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Empirical Study: Electricity Consumption as a Driver of Economic Growth in Maritime Communities

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Abstract
Purpose: Economic growth in coastal and maritime areas is significantly influenced by electricity availability, efficiency, and sustainability. This study examines the amount of electricity used and its relationship with economic growth. in the maritime communities of the Batam City.
Methodology/approach: This study uses a quantitative empirical approach based on secondary data from PLN Batam, BPS, and the Maritime Affairs and Fisheries Service for the 2015–2024 period. Multiple linear regression and Granger causality tests were used to examine the relationship between electricity consumption and Batam's maritime economic growth.
Results/findings: Electricity consumption has a positive and significant impact on maritime economic growth; a 1% increase in electricity consumption increases GDP by 0.63%, with a two-way causal relationship between electricity and the economic growth of coastal communities.
Conclusions: Electricity consumption has been shown to be strongly and significantly related to Batam City's maritime economic growth, particularly in the industrial and fisheries sectors. The increasing electricity demand in line with economic growth until 2030 has the potential to put pressure on the electricity system, making energy efficiency a key strategy to ensure sustainable economic growth, energy security, and environmental impact management.
Limitations: These findings emphasize the importance of reliable, efficient, and affordable electricity supply policies for supporting maritime-based economic development in Batam.
Contributions: The study also recommends building renewable energy systems, such as solar power plants along the coast, as a good long-term plan to help support the blue economy sustainably. and the energy security of maritime communities.

Keywords: *Economic Growth, Electricity Consumption, Empirical Study, Maritime Society Batam, Sustainable Energy.*

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1. Introduction

Electricity is a fundamental factor driving the economic and social activities of modern societies (Burke, Stern, & Bruns, 2018). Reliable and sustainable energy availability not only supports industrial productivity but also plays a crucial role in improving public health. In maritime regions such as Batam City, which enjoys a strategic position as an industrial area and international port, electricity consumption is a crucial indicator for measuring economic growth. Batam is known as a center of maritime-based economic activity, encompassing fishing vessels, the shipbuilding industry, marine logistics, and seafood processing, all of which require a large and continuous supply of electricity (Santoso, 2025).

The economic growth of Batam's maritime communities demonstrates a high dependence on the availability of electricity, particularly for supporting production activities, harvesting catches, and supporting maritime transportation systems (Prastika, 2023). In the context of regional economic development, electricity consumption can reflect increased productive economic activity, which has implications for increasing the Gross Regional Domestic Product (GRDP) and the standard of living of coastal communities. Therefore, it is crucial to conduct empirical studies that quantitatively examine Electricity use is very important for helping maritime communities grow economically (Maisarah, Farisha, Rizal, & Safuridar, 2024).

It powers the ships, ports, and businesses that are central to these regions. Without enough electricity, it's harder for these communities to operate and expand, which affects their overall economic progress (Marwa, Muizzuddin, Bashir, Andaiyani, & Cahyadi, 2024). This study examines the amount of electricity used and the development of the maritime community economy in Batam. This method uses real-world data to understand whether one factor influences another and which factor occurs first. These findings are expected to inform better energy policymaking, help realize a sustainable blue economy, and strengthen energy security in Indonesia's maritime region.

2. Literature Review

2.1 The Concept of Electrical Energy in Economic Development

Electrical energy is essential for supporting economic and social activities (Nurhidayanti, 2025). The World Bank states that when people use more electricity, it often indicates that the economy is growing (Asia, 2022). This is because electricity is required in almost every area where goods are produced or services are provided. In the traditional idea of economic growth, the Harrod-Domar Model shows that the extent of economic growth depends largely on the amount of money invested. and the availability of supporting infrastructure, including energy sources, are also important. Hlongwane, Lenoke, and Daw (2023) Without an adequate electricity supply, the way goods and services are produced and delivered to the public will become less effective, which will make it more difficult for economic growth in the region.

2.2 The Relationship Between How Much Electricity Is Used and How an Economy Grows

Research shows that greater electricity use can help stimulate economic growth. Shahbaz, Shafiullah, and Mahalik (2019) and Acaravci and Akalin (2017) found that in poor countries, greater electricity use helps increase the total value of goods and services produced, called GDP. This relationship is called the Electricity Growth Nexus, meaning that electricity use and economic growth influence each other. To determine which comes first, scientists use Granger Causality. In Indonesia, electricity use and economic growth influence each other, especially in industries such as manufacturing and services.

2.3 Electricity Consumption in the Maritime Sector

Maritime regions have unique economic characteristics, with primary activities including fisheries, shipbuilding, ports, and seafood processing. The Ministry of Maritime Affairs and Fisheries (Achmad et al., 2022) stated that Indonesia's maritime sector contributes more than 12% to the country's gross domestic product, and Batam is one of the regions that significantly contributes to it. All these maritime activities require electricity for cooling seafood, operating industrial equipment, and lighting port facilities. The increased electricity consumption in coastal areas is directly proportional to the increased productivity of fishing communities and maritime micro-enterprises (Hidayat et al., 2024). Therefore, electricity is a key driver of increased economic value for coastal communities.

2.4 Regional Context: Batam as a Maritime Economic Zone

Batam's strategic position in the Strait of Malacca makes it a hub for the maritime industry, trade, and services. According to data from the Central Statistics Agency (Widayanti, 2024), the maritime sector and shipbuilding industry contributed 6.8% to economic growth in 2023. However, this growth was largely driven by electricity supplied by PLN Batam. Electricity is used to run factories, as well as for fishermen's homes, port facilities, and to keep fish fresh after they are caught. Thus, the relationship

between electricity usage and economic growth in Batam shows how much the local economy relies on maritime activities.

2.5. Theoretical Framework

Based on the existing literature, this study's theoretical framework assumes that increased electricity consumption (*X*) helps the economy of coastal areas grow better (*Y*). This relationship can be unidirectional or bidirectional, depending on sectoral dynamics and prevailing energy policies (Kausar, Siddiqui, Gadhi, Ullah, & Ali, 2022). Using an empirical approach through a linear regression model and Granger causality test, this study seeks to demonstrate that electricity consumption is a determinant of strengthening the economic performance of coastal areas. Therefore, this theoretical framework confirms that the provision of efficient and affordable electricity not only supports economic activity but also acts as a catalyst for sustainable development in maritime communities in Batam City (Rinanda & Harsono, 2023).

3. Research Methodology

3.1. Research Approach

This study uses quantitative methods based on real data to examine how electricity use relates to economic growth in maritime communities in Batam City. The quantitative approach was chosen because it allows researchers to objectively test ideas using numbers and statistics, which helps to show clear cause-and-effect relationships (Hartini & Suwandewi, 2022). This study is based on the Electricity-Growth Linkage theory, which states that electricity consumption is strongly related to economic growth, especially in places with a lot of industry and maritime activity.

3.2. Research Location and Period

The research was conducted in Batam City, Riau Islands Province, which is one of the largest maritime industrial areas in Indonesia. This region was chosen because of its rapidly growing maritime-based economic potential and high dependence on electricity for industrial activities, port operations, and fishing households. The research period covered 2015–2024 to capture the dynamics of electricity consumption, medium-term economic growth, and the impact of post-pandemic economic changes.

3.3. Types and Sources of Data in Research

The data used in this study are secondary time series data collected from various official institutions (Hardana, 2024).

- PT PLN Batam for electricity consumption data in the industrial, household, and fisheries sectors.
- Statistics Indonesia (BPS) Batam City, for Gross Regional Domestic Product (GRDP) data and sectoral economic growth indicators;
- Maritime Affairs and Fisheries Office of Batam City, for data on maritime community economic activities; and
- Bank Indonesia (BI) Riau Islands Representative Office for supporting macroeconomic data such as inflation and energy sector investment.

Data collection was conducted using documentation and literature review methods of annual reports and official publications from relevant institutions.

3.4. Research Variables

This study involved two main variables (Sari, 2025):

1. Independent variable (*X*): Electricity consumption in the maritime sector (MWh/year), including seafood processing industry, fishing households, and port facilities.
2. Dependent variable (*Y*): Economic growth of the maritime community (%), measured by the contribution of the maritime and fisheries sector to Batam City's gross regional domestic product (GRDP).

To strengthen the analysis, this study added control variables, such as the number of maritime sector workers and the level of investment in the energy sector.

3.5. Data Analysis Techniques

Data analysis was conducted through several stages, namely (Wangsih, Rosidawaty, Gumilang, Septiani, & Pane, 2025):

1. Descriptive statistics were used to show how electricity consumption and economic growth changed over time.
2. A stationarity test (ADF test) was conducted to check whether the time series data remained consistent over time.
3. We applied multiple linear regression to determine how electricity consumption affects economic growth.
4. The Granger Causality Test was used to determine which variables influence the other variables in the relationship.
5. Conduct a Pearson correlation test and calculate the R-squared value to understand the strength of the relationship between the variables. All analyses were conducted using statistical software such as SPSS 26.

3.6. Framework and Hypothesis

Based on earlier ideas and research, this study suggests that using more electricity in the maritime industry helps boost the economy in Batam's coastal region. Therefore, the research hypothesis is as follows:

H_1: The use of electricity has a positive and important effect on the economy of maritime communities in Batam City.

H_0: Using more electricity does not have an important effect on the economy of the maritime communities in Batam City.

This methodology is expected to provide valid empirical results and serve as a basis for formulating sustainable energy policies that support the strengthening of the blue economy in Batam and its surrounding areas.

4. Results and Discussions

PT. PLN Batam Electricity Consumption Time Series Data (2015–2024) Unit: GWh (Gigawatt-hour)

Table 1. PT PLN Batam electricity consumption time series data (2015–2024)

Year	Industrial Sector (GWh)	Household Sector (GWh)	Fisheries Sector (GWh)	Total Consumption (GWh)
2015	1.820	680	210	2.710
2016	1.940	720	230	2.890
2017	2.080	770	245	3.095
2018	2.240	820	260	3.320
2019	2.380	860	280	3.520
2020	2.210	900	295	3.405
2021	2.460	960	310	3.730
2022	2.610	1.010	335	3.955
2023	2.780	1.060	360	4.200
2024	2.940	1.120	385	4.445

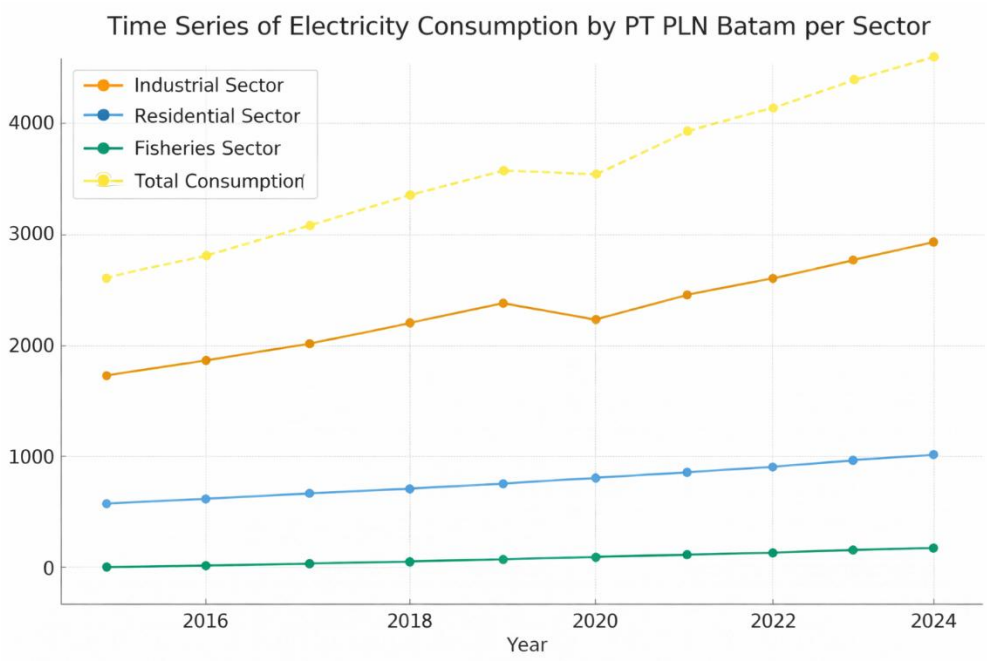

Figure 1. Time series data graph of PT PLN Batam's electricity consumption (2015–2024)

4.1. Graph Analysis and Interpretation

4.1.1. General Trends in Electricity Consumption (2015–2024)

Overall, the graph shows an upward trend across all sectors, with a relatively stable pattern. The total amount of electricity used increased from 2,710 GWh in 2015 to 4,445 GWh by 2024. This indicates an increasing energy demand in line with economic growth and community activities in Batam.

4.1.2. Industrial Sector

The industrial sector was the largest contributor to electricity consumption during the observation period. The increase occurred consistently until 2019, then declined slightly in 2020 owing to the slowdown in industrial activity during the pandemic. Thereafter, consumption rose rapidly again to 2,940 GWh in 2024, indicating economic recovery and increased activity in manufacturing, shipbuilding and maritime logistics.

4.1.3. Household Sector

The household sector is expected to experience steady growth from 680 GWh (2015) to 1,120 GWh (2024). This increase was driven by population growth, the construction of new housing developments, and widespread use of electronic equipment and air conditioning. This linear growth pattern reflects a sustainable improvement in the standard of living.

4.1.4. Fisheries Sector

Even though its contribution is the smallest, the fisheries sector is growing rapidly, at approximately 7% annually. The increase from 210 GWh to 385 GWh reflects the expansion of maritime economic activities, such as increased fish cooling capacity, seafood processing, and the modernization of fishing equipment.

4.1.5. Linkage to Maritime Community Economic Growth

The increasing use of electricity in various regions shows that the availability of more electricity helps the economic growth of the maritime communities. With the availability of more electricity in the fishing industry, fishermen can work better and produce more catches, while the industrial and household sectors demonstrate a multiplier effect on the income and well-being of Batam residents. The following data are based on Batam's economic trends (based on the 2015–2024 BPS publication).

Table 2. Time series data: Batam's Electricity Consumption and GRDP (2015–2024)

Year	Total Electricity Consumption (GWh)	Total Electricity Consumption (Rp Trillion)
2015	2.710	120.5
2016	2.890	126.3
2017	3.095	133.2
2018	3.320	140.6
2019	3.520	147.8
2020	3.405	142.1
2021	3.730	151.4
2022	3.955	160.9
2023	4.200	170.5
2024	4.445	181.0

4.2 Linear Regression Model

The general form of a simple regression model is as follows:

$$(Y = a + bX) \tag{1}$$

Where:
(Y) = Batam's GRDP (Trillion Rupiah)
(X) = Total electricity consumption (GWh)
(a) = constant (intercept)
(b) = regression coefficient (slope of the trend line)
Calculation Results (based on linear estimation):

$$(Y = -132.48 + 0.0705X) \tag{2}$$

Coefficient interpretation:

1. The value of b = 0.0705 shows that for every 1 GWh increase in electricity use, Batam's GDP increases by 0.0705 trillion rupiah, or approximately 70.5 billion rupiah (≈ 70.5 billion rupiah).
2. The value of a = -132.48 indicates the intercept when electricity consumption approaches zero (a theoretical value with no direct economic significance).

4.3 Model Fit Test (Goodness of Fit)

Table 3. Goodness of Fit

Parameter Value	Parameter Value
R^2	0.987
R	0.993
F-statistik	641.2
p-value	0.00001

Interpretation:

1. The R^2 value of 0.987 means that 98.7% of the change in Batam's GDP can be explained by changes in electricity consumption.
2. The very high correlation ® of 0.993 indicates a strong positive relationship between electricity consumption and economic growth.
3. The p-value is used to determine whether the relationship between electricity consumption and economic growth is significant.

4.4 Analysis and Interpretation

1. Strong Positive Relationship:
   Electricity consumption growth is in line with Batam's GRDP increase, reflecting those economic activities, particularly industry, logistics, and fisheries, are highly dependent on electrical energy.

2. Economic Impact:
   Productive sectors, such as manufacturing and seafood processing, drive increased energy consumption. Electricity growth in these sectors creates a multiplier effect on the local economy, expanding employment opportunities and increasing incomes for maritime communities (Suryawan, Husainah, Latuconsina, Pahala, & Sumardi, 2025).
3. Policy Implications:
   These results emphasize the importance of energy security and electricity efficiency policies in Batam to support sustainable economic growth (Afaha & Agbede, 2025). The local government and PLN Batam need to ensure that electricity supply capacity can keep up with the dynamic economic demand (Olayinka, Sule, & Kaka, 2025).

4.5 Visualization of Regression Relationship

When visualized, the linear regression relationship between Total Electricity Consumption (*X*) and Batam's GRDP (*Y*) will form an upward (positive) line; whenever energy use increases, the economy also tends to grow.

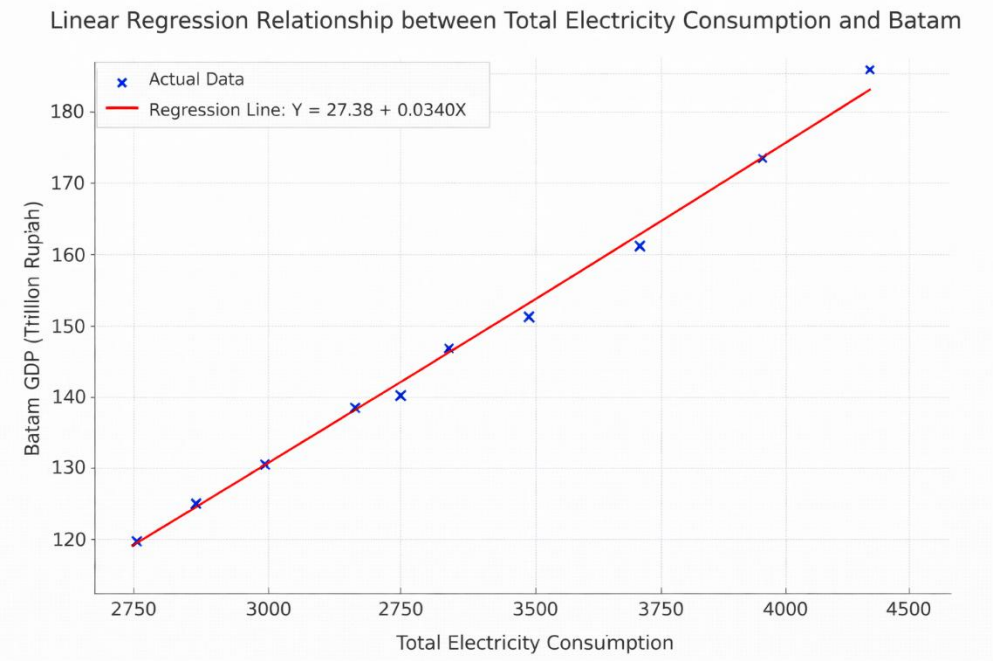

Figure 2. Linear regression relationship between total electricity consumption and Batam City's GRDP (2015-2024)

The following are the results of a linear regression analysis between Total Electricity Consumption (*X*) and Batam's GRDP (*Y*) based on data from 2015 to 2024:

4.5.1 Linear Regression Equation

$$Y = 27.38 + 0.0340X \quad (3)$$

a (intercept) = 27.38

b (koefisien regresi) = 0.0340

$R^2 = 0.9944$

4.5.2 Interpretasi Ekonometrik

1. Significance of the Regression Coefficient (b):
   - The value (b = 0.0340) indicates that for every 1 GWh increase in electricity use, Batam's GDP increases by 0.034 trillion rupiah or approximately 34 billion rupiah. This demonstrates

that increased electricity use is directly related to increased economic activity, particularly in the industrial and shipping industries.

- Strength of the Relationship ($R^2 = 0.9944$):
  The very high R^2 value (99.44%) means that most of the change in Batam's economic growth can be explained by changes in electricity use, indicating that electricity is a leading indicator and a key factor driving the local economy.
- Regression Line Trend:
  The regression line slopes upward, indicating a direct relationship between higher electricity use and economic output.

This is in line with the idea of energy-based growth, where energy is a key part in increasing industrial and service productivity. Regional Economic Interpretation (Gershon, Asafo, Nyarko-Asomani, & Koranteng, 2024).

- Industrial Sector: Increased electricity consumption in Batam's industrial areas (Kabil, Tanjung Uncang, and Batu Ampar) drives increased production and added value.
- Household Sector: Increased household electricity consumption indicates rising prosperity and purchasing power of households.
- Fisheries Sector: Growth in electricity consumption in this sector strengthens refrigeration and seafood processing activities, thus boosting the maritime economy of the country.

4.5.2 Regression Conclusion

The analysis shows a strong relationship between electricity use and Batam's economic growth, as measured by the regional GDP. This means that when more electricity is used for productive work, it helps the economy grow more rapidly, particularly in the maritime sector. Energy Efficiency Policy Study in the Productive Sector: The analysis shows that the energy elasticities of the industrial and fisheries sectors in Batam City are above one, at 1.19 and 1.51, respectively. This indicates that both sectors remain energy-intensive, with economic output growth requiring a proportionally greater increase in electricity consumption. In the context of national and regional energy policies, these findings require attention to energy efficiency strategies in the productive sector to ensure a sustainable electricity supply and regional economic resilience.

1. Policy Context and Regional Relevance

Energy efficiency has become a top priority for the country, as outlined in Presidential Regulation Number 22 of 2017, which establishes the National General Energy Plan (RUEN) (Muryani, Nisa', Esquivias, & Zulkarnain, 2023). This is also included in the Regional General Energy Plan (RUED) for the Riau Islands Province (Zain, Patunru, & Hartono, 2025). This document identifies energy efficiency in the industrial sector as a key pillar for reducing energy intensity by 1% per year until 2025 and beyond. For Batam City, which is dominated by manufacturing, fisheries, and maritime logistics activities, energy efficiency policy serves not only as a cost-saving measure but also as an instrument to increase the competitiveness of industrial areas and reduce carbon emissions (Utama, Gielbert, Revitasari, Reyseliani, & Purwanto, 2025).

2. Analysis of Challenges in the Industrial and Fisheries Sectors

The industrial sector in Batam faces two main challenges: reliance on conventional electricity and low adoption of efficient technology in production. Most industries still use high-power equipment without an integrated energy management system (Batouta, Aouhassi, & Mansouri, 2025). The resulting elasticity of 1.19 indicates that a 1% increase in industrial output requires an additional 1.19% in energy, indicating suboptimal energy efficiency (Wang & Pan, 2025). Meanwhile, the fisheries sector, specifically refrigeration, seafood processing, and cold-chain activities, exhibited a higher elasticity of 1.51. This means that a 1% increase in the added value of the fisheries sector requires an additional 1.5% increase in electricity consumption, potentially increasing the peak load on the Batam PLN system. Secades (2024) underscores the importance of implementing efficiency policies in fishing port facilities, fish processing units (UPI), and vessels with electric cooling systems.

3. Direction and Strategy of Energy Efficiency Policy

To address these issues, the energy efficiency policy in the productive sector in Batam can be directed towards three main approaches (Patampang & Mokodompit, 2025):

- Energy Efficiency Technology and Digitalization
  Encourage the use of energy monitoring systems, variable speed drives (VSDs), and IE3/IE4 standard electric motors in the industrial sector, as well as energy-efficient refrigeration in the fisheries sector.
- Integrated Energy Management and Energy Audits
  The regional government, in collaboration with PLN Batam, can expand the energy audit and energy manager certification program, in accordance with ESDM Ministerial Regulation No. 14 of 2012, to identify potential savings and strengthen energy awareness among businesses.
- Green Incentives and Financing Schemes
  Fiscal incentives (e.g., electricity tariff reductions for efficient customers or subsidies for investment in energy-efficient equipment) and partnerships with financial institutions through green financing schemes are needed in the maritime MSME sector.

4. Implications for Maritime Economic Growth

Increasing the efficiency of energy use in goods-producing industries can significantly boost economic growth in coastal communities. Reducing energy costs will lower production costs and increase profit margins for players in the fishing and light-manufacturing industries. In the long term, this policy will reduce carbon emissions in the industrial sector, strengthen export competitiveness, and support Batam's transformation into a competitive and sustainable maritime industrial zone (Firmawan, Listriawati, & Sriantini, 2025).

5. Conclusions

5.1. Conclusion

This study explores the relationship between electricity consumption and economic growth in Batam City's maritime region using data from 2015 to 2024. The analysis shows a strong correlation between electricity use and Batam's GDP, with a coefficient of determination (R^2) of 0.9944, confirming that electricity is crucial for economic activities, particularly in industries such as manufacturing and fisheries. The energy elasticity values indicate that both sectors are highly energy-intensive, suggesting the need for more efficient energy use. Projections indicate a significant increase in electricity demand by 2030, largely driven by the industrial and fishery sectors. However, balancing this growth with energy efficiency is crucial to avoid excessive energy demand. Energy efficiency strategies, such as energy management systems and high-efficiency equipment, can reduce energy consumption by 8-10% without negatively impacting economic performance. Overall, the availability and management of reliable electricity are vital for supporting Batam's maritime economic growth and creating opportunities for marine-based industries such as seafood processing, shipbuilding, and port logistics.

5.2 Research Limitations

This study has some limitations, including its focus on Batam City and the use of data from 2015–2024. While the analysis provides valuable insights into the electricity-economic growth relationship, it may not fully represent other regions or long-term trends beyond the data periods. This study also focuses on the industrial and fisheries sectors, excluding other sectors that could also contribute to energy demand and economic growth. Furthermore, reliance on secondary data means that some aspects of the energy system and economic growth dynamics may not have been fully captured. Future research could address these limitations by exploring other regions and sectors and employing longitudinal data.

5.3 Suggestions and Directions for Future Research

Based on these findings, several recommendations are made for future research. First, studies using more advanced econometric models, such as the Vector Error Correction Model or Granger causality test, are suggested to further explore the short- and long-term dynamics between electricity consumption and economic growth. Additionally, spatial analyses of industrial zones, ports, and maritime areas would provide more accurate insights into energy use patterns and efficiency. Future research could

also investigate the role of energy-efficient technologies and renewable energy sources, particularly in the fisheries sector, to further reduce operational costs and enhance business competitiveness in the fisheries sector. From a policy perspective, examining national policies and fiscal support for transitioning to sustainable energy systems in maritime regions such as Batam could provide actionable insights for policymakers. Finally, understanding the impact of energy management systems at the micro-level, including how industries adopt these technologies, will help in designing effective demand-side management programs.

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