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# ENERGY RESOURCE ASSESSMENT THROUGH HYDRODYNAMIC MODELING OF MARINE CURRENTS IN PULAU PISANG STRAIT, PESISIR BARAT, LAMPUNG

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***Abstract***
*As an archipelagic nation, Indonesia holds tremendous potential for the development of renewable energy, one of which is ocean current energy, recognized for its stability, cleanliness, and sustainability. Pesisir Barat Regency in Lampung Province is a coastal region rich in marine resources, yet it still faces challenges related to dependence on fossil fuels and limited electricity infrastructure, particularly on Pulau Pisang. Despite being a world-class tourism destination, Pulau Pisang remains off-grid and relies solely on diesel generators. This study aims to address these issues by conducting hydrodynamic modeling using Delft3D software across 11 coastal districts and mapping the potential of Ocean Current Power Plants. The simulation results highlight the Pulau Pisang strait, the strait between Pulau Pisang and the mainland, as the most promising location. This area features mixed semidiurnal tidal characteristics, with average current velocities reaching 0.52 m/s and peak velocities up to 5.40 m/s. Based on the hydrodynamic profile and energy conversion efficiency, the Gorlov turbine is identified as the most suitable technology, with an estimated maximum energy output of 94,647.79 kW. The generated energy is intended to supply Pulau Pisang, supporting its transformation into an energy-independent and sustainable tourism zone, and paving the way for a clean energy-driven local economic transition.*

***Keywords:***
*Energy; hydrodynamic; modeling; marine Currents; pulau pisang strait; lampung*

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## 1. Introduction

Indonesia's rapid population growth has increased the demand for energy. At the same time, fossil fuels, which remain the primary source of power, are becoming less available. This condition creates a serious challenge for the country's energy security. Indonesia's energy demand keeps increasing, reaching more than 1,200 million BOE in 2024 [1]. BOE stands for Barrel of Oil Equivalent, which is a standard unit to compare different energy sources on the same basis. One BOE equals about 5.8 million BTU, or roughly 1,700 kilowatt-hours of energy.

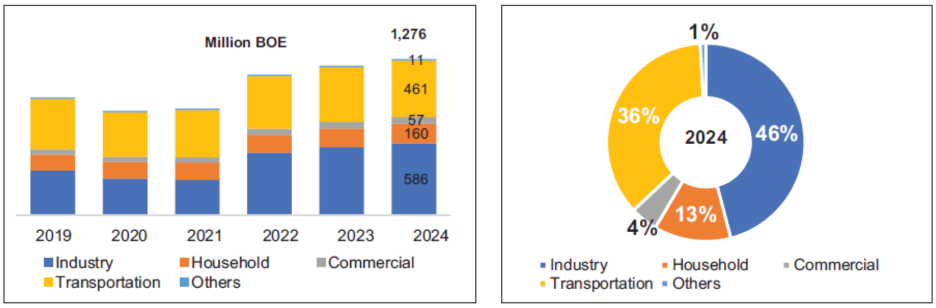

Figure 1. Indonesia Final Energy Consumption [1]

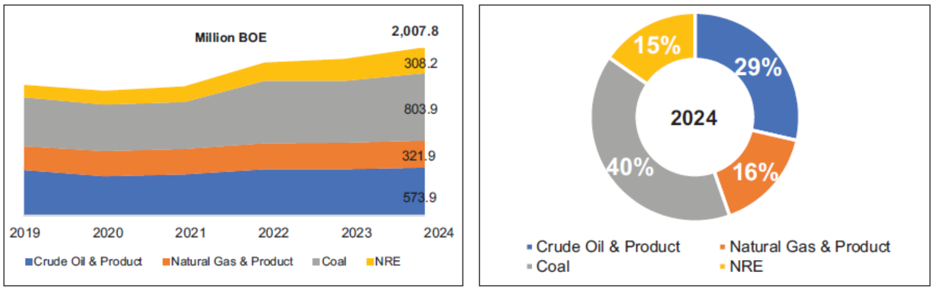

Figure 2. Primary Energy Supply [1]

Aligned with Indonesia's economic growth, the nation's energy supply in 2024 is projected to rise by 7.3% compared to the previous year, reaching 2,007 million BOE its highest level in the past decade. Supplies of fossil energy sources such as crude oil and petroleum products increased by 3.5%, while coal rose by 9.3%. Meanwhile, natural gas grew by 1.5%, and new and renewable energy (NRE) expanded significantly by 17.2%. The primary energy mix remains dominated by coal at 40.37%, followed by petroleum at 28.82%, natural gas at 16.17%, and NRE at 14.65%. By 2025, the share of NRE is targeted to reach 23% [1]. To achieve this target, it is crucial to intensify research and development on renewable energy potential, particularly from Indonesia's marine sector, which holds vast untapped resources.

Indonesia holds significant potential for renewable energy through ocean currents, waves, and tides. In particular, Sumatra Island has several straits that could be developed, including the Pulau Pisang Strait. Straits represent favorable sites for ocean-current energy because their narrow geometry accelerates tidal and residual flows, increasing current velocity and, therefore, the available kinetic power density. This is evidenced by nearby examples in Indonesia: modeled peak tidal streams of ~2–3 m/s in the Sunda Strait with extractable power on the order of ~300 MW, and multi-strait national assessments identifying gigawatt-scale opportunities [2].

Along Sumatra's west coast (exposed to the Indian Ocean), wave-energy flux commonly spans ~10–25 kW/m offshore, with seasonal strengthening during the southeast monsoon indicating a promising complementary resource to tidal streams for hybrid marine energy schemes [3]. Regional hindcasts and multi-dataset ensembles consistently highlight elevated wave power off southern Java–western Sumatra, including waters adjacent to Lampung.

Pulau Pisang, situated on the outermost boundary of Lampung Province, is characterized by its clear waters, white sandy beaches, natural coral reefs, and frequent dolphin sightings along the coast. The island holds high potential for tourism development, appealing to both domestic and international visitors. As of 2024, the area with a population of approximately 1,739 people and 400–600 households remains heavily dependent on diesel generators as its primary electricity source [4]. This reliance has been exacerbated by the failure of the subsea PLN transmission cable, which was damaged by strong waves and currents in 2021 and has not yet been repaired. Consequently, the community's electricity demand continues to be met exclusively by diesel gensets, resulting in high operational costs, unstable supply, and adverse environmental impacts. The central challenge, therefore, is to develop sustainable energy solutions particularly through research and deployment of marine-based renewable energy resources such as currents, waves, or hybrid systems. Therefore, the objectives of this research are to model current patterns in the Pulau Pisang Strait using Delft3D software, estimate the energy potential of ocean currents, and conduct a preliminary mapping of areas suitable for Ocean Current Power Plant (PLTAL) development in the waters of the Pulau Pisang Strait.

Figure 3. Research Study Area

## 2. Method

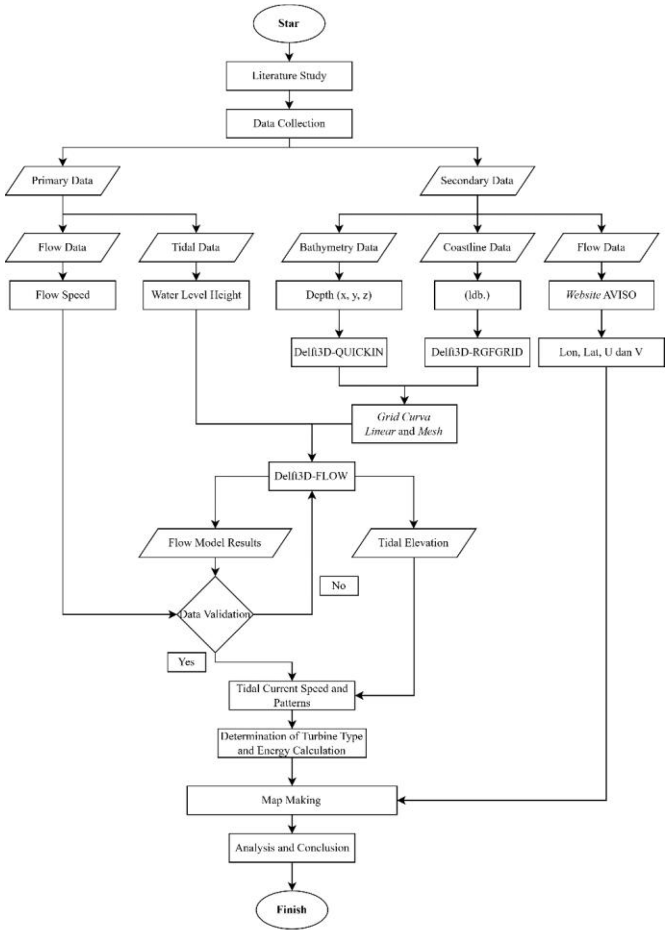

Figure 4. Research Methodology Flow Chart

### 2.1 Hydrodynamic Modelling

Delft3D-4, developed by Deltares, is a numerical modeling system designed to represent hydrodynamic processes, sediment transport, morphological evolution, and water quality in riverine, estuarine, and coastal environments. The model solves the nonlinear shallow-water equations, which are derived from the three-dimensional Navier–Stokes equations for incompressible free-surface flows. Its governing equations comprise the continuity equation and the horizontal momentum equations [5]-[8].

$$\frac{\partial \zeta}{\partial t}+\frac{\partial(\zeta+d)u}{\partial x}+\frac{\partial(\zeta+d)v}{\partial y}=0 \tag{1}$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+\frac{w}{(\zeta+d)}\frac{\partial u}{\partial \sigma}=fv-\frac{1}{\rho_0}P_x+F_x+\frac{1}{(\zeta+d)^2}\frac{\partial}{\partial \sigma}\left(\nu_v\frac{\partial u}{\partial \sigma}\right)\&+M_x \tag{2}$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+\frac{w}{(\zeta+d)}\frac{\partial v}{\partial \sigma}=-fu-\frac{1}{\rho_0}P_y+F_y+\frac{1}{(\zeta+d)^2}\frac{\partial}{\partial \sigma}\left(\nu_v\frac{\partial v}{\partial \sigma}\right)\&+M_y \tag{3}$$

In this formulation, $\zeta$ denotes the water surface elevation relative to mean sea level, while x and y are Cartesian coordinates and u and v represent the horizontal velocity components in the respective directions. The parameter d corresponds to water depth, and $\sigma$ is the scaled vertical (sigma) coordinate. The Coriolis parameter is expressed as f, and $\rho_0$ is the reference water density. $P_x$ and $P_\gamma$ indicate the hydrostatic pressure gradients in the x and y directions, whereas $F_x$ and $F_\gamma$ represent the radiation stress gradients. The term $\nu_v$ refers to vertical eddy viscosity, while $M_x$ and $M_\gamma$ denote external momentum sinks or sources in the horizontal directions.

### 2.2 Model Validation Method

The tidal model was validated against field measurements obtained from on-site instrument installations. Model outputs were compared with observed data at the study location to evaluate the degree of agreement between simulations and reality. This verification process was conducted using the Root Mean Square Error (RMSE) method, which quantifies the accuracy of predictions relative to historical measurements. RMSE is particularly advantageous because of its high sensitivity to deviations, making it a reliable indicator of model performance. The formulation of RMSE is presented in Equation 4.

$$\text{RMSE} = \sqrt{\sum_{i}^{n}\frac{(X_{\text{observasi}}-X_{\text{model}})^2}{n}} \tag{4}$$

Where:
$X_{obs}$ = Field Measurement Data
$X_{model}$ = Result of Model Data
n = Amount of Data

According to research [9] using the RMSE formula, it can be seen that the classification of the error rate based on the RMSE value obtained is shown in Table 1.

Table 1. RMSE Value Classification

| RMSE Value | Error rate |
|---|---|
| 0,00 – 0,299 | Small |
| 0,30 – 0,599 | Medium |
| 0,60 – 0,899 | Large |
| >0.90 | Very Large |

### 2.3 Tidal Data Processing

From the analysis of tidal component data, additional information regarding tidal types can be derived. The classification of tidal type is determined using the Formzahl number, as expressed in Equation 5 [10]

$$F = \frac{(K1 + O1)}{(M2 + S2)} \tag{5}$$

There are four tidal types based on what is shown in Table 2

Table 2. Formzahl Number

| Tidal Type | Formzahl Number |
|---|---|
| Semi-Diurnal | F ≤ 0,25 |
| Mixed Semi-Diurnal | 0,25 < F ≤ 1,5 |
| Mixed Diurnal | 1,50 < F ≤ 3,0 |
| Diurnal | F > 3,0 |

A diurnal tide is characterized by one high water and one low water within a 24-hour period, whereas a semi-diurnal tide produces two high waters and two low waters per day, with an average tidal period of approximately 12.4 hours. To estimate water surface elevation caused by tidal oscillations, the amplitude values of the respective tidal constituents are applied.

### 2.4 Marine current turbine

A marine current turbine is a device designed to harness the kinetic energy of ocean currents and convert it into electrical power. Its working principle is analogous to that of a wind turbine, in which the kinetic energy of moving seawater is captured and transformed into electricity. Specifically, the horizontal flow of water drives the rotation of turbine blades connected to a generator, which subsequently converts mechanical energy into electrical energy [11]. The selection of an appropriate turbine type is crucial to ensure compatibility with local hydrodynamic conditions and to optimize power generation. Considering the flow characteristics of the Sunda Strait, two turbine types have been identified as suitable candidates: the Darrieus turbine and the Gorlov turbine, as illustrated in Figure 5.

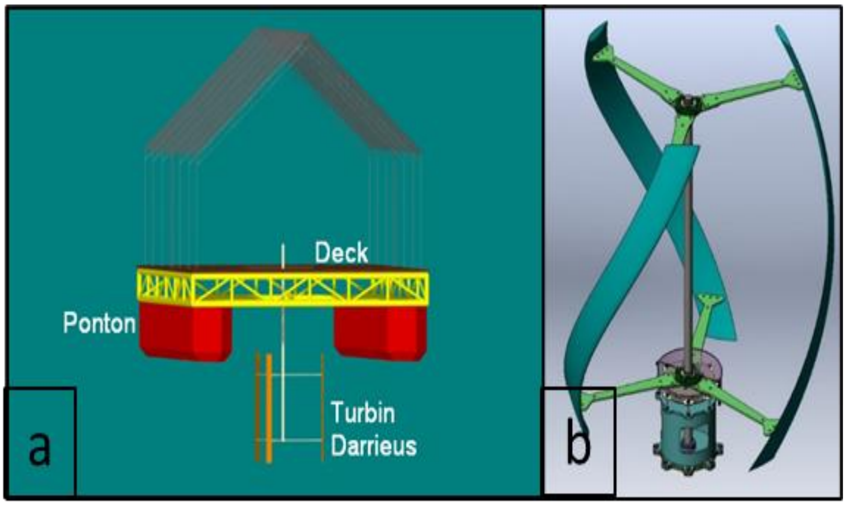

Figure 5. Darrieus turbine (a) ; Gorlov Turbine (b)

The Darrieus turbine. Its symmetrical configuration allows for reduced sensitivity to flow direction, and it is capable of operating under relatively low current velocities. Nonetheless, a key limitation is the tendency to produce significant vibrations at higher flow speeds. With a rotor cross-sectional area of 3 m², the Darrieus turbine has been demonstrated to generate approximately 2 kW of electricity at a current velocity of 1.4 m/s [12][13].

### 2.5 Energy Calculations

To determine the value of electrical energy from the current speed [14] use Equation 6

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$$P = 0.5 \times \eta \times \rho \times A \times V^3 \tag{6}$$

With:
$P: Electricalenergyproduced(kW)/Power$
$\eta: Turbineefficiency(35$
$\rho$ : Specific gravity of water $= 1025\ \mathrm{kg/m^3}$
A : Cross sectional area ($\mathrm{m^2}$) of the turbine
$V: Currentspeed(m/s)$

## 3. Result and Discussion

### 3.1 Hydrodynamic Modelling

The modeling domain adopts a curvilinear grid in spherical coordinates with a spatial resolution of 30 m x 50 m for the finest grid and 120 m x 120 m at the boundary. The bathymetric data used as a reference were obtained from BATNAS. The TPXO database was used to generate the tidal harmonic constituents at open boundaries.

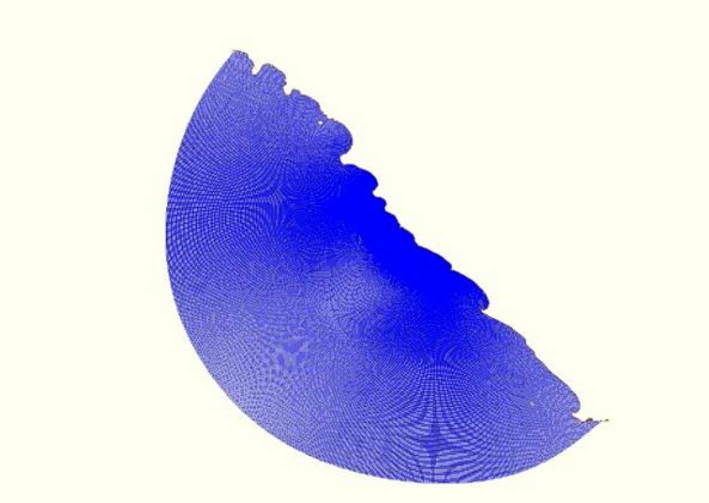

Figure 6. Grid Model

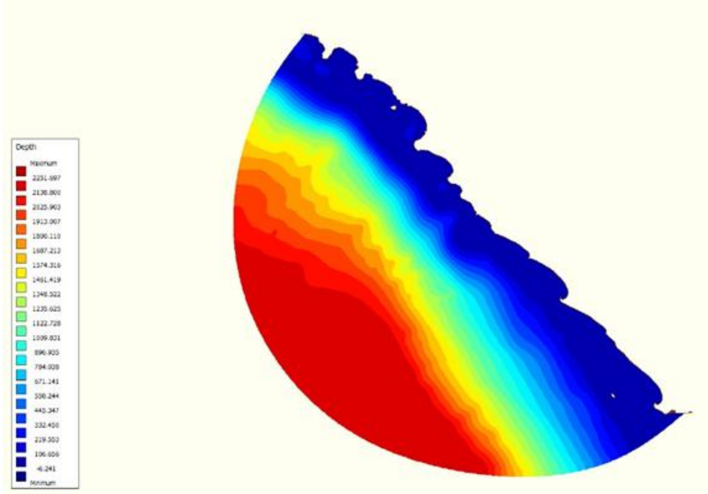

Figure 7. Depth Model

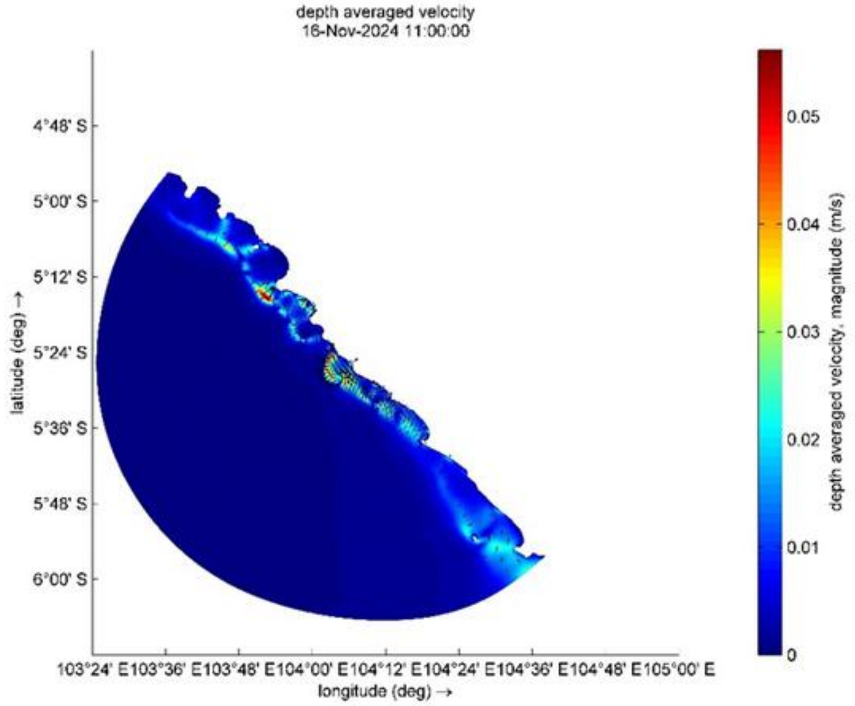

Figure 8. Current Result Model

Current Output

In this study, ocean current modeling was carried out at 11 observation points distributed along the western coastal region of Lampung, specifically in Pesisir Barat Regency. Each location shows different current characteristics in terms of average, maximum, and minimum velocity recorded during the modeling period.

Table 3. Current Speed Result

| No | Location | Longitude | Latitude | Avg.Current (m/s) | Max Current (m/s) | Min Current (m/s) |
|---|---|---|---|---|---|---|
| 1 | Lemong | 5°15,12" | 103°42'15,85" | 0.0015 | 0.0047 | 0.0002 |
| 2 | Pesisir Utara | 5°3'59,31" | 103°44'35,27" | 0.20 | 0.80 | 0.003 |
| 3 | Pulau Pisang | 5°7'30,52" | 103°49'6,39" | 1.67 | 5.09 | 0.03 |
| 4 | KaryaPenggawa | 5°8'36,75" | 103°52'56,84" | 0.25 | 1.04 | 0.0004 |
| 5 | Way Krui | 5°9'59,64" | 103°54'57,33" | 0.17 | 2.90 | 0.0021 |
| 6 | Pesisir Tengah | 5°11'11,00" | 103°54'9,10" | 0.59 | 5.41 | 0.010 |
| 7 | Krui Selatan | 5°15'7,11" | 103°56'50,22" | 0.002 | 0.009 | 0.001 |
| 8 | Pesisir Selatan | 5°16'58,49" | 103°57'18,50" | 0.115 | 2.11 | 0.0001 |
| 9 | Ngambur | 5°26'46,82" | 104°5'53,85" | 0.00097 | 0.0064 | 0.0028 |
| 10 | Ngaras | 5°30'47,55" | 104°11'34,59" | 0.2003 | 1.70 | 0.0008 |
| 11 | Bengkunat | 5°36'36,82" | 104°18'0,06" | 1.25 | 3.24 | 0.02 |

Among these, Pulau Pisang stands out as a site with very strong currents, with an average velocity of 1.67 m/s and a maximum reaching 5.09 m/s. These values indicate that the waters surrounding Pulau Pisang possess significant potential for marine current energy utilization.

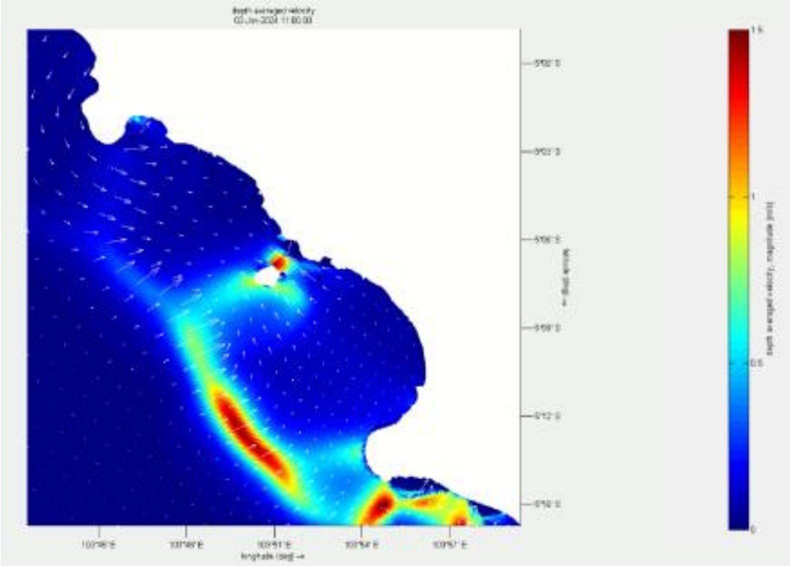

Figure 9. Pulau Pisang currents

Model Validation

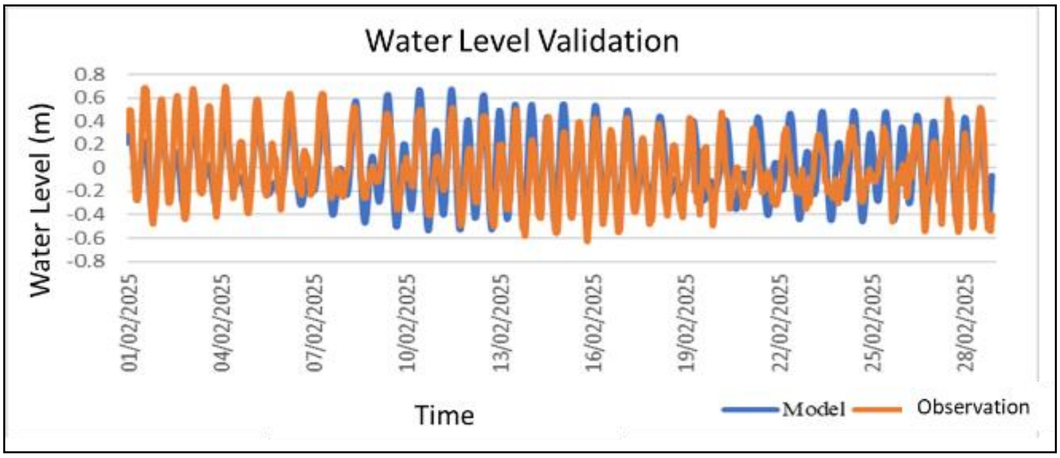

Figure 10. Model Validation

Model validation against tidal field data indicates an error of 0.2, classified as small. This validation of the model's capability in replicating water level trends enhances confidence in its suitability for simulating tidal dynamics within the Pulau Pisang Strait and adjacent coastal regions.

### 3.2 Estimated Power

Table 4. Estimated Power

| Month | Darrieus Turbine (kW) | Gorlov Turbine (kW) |
|---|---|---|
| January | 3,736.46 | 7,472.92 |
| February | 3,822.80 | 7,645.59 |
| March | 4,406.77 | 8,813.54 |
| April | 4,257.68 | 8,515.35 |
| May | 3,955.36 | 7,910.71 |

| Month | Darrieus Turbine (kW) | Gorlov Turbine (kW) |
|---|---|---|
| June | 4,063.90 | 8,127.80 |
| July | 3,836.81 | 7,673.62 |
| August | 4,133.68 | 8,267.37 |
| September | 3,987.44 | 7,974.89 |
| October | 3,960.95 | 7,921.89 |
| November | 3,595.29 | 7,190.58 |
| December | 3,517.21 | 7,034.43 |
| Total | 47,323.89 | 94,647.79 |

Darrieus can produce 47,323.89 kW and Gorlov 94,647.79 kW, respectively in one year.

## 4. Conclusion

A hydrodynamic modeling was conducted to simulate tidal current at Pesisir Barat Regency, Lampung. The model validation, water level suggests that the model can simulate the hydrodynamic condition in the study area with satisfactory accuracy. The results of the modeling indicated potential locations for ocean tidal power plants at Pulau Pisang Strait.

The locations have median current speeds over 1.67 m/s and maximum current speeds exceeding 5.09 m/s. To quantify the potential power, a turbine is tested which features a cross-sectional area of 3 $m^2$ for Darrieus and 6 $m^2$ for Gorlov and an efficiency of 0.35 (35%). with a nominal power of 47,323.89 kW and 94,647.79 kW

## References

[1] Ministry of Energy and Mineral Resources, Handbook of Energy and Economic Statistics of Indonesia 2024. Jakarta, Indonesia: Republic of Indonesia, 2024.

[2] K. Orhan, R. Mayerle, and B. Mayer, “About the Influence of Density-Induced Flow on Tidal Stream Power Generation in the Sunda Strait, Indonesia,” in *Proc. 38th IAHR World Congress*, Panama City, Panama, Sep. 2019, doi: 10.3850/38WC092019-1725.

[3] B. Y. Suprapto, “Pemodelan tinggi gelombang untuk kajian energi gelombang laut di perairan barat Provinsi Lampung,” *Wave: Jurnal Ilmiah Teknologi Maritim*, vol. 15, no. 2, pp. 75–84, 2022, doi: 10.29122/jurnalwave.v15i2.4958.

[4] BPS Pesisir Barat, *Pesisir Barat Regency Population Report 2024*. Pesisir Barat, Indonesia: Statistics Indonesia, 2024.

[5] A. Kurniawan, M. Azmiwinata, M. B. Pratama, and C. Kusuma, “Tidal current power in Capalulu Strait, North Maluku: A feasibility study”, *International Journal of Renewable Energy Development*, vol. 13, no. 3, pp. 375–385, May 2024, doi: 10.61435/ijred.2024.60132.

[6] H. Ajiwibowo and M. B. Pratama, “Hydrodynamic model and tidal current energy potential in Lepar Strait, Indonesia”, *International Journal of Renewable Energy Development*, vol. 11, no. 1, pp. 123–130, 2022, doi: 10.14710/ijred.2022.38545.

[7] S. Suciana, E. R. Kencana, R. Al-Ghazali, dan Sumartini, “Assessment of Current Energy and Power Generation in the Sunda Strait through Hydrodynamic Modeling with Delft3D and Turbine Evaluation,” *Zona Laut: Journal of Ocean Science & Technology Innovation*, vol. 6, no. 2, hal. 256–266, Jul. 2025.

[8] Deltares, “User Manual Delft3D-FLOW: Simulation of Multi-Dimensional Hydrodynamic Flows and Transport Phenomena, Including Sediments”, Delft, The Netherlands: Deltares, 2016.

[9] F. H. Putra and D. G. Pratomo, “Analisis arus dan transpor sedimen menggunakan pemodelan hidrodinamika 3 dimensi (studi kasus: Teluk Ambon, Kota Ambon, Maluku”, *Jurnal Teknik ITS*, vol. 8, no. 2, pp. A124–

A129, 2019, doi: 10.12962/j23373539.v8i2.51760.

[10] C. R. Handoko, M. Mukhtasor, and E. S. Koenhardono, “Performance evaluation of permanent magnet synchronous generator (PMSG) on tidal power generation optimization”, *IOP Conference Series: Earth and Environmental Science*, vol. 1166, no. 1, art. 012023, 2023, doi: 10.1088/1755-1315/1166/1/012023.

[11] W. A. Prayoga and R. Permatasari, “Perancangan dan pemodelan turbin Darrieus untuk pembangkit listrik tenaga arus laut (PLTAL)”, *MESIN: Jurnal Ilmiah Teknik Mesin*, vol. 10, no. 1, pp. 1–8, 2019, doi: 10.24114/mesin.v10i1.12750.

[12] D. D. A. Irfanto, “Studi perancangan combined marine power plant berbasis kombinasi Gorlov helical turbine dengan linear generator di Selat Sunda”, Doctoral dissertation, Institut Teknologi Sepuluh Nopember, 2020.

[13] A. A. Arafat and Y. Arafat, “Assessment of tidal energy resources in Bali Strait, Riset Sains dan Teknologi Kelautan”, vol. 6, no. 2, pp. 125–133, Nov. 2023, doi: 10.62012/sensistek.v6i2.31737.

[14] A. Y. C. Nee, “Power from marine currents, in Proceedings of the 3rd International Conference on Power Electronics Systems and Applications”, Hong Kong, 2009.