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# Design and Performance Analysis of a Floating Solar Power System in Situ Tunggilis

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**Abstract**

Situ Tunggilis is a regional government asset included in an optimization plan by the Central Government through the Ministry of Public Works. One potential utilization of the area is its development as a tourist destination, which requires adequate infrastructure such as public street lighting and reliable internet facilities. Considering limited land availability and the need for operational cost efficiency, a Floating Solar Power Plant (FSPP) is proposed as a sustainable energy solution. This study focuses on designing a floating solar power plant system to supply independent energy for lighting and internet services in the tourist area. The scientific novelty of this work lies in the integrated planning of a small-scale, off-grid FSPP specifically optimized for dual public facility functions—namely street lighting and Wi-Fi services—in a non-remote tourism context. Unlike most previous floating solar studies that emphasize large-scale generation or grid-connected systems, this research addresses the technical feasibility and performance of a localized, infrastructure-oriented FSPP design. The method involves technical calculations based on field measurements and publicly accessible secondary data, combined with system performance simulations. The results demonstrate that the proposed floating solar power plant system can meet the electricity demand for lighting and internet services in the pedestrian area, achieving a performance ratio of 71% and utilizing approximately 75% of the available solar energy. In addition, the planned Wi-Fi network satisfies the required internet coverage radius. The proposed system enhances sustainability by reducing reliance on grid electricity and lowering long-term operational costs through zero fuel consumption and low maintenance.

***Keywords***: *Floating Solar Power Plant; Infrastructure; Tourism Area; Renewable Energy; Tourist Village*

## 1. Introduction

Situ Tunggilis is one of 93 lakes in Bogor Regency, administratively located in Situsari Village, Cileungsi District. Situ Tunggilis is a wetland with an area of 35 Ha, the existence of which is very important for the sustainability of the lives of the surrounding community, especially in the fields of fisheries and irrigation. In terms of equitable development, it is necessary to have the potential owned by the village government [1]. Situ Tunggilis is a regional government asset owned by the Public Works Service of West Java Province which is included in the optimal planning by the Central Government through the Ministry of Public Works [2]. One way to utilize the Situ Sari area is to develop it as a tourist area.

In optimizing the function of the Situ Tunggilis area as a tourist destination, adequate infrastructure is needed, including public street lighting and internet facilities in the tourist area. Public street lighting is useful for lighting the road at night, thereby increasing safety for everyone who crosses the Situ Tunggilis area. Meanwhile, internet facilities play a role in supporting the digitalization of marketing for local micro, small and medium enterprises, increasing visitor appeal, and as an asset for the development of smart infrastructure in the future. The use of floating solar power plants can be a solution to meet the energy needs of public street light and internet devices amidst the limited land available and the need for operational cost efficiency in tourist areas.

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The potential for utilizing electrical energy from solar energy in Indonesia is very promising because of its geographical location on the equator. Indonesia has great solar energy potential with an average solar radiation (insolation) reaching 4.5-4.8 kWh/m² per day [3][4]. Meanwhile, according to one study, the Cileungsi area itself has a daily radiation of 4.5 kWh/m² [5]. It is a shame if this great potential is not utilized properly to become the pillars of the development of the Situ Sari Tourism Village.

Several studies on floating solar power plants (FSPP) have been conducted by previous researchers. For instance, [6] investigated the development of a floating solar power plant in the Cirata Reservoir, Purwakarta Regency, with a primary focus on large-scale electricity generation for grid-connected applications. Study [7] discussed the design of an FSPP installed on a regulating pond at PLTA Renun UPDK Pandan PLN Kitsbu, emphasizing technical feasibility and hybrid operation with hydropower systems. Research by [8] examined the potential and design of a floating solar power plant on Lake Batur to support Bali's clean energy transition, concentrating mainly on energy yield estimation and system sizing. Although these studies contribute valuable insights into the technical and economic aspects of floating solar power plants, they predominantly focus on large-scale or grid-connected systems and are generally implemented in non-tourism areas. Moreover, previous works rarely consider the direct integration of FSPP with public facility loads, such as public street lighting and internet infrastructure, nor do they provide a detailed assessment of lighting standards and internet coverage requirements in a tourism context.

**Table 1.** Comparison of Previous Floating Solar Power Plant Studies and This Study

| Study | Location | System Scale | Application Context | Load Type Considered | Tourism Area | Internet Integration | Key Focus |
|---|---|---|---|---|---|---|---|
| [6] | Cirata Reservoir, Purwakarta | Large-scale | Grid-connected power generation | General electrical load | No | No | Energy production and grid integration |
| [7] | Regulating Pond, PLTA Renun | Medium-scale | Hybrid hydropower–solar system | General electrical load | No | No | Technical feasibility and hybrid operation |
| [8] | Lake Batur, Bali | Large-scale | Clean energy support | General electrical load | No | No | Energy potential and system sizing |
| This Study | Situ Tunggilis, Bogor | Small-scale | Off-grid public facilities | Public street lighting and Wi-Fi | Yes | Yes | Integrated design for tourism infrastructure, lighting standards, and internet coverage |

Therefore, the research gap lies in the lack of studies that design and evaluate a small-scale, off-grid floating solar power plant specifically for dual public facility applications in a tourist area. This study addresses that gap by integrating FSPP planning with quantified lighting needs, Wi-Fi network coverage analysis, and system performance simulation. In doing so, it extends prior research by providing a practical and replicable framework for applying floating solar energy to support tourism infrastructure under land-constrained conditions.The purpose of the research conducted is to create a design plan for the floating solar power plant system and landscape to meet the needs of public facilities in the Situ Tunggils tourist area as well as planning the needs of public street lighting and local internet needs for the Situ Tungglis tourist area.

## 2. Methods

The research method used in the design and performance analysis of a floating solar power system to facilitate the needs of public facilities such as lighting and internet resources in the Situ Tunggilis tourist area as illustrated in Figure 1. The methode beginning with literature review and site survey to collect field and secondary data. The collected data are used for load demand analysis and solar resource assessment, which form the basis for system sizing and technical calculations of the floating solar power plant components. The designed system is then evaluated using PVsyst simulation to estimate energy yield, system losses, and performance ratio. Finally, the technical feasibility and sustainability implications of the proposed system are assessed to support design conclusions and recommendations.

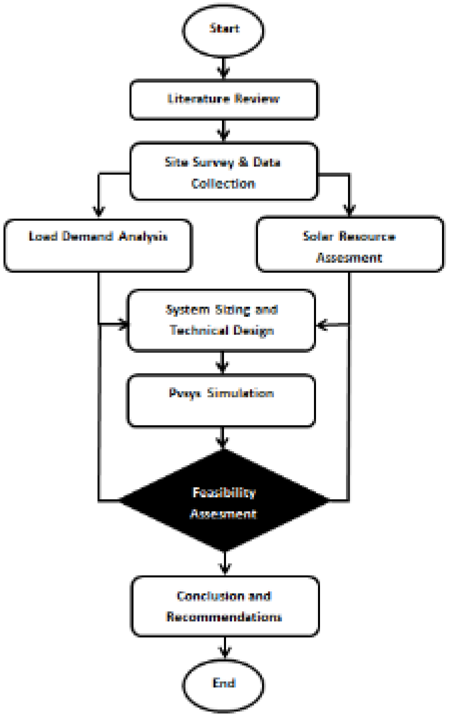



**Figure 1**. Research flow chart

The planned location point for the installation of the floating solar power plant is above the waters of Situ Tunggilis which stretches along the side of the lake. The dimensions of the area that will be used for the installation of solar panels are adjusted to the previously designed floating pedestrian design. The floating pedestrian is planned to stretch along the side of the lake approximately 170 meters and there is a special place for placing the solar panel array. Beside it, there is a previously existing land pedestrian approximately 220 meters. Determining the floating and land pedestrian areas in the area is very useful for the calculation needs of planning the placement of public street lighting points, the internet coverage that must be provided and the placement of the floating solar power plant. Based on the conditions of the area in the Situ Tunggilis area,the following is a description of the area that is planned to be made as a floating pedestrian which will also support the solar panel array later, as seen in Figure 2.

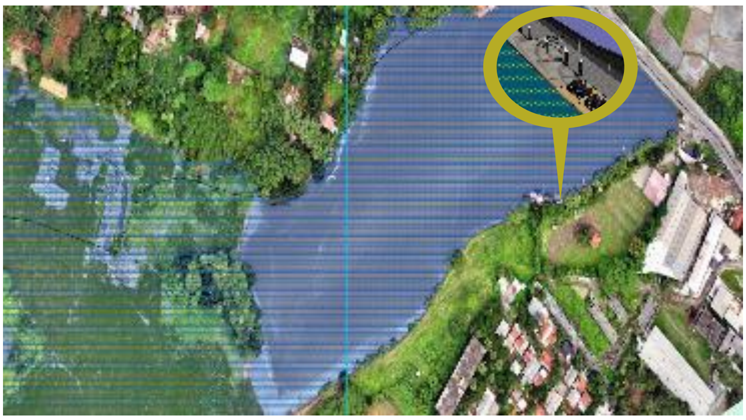


**Figure 2**. Floating solar power plant location area on Situ Tunggilis

### 2.1 Street Pedestrian Lighting and Internet Planning

The planning of lighting and internet loads was conducted to determine the electrical demand that must be supplied by the floating solar power plant system. The main loads considered include pedestrian lighting along the lakeside walkway, internet communication equipment, and auxiliary system components such as the solar tracking motor.

The street lighting requirements were determined by referring to the Indonesian National Standard SNI 7391:2008 for public street lighting [9] and national regulations on pedestrian lighting geometry. Although the standard does not explicitly address floating pedestrian facilities, its illumination level, pole height, and lamp spacing criteria were adapted to the local site conditions. The use of LED luminaires was selected due to their high luminous efficacy and low energy consumption, enabling adequate illumination levels to be achieved with minimal electrical demand [10]. This approach directly reduces the required photovoltaic and battery capacities, improving overall system efficiency and cost-effectiveness.

The total lighting load was estimated based on the required illuminance level, pedestrian area coverage, and recommended lamp spacing [11]. Rather than emphasizing procedural calculations, the resulting lighting demand was used as a critical input for sizing the photovoltaic array and energy storage system. The analytical implication is that compliance with national lighting standards can be achieved while maintaining a relatively low installed PV capacity, demonstrating the feasibility of integrating public lighting into floating solar applications. Another policy that regulates the public street lighting load is [12]. The regulation states that the ideal lighting height for pedestrians on the pedestrian is 4 meters and the distance between lights is 10 meters.

The need for light flux (Ø) can be found using equation (1), namely the multiplication of light intensity (E) by the area of the plane (A) to be illuminated by light, then the required light flux can be calculated as follows: [11]

$$\emptyset = E \, x \, A \tag{1}$$

The power requirement for the lamp (W) can be calculated using Equation (2), which can be calculated using the light flux requirement (Ø) and the specific lamp flux ($\emptyset specific$) as follows :

$$W = \frac{\emptyset}{\emptyset_{Specific}} \tag{2}$$

The next step is to determine the number of lighting points (T) by taking into account the length of the pedestrian (L) and the distance from point to point (S) based on the recommended rules, which can be shown in (3) below: [13]

$$T = \frac{L}{S} \tag{3}$$

For internet services, the load estimation focused on practical communication needs within the tourist area. A low-power wireless router and access points were selected to minimize energy consumption while ensuring sufficient network coverage. The total internet load represents a small fraction of the overall system demand, yet its inclusion is analytically important because it demonstrates that non-lighting public facility loads can be reliably supported by the same floating solar power system.

Overall, the integration of lighting and internet loads into the floating solar design highlights that multi-purpose public facility support is technically feasible without significantly increasing system size. This reinforces the suitability of floating photovoltaic systems for tourist areas with limited land availability and moderate infrastructure energy requirements.

### 2.2 Planning a Floating Solar Power Plant System

In calculating the configuration of the required solar panels, not only the total electrical energy consumption is considered, but also the average daily solar irradiation at the project location, expressed as Equivalent Sun Hours (ESH) [14]. The ESH value represents the number of hours per day during which solar irradiance is equivalent to 1,000 W/m². In this study, the ESH value was obtained from long-term solar irradiation data for the Situ Tunggilis area derived from publicly accessible global solar atlas sources [15]. An average ESH in the range of 5–6 hours per day was adopted to represent typical operating conditions in tropical regions and to avoid optimistic assumptions that could lead to undersized system design.

The power requirements to be generated by the solar power plant are calculated using (4) as follows :

$$Power\ Requirement = \frac{Amount\ of\ Energy\ Needed\ (Wh)}{Equivalent\ Sun\ Hours\ (h)} \tag{4}$$

The capacity of the solar panel needs to be determined based on the specifications it has, to determine the number of solar panels needed. The number of solar panels needed can be calculated using (5) below :

$$Amount\ of\ Solar\ Panel = \frac{Power\ Requirement\ (kW)}{Solar\ Panel\ Capacity\ (Wp) x\ ESH\ (h)} \tag{5}$$

The selected solar panel capacity of 200 Wp per module was based on supported by existing research showing that 200 Wp panels are effective and commonly applied in off-grid PV designs, particularly for small renewable energy systems serving lighting and basic loads.[16]

In the floating solar power system, it is planned to use an energy storage system using a battery bank. In determining the number of batteries (Σ B), it is necessary to calculate the total energy used by the system (TE), the battery capacity to be used (BC), determining the battery discharge capability / Depth of Discharge (DoD) and autonomy day (how long / day the battery supplies energy to the system) using the following (6) :

$$\sum B = \frac{Total\ Energy\ (TE)}{BC\ .DoD}\ Outonomy\ Day \tag{6}$$

The type of battery used is Valve Regulated Lead Acid (VRLA) with a DoD value set at 50%. DoD is usually adjusted to manufacturer standards with the aim of increasing battery life, reducing the effects of sulfation, and improving long-term system reliability. This value represents a compromise between maximizing usable storage capacity and maintaining battery health under daily cycling conditions [17].

After calculating the load requirement planning, solar panels, batteries, solar chargers and inverters used, a scheme of the floating solar power plant system to be created can be made as shown in figure 3 below :

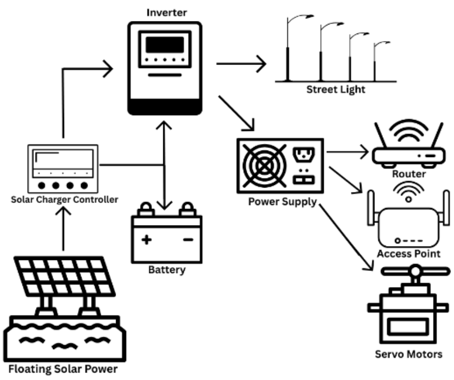



**Figure 3**. Floating solar power system schematic with solar tracker

It is projected that the system accommodates AC electrical loads including lighting and DC loads in the form of internet resources and solar panel tracker automation systems. The solar tracker floating solar power plant system uses batteries, Solar Charge Controller (SCC), and inverters. Solar panels are equipped with a solar tracker mechanism whose power comes from batteries, its function is to follow the movement of the sun in order to maximize the absorption of solar energy, then convert it into electrical energy in the form of direct current (DC). This electrical energy is sent to the solar charge controller (SCC) which functions to regulate battery charging, prevent overcharging and deep discharge, so that the battery is charged safely and efficiently. The energy stored in the battery can be used when the solar panels are not generating electricity, such as at night or when the weather is cloudy. Furthermore, electrical energy from the battery (DC) is sent to the inverter which converts it into alternating current (AC) according to the needs of electrical equipment.

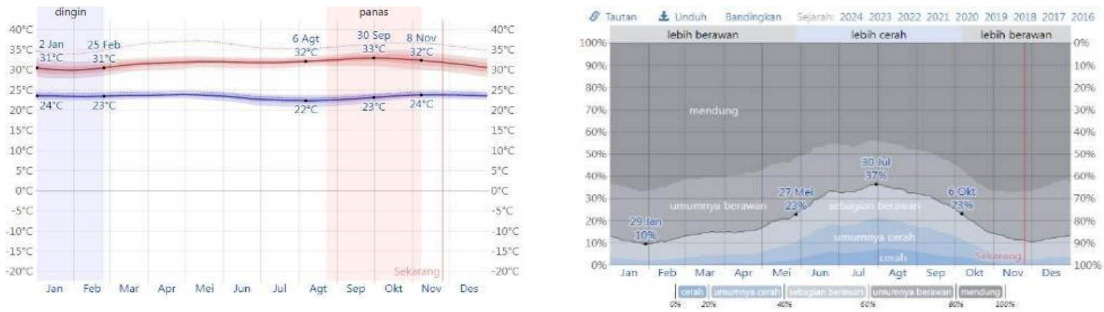
### 2.4 Performance Ratio of Floating Solar Power Plant System

Performance Ratio (PR) is the comparison between the actual energy produced by the solar power plant system ($E_{AC}$) and the expected energy produced by the solar power plant ($E_G$). The level of performance ratio is influenced by several indicators such as radiation intensity, construction location, weather conditions, solar power plant capacity size and the quality selected for the solar power plant system. The minimum performance ratio value for a solar power plant system to be declared feasible to be realized is 70% [18]. Equation (7) below is used to find the performance ratio value [19].

$$PR = \frac{E_{AC}}{E_G} \tag{7}$$

### 3. Result and Discussion

Situ Tunggilis Tourism Area has a climate that is sufficient to support the use of PLTS in various variations of its systems. This is based on data presented by [20] which provides detailed reports on typical weather in 145,479 locations worldwide and [15] .




a.

b.

**Figure 4**. a. Average Highest and Coldest Temperatures in Cileungsi District, Bogor. b. Cloud Cover Graph in Cileungsi District Bogor

The Cileungsi area, including the Situ Tunggilis Tourism Area, has temperatures varying from 22°C to 33°C almost all year round and rarely below 22°C or above 33°C. The area also has a brighter weathe period every year which lasts for 4.3 months. Based on the data, the brightest month of the year in Cileungsi is August, where the average clear sky, mostly clear or partly cloudy is 34%. The cloudier period is usually between October and lasts for 7.7 months, ending around May. While the cloudiest month of the year is January, with an average of cloudy or mostly cloudy skies 89% of the time.

#### 3.1 Solar Energy Potential in Situ Tunggilis Tourism Area

The intensity of sunlight refers to the data available on the Global Solar Atlas (GSA), Situ Tunggilis has a fairly good radiation intensity. This makes this area suitable for the implementation of the solar power plant system because the sun is the main source of energy seen every day. The following is a map and data on solar energy potential in the Situ Tunggilis Tourism Area, Cileungsi District, Bogor Regency.

**Table 2**. Solar Energy Potential Data for Lebakmuncang Village, Ciwidey District, Bandung Regency

| Parameters | Potential Nominal |
|---|---|
| Direct Normal Iradiation | 2,830 kWh/m$^2$ per day |
| Global Horizontal Iradiation | 4,810 kWh/m$^2$ per day |
| Diffuse Horizontal Iradiation | 2,667 kWh/m$^2$ per day |
| Temperature | 26,0ºC |

Global horizontal irradiation is the total amount of radiation received by the horizontal surface of the land. The global irradiation value is one of the parameters in the installation of solar panels that affects the amount of electrical energy that will later be converted by the solar panels [21]. In the data presented above, the potential for global solar energy radiation is 4,810 kWh/m$^2$ per day, which shows the average potential for solar energy in Indonesia, ranging from 4.5 -5.5 kWh/m$^2$ per day. These data show that Situ Tunggilis is relevant if the use of solar energy is applied as one of the local alternative energy sources.

#### 3.2 Artificial Lighting Needs

Based on the SNI 03-6575-2001 and SNI 7391-2008 standards, it was found that the amount of illumination needed for pedestrian lighting in this case pedestrians is a minimum of around 4 Lux. The width of the land pedestrian road is 2 meters while the floating pedestrian is 3 meters. The height of the installed lights is 4 meters and the distance between lights is 10 meters according to PUPR Regulation no.

3 of 2014 concerning pedestrian guidelines. The length of the land pedestrian planned to be installed with public street light is 220 meters, while the length of the floating pedestrian is 170 meters. So the need for lighting poles is 22 lamp posts for land pedestrians and 17 lamp posts for floating pedestrians. After knowing the standard light intensity in the pedestrian area is 4 Lux, the required light flux can be calculated as follows:

- The light flux requirements for land pedestrian :
$$\emptyset = E\ x\ A$$
$$= 4\ lux\ x\ 440\ m^2$$
$$= 1760\ Lumen$$

- The light flux requirement for floating pedestrians :
$$\emptyset = E\ x\ A$$
$$= 4\ lux\ x\ 510\ m^2$$
$$= 2040\ Lumen$$

- The power requirements for land pedestrian lighting are :
$$W = \frac{\emptyset}{\emptyset_{Spesific}}$$
$$= \frac{1760}{139{,}369} = 12\ Watt$$

- The power requirements for floating pedestrian lighting are :
$$W = \frac{\emptyset}{\emptyset_{Spesific}}$$
$$= \frac{2040}{137{,}369} = 14\ Watt$$

The need for LED lights for pedestrian lighting is equalized at each point to 15 Watts and will be installed along the land and floating pedestrian areas, adjusted to the distance of the lights according to PUPR regulations of 10 meters per pole, so that the lights needed are:

- Land Pedestrians
$$Many\ of\ Lamps = \frac{220\ m\ (\text{Length of Road})}{10\ m} = 22\ Lampu$$

- Floating Pedestrians
$$Many\ of\ Lamps = \frac{170\ m\ (\text{Length of Road})}{10\ m} = 17\ Lampu$$

Total lamp requirement is 39 LED lamps

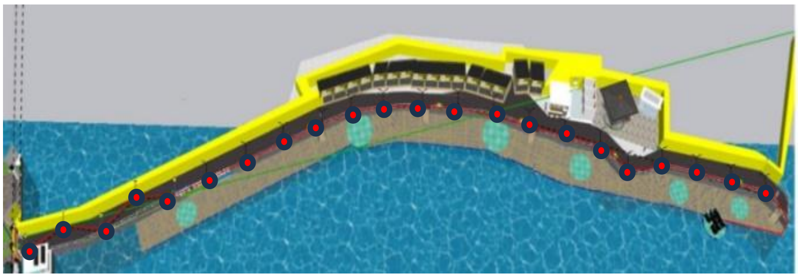
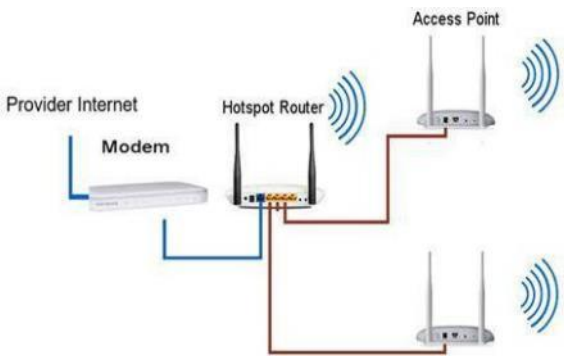


**Figure 5**. Placement point to public street light

**3.3 Internet Resource Requirements**

The resources for internet devices will later be connected to one of the networks of a local internet provider via a 2.85 Watt wireless router and then distributed widely using two 2.85 Watt access points, so that the total power requirement for local internet facilities supplied by the floating solar power plant is 8.55 Watts.

In building Wi-Fi in the Situ Tungggilis area by choosing one of the providers for internet access, the




Wi-Fi router for the internet can use Wi-Fi with a frequency of 2.4 GHz. Wi-Fi with this standard has a data rate of 1 Mbps to 11 Mbps. While the signal range can reach 20 to 100 meters [22].

The main difference between 2.4 GHz and 5 GHz WiFi is the speed and range. 2.4 GHz WiFi has a wider range, while 5 GHz WiFi has a higher speed.

In order for the network coverage to reach the entire Situ Tunggilis area, it is necessary to add a signal amplifier or access point. In this area, 2 access points are needed, as shown in (7) below.

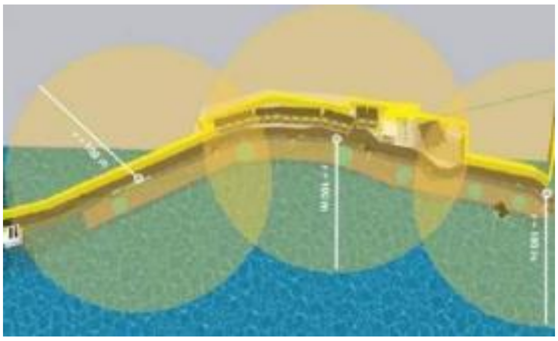


**Figure 6.** Wifi network configuration and coverage area

### 3.4 Floating Solar Power Plant Electrical Energy Load

The daily load of the Floating Solar Power Plant is the electrical energy consumption load for lighting, internet and solar tracker needs to drive the solar panel mounting. The following is Table (3) of the electrical energy needs of the Floating Solar Power Plant :

**Table 3**. Data on the daily consumption load of the floating solar power plant

| No. | Name of Equipment | Power (Watt) | Total | Operation (Hour) | Energy (Wh) |
|---|---|---|---|---|---|
| **1.** | LED Lamp | 15 | 39 | 9 | 5265 |
| **2.** | LED Strip 10 meters | 10 | 1 | 9 | 90 |
| **3.** | Motor Steper | 45 | 5 | 6 | 1350 |
| **4.** | Access Point & Router | 2,85 | 3 | 24 | 205,2 |
| | **TOTAL** | | | | **6910 Wh/Day** |
| | **Monthly Energy** | | | | **207,4 kWh/Mth** |

When designing the application of solar panels with a solar power plant system, the losses factor must also be taken into account. The losses factor can be caused by various factors such as a long cable installation system, loss of voltage on the connector and the efficiency of the solar panel itself and also the level of solar radiation. For this reason, it is necessary to add a power value of 20% of the initial value, namely :

$6910 \, x \, 20 \, \% = 1382 \, Watt \, Hour$

$6910 + 1382 = 8292 \, Watt \, Hour$

**3.5 Solar Panel Configuration**

The energy requirement needed to accommodate the load is 8,292 kWh. Based on data from GSA, Cileungsi District has Equivalent Sun Hours (ESH) of around 6 - 5 hours per day. However, in this case, the lowest scenario will be used, namely 5 hours in choosing ESH to anticipate the possibilities that occur related to the fluctuation of sunlight. The power requirement that will be generated by the floating solar power plant is calculated using the following equation :

$$Solar\ Power\ Requairement = \frac{Total\ of\ Energy\ Needed\ (Wh)}{Equivalent\ Sun\ Hours\ (h)}$$

$$= \frac{8292}{5} = 1658{,}4\ W \sim 1{,}658\ \text{kW}$$

The capacity of the solar panel to be used in this sample is 200 Wp mono crystalline type which has good efficiency. The number of solar panels needed can be calculated as follows :

$$Total\ of\ Solar\ Panel = \frac{Power\ Needed\ (kW)}{Solar\ Panel\ Capacity\ (Wp) x ESH(h)}$$

$$= \frac{8292\ W}{200\ Wp\ x\ 5} = 8{,}29 \sim 8\ Solar\ Panel$$

So that :

$$8\ pcs\ \cdot 200\ Wp \cdot 5\ hour = 8000\ Wh\ (Totally\ Energy)$$

The battery bank used uses a 12 Volt system with a discharge rate / DoD of 50%, with a capacity of each battery of 100 Ah.

$$\Sigma\ B = \frac{8334}{(12\ VDC.100\ Ah).\ 0{,}5} \cdot 1\ day$$

$$= \frac{8334}{600} = 13{,}8\ \approx 14\ unit\ of\ batterry$$

Verificiation :

$$14\ unit\ of\ batterry\ .12\ VDC\ .100\ Ah\ .0{,}5 = 8400\ \ watt\ hour$$

So to meet the needs of 1 day operation, 14 units of batteries with a capacity of 12 VDC 100 Ah are needed. The configuration of solar panels and batteries depends on the rated voltage on the solar charger controller PWM / MPPT and Inverter (in this case, you can use a Pure Sine Wave Inverter with a capacity of 10 Kilowatt).

**3.6 Design of Solar Power Plant System and Internet Network**

Seeing the potential that is matched with the existing conditions of public facilities that already exist in the Situ Tunggilis Tourism Area, the application of local solar energy utilization will be more appropriate if applied to meet the development of public facilities such as public street lighting and internet needs for household loads, especially for the development of public street lighting along the side of the lake and floating roads that stretch to the island and out of the island (development plan). This public street lighting will add to the aesthetic power of the Situ Tunggilis Tourism Area, especially at night which usually looks rather dark. In addition, with the extension of a local internet network specifically for tourism that covers the Situ Tunggilis island area and its surroundings, it will further strengthen the reach of quality internet facilities.

In the design plan in Figure 8, a floating solar power plant concept is created where solar panels are installed on the flying deck / floating pedestrian. Solar panels are installed on the floating pedestrian at the beginning of the pedestrian. The lighting load and internet resources along the pedestrian are accommodated by the solar power plant system.


**Figure 7.** Floating solar power plant building design

**3.7 Feasibility Study Analysis**

Technical Analysis

This study uses the PVSys software tool to simulate the floating solar power plant system that has been calculated previously. The simulation of the floating solar power plant system aims to analyze the technical results of the design that has been made. In conducting the floating solar power plant simulation in the Situ Tunggilis Tourism Area, the factors that are of concern are the performance ratio (work ratio), shading (shadow effect), energy production and Losses value (losses) from the designed design.

In the simulation results carried out using PVsyst software, a performance ratio value of 71.2% was produced. The expected energy produced by the floating solar power plant is obtained by multiplying the GHI value, the floating solar power plant area that receives radiation and the efficiency of the solar panels. As seen in Figure 9. from the performance ratio value generated by the PVsyst software, the performance of the planned offgrid floating solar power plant system is included in the category above the feasibility standard and is feasible to be implemented (above 70%). Based on the performance ratio of the solar power plant system, it can be said to be feasible because the system is considered quite efficient in converting solar energy into electrical energy to be used.

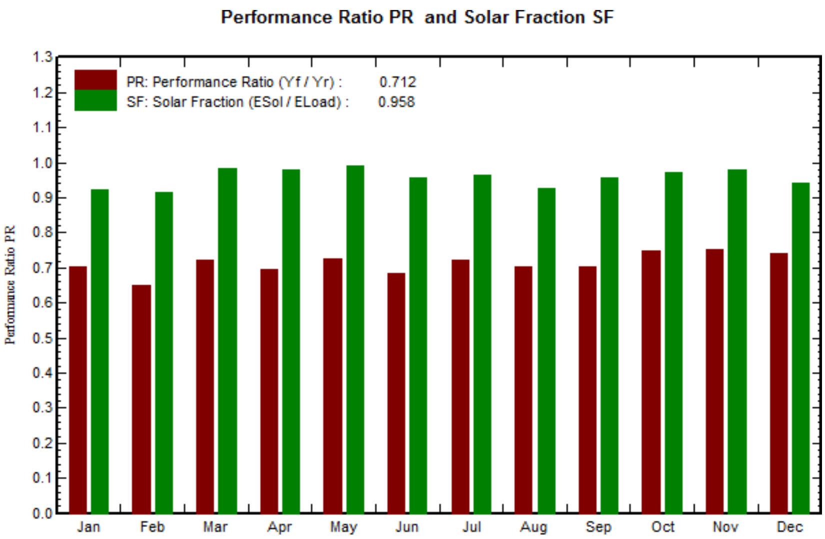



**Figure 8**. Performance ratio graph

The obtained PR value of 71%, although it is slightly lower than values reported in some grid-connected or larger-scale installations. For example, a floating PV study conducted at Lake Batur, Indonesia, reported PR values in the range of 75–85%, depending on system configuration and design scenarios [8]. Similarly, a grid-connected floating PV feasibility study in West Java reported PR values between 0.74–0.75 under comparable climatic conditions [23]. In a broader comparative analysis, floating PV systems were shown to exhibit performance advantages over ground-mounted systems due to cooling effects from water surfaces, with reported PR improvements of 3–8% relative to land-based installations [24].

Compared with these findings, the PR value obtained in this study is approximately 4–14 percentage points lower than the upper range reported for large-scale floating PV systems. This difference is primarily attributed to the off-grid configuration, the use of VRLA batteries, and additional conversion losses associated with energy storage. Battery charge–discharge inefficiencies and the conservative Depth of Discharge (DoD) of 50% reduce the fraction of usable energy delivered to the loads. Furthermore, constraints in module tilt angle and array orientation imposed by the floating platform geometry, as well as partial shading from surrounding vegetation, contribute to additional performance losses.

Despite these limitations, the PR value of 71% demonstrates that the proposed floating solar system is capable of reliably supplying the required electrical energy for public lighting and internet services in the tourist area. The result confirms the technical feasibility of integrating multi-purpose public facility loads into a floating photovoltaic application under land-constrained conditions.

Several strategies could be adopted to improve system performance. The use of higher-efficiency inverters and optimized cabling layouts could reduce electrical losses. Replacing VRLA batteries with lithium-ion or lithium iron phosphate ($LiFePO_4$) batteries, which typically offer round-trip efficiencies above 90–95%, could increase the usable energy fraction and raise the overall PR value. In addition, optimizing module tilt and spacing to minimize shading losses, implementing string-level maximum power point tracking (MPPT), and scheduling periodic module cleaning could further enhance energy yield.

Overall, the comparative and quantitative analysis indicates that while the obtained PR value is lower than that reported for some large-scale floating PV systems, it remains within an acceptable operational range for a small-scale off-grid floating solar application supplying public lighting and internet loads [16]. The results also highlight clear pathways for technical optimization that could increase the PR value toward the 75–80% range reported in similar floating PV studies.

Energy production and losses in the floating solar power system based on the results of the PVSys simulation that was designed can be seen in (11) below :

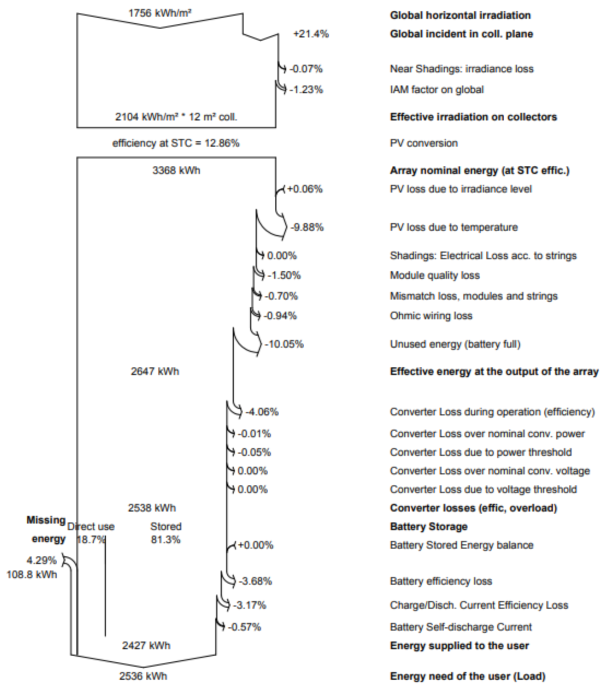



**Figure 9**. Losses of solar energy systems and production

The image above shows that the largest system losses lie in temperature losses of 9.88% and in unused battery energy of 10%. According to [25] in fact, floating solar power plant excels in terms of temperature stability which makes it compared to land-based solar power plant, so that floating solar power plant remains optimally operating, the temperature difference is 60°C lower than land-based solar power plant. While the unused battery energy is due to the State of Charge (SoC) of the battery, which should not use all the energy in the battery because it will reduce the battery life. As a result of the losses that occur, the energy captured by the PLTS system from 3368 kWh to 2536 kWh or down 25%. The decrease in the amount of energy that can be utilized by the PLTS to accommodate the load is still within the tolerance limit because its performance ratio is still 71%.

Economic and Environmental Analysis

From a simplified economic perspective, the proposed floating solar power plant system has a total installed capacity of 1.6 kWp, consisting of eight 200 Wp photovoltaic modules and an energy storage system of fourteen 12 V, 100 Ah VRLA batteries. The total nominal battery storage capacity is approximately 16.8 kWh, of which about 8.4 kWh is usable under the applied Depth of Discharge (DoD) of 50%. Based on the PVsyst simulation results and the estimated annual energy production, the system is expected to offset electricity consumption that would otherwise be supplied by the national grid.

Using the non-subsidized electricity tariff for 1,300–22,000 VA customers in Indonesia, which is IDR 1,444.70 per kWh [26], the annual economic benefit can be approximated from the avoided electricity cost. Assuming the simulated energy yield is fully utilized for public lighting and internet services, the system would generate annual savings proportional to its yearly energy output. Although a detailed capital cost estimation was not conducted in this study, the relatively small system size, the use of standardized 200 Wp modules, and low-power end-use loads indicate that the initial investment remains moderate for a public facility application.

From a qualitative payback perspective, the combination of zero fuel costs, low routine maintenance requirements, and a long photovoltaic module lifetime of approximately 20–25 years suggests that the system has favorable long-term economic potential. While VRLA batteries typically require replacement every 4–6 years depending on operating conditions, their relatively low upfront cost compared to lithium-based alternatives partially offsets this drawback. Overall, the proposed floating solar power plant is economically reasonable for supplying public lighting and internet infrastructure in tourist areas, particularly in locations where grid extension or diesel-based power generation would incur higher long-term costs.

In addition to economic considerations, several environmental and operational risk factors must be acknowledged. Environmental risks include high humidity levels that may accelerate corrosion of electrical connectors, seasonal variations in solar irradiation, partial shading from surrounding vegetation, and wind or small-wave effects on the floating platform. Operational challenges include VRLA battery degradation over time, fouling of photovoltaic modules due to dust or biological growth, and the risk of vandalism or unauthorized access in public

## 4. Conclusion

This study presents the design and performance-based planning of a floating solar power plant to supply electrical energy for public street lighting and internet infrastructure in the Situ Tunggilis Tourism Area. PVsyst simulation results indicate that the proposed system can meet the operational energy demand of lighting and internet services in the pedestrian area, achieving a performance ratio of 71% and utilizing approximately 75% of the available solar energy. The planned Wi-Fi network configuration also satisfies the required coverage radius, ensuring reliable internet connectivity throughout the tourist area. The main scientific contribution of this research is the integrated application of a small-scale, off-grid floating photovoltaic system for multi-purpose public facility loads in a non-remote tourist area, combining energy system design with lighting and internet infrastructure planning. This approach extends existing floating PV studies that predominantly focus on large-scale or grid-connected systems. This study is limited by its reliance on simulation-based performance evaluation and the absence of a quantitative economic feasibility analysis. Environmental and operational factors such as battery degradation, module fouling, and floating platform dynamics were not explicitly assessed. Future work should include long-term field validation, detailed techno-economic analysis, and exploration of advanced energy storage or hybrid renewable energy integration to improve system efficiency and scalability. Overall, the proposed floating PLTS system represents a viable alternative energy solution for supplying lighting and internet infrastructure in tourist areas.

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