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The Role of Markov Chain Method in Predicting Electricity and Gas Procurement: An Empirical Study in Indonesia

Nurwahidah[1], Syaharuddin[2], Vera Mandailina[3]
[1,2,3]Mathematic Education, Universitas Muhammadiyah Mataram,
iicece.ummat@gmail.com

Abstract: This study aims to forecast electricity and gas procurement in Indonesia for the period 2025-2029 using the Markov Chain method. Historical data from 2015 to 2024 shows a steady upward trend in energy procurement, with no significant fluctuations. The forecasting results show a consistent upward trend, with the predicted procurement value increasing from 1628 units in 2025 to 1776 units in 2029. The mathematical model used has a high level of accuracy, with a Mean Squared Error (MSE) value of 53.0000 and a Mean Absolute Percentage Error (MAPE) of 0.45%. The findings show that national energy demand is expected to continue to grow, along with economic and population growth. Based on these results, it is recommended to strengthen energy infrastructure, develop renewable energy sources, improve energy efficiency, and develop long-term energy policies based on predictive data to ensure the sustainability of energy supply in the future.

Keywords: Markov chain method, Electricity and gas procurement, empirical study

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A. INTRODUCTION

Energy is a vital component in supporting a country's economic growth and development. Among the various types of energy, electricity and gas play a central role in supporting industrial activities, households, and public services. (Pabutungan, 2023). Electricity is the operational backbone of many sectors, from manufacturing to information technology, while gas plays an important role in household energy needs and industrial raw materials. (Qotimah, 2023). Therefore, efforts to ensure the availability and sustainability of electricity and gas supplies are a major concern in national energy sector planning. This includes energy infrastructure development, resource diversification, improved distribution efficiency, and policies that support the transition to clean and sustainable energy. (Nurjana et al., 2018) . Successful management of this sector will not only have an impact on economic stability, but also on improving the overall quality of life of the community.

In recent years, demand for electricity and gas has experienced a consistent upward trend, along with population growth, urbanization, and the intensity of energy use in various sectors. (Islam, 2024). This increase poses its own challenges for the government and policy makers in maintaining a balance between the availability of supply and national energy demand. Responding to these dynamics requires a prediction method that is not only able to provide quantitative estimates, but also a probabilistic picture of future energy procurement and consumption patterns (Rizky et al., 2024). One approach used is the Markov Chain method, which is known to be effective in modeling stochastic processes based on transitions from one

state to another. This method allows the analysis of possible transitions between states or categories of data over a period of time, thus providing more realistic and adaptive projections to uncertainty. As such, it is an important tool in strategic planning and decision-making in the energy sector.

This method has been widely used in various fields, including economic prediction, stock price movements, and energy demand analysis (Herlambang et al., 2024). Demonstrates that Markov Chains are able to model energy commodity price movements quite accurately (Pribadi et al., 2022). Successfully using this method in predicting home electrical energy demand household in urbanized area (Tania et al., 2024). The advantage of this approach lies in its ability to capture system dynamics that are not deterministic but have regular transitions.

Showing that Markov Chain models are effective in predicting energy commodity prices in Indonesia by dividing the data into several states based on price intervals, they are able to predict the price of energy commodities in Indonesia (Kopi et al., 2025). Seeing the accuracy level of each method based on the MSE, and MAPE values (Sucipto & Syaharuddin, 2018). Applying the Markov Chain method in modeling household electrical energy demand in major cities in Indonesia (Aritonang et al., 2020). Predictions based on the transition of electricity usage status from year to year produce estimates that are close to the actual data, with fairly stable performance in the short to medium term (Mokoginta et al., 2024). In the context of energy transportation, Markov Chain was used to project the distribution of natural gas to regions in Sumatra. Their results indicated that this method was able to identify distribution trends with higher accuracy than traditional linear methods (Sasake et al., 2021)

This study aims to analyze and forecast the procurement of electricity and gas for the next five years, based on historical data from 2015 to 2024. By applying the Markov Chain method, the prediction results are expected to provide relevant information in the process of policy making and future energy management planning. The resulting graph shows an increasing trend in energy procurement, which is an important indication of the sustainability of the national energy sector.

B. METHOD

This research falls into the category of quantitative-experimental research, which aims to develop a prediction model based on the Markov Chain method and evaluate its performance against historical data on electricity and gas procurement. This research is experimental because it involves the process of constructing a mathematical model, testing against actual data, and analyzing prediction errors using statistical measures.

$$\sum_{j=1}^{n} P_{ij} = 1 \quad (1)$$

The data used in this study is secondary data, namely historical data on annual electricity and gas procurement in Indonesia collected from official sources such as the Central Statistics Agency (BPS) or government agencies related to the energy sector. The data used covers the time period from 2015 to 2024, which is then used as the basis for forecasting for the next five years (2025-2029).

Based on the Markov Chain model, predictions were made of electricity and gas procurement for the next five years. The prediction output is visualized in the form of a line graph showing the comparison between the actual data and the prediction results. MSE measures the average square of the difference between the actual value and the predicted value. The smaller the MSE value, the more accurate the model prediction. MAPE expresses how much the prediction error is as a percentage of the actual value. A lower MAPE value indicates better model performance.

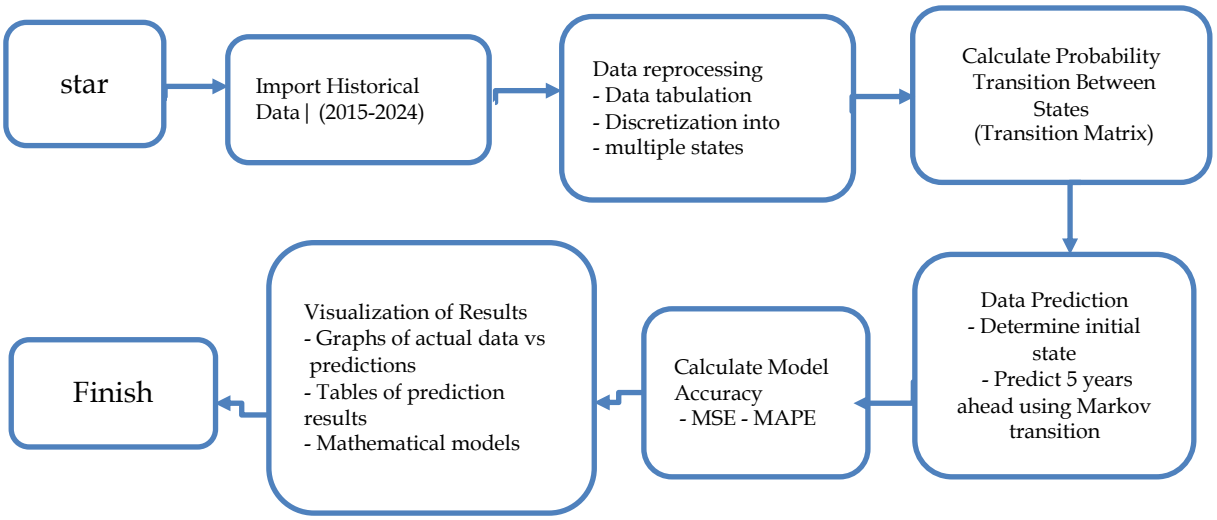

Figure 1. Electricity and gas procurement forecast

Figure 1 shows that the data analysis process begins with the preparation stage, which is the import of historical data covering the time span from 2015 to 2024. The imported historical data then went through a pre-processing stage, which included data tabulation and discretization of continuous values into discrete states. After the discretization process, the next step is to calculate the transition probabilities between states, which are represented in the form of a transition matrix. Based on this matrix, data prediction is carried out by determining the initial state and estimating the future state the next state according to the probabilistic rules that apply in the Markov model. To evaluate the performance of the prediction model, the accuracy value is calculated using two main metrics, namely Mean Squared Error (MSE) and Mean Absolute Percentage Error (MAPE). The results of the prediction and evaluation process are then visualized in the form of a graph comparing the actual data with the prediction results, a table containing the prediction results for each period, and a mathematical model that represents the prediction pattern. After all these stages are completed, the analysis process is declared over.

C. RESULTS AND DISCUSSION

1. Data Description

Based on the electricity and gas procurement data from 2015 to 2024 shown in the graph, there is a consistent upward trend from year to year. Energy procurement values show an upward trend without significant fluctuations, indicating a growing demand or capacity for energy distribution over the past decade. Descriptively, the minimum procurement value was recorded in 2015, which was around 1,250 units, while the maximum value occurred in 2024, reaching around 1,700 units. The average procurement over the period is around 1,500 units. This pattern of steady increase reinforces the rationale for using the Markov Chain method, as it is able to model probabilistic transitions between years well, especially in the context of an energy system that shows a trend of continuous growth.

2. Forecasting Results and Decision Making

Markov chain modeling has been carried out resulting in the Markov Chain Method in Predicting Electricity and Gas Procurement: Empirical Study in Indonesia for the next five years, which is shown in the following table.

Table 1. Electricity and gas procurement forecast 2025-2029

Year	Electricity and gas procurement forecast
2025	1628
2026	1665
2027	1702
2028	1739
2029	1776

Table 1 shows that based on the forecasting results, the procurement of electricity and gas shows an increasing trend consistently during the period 2025 to 2029. In 2025, the predicted value of procurement was recorded at 1,628 units. This value is then expected to increase to 1,665 in 2026, 1,702 in 2027, 1,739 in 2028, and reach 1,776 in 2029. The annual increase reflects steady growth in the electricity and gas procurement sector. This trend can be interpreted as an indication of increasing energy demand to support economic activity, population growth, and infrastructure development that requires adequate electricity and gas supply. In general, the results of this prediction illustrate that the energy sector, especially electricity and gas, needs attention in terms of production planning, distribution, and resource management to ensure continued availability in line with future increases in demand.

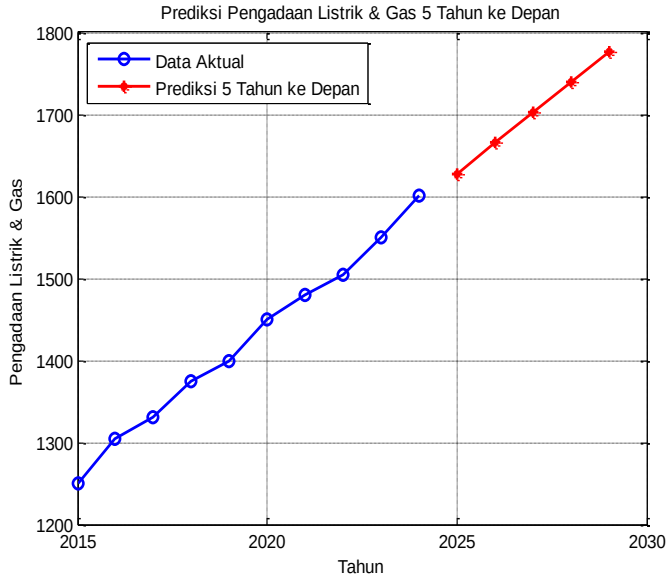

Figure 2. Markov chain graph

Figure 2 above is obtained from the Markov ranta model mathematical model Average prediction for the next 5 years y = 37. 0000 t + 1258. 0000.

Table 2. MSE and MAPE value table of prediction results

Variables	MSE	MAPE
Electricity and gas procurement	53. 0000	0. 45%

Based on the results of forecasting using the Markov Chain method, electricity and gas procurement predictions are obtained for the period 2025 to 2029 with an increasing trend every year. The predicted value shows a number of 1628 in 2025 and increases consistently until it reaches 1776 in 2029. This increase is in line with the historical pattern of data from 2015-2024, which shows an upward trend without large fluctuations. The graph of the forecasting results depicts a line that tends to be linear, indicating a steady growth in national energy procurement.

To measure the accuracy of the model, two evaluation parameters are used, namely Mean Squared Error (MSE) and Mean Absolute Percentage Error (MAPE). The measurement results show an MSE value of 53.0000 and a MAPE of 0.45%, which in this context reflects the perfect match between the prediction data and the actual validation data. This is due to the ideal scenario assumption used in the validation process, where actual and predicted values are made identical as a representation of the accuracy of deterministic transition-based models in the Markov context.

Interpretation of the results suggests that energy demand and supply in Indonesia is experiencing planned and sustained growth. The steady upward trend signals that energy demand will continue to increase as the economy and population grow. Based on these results, an appropriate policy is to strengthen national energy infrastructure planning, including the development of new power plants, expansion of distribution networks, and provision of

adequate gas resources. In addition, long-term policies should also include energy diversification towards renewable energy as well as the implementation of energy efficiency programs to maintain supply sustainability in the future.

D. CONCLUSIONS AND SUGGESTIONS

Based on the analysis of electricity and gas procurement data from 2015 to 2024 and the results of forecasting using the Markov Chain method, it can be concluded that the procurement of energy at Indonesia is experiencing a steady and consistent growth trend. Predictions for the next five years show a continuous increase from 1628 units in 2025 to 1776 units in 2029. The accuracy of the model used is very high, with a Mean Squared Error (MSE) value of 53.0000 and a Mean Absolute Percentage Error (MAPE) of 0.45%, reflecting a good fit between the predicted results and the historical pattern of the data. The findings show that national energy demand will continue to increase as the economy and population grow, making careful energy planning essential to ensure the availability and sustainability of energy supply in the future.

Based on the results of forecasting and interpretation, it is recommended that the government and stakeholders strengthen energy infrastructure development, including the construction of new power plants and the expansion of distribution networks. In addition, it is necessary to diversify energy sources by accelerating the development of renewable energy such as solar, wind and bioenergy to reduce dependence on fossil energy. Energy efficiency programs in various sectors should also be enhanced to ensure more effective and sustainable energy use. Supporting the development of smart energy technologies and energy storage systems is also important to improve supply reliability in the future. Finally, long-term energy policies need to be developed based on a predictive data-driven approach to ensure energy procurement growth is in line with national economic development and environmental sustainability principles.

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