Analysis of the Renewable Energy Potential in Tidung Island

Aditya Moralia[1*], Murie Dwiyaniti[2], Yogi Widiawati[3]
[1,2,3]State Polytechnic of Jakarta
[1,2,3]Jl. Prof. DR. G.A. Siwabessy, Depok, Jawa Barat 16425, Indonesia (10pt)
[1]adityamoralia.te23@stu.pnj.ac.id
[2]murie.dwiyaniti@elektro.pnj.ac.id
[3]yogi.widiawati@elektro.pnj.ac.id

Abstract – ***Tidung Island, as part of the Kepulauan Seribu (Thousand Islands) region, possesses natural resource potential that can be utilized as a source of renewable energy (RE). However, the utilization of renewable energy in this area remains very limited. This research aims to analyze the potential of renewable energy on Tidung Island, focusing on solar and wind energy, based on factual data collected on the island and secondary data from the Global Solar Atlas and Global Wind Atlas. The research employs a quantitative, comparative, and descriptive approach, with primary data obtained through field surveys and compared to secondary data from the aforementioned global atlases. The analysis is conducted using deviation comparison methods, such as Standard Deviation, Mean Absolute Deviation (MAD), and Percentage Deviation. The results show that Tidung Island has an average daily solar irradiance potential of approximately 210.15 watts per square meter (W/m²) and an average daily wind speed of around 3.27 meters per second (m/s). When converted into average daily energy, the solar energy potential is approximately 89,31 Wh/day, while the wind energy potential is about 670.8 Wh/day.***

Keywords: Tidung Island, Renewable Energy, Wind Energy, Solar Energy, Deviation

I. INTRODUCTION

Electric energy is one of the most important aspects of various technological fields [1]. A good power system is one that can sustainably meet energy demand without disruptions [2]. Currently, the power generation sector is still dominated by fossil fuels, particularly coal and diesel [3]. However, the central government is currently striving to accelerate the development of new renewable energy power plants [4]. At present, Tidung Island still relies on electricity from outside the island, even though Tidung Island itself has abundant renewable energy sources, especially wind and solar energy [5]. By utilizing renewable energy in island regions like Tidung Island, this represents a form of energy independence for remote areas that are far from electricity supply [6]. In addition, energy independence in island regions can minimize disruptions in the electricity distribution network from external sources [7], [8], [9], [10].

With this research, it is hoped to assist the central government or academic parties who want to implement renewable energy in island regions, especially Tidung Island. This research offers factual data on renewable energy available on Tidung Island with variables such as light intensity value (lux), solar irradiation value (W/m²), wind speed value (m/s), and daily power value (Wh/day) in the form of estimation calculations for the potential of wind and solar energy. This research uses quantitative, comparative, and descriptive methods to obtain and process primary data. To measure and read the values of solar irradiation and wind speed, measuring instruments and sensors play an important role in this research. The measuring instruments used include a solar power meter and anemometer, which are used to measure and compare solar irradiation values and wind speed on sensors. The sensors used in this research are intended to create data logging for the research, which serves as primary data [11], [12]. The collected primary data will be analyzed and compared using quantitative, comparative, and descriptive methods. The reference for this research is the Global Solar Atlas and Global Wind Atlas as secondary data [13], [14].

II. METHODS

This research uses a quantitative, comparative, and descriptive approach to the potential of renewable energy on Tidung Island. This approach has been widely used before, supported by calculation models similar to those used in previous research, including standard deviation, mean absolute deviation (MAD), and percentage deviation models [15], [16], [17]. This research is conducted on Tidung Besar Island, more precisely at the Love Bridge with coordinates 5°48'10" S, 106°30'51" E [18], starting from December 4, 2024, until June 2025. Data is acquired through an IoT monitoring system.

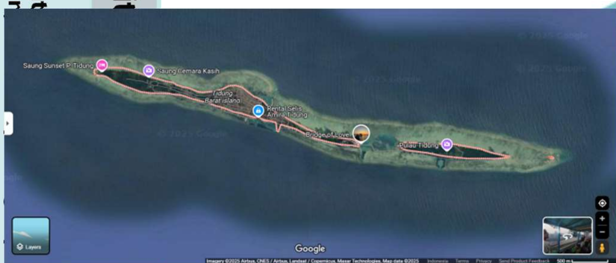

Figure 1. Location of research

To compare a variable, the variable must have the same unit. In this research case, there is a difference in units for the solar irradiation variable, where the lux sensor has a unit of light intensity (lux), but the solar power meter and Global Solar Atlas have units of watts per square meter (W/m²). Therefore, the value of the lux sensor must be converted into W/m². The following is the formula for converting light intensity value (lux) into solar irradiation value (W/m²).

$$Radiasi\ matahari = \frac{Lux}{120} = w/m^2 \qquad (1)$$

The constant 120 is a standard from Air Mass 1.5, which is used as a constant for converting instantaneous outdoor light intensity values into solar irradiation values [99]. After converting the lux sensor, the standard deviation, mean absolute deviation (MAD), and percentage deviation calculation models can be applied appropriately. These models are used to determine the magnitude of the deviation in the primary data compared to the secondary reference data. However, before comparing with secondary data, these models are used to measure the deviation between primary data measured by the solar power meter and anemometer and the measurements from the lux sensor, which have been converted into solar irradiation values (W/m²) and ultrasonic wind speed sensors. The standard deviation, mean absolute deviation (MAD), and percentage deviation calculation models are formulated as follows in formulas (2), (3), and (4):

$$Standard\ Deviasi = \sqrt{\frac{1}{n-1}\sum(xi - x)^2} \qquad (2)$$

Explanation:

xi = the i-th data value

x = the average of all data

n = number of data

∑ = total sum

√ = square root

$$MAD = \frac{1}{n}\sum(xi - x)^2 \qquad (3)$$

Explanation:

xi = the i-th data value

x = the average of all data

n = number of data

∑ = total sum

After performing comparisons using the standard deviation, mean absolute deviation (MAD), and percentage deviation calculation models, the sensor measurements from the lux sensor and the ultrasonic wind speed sensor are converted into daily power estimates (Wh/day) that can be generated from solar irradiation values (W/m²) and wind speed (m/s). Converting solar irradiation values (W/m²) into daily power estimates can be done by calculating the average daily solar irradiation values with the duration of PV panel exposure, efficiency, and type of PV panel, as well as the size of the PV panel in square meters. In this research, the specifications of the PV panel used as a reference for the estimate are monocrystalline type, 20% efficiency, 50 cm² PV panel area, and 5 hours of exposure duration. The following is the formula for converting the average daily solar irradiation values into daily power estimates, as outlined in formula (5).

$$Estimasi\ daya\ PV = w/m^2 \times T \times EfPV \times lp\ (m^2) = wh/hari \qquad (5)$$

Where:
W/m² = solar radiation (W/m²)
T = duration of solar exposure (hours)
efPV = PV efficiency
lp = PV panel area (m²)

Converting wind speed (m/s) into daily power estimates (Wh/day) can be done by calculating the average daily wind speed values with the unit of cubic meters per second (m/s³) with air density, turbine blade swept area, and turbine efficiency. In this research, the specifications of the turbine used as a reference for the estimate are horizontal type, 40% efficiency, 100 cm² blade swept area, and 24 hours of wind exposure. The following is the formula for converting average wind speed into daily power estimates, as outlined in formula (6).

$$P = \frac{1}{2} \times \rho \times A \times v^3 \times ef \qquad (6)$$

Where:
P = Wind power (in watts)
ρ = Air density (1.225 kg/m³ at sea level)
A = Swept area of the turbine blades (m) => A = πr²
V = Wind speed (m/s³)
Ef = Turbine efficiency

All calculation models, starting from converting lux values into solar irradiation values, standard deviation, mean absolute deviation (MAD), and percentage deviation, as well as daily power estimates for solar and wind energy potential, are based on international standards such as Air Mass 1.5 and IEC 61400-1 [19], [20]. In this research, various instruments are used for measurement, including:

Table 1. Research Instrument Specifications

Keterangan Fitur	Pengukuran kecepatan angin		Pengukuran daya cahaya matahari	
	Alat ukur	Sensor	Alat Ukur	Sensor
	Anemometer GM8902	Sensor Kecepatan	Solar Power Meter SPM-	Sensor Lux CWT-BY

		Angin Ultrasonik	1116SD	
Akurasi	±3%±0,1	±2%±0,5	±10 atau ±5%	±7%
Satuan pembacaan	m/s	m/s	w/m²	Lux

Measuring wind speed values using an anemometer and an ultrasonic wind speed sensor. Anemometers are used as initial comparisons for wind speed measurements with the ultrasonic wind speed sensor in units of m/s. For the other variable, measuring solar irradiation, a solar power meter is used. This device reads solar irradiation and displays the unit in W/m². This measuring device is used as an initial comparison for solar irradiation measurements with the lux sensor measurements. However, the lux sensor can only read solar light intensity (lux), so these values must be converted into solar irradiation values (W/m²).

III. RESULT AND DISCUSSION

The following table data is the result of the data obtained in the research, as well as the results of data processing with standard deviation, mean absolute deviation (MAD), and percentage deviation calculation models, and the conversion from lux to irradiance and the calculation of solar and wind energy potential.

Table 2. Wind Speed Sensor vs Measuring Device Comparison Results

Hasil Perbandingan Sensor Kecepatan Angin Ultrasonik dengan Alat Ukur Anemometer	
Standar Deviasi	0,01
Mean Absolut Deviasi	0,01
Persentase Deviasi	5,72%
Rata-rata Selisih Deviasi	0,20
Rata-rata Sensor Kecepatan Angin	3,27 m/s
Rata-rata Alat Ukur Anemometer	3,46 m/s

Table 3. Wind Speed Sensor vs Global Wind Atlas Comparison Results

Hasil Perbandingan Sensor Ultrasonic Wind Speed dengan Global Wind Atlas	
Standar Deviasi	0,0
Mean Absolut Deviasi	0,0
Persentase Deviasi	0,21%
Rata-rata Selisih Deviasi	0,01
Rata-rata Kecepatan Angin Sensor	3,27 m/s
Rata-rata Kecepatan Angin Global Wind Atlas	3,26 m/s

Tables 2 and 3 show comparisons of wind speed measurement data between the sensor and the measuring device and the Global Wind Atlas data. From the comparisons using standard deviation, mean absolute deviation (MAD), and percentage deviation models, it was found that the deviation between the sensor and measuring device readings had a standard deviation and mean absolute deviation (MAD) of 0.01. This indicates minimal data error spread between the sensor and measuring device readings, so the sensor and measuring device readings are considered the same or identical, with a measurement error percentage of 5.72%, which is still considered acceptable. This difference comes from the accuracy specifications and types of measuring devices used. Whereas, the comparison of sensor measurements with Global Wind Atlas data resulted in a percentage of 0.21% and standard deviation and mean absolute deviation (MAD) values of 0.0, indicating no data error spread in the sensor data readings compared to the Global Wind Atlas.

Table 4. Lux Sensor vs Solar Power Meter Comparison Results

Hasil Perbandingan Sensor Lux dengan Alat Ukur Solar Power Meter	
Standar Deviasi	0,0
Mean Absolut Deviasi	0,0
Persentase Deviasi	0,01%
Rata-rata Selisih Deviasi	0,03
Rata-rata Iradiasi Matahari Sensor (telah dikonversi)	210,15 w/m²
Rata-rata Iradiasi Solar Power Meter	210,18 w/m²

Table 5. Wind Speed Sensor vs Global Solar Atlas Comparison Results

Hasil Perbandingan Sensor Lux dengan Global Solar Atlas	
Standar Deviasi	0,0
Mean Absolut Deviasi	0,0
Persentase Deviasi	0,87%
Rata-rata Selisih Deviasi	1,82
Rata-rata Iradiasi Matahari Sensor (telah dikonversi)	210,15 w/m²
Rata-rata Iradiasi Matahari Global Solar Atlas	208,33 w/m²

Tables 4 and 5 show the results of comparing solar irradiation measurement data between the sensor and the measuring device and the Global Solar Atlas data. From the comparisons using standard deviation, mean absolute deviation (MAD), and percentage deviation models, it was found that the deviation between the sensor and measuring device readings had a deviation value of 0.0, which indicates minimal data error spread between the sensor and measuring device readings, so the sensor and measuring device readings are considered the same or identical with a measurement error percentage of 0.01%, which is considered identical. This difference comes from the accuracy specifications and types of measuring devices used. Whereas, the comparison of sensor measurements with Global Solar Atlas data resulted in a percentage of 0.87%, which is still considered identical or similar to the reference data (Global Solar Atlas), and standard deviation and mean absolute deviation (MAD) values of 0.0, indicating no data error spread in the sensor data readings compared to the Global Solar Atlas.

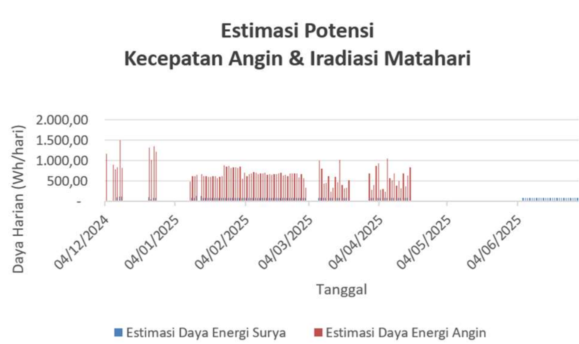

Figure 2. Daily Power Potential Estimation Graph Generated

by Solar Irradiation and Wind Speed damage.

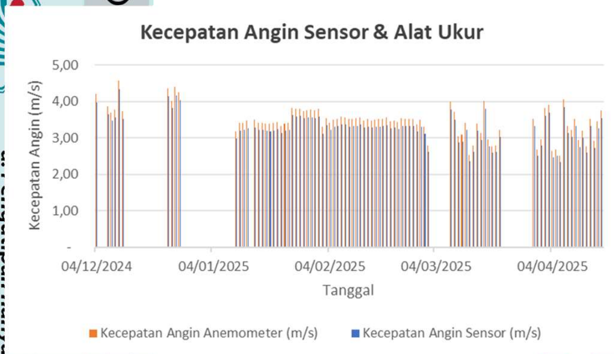

Figure 3. Wind Speed Value Graph

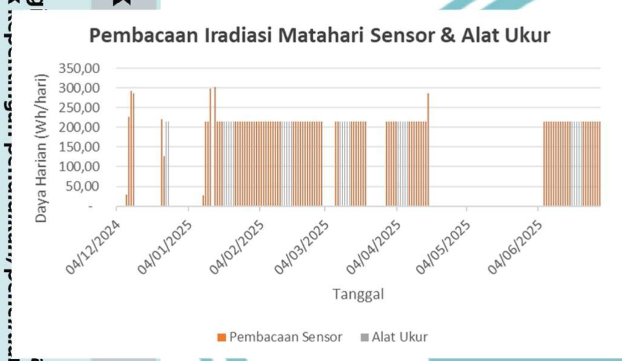

Figure 4. Solar Irradiation Value Graph

Table 6. Daily Power Potential Results for Solar and Wind Energy

Potensi daya harian pada energi surya dan energi angin		
Variabel	Rata-rata harian	Rata-rata harian estimasi daya
Energi Surya	210,15 w/m²	89,31 Wh/hari
Energi Angin	3,27 m/s	670,8 Wh/hari

From Figure 2 and Table 6, the average daily power value that can be obtained from solar energy potential is 89.31 Wh/day from the period of December 4, 2024, to June 30, 2025, and wind energy potential is 622.7 Wh/day from the period of December 4, 2024, to April 17, 2025. In this research, constraints were found in the form of incomplete data transmission, resulting in incomplete primary data for December 2024, January, March, April, May, and June 2025 due to IoT system internet connectivity and infrastructure problems during the measurement period.

From Figure 3, the average wind speed on Tidung Island was found to be 3.27 m/s for ultrasonic wind speed sensor measurements and 3.46 m/s for anemometer measurements, with a data collection period from December 4, 2024, to April 17, 2025, due to damage to the ultrasonic wind speed sensor.

From Figure 4, the average solar irradiation value on Tidung Island was found to be 210.15 W/m² for the converted lux sensor measurements and 210.18 W/m² for the solar power meter measurements, with a data collection period from December 4, 2024, to June 30, 2025, due to infrastructure

IV. CONCLUSION

This research provides factual data on Tidung Island in the context of renewable energy, including wind speed and solar irradiation values for the research period from December 4 to June 10, 2025. It was found that the deviation values of the primary wind speed and solar irradiation data (sensor) were comparable to those in the Global Solar Atlas and Global Wind Atlas references, with a deviation percentage of 1.82% for the comparison of solar irradiation values and 0.21% for the comparison of wind speed values. Daily power estimates were also obtained based on calculations performed with PV panel and wind turbine specifications, including monocrystalline PV panels with an area of 50 cm² and an efficiency of 20%, while the wind turbine specifications included horizontal type turbines, 40% efficiency, and a blade swept area of 100 cm². Based on these PV panel and turbine specifications, the estimated daily power was found to be 89.31 Wh/day for solar energy and 622.7 Wh/day for wind energy. The daily power estimate can vary depending on the PV panel and turbine specifications, as well as the solar irradiation and wind speed values.

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