29,7
13	637,593	29,7
14	511,309	29,3
15	405,432	28,6
16	288,782	27,6
17	169,676	26,3
18	23,076	25,4

(Source: NSRDB (2016-2020)

4.2 System FPV

The Global Horizontal Irradiation (GHI) data used in the calculations was obtained from the NSRDB database. Based on the literature, the efficiency of each system component is as follows: solar modules with the type JKM-440-54hl4r have an efficiency of 22%(Jinko, 2024), inverters with the type sungrow sg4400UD-MV have an efficiency of 99% (Sungrow, 2024), cable efficiency of 98% (Deshmukh & Chandrakar, 2022; Ekici & Kopru, 2017). the shading factor can affect efficiency by around 5% and dust can affect by 1% this can happen because of dirt such as leaves falling on the panel and dust that is scattered so that it can be cleaned periodically(Fouad et al., 2017), the power loss factor that occurs due to mismatch which can be caused by mismatches in current, voltage and power because the arrangement of the pv module can reach around 2% and the availability factor is around 3% which can occur due to the cessation of PLTS operations due to periodic repairs and several other operational factors (Amal, 2022). So the shading factor is 95%, soiling is 99%, mismatch is 98% and availability is 99%. The total combined efficiency is calculated as 0.1929 or 19.29%.

The temperature of the PV panels also affected the efficiency of the power output. The PV modules at the Mrica Reservoir experienced temperature variations due to solar radiation, which resulted in power loss factors, as shown in Figure 2.

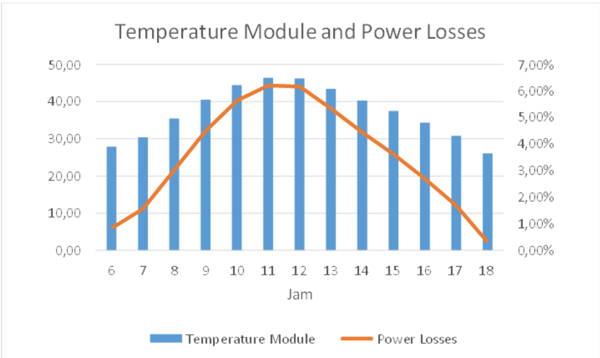

Figure 2. Temperature Module and Power Losses

It was observed that the temperature of the PV modules fluctuated throughout the day during solar exposure. The highest temperature occurred between 11:00 AM until 12:00 PM, reaching 46°C, with a power loss factor due to temperature changes of approximately 6%. Consequently, the power output of the floating solar power plant varied hourly. The power output generated by the PLTS Terapung is illustrated in Figure 2.

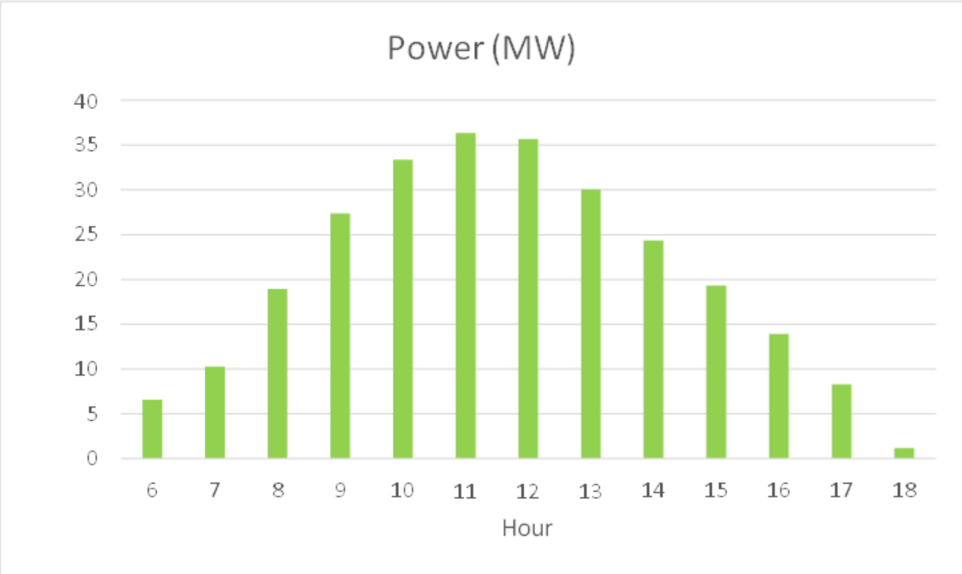

Figure 3. Average Daily Power of Mrica Reservoir Floating Solar Power Plant Per Hour

IAs shown in the figure, the highest power output occurred at 11:00 AM, influenced by the peak solar irradiation at that time. Subsequently, the energy output of the system was calculated on a monthly basis. The energy output was derived from the power data in Figure 2. The monthly energy calculations are shown in Figure 3.

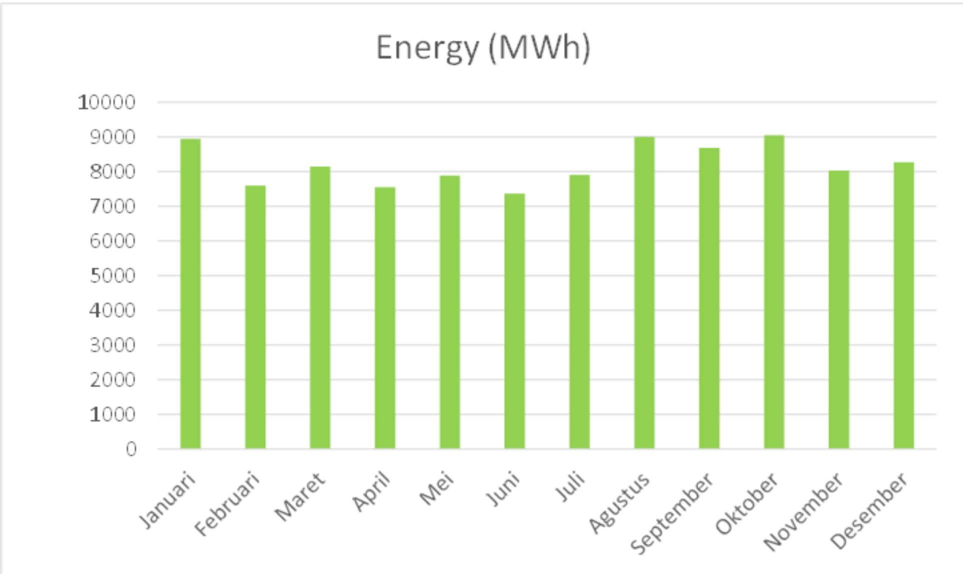

Figure 4. Energy generated by the Mrica Reservoir Floating Solar Power Plant

The energy output was adjusted based on solar irradiation data from the NSRDB NREL database (2016–2020) for a 12-hour sunlight exposure period, starting from 6:00

AM to 6:00 PM, with days adjusted for each month. The highest energy output was recorded in October, reaching 8,857.86 MWh.

The PV modules designed for the floating solar power plant at the Mrica Reservoir have a lifespan of up to 30 years (Jinko, 2024). According to the datasheet, the PV modules experience a degradation rate of 0.4% annually during their operational life. Therefore, the energy output will decline yearly. As illustrated in Figure 4.16, the first year's energy output was 98.45 GWh, while the 30th year's energy output decreased to 87.64 GWh.

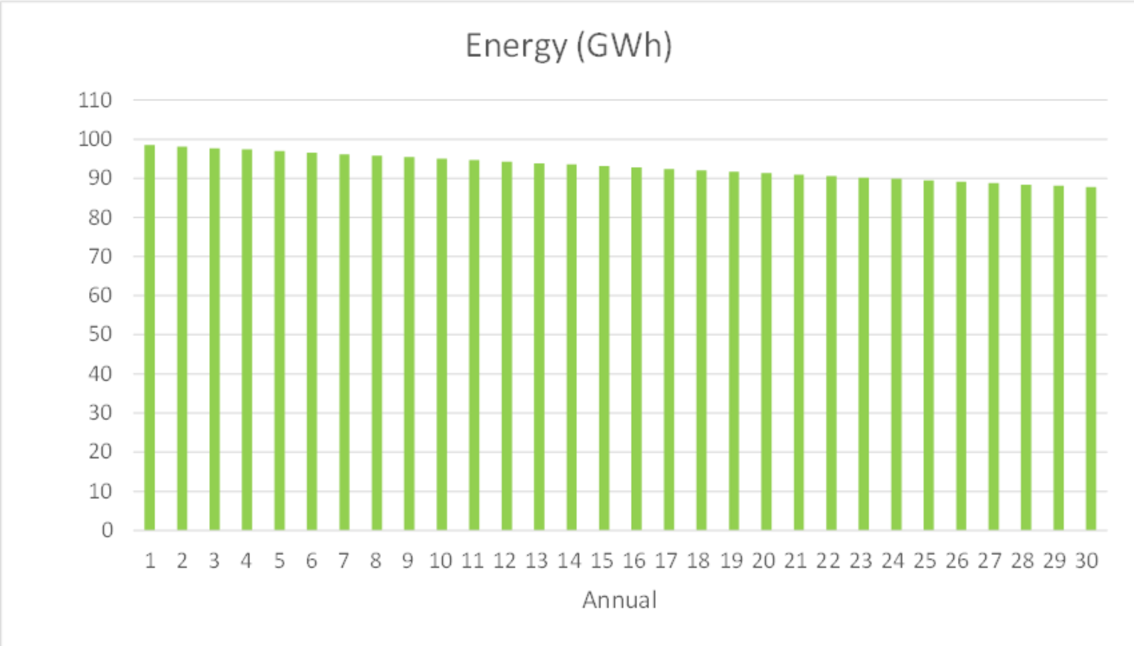

Figure 5. Annual Energy Degradation

The next step involved calculating the system performance, including energy, capacity factor (CF), performance ratio (PR), and efficiency. This analysis determined whether the designed system was technically feasible. A floating solar power plant is considered technically feasible if it meets specific technical criteria:

- The efficiency of the designed PLTS must exceed 13%.
- The capacity factor should range between 14% and 35%.
- The performance ratio should be within 70% to 90%.

The results of the system performance calculations are presented in Table 3. Once the technical feasibility is confirmed, an economic analysis can be conducted to determine the investment costs for the floating solar power plant design at the Mrica Reservoir.

Table 3. Result Performance System

Parameter	FPV Mrica Reservoir
Annual Energy (GWh)	92,94
Effciency (%)	19,29 %
Capacity Factor (%)	19,84%
Performance Ratio (%)	83,65%

4.2 Economi Analysis

The economic analysis aimed to determine the feasibility of constructing the floating solar power plant (PLTS Terapung) at the Mrica Reservoir with a lifespan of 30 years. The total investment cost, commonly referred to as CAPEX, was categorized in this design as follows: (1) costs of components used, balance of system costs, and other associated expenses; (2) costs for installation and construction processes; and (3) costs for component replacement at predetermined intervals. These costs were determined based on references (Kinanti et al., 2021; World Bank, 2019) and market prices obtained from the "Alibaba.com" marketplace. The calculations used the exchange rate of USD to Indonesian Rupiah on January 3, 2025, which was IDR 16,217.23.

The costs associated with the construction of the floating solar power plant included purchasing equipment for the PLTS system, such as PV modules, DC Combiner Boxes, and floaters. Since the components were sourced from outside Indonesia, they were subject to import duties at a rate of 7.5% as in Regulation No. 199 of 2019 (Ministry of Finance, 2019) and VAT at a rate of 12%, in accordance with Regulation No. 131 of 2024 (Ministry of Finance, 2024). Additionally, the economic calculations were influenced by a bank interest rate of 6% and an inflation rate of 2.3%, which was the average annual rate in 2024 (Bank Indonesia, 2024). The detailed total costs (CAPEX and OPEX) are presented in Table 4.

Table 4. Capex and Opex

Component	**Harga Satuan (USD)**	**Harga Total (USD)**
Modul PV	0,17 $/Wp	$ 11.707.936,99
DC *Combiner Box*	425 $/Unit	$ 110.598,84
Inverter	0,06 $/Wp	$ 4.132.213,06
Floating, Mooring dan *Anchoring*	0,12 $/Wp	$ 8.264.426,11
Balance of System	0,1 $/Wp	$ 6.887.021,76
Engineering	0,14 $/Wp	$ 7.928.876.08
Construction	0,1 $/Wp	$ 5.663.482,91
License	0,01 $/Wp	$ 566.348,29
Capital Expenditure (CAPEX)		$ 45.260.904,04
Office Operation	0,00167 $/Wp/Tahun	$ 94.580,16
SPV *Operation Salary*	0,00196 $/Wp/Tahun	$ 111.004,27
Operational dan *Maintenance*	0,00269 $/Wp/Tahun	$ 152.347,69
Insurance	0,00302 $/Wp/Tahun	$ 171.037,18

Operational Expenditure (OPEX)	$ 528.969,30

The economic calculations aimed to evaluate feasibility based on the following indicators: NPV (Net Present Value), PI (Profitability Index), IRR (Internal Rate of Return), and PP (Payback Period) to assess economic viability, as well as LCOE (Levelized Cost of Energy) to evaluate the cost of energy production from the floating solar power plant.

Table 5. Result Economy Analysis

Parameter	Nilai
NPV (IDR)	$10.837.499,35
PI	1,23
IRR (%)	8%
PBP	12 Tahun
LCOE (Rp/kWh)	$0.045

CONCLUSION

This study concludes that of the Economic Feasibility Analysis on the Development of Floating PLTS by analyzing the Effeciency, Capacity Factor, Performance Ratio FPV Net Present Value, Probability Index, Internal Rate of Return, Payback Period, and Levelized Cost of Energy are declared feasible. It can be feasible based on the values that have calculated by indicators. The investment in constructing a 56.6 MWp Floating Solar Power Plant at Mrica DAM, within the PT PLN Indonesia Power operational area, is deemed technically and economically feasible. The analysis results indicate that the FSPP system has an efficiency of 19.29%, a Capacity Factor of 19.84%, and a Performance Ratio of 83.65%. Over a 30-year operational lifespan, the system is projected to produce an annual energy output of 92.94 GWh. Economically, the NPV is valued at $10,837,499.35, with an IRR of 8%, a PI of 1.23, and a Payback Period achieved in the 12th year. These findings demonstrate that the investment in this Floating Solar Power Plant offers long-term profitability and supports the utilization of renewable energy sources in Indonesia.

REFERENCES

Ahmed, S. (2012). *On being included: Racism and diversity in institutional life*. Duke University Press.

Amal, D. F. (2022). *ANALISIS KINERJA, EMISI KARBON, DAN EKONOMI PADA RANCANGAN PEMBANGKIT LISTRIK TENAGA SURYA (PLTS) TERAPUNG DI DESA SAMBINASI, NUSA TENGGARA TIMUR*.

CFSS. (2024). *Solar PV Energy*. Center for Sustainable Systems, University of Michigan. 2024. “Photovoltaic Energy Factsheet.” Pub. No. CSS07-08.

Deshmukh, A. N., & Chandrakar, V. K. (2022). Design and Performance Analysis of Grid-Connected Solar Photovoltaic System with Performance Forecasting Approach (PFA). *Journal of The Institution of Engineers (India): Series B*, *103*(5), 1521–1532. https://doi.org/10.1007/s40031-022-00779-7

Ekici, S., & Kopru, A. (2017). Investigation of PV System Cable Losses. In *INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH S.Ekici and M.A.Kopru* (Vol. 7, Issue 2).

Fouad, M. M., Shihata, L. A., & Morgan, E. S. I. (2017). An integrated review of factors influencing the performance of photovoltaic panels. In *Renewable and Sustainable Energy Reviews* (Vol. 80, pp. 1499–1511). Elsevier Ltd. https://doi.org/10.1016/j.rser.2017.05.141

Hariyati, R., Muchamad, ;, Qosim, N., Aas, ;, Hasanah, W., Elektro, T., Tinggi, S., & Pln, T. (2019). Konsep Fotovoltaik Terintegrasi On Grid dengan Gedung STT-PLN. *Jurnal Ilmiah*, *11*(1).

Hidayat, M. W., Rizqullah, M. J., Lukmanto, Y. I., & Febriani, S. diah ayu. (2024). Analisis Tekno Ekonomi Pemasangan PLTS Rooftop On Grid 120 Kw (Studi Kasus PLTS di PT Santinilestari Energi Indonesia). *Jurnal Teknik Terapan*, *2*(2). https://doi.org/10.25047/jteta.v2i2.31

Ifa, L., & Nurdjannah. (2017). *Ekonomi Pabrik* (Team WADE Publish). Team WADE Publish. Jinko. (2024). *Tiger Neo MONO-Facial Module 54HL4R DataSheet*. www.jinkosolar.com Kementrian ESDM. (2021). *Panduan Perencanaan PLTS Terapung*. Jakarta

Kinanti, S. P., Moeis, A. O., & Kaharudin, D. (2021). *Feasibility Analysis of a Large Scale Floating Photovoltaic Power Plant Investment Using Financial Modeling with the Consideration of Uncertainties Factors*.

PLN. (2021). *Rencana Usaha Penyediaan Tenaga Listrik*. Jakarta

PLN. (2023). *Laporan Statistik Perusahaan Listrik Negara 2023*. Jakarta

Rosa-Clot, M., & Tina, G. M. (2018). SUBMERGED AND FLOATING PHOTOVOLTAIC SYSTEMS. In

Submerged and Floating Photovoltaic Systems (pp. i–iii). Elsevier. https://doi.org/10.1016/b978-0-12-812149-8.09987-7

Sungrow. (2024). *SG4400UD-MV-20 MV Grid-connected PV Inverter for 1500Vdc System Data Sheet*.

Tim KIC. (2022). *INDONESIA CARBON TRADING HANDBOOK*. Jakarta

World Bank. (2019). *Where Sun Meets Water FLOATING SOLAR MARKET REPORT*. www.worldbank.org