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*Original Article*

# Potential Analysis of Electricity Infrastructure Development Using Geographic Information System (GIS)-Fuzzy Logic - Solar PV Power Plant on Sumba Island

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***Abstract*** - *As Indonesia's electricity demand grows, the shift from coal to renewable energy sources, especially solar power, is crucial. This study uses GIS and fuzzy logic to assess the potential for solar PV development on Sumba Island, a key renewable energy site. Evaluating 14 criteria and 8 constraints, the analysis identifies optimal locations for solar PV installation. Results reveal a potential capacity of 21,230.42 MWp, which could supply 52.32% of Indonesia's projected 2030 electricity demand. Economic evaluations show a Levelized Cost of Electricity (LCOE) of 0.0478 to 0.0602 USD/kWh, a positive Net Present Value (NPV), and a Simple Payback Period (SPP) of 4.03 to 6.34 years. Additionally, this development could reduce CO2 emissions by up to 29,326,836.29 tons annually. These findings highlight Sumba Island's significant role in advancing Indonesia's renewable energy goals and suggest further studies on integrating solar power into the national grid and optimizing HVDC transmission for efficient energy distribution.*

***Keywords*** - *PV, GIS, Fuzzy logic, Renewable energy, Sumba island.*

## 1. Introduction

The role of electricity infrastructure in supporting daily activities and economic growth is crucial. Electricity is an essential infrastructure for people to support their daily activities. The national demand for electrical energy continues to increase every year. The electricity demand will grow by 4.9% annually, or 40,575 MW, until 2030 [1]. The addition of power plant capacity continues to meet the increasing demand for electrical energy. This aligns with Indonesia's commitment to contribute to the Paris Agreement by reducing greenhouse gas emissions by 29% by 2030 and achieving net zero emissions by 2060. Furthermore, Indonesia has a national energy mix target of 23% by 2025 and 31% by 2050 for renewable energy use [2]. This highlights the importance of integrating renewable energy into expanding new power generation capacities. Indonesia boasts a renewable energy potential of 443,208 MW, encompassing geothermal, hydro, bioenergy, solar, wind, and marine energy sources spread throughout its territory. Solar energy dominates the renewable energy potential with 207,898 MW. In addition, from 2010 to 2022, the price of renewable energy plants, especially solar energy, continued to experience a significant decline. Solar energy experienced the largest price decline of 83% [3], making it the lowest-cost renewable energy plant to date. As a result, developing solar PV power plants is the best solution for encouraging the acceleration of renewable energy utilization and meeting national electrical energy needs. Recognizing Sumba Island as a renewable energy island, the government designated it as the Sumba Iconic Island in East Nusa Tenggara Province. This selection is based on Sumba Island has a wealth of renewable energy potential, such as water, bioenergy, wind, and solar [4]. Having the highest average irradiation among all regions in Indonesia, Sumba Island boasts a massive solar energy potential, estimated at up to 20,000 MW. The extensive unproductive land on Sumba Island offers significant potential for establishing high-capacity solar power plants, potentially resulting in more competitive energy prices. Despite its relatively small projected electricity demand, Sumba's potential to utilize solar PV power plants can help meet national energy requirements in Java and Bali via High Voltage Direct Current (HVDC) interconnection technology. Regions in Indonesia, including Sumba Island, which are conducive to solar PV development, often exhibit significant geographical intricacies. This includes topographical variations, different sunlight intensities, and varying weather patterns. The manual collection and analysis of extensive and diverse geographical data present substantial challenges regarding time requirements and complexity. In order to optimize the establishment of PV power plants, it is also necessary to conduct a meticulous multi-criteria analysis of various factors, including technical, social, environmental, and economic. At the same time, Geographic Information Systems (GIS) and fuzzy logic have shown strong and rapid capabilities in analyzing, modeling, and optimizing the development of renewable energy potential, especially PV power plants. GIS technology accelerates the analysis process by converting extensive geographical and multi-criteria data into spatial data. However, some criteria, such as environmental impact or social acceptance, may pose challenges in quantification during spatial data analysis. To address the challenge of quantifying complex criteria in spatial data analysis, researchers utilize linguistic variables to express these criteria and capture human concepts through qualitative data [5].

Zadeh introduced fuzzy logic in 1965, which enables the expression of a criterion as a linguistic variable. Fuzzy logic, as a tool, offers more flexible analysis capabilities for spatial data where clear distinctions between suitable and unsuitable are not well-defined. This utilization of fuzzy logic enhances the optimality and realism in decision-making processes. It explains why it is a preferred choice among researchers for evaluating and selecting power plant locations [6]. The study aims to integrate GIS and fuzzy logic to accurately represent human concepts and qualitative data in decision-making processes concerning spatial data analysis, such as selecting PV power plant sites. Fuzzy logic enables the articulation of criteria as language variables, facilitating a more adaptable and realistic analysis in contexts where appropriate and unsuitable distinctions are ambiguous. This methodology improves the efficacy and authenticity of decision-making processes, rendering it a favored option among researchers across many disciplines.

## 2. Literature Review

GIS technology enhances efficiency in solar power plant selection in Indonesia by integrating spatial data to analyze factors such as solar radiation, land availability, and grid connectivity. This helps identify the most efficient locations for solar power installations based on quantitative and qualitative criteria, ultimately optimizing site selection for cost-effective renewable energy supply [7, 8]. GIS is used in solar PV site selection by considering factors such as solar radiation, elevation, temperature, and economic aspects. Previous research has employed decision-making techniques such as AHP and GIS to determine the optimal locations for PV plants based on various criteria. Directly implementing PV power-generation data can aid in energy management and economic feasibility; solar irradiation is critical to site selection. Despite challenges related to historical data and topographical effects, GIS is crucial in selecting suitable regions for solar PV power plants [9, 10]. The accuracy of GIS data impacts site selection by providing precise location information that helps make informed decisions about suitable locations for various facilities or projects [11, 12]. Multi-Criteria Decision Analysis (MCDA) and fuzzy logic each affect the accuracy of GIS for choosing a site for a PV power plant by looking at important factors like weather, topography, economic and social factors, and land use using Geographic Information System (GIS) software and MCDA techniques. Several studies have used GIS and MCDA to find the best places for PV farms. Different methods, such as AHP, fuzzy-boolean logic, and TOPSIS, have been used to evaluate potential sites. These approaches help determine the best locations for solar power plants based on various factors, leading to accurate site selection for PV power plant installations [13–15].

Fuzzy logic is the optimal choice for selecting PV power plants when combined with GIS, as it enables the incorporation of various criteria, including environmental, economic, technical, and social factors, to identify which location is best for PV power plants [16, 17]. Fuzzy logic improves decision-making in GIS by allowing for the representation of imprecise and uncertain data, which is common in spatial analysis. It provides a way to handle vagueness and ambiguity in data, enabling more flexible and nuanced decision-making processes [18]. In addition to site selection, utility-scale solar PV plants can utilize GIS for economic assessment by analyzing land eligibility, conducting techno-economic assessments, and estimating the Levelized Cost of Electricity (LCOE) [18, 19]. Some advantages of using GIS for economic assessment include improved decision-making, better task performance, and enhanced spatial data visualization [20].

## 3. Research Methods

The following approach is suggested for applying fuzzy logic and Geographic Information Systems (GIS). Geographical data, including solar radiation, climatology, topography, land use, and approximate distance from infrastructure, will be transformed into spatial data using GIS. The transformation of the spatial data into fuzzy values will enhance the flexibility and suitability of the analysis for decision-making processes. There are no apparent differences between what is suitable and unsuitable. This enables the selection of PV power facilities to be more realistic and optimal. Subsequently, the ambiguous value will produce models and simulations to determine the most suitable location for a PV power plant. ArcGIS will be used with the weighted overlay method to determine the most optimal location for the PV power plant during the fuzzy value analysis process. An optimal location analysis will be conducted to help assess the potential for power generation, energy production, economics, and emission reduction. Figure 1 illustrates the flowchart for the upcoming research.

### *3.1. Site Selection Data*

Global Horizontal Irradiance (GHI) is one of the most important criteria affecting the production of electrical energy from solar panels [21]. Building PV power plants in areas with an average daily GHI value of 4 kWh/m2/day is economically feasible and profitable [22]. Temperature will greatly affect the efficiency and performance of solar panels [23]. Every 1 $^{o}$C increase in temperature beyond the STC condition temperature of 25 $^{o}$C leads to a 0.4%–0.5% reduction in energy production [24]. The Indonesia region's GHI and temperature data sources are from Solargis at a spatial resolution of 250 meters. NASA POWER provides essential climatological data for regional solar mapping, particularly in regions lacking local data. The GIS-based MCDM model effectively identifies solar farms, showing no significant differences between the data and ground-measured data.

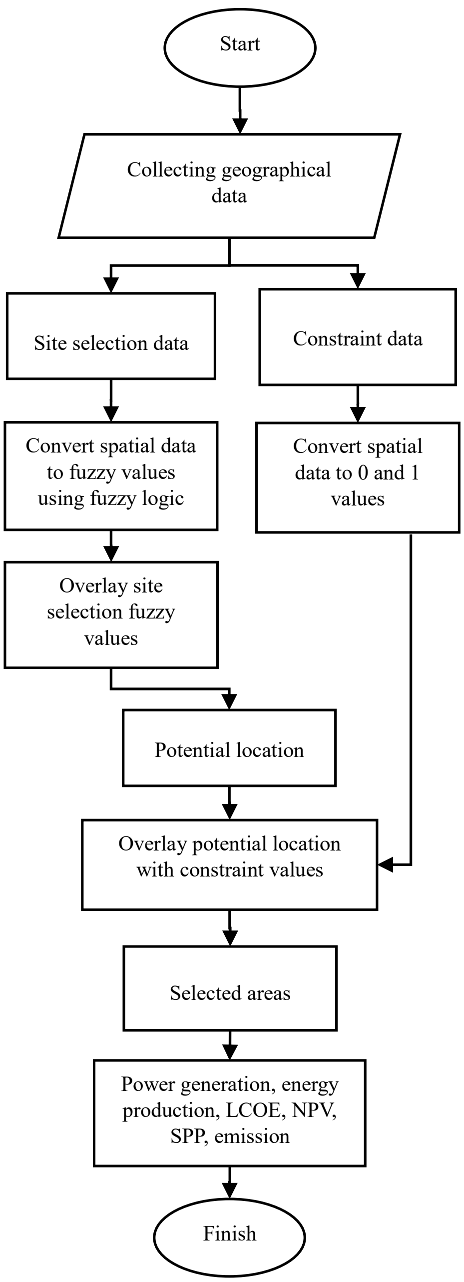


**Fig. 1 Research flowchart**

This indicates an ability to use NASA POWER data for optimal PV power plant site selection [25]. For this study, the climatology data, such as relative humidity, rainfall, and sunshine duration from NASA POWER from 1981 to 2022, were used. The relative humidity is the amount of water vapor present in the air that will affect the efficiency of solar panels through absorption, reflection, refraction, and collision of solar radiation with water vapor particles [26]. If the relative humidity reaches 85%, it will negatively impact the performance of solar panels [27]. The high amount of rainfall and clouds will significantly reduce the energy production of solar power plants. Energy production will drop by 10% to 25% of its maximum potential [28]. The sunshine duration will significantly reduce the energy output from PV power plants.

A shorter sunshine duration will result in less solar radiation reaching the solar panels [29]. Topography data, such as elevation, slope, and aspect, was obtained from processing Digital Elevation Model Nasional (DEMNAS) data published by the Indonesian Geospatial Information Agency. The DEMNAS data has a spatial resolution of 8.1 meters. Higher elevations can increase solar panels' ability to receive solar radiation. This is because the thickness and compounds of the atmosphere affect the entry of solar wave energy into the earth. The lower an area's elevation, the greater the thickness of the atmosphere [30]. However, this will also increase the logistics costs of sending equipment to these areas [25]. Proper slopes will have a significant impact on solar farm site selection. A sufficient slope will help reduce dust accumulation on solar panels [25]. Slopes over 11% are unsuitable for solar farm development [30]. The aspect direction is determined based on the eight cardinal directions.

This orientation is essential to ensure solar panels can obtain solar radiation [31]. Soil data for the Indonesia region, like soil type and soil texture, was obtained by processing data from the world soil map that was published by the Food and Agriculture Organization (FAO). Soil types that have a high sensitivity to erosion will provide poor foundation resistance to the construction of solar power plants on them. Soils in different regions have different conditions depending on their origin, composition, geological history, and many other factors. This will closely correlate with the erosion level and construction sensitivity. The compaction techniques used for building will closely correlate with the soil texture. Soils with a coarse texture will be easier to compact to provide high shear strength, while soils with fine textures tend to be challenging to compact [32]. To minimize adverse effects on a settlement's growth, the site analysis should exclude settlements within 500 meters [33]. Meanwhile, a viable PV power plant site should consider a minimum distance of 100 meters from main roads to avoid dust exposure and prevent potential road widening. The solar farm site should be at least 10 kilometers away from the road to avoid potential social issues during construction and higher construction expenses, particularly for material transportation [34]. PV power plants are unsuitable for water bodies such as rivers, lakes, and reservoirs, with the closest buffer radius of 500 meters and the farthest distance of 20 kilometers [6]. The Indonesian Geospatial Information Agency published the Indonesian topographic map (RBI), which includes data such as the distances to settlements, main roads, and water bodies.

### *3.2. Constraint Area Data*

Constraint factors eliminate, limit, and must be met because this constraint area is land that absolutely cannot be built for PV power plants. The constraint area prevents any adverse effects on the local environment and communities surrounding the PV power plant location. The data source is the Indonesian Geospatial Information Agency, which provides the distance to the main road, settlement, water bodies, and land use. The Ministry of Environment and Forestry provides different kinds of data, including the distance to protected areas, faults, and disaster areas. This data establishes constraints on the area based on several reviewed criteria, as specified in Table 1. The constraint data is obtained by converting the raster data of criteria in Table 1 into 0 and 1 values using raster calculator tools. The 0 values indicate prohibited locations that cannot be utilized for developing PV power plants, while the 1 values show areas that are available for development.

### *3.3. Fuzzy Map Generation*

Fuzzy logic, introduced by Zadeh in 1965, is a development of classical set theory based on two logical values: in and out [35]. Fuzzy elements can be member or non-member elements, and their membership level is expressed as a truth value ranging from 0 to 1 [33]. The truth value between 0 and 1 indicates that the element is between true and false; the closer it is to 1, the true value is true. The process involves assessing the element as a membership function, illustrated by a curve that maps input points to their member values within an interval between 0 and 1. As previously explained, Figure 2 and Figure 3 depict the fuzzy membership function in various curves, including linear, triangular, trapezoidal, and sigmoidal curves.

**Table 1. Constraint area generation parameters**

| Criteria | Constraint Limitation |
|---|---|
| Distance to the main road | > 10,000 meters |
| Distance to settlement | < 500 meters & > 20,000 meters |
| Distance to protected areas | < 1,000 meters |
| Distance to water bodies | < 500 meters & > 20,000 meters |
| Distance to faults | < 1,000 meters |
| Land use (forest & agricultural) | < 1,000 meters |
| Obstacle Limitation Surface (OLS) area | < 3,030 meters |
| Disaster area | High risk index |

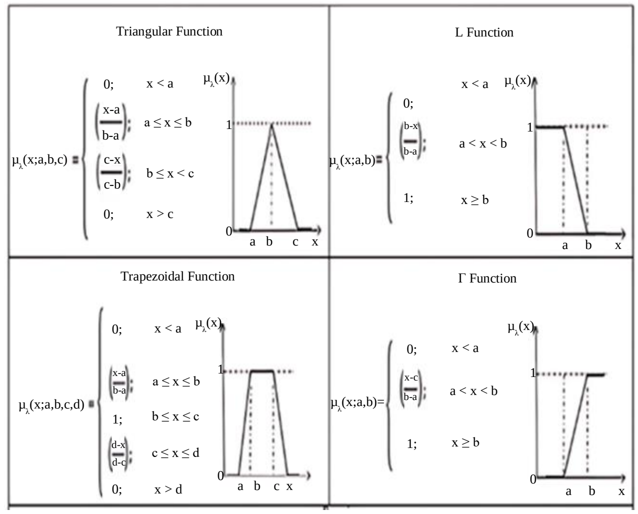


**Fig. 2 Fuzzy membership function (Linear, Triangular, Trapezoidal)**

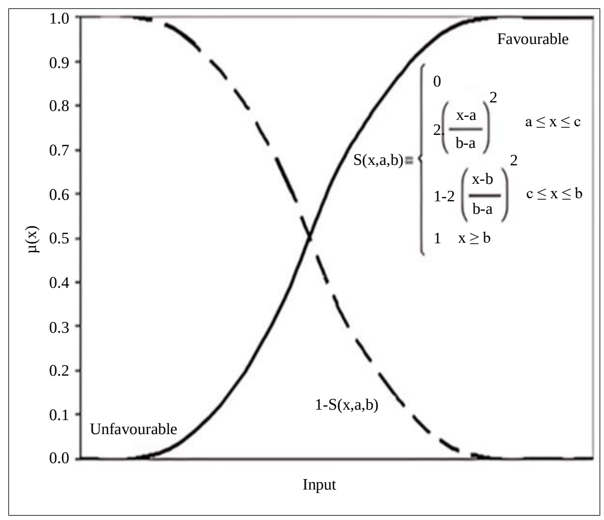


**Fig. 3 Fuzzy membership function (Sigmoidal)**

**Table 2. Fuzzy membership and weight of criteria for site selection**

| Criteria | Membership Function | Weight |
|---|---|---|
| GHI | Sigmoidal | 0.1872 |
| Temperature | Sigmoidal | 0.0810 |
| Relative humidity | Sigmoidal | 0.0746 |
| Rainfall | Sigmoidal | 0.0714 |
| Duration of sunshine | Sigmoidal | 0.0996 |
| Cloud cover | Sigmoidal | 0.0685 |
| Elevations | Linear | 0.0539 |
| Slopes | Linear | 0.0650 |
| Aspect | Trapezoidal | 0.1000 |
| Soil types | Linear | 0.0224 |
| Soil texture | Linear | 0.0315 |
| Distance to road | Linear | 0.0502 |
| Distance to settlement | Trapezoidal | 0.0478 |
| Distance to water bodies | Trapezoidal | 0.0513 |

The membership function for site selection criteria was selected based on the characteristics of each criteria. Membership functions are used to convert the spatial data to fuzzy values that will be used to analyze the site selection. The analyzed process will use the weighted overlay method. The membership function and weight of criteria for site selection will be used as parameters in Table 2.

### 3.4. Site Selection

GIS-based location suitability determination is based on Multi Criteria Evaluation (MCE) to solve complex problems with multiple criteria [36]. MCE serves as a decision-making tool, ranking several alternatives according to criteria that may have varying units. By normalizing the multiplication of raster from fuzzy membership function processing with weights and raster from constraint area data, we can determine which places would be suitable for building a PV power plant. The analysis of location suitability employs the following Equation (1):

$$S = X * \sum_{i=1}^{n}(N_i * W_i) \quad (1)$$

Where S is the suitability index, X is the constraint area raster, Ni is the normalized raster of criterion i, and Wi is the weight of criterion i. The suitability index value or fuzzy membership value, which indicates least suitable (below 0.5), moderately suitable (0.5-0.7), and most suitable (above 0.7), can determine the suitability of a PV power plant development site.

### 3.5. PV Power Plant Potential Analysis

Once the optimal PV locations have the potential power generation, energy production, economics, and emission reduction, they will be analyzed using ArcGIS Pro. To calculate the potential power generation from the chosen location, we can use the following Equation (2):

$$P_{PV} = A * PD \quad (2)$$

Where $P_{PV}$ is the potential generation (MWp), A is the area of the PV power plant ($Km^2$), and PD is the power density for a PV power plant with values 0.6 MWp/Hectare [37]. We use the P90 value as the basis for calculating the economic potential. P90 represents the annual energy production threshold, which has a 90% chance of being exceeded. This value is used to mitigate risks from uncertain factors in energy calculations. To estimate the energy output in a year, we will use the following Equation (3):

$$P_{90} = SR * CA * D_y * \eta * \eta_d * PR * FK \quad (3)$$

Where P90 is the energy produced in a year with 90% probability (kWh/year), SR is averaged daily GHI (kWh/m2/day), CA is the area of PV power plant development (m2), dan $D_y$ is the number of days in a year (365 days). While η is the solar panel efficiency of 16% [7], ηd is the DC to AC current conversion factor of 0.77 [38], PR is the performance ratio of the PV power plant with the value of 75% [39] dan FK is bias correction factor of 0.83 [40]. The calculation of the economic potential of the PV power plant development is reviewed based on 3 parameters, namely Levelized Cost of Electricity (LCOE), Net Present Value (NPV), and Payback Period. LCOE is defined as the selling price of electricity required to break even on a solar power plant project's economics. Additionally, the calculation of the cost of production for one kilowatt-hour (kWh) of electrical energy uses LCOE as a reference. First, the costs that are affected by investment, maintenance, and operation must be calculated [41].

$$LCOE = \frac{(I*CRF)+(C_{OM}+C_{tax})}{P_{90}} \quad (4)$$

$$CRF = \frac{i*(1+i)^n}{(1+n)^n-1} \quad (5)$$

The study guide defines I as the total investment cost, CRF as the capital recovery factor, $C_{OM}$ is the operation and maintenance cost of the PV power plant per year, $C_{tax}$ is income tax, i as the discount rate, dan n as the economic life of the PV power plant, which is 20 years [42]. The total investment cost refers to the total cost of installing the PV power plant per kW, including the cost of connecting it to the main road. The PV power plant installation cost per kW is 790 USD, and the annual maintenance and operation cost is 14.4 USD/kW [43]. Meanwhile, the connection to the main road costs 196,000 USD/km [7]. The discount rate used in the calculation is 11.3% [44]. The sum of the present values of the difference between cash inflows and outflows is called NPV in finance. NPV is the fundamental instrument for long-term project feasibility analysis [45]. It is considered feasible if a project has a positive NPV value (NPV below 0) and a negative NPV (NPV above 0). In this study, the cash flow remains constant annually until the end of the economic life and can be expressed using Equation (6) :

$$NPV = \sum_{n=1}^{N}\frac{(B_n-C_{OM}-C_{tax})}{(1+i)^n} - I \quad (6)$$

The annual revenue from energy production is represented in $B_n$ (USD). We obtain the annual revenue by multiplying P90 by the Feed in Tariff (FiT) of 0.0695 – 0.0834 USD/kWh for years 1 to 10 and a maximum of 0.0417 USD/kWh for years 11 to 30 [46]. The payback period is the duration necessary for the total incoming returns to match the total investment cost expressed in years. The indicator shows the risk and uncertainty of project investment. This study uses the Simple Payback Period (SPP), assuming a constant yearly cash flow. The SPP value is feasible if it is less than 10 years [47]. The SPP value can be calculated with the Equation (7):

$$SPP = \frac{I}{CF} \quad (7)$$

The economic evaluation should involve a sensitivity analysis to consider variables that may affect the LCOE, NPV, and repayment period. This will contribute to the economic discussion. The sensitivity analysis will be conducted based on the difference in FiT,

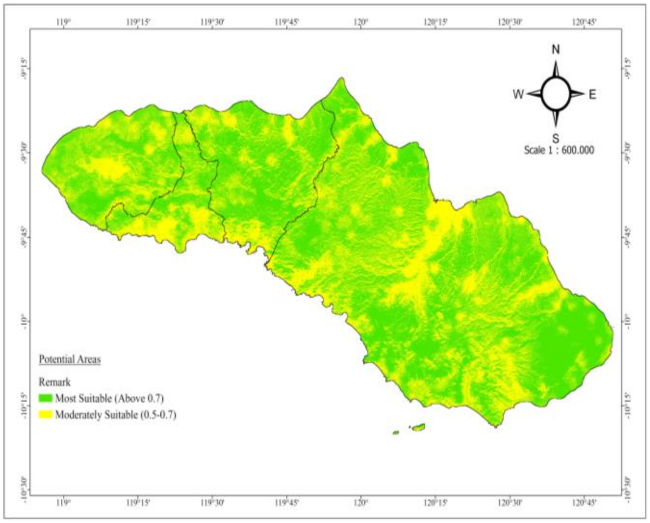


**Fig. 4 Potential areas for PV power plants**

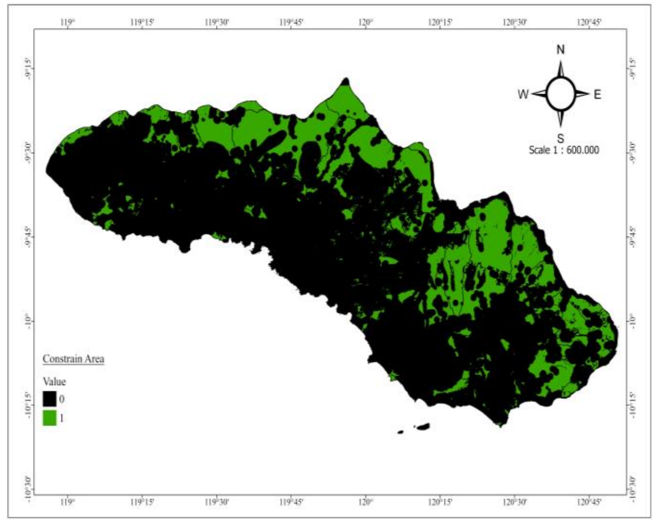


**Fig. 5 Constraint areas for PV power plants**

Based on Indonesian regulations, the FiT for PV power plants is 0.0695 USD/kWh and 0.0834 USD/kWh. In addition to the FiT difference, the analysis indicates a -10% and +10% change in the accommodation installation price.

Emission reduction, especially $CO_2$ with the development of PV power plants, can be an important indicator for energy planners to carry out renewable energy planning on a regional and national scale. We can calculate the $CO_2$ reduction potential using the following Equation (8):

$$R_i = P_{90} * EF \quad (8)$$

EF represents an emission factor of 0.54 tons $CO_2$/MWh [48], and $R_i$ represents the potential $CO_2$ reduction in 1 year (tons $CO_2$eq).

## 4. Results and Discussion

Figure 4 illustrates the data analysis and modeling of each criterion that influences the selection of PV power plants on Sumba Island, utilizing a combination of GIS and fuzzy logic. The fuzzy value for each criterion falls within the range of 0.50-0.89, as determined by the fuzzy map overlay results. The area with a moderately suitable category (0.5-0.7) amounted to 4581.79 km$^2$, and the area with the most suitable category (above 0.7) amounted to 6332.63 km$^2$.

In the constrained area determined by the GIS overlay, the available area for PV power plant development is 2559.94 km², as illustrated in Figure 5. Furthermore, the optimal location is obtained by multiplying the selected location map raster with the constraint area raster.

The data processing and modeling results identified 96 optimal sites for the location of PV power plants on Sumba Island. Figure 6 indicates that the optimal place for development is 353.84 km² or 3.24% of Sumba Island's total area.

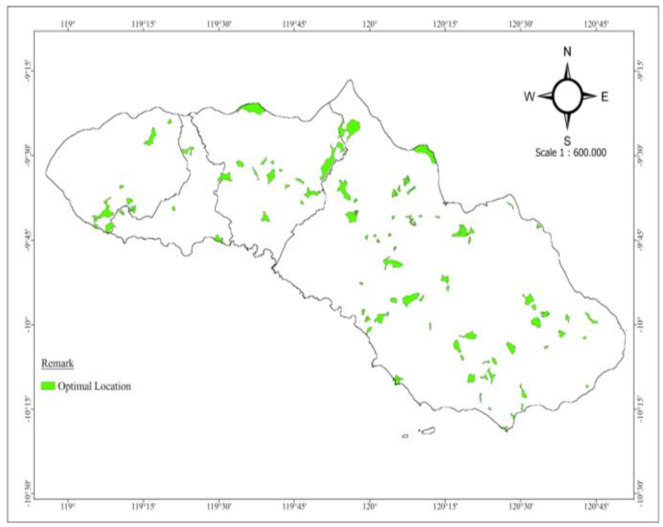


**Fig. 6 Optimal location for PV power plants**

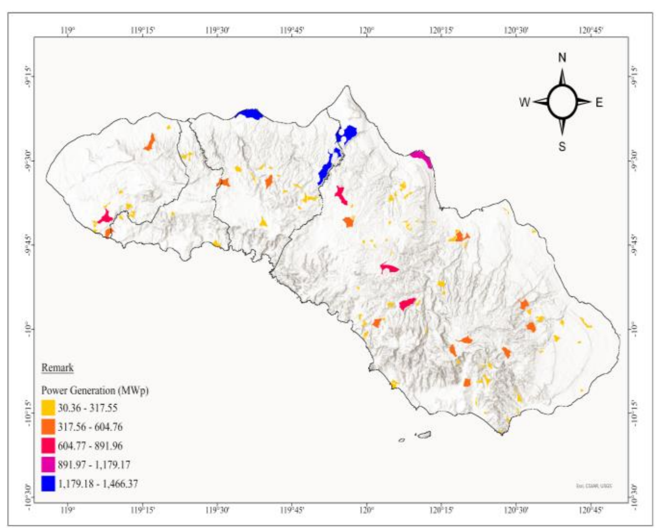


**Fig. 7 The potential for power generation**

### *4.1. Power Generation and Energy Potential*

The development site's area determines the potential for power generation and energy, as shown in Figure 7. The data processing results reveal that PV power plants can generate a potential capacity ranging from 30.36 to 1,466.37 MWp, totaling 21,230.42 MWp. Until 2030, the total capacity can meet the projected electrical energy demand of 52.32% of 40,575 MW. Furthermore, a potential capacity of 21,230.42 MWp can elevate the renewable energy mix's aim from 15.05% to 27.21%. This makes achieving a 23% renewable energy mix by 2025 attainable. As determined by data analysis, the annual potential energy output of PV power plants ranges from 0.09 to 4.09 TWh.

### *4.2. Economic Potential of the Development PV Power Plant*

The economic analysis of PV power plants on Sumba Island is conducted by calculating three parameters: Levelized Cost of Electricity (LCOE), Net Present Value (NPV), and Simple Payback Period (SPP) with 6 different scenarios. The analysis for 6 scenarios shows that the LCOE value is between 0.0478 and 0.0602 USD/kWh, as shown in Table 3. The LCOE value from the analyzed PV power plant sites is lower than Presidential Regulation No. 112 of 2022, which sets a FiT of USD 0.0695-0.0834/kWh. This shows that PV power plants can potentially provide economic benefits when they develop.

The NPV of the PV power plant locations, across 6 different scenarios, ranges from 4.15 to 800.48 million USD. The NPV analysis results show a positive NPV value (NPV above 0), indicating the feasibility of developing PV power plants at these locations. The payback period is the duration necessary for the cumulative returns to match the cumulative investment cost, expressed in years. The analysis's results are then summarized in Table 3. The PV power plant locations' SPP values fall within the range of 4.03 to 6.34 years, enabling a return on investment to occur before 10 years. The analysis of the three reviewed parameters under 6 different scenarios, such as FiT and installation cost, revealed that they all meet the requirements for economic feasibility.

### *4.3. Emission Reduction Potential*

The amount of potential $CO_2$ gas emission reduction each year by developing PV power plants on Sumba Island is 41,977.08 to 2,206,755.50 Ton$CO_2$eq, as shown in Figure 8, or equivalent to a total of 29,326,836.29 Ton$CO_2$eq. This $CO_2$ emission reduction supports Indonesia's $CO_2$ emission reduction target 2030 of 835 million Ton$CO_2$eq. This aligns with the Law of the Republic of Indonesia Number 16 Year 2016, which mandates a 29% reduction in carbon emissions through one's efforts and a 40% reduction through international cooperation, assuming no action or business as usual in 2030.

**Table 3. The Sensitivity analysis of the PV power plant on Sumba Island**

| No | Scenario | LCOE (USD/kWh) | NPV (in million USD) | Payback Period (Years) |
|---|---|---|---|---|
| 1 | FiT 0.0695 USD/kWh | 0.0506 – 0.0538 | 6.33 – 438.23 | 5.32 – 5.80 |
| 2 | FiT 0.0834 USD/kWh | 0.0537 – 0.0568 | 11.40 – 704.73 | 4.42 – 4.82 |
| 3 | FiT 0.0695 USD/kWH, installation cost +10% | 0.0538 – 0.0572 | 4.15 – 332.90 | 5.81 – 6.34 |
| 4 | FiT 0.0834 USD/kWH, installation cost +10% | 0.0568 – 0.0602 | 9.22 – 599.40 | 4.84 – 5.27 |
| 5 | FiT 0.0695 USD/kWH, installation cost -10% | 0.0478 – 0.0507 | 8.31 – 533.98 | 4.86 – 5.30 |
| 6 | FiT 0.0834 USD/kWH, installation cost -10% | 0.0508 – 0.0537 | 13.38 – 800.48 | 4.03 – 4.40 |

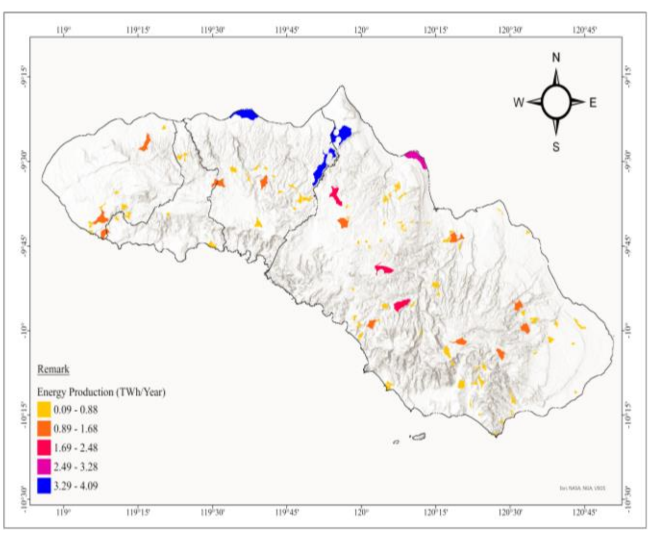


**Fig. 8 The amount of potential $CO_2$ gas emissions reduction**

## 5. Conclusion

The results of the potential analysis using GIS and fuzzy logic show that Sumba Island has a potential solar PV power plant of 21,230.42 MWp. That will meet the projected national electrical energy demand of 52.32% of the total 40,575 MW by 2030. The goal of increasing the renewable energy mix from 15.05% to 27.21% can be achieved. This makes the projected Indonesia renewable energy mix target of 23% in 2025 realistic. Examining the three analyzed parameters over 6 different scenarios, including FiT and installation costs, demonstrated that they all satisfy the criteria for economic feasibility. The analysis reveals that the LCOE value is 0.0478 - 0.0602 USD/kWh, below the FiT of USD 0.0695 - 0.0834/kWh. The NPV of the PV power plant on Sumba Island is between 4.15 and 800.48 million USD, a positive NPV value (NPV above 0), indicating the feasibility of developing a PV power plant. SPP values show the range of 4.03 to 6.34 years, enabling a return on investment to occur within 10 years. With potential energy production of 0.09–

4.09 TWh/Year, developing PV power plants on Sumba Island reduces potential $CO_2$ gas emissions by 29,326,836.29 TonCO2eq each year. This $CO_2$ emission reduction supports Indonesia's $CO_2$ emission reduction target 2030 of 835 million tons CO2 eq. This research demonstrates that developing solar PV power plants on Sumba Island is one of the best solutions for accelerating renewable energy utilization and meeting national electrical energy needs. In addition to this research, the feasibility study on the operation of the existing electrical system guarantees its reliability. Furthermore, the comprehensive studies on HVDC transmission aim to efficiently distribute electrical energy from Sumba Island to other islands, thereby ensuring proper channeling of the generated energy from the developed PV power plant.

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