Projection of Electrical Energy Needs in Bali Using Econometric Methods

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Abstract – Bali is one of the provinces in Indonesia with a densely populated area because it is recognized as the best and most beautiful tourist destination island. This makes the demand for the availability of electrical energy in Bali will increase every year. To solve this problem, forecasting the need for electrical energy in Bali was carried out in 3 scenario modeling. In modeling this scenario, an econometric method is used to project electrical energy needs in Bali in 2024 –2045. The results of this study indicate that the optimistic scenario undergoes an average growth in electricity needs of 8.99% per year with a per capita energy projection of 87,10.13 kWh/capita in 2045. In a moderate scenario, the average growth in electrical energy consumption needs is 6.98% per year with an energy projection per capita is 5,623.91 kWh/capita in 2045. In a pessimistic scenario, the average growth in electrical energy consumption needs is 5.44% per year with an energy projection per capita is 3,913.77 kWh/capita in 2045. Thus, optimistic scenario modeling has the highest growth in electrical energy consumption compared to other scenario modeling.

***Index Terms*—Projection, Econometrics, Electrical Energy.**

I. INTRODUCTION

The development of the modern era along with the increasing population growth has caused the demand for the availability of electrical energy increases every year. Nowadays, the non-renewable power is still dominated compared to the renewable power to fulfill the demand for electricity [1]. Non-renewable power is currently being reduced in use because it is the largest contributor to emissions compared to other types of power [2]. The availability of sufficient, efficient, and effective demand for electrical energy in its use has an important role in supporting the planning of a development and can improve the quality of life. Thus, the availability of electrical energy needs to be considered to minimize the occurrence of *oversupply* of electrical energy.

Bali is one of the provinces in Indonesia with a densely populated area because it is recognized as the best and most beautiful tourist destination island. Natural beauty and supported by the uniqueness of Balinese culture, which makes it recognized as the best tourist destination island. This makes the demand for the availability of electrical energy in Bali also increase every year. In fulfilling the demand for the availability of electrical energy in the future, it is necessary to consider minimizing the oversupply of electrical energy. In addition, this is also in accordance with efforts to realize Bali *Net Zero Emission* 2045 with an energy transition, by minimizing the use of non-renewable power that will be transitioned using renewable power [3]. Thus, the demand for the availability of electrical energy needs to be considered effectively and efficiently. This has an important role in adjusting infrastructure development to meet the demand for electrical energy to prevent financial losses.

Based on these problems, thorough and detailed planning is needed to be able to estimate the demand for electrical energy in Bali. As of that there is no oversupply of electrical energy to prevent financial losses in future infrastructure development. So, a technique is needed that can be used to predict something in the future. One of the methods that is often used in predicting something in the future is the forecasting method.

Forecasting techniques are activities that aim to predict and find out what will happen in the future using historical data [4]. In meeting the demand for the availability of electrical energy in Bali in the future, the forecasting method that will be used in this study is the econometric method.

The econometric method is a forecasting method used to make an approach based on statistical and economic data from a region [5]. This forecasting method is carried out to overcome this problem by estimating the demand for the availability of electrical energy in Bali. The reason the researcher uses this econometric method is because it is based on the data obtained, namely periodic data. This method is used to solve forecasting problems based on an approach according to the actual conditions of an area [5]. This research can estimate the demand for the availability of electrical energy in Bali in the future based on the approach of economic conditions so as not to experience an excess or shortage of electrical energy.

II. LITERATURE REVIEW

A. State off The Art

In this study, the five previous studies were used as comparison and reference materials in the process of making research because the theory used in the study was relevant. In the first study conducted by Sahrul *et al*. [5], analyzed the forecast of electricity energy needs in 2023 – 2032 in Kubu Raya Regency. The forecast results used a combined method on the number of customers data with a growth rate of 5.04% per year, on the data on electrical energy consumption with a growth rate of 7.13% per year, and on the connected power data with a growth rate of 5.04% per year.

In the second study conducted by Purnama [6], the needs of the household sector in East Java were analyzed using the *time series analysis method* with quadratic trend *projection* and linear regression based *on minitab* v19 software. Based on the comparison of MAPE values generated by the *time series method with* quadratic *trend projection*, it has a better forecasting rate compared to the *time series* method with linear regression trend projection because it has *a smaller* error value.

In the third study conducted by Adamma *et al*. [7], analyzed the need for electrical energy projection in Bali in the range of 2020 – 2030 using *Matlab* software using *the neural network* method. In this study, the results of forecasting electricity demand in Bali in 2020 amounted to 5,772 GWh and in 2030 amounted to 8,551 GWh. The forecast resulted in a MAPE of 3.29% against the 2019 RUKN which is still under the provisions of PLN, which is 10%.

The fourth research conducted by Gian *et al*. [4], analyzed the comparison of linear regression methods with quadratic non-linear methods in forecasting drinking water sales in Perumda Tirta Raharja Drinking Water. The results of the study show that the non-linear regression method has an *error* value of 1%, while the linear regression method has an *error* value of 1.75%.

In the fifth study conducted by Ida Nabillah *et al*. [8], analyzed the forecast of marine commodities, namely octopus supply against the prediction model used. The results of the forecast in the study used a linear regression equation for octopus supply needs in January with an accuracy of 70%.

From all the research described above, there are similarities and differences in this study. The difference is that this study designs projections based on the approach of the actual conditions of an area. Meanwhile, in this study, a forecasting system will be developed with 3 scenario modeling in estimating the demand for the availability of electrical energy in Bali. This forecast is carried out based on statistical and economic data in Bali using the econometric method.

B. Factors Affecting Energy

Based on the results of research conducted by Azam *et al*. [9], the results of this study show several factors that cause the rise and fall of energy consumption, including:

1) Economics

Economic factors greatly affect the level of energy demand which can be measured through Gross Domestic Product (GDP) or Gross Regional Domestic Product (GDP).

2) Trade Openness

Trade openness is stated in trade data (% of GDP) is a comparison of the number of exports, imports of goods and services with other countries measured as part of GDP.

3) Human Development Index (HDI)

HDI is a summary of the combined calculation of the average achievement in an area in three basic aspects, namely health, knowledge and standard of living.

4) Foreign Direct Investment (FDI)

FDI is a parameter that includes investment in property assets for the purposes of an activity. If the value of FDI increases, energy consumption will also increase.

5) Population Growth Factors

This factor has an important role in energy needs. In accordance with demographic principles, population growth will continue to increase every year if it is in stable conditions.

C. GDP

The demand for electrical energy is closely related to all economic activities and population activities [9]. In measuring an economic development of a region, it can be determined through the value of GDP, this GDP value serves as a reference to measure the development of an economy in a region by excluding changes in economic structure or an increase in population growth that is larger or smaller [10].

GDP can be classified into 2 parts, namely GDP on the basis of constant prices and on the basis of prevailing prices [14]. Constant price GDP is used to determine the actual economic growth from each year. Meanwhile, GDP on the basis of prevailing prices is generally used to determine the capacity of economic resources, shifts and economic structure of a region.

D. Forecasting

Forecasting is a technique used to predict a condition that will occur in the future based on conditions that occur in the past and present [4]. Forecasting is carried out by considering past or current data or information mathematically or statistically. Mathematically, there are 2 methods that can be used in forecasting, namely [4]:

1) Linear Regression Method

This method is a statistical method that is carried out to determine the mathematical relationship between dependent variables and independent variables linearly. The equation of linear regression is as follows:

$$\hat{Y} = \alpha + bX \tag{1}$$

Information:

$\hat{Y}$ = Dependent variable

α = Coefficient of regression independent
b = Intercept
X = Independent variable

2) Methome Regresi Non-Linier

This method is a statistical method carried out to determine the mathematical relationship between dependent variables and independent variables quadratic. The equation of linear regression is as follows:

$$\hat{Y} = \alpha + bX + cX^2 \quad (2)$$

Information:
$\hat{Y}$ = Dependent variable
X = Independent variable
α, b, c = Intercept

E. Methods Of Economics

The econometric method is a forecasting method that is carried out with an approach based on statistical and economic data from a region. In approaching using this econometric method, it is necessary to have the availability of data sources that state that electricity drives economic activities in a region [5]. In the econometric method, an approach can also be made by adding basic assumptions that make forecasting using this method in accordance with actual conditions based on data sources that state that electric power can drive economic activity in a region. The basic assumptions related to the econometric method include [5]:

1) Growth in the number of subscribers

On this basic assumption, calculations are made to determine the growth of the number of customers which can be calculated through the following equation:

$$pP = \left(\frac{Pel_t}{Pel_{t-1}} - 1\right) \times 100\% \quad (3)$$

Information:
Pp = Customer growth
Pel_t = Current number of customers
Pel_{t-1} = Number of customers in the previous year

2) Growth in Electrical Energy Consumption

On this basic assumption, calculations are made to determine the growth of the consumption of electrical energy used, which can be calculated through the following equation:

$$pE = \left(\frac{E_t}{E_{t-1}} - 1\right) \times 100\% \quad (4)$$

Information:
Pe = Growth in electrical energy consumption
Et = Current use of electrical energy
E_{t-1} = Electrical energy consumption in the previous year

3) Energy Elasticity

Energy elasticity is a comparison between the growth of electrical energy consumption used and the economic growth of a region, where energy elasticity can be calculated through the following equation:

$$eE = \frac{pE}{g} \quad (5)$$

Information:
Ee = Energy elasticity
Pe = Growth in electrical energy consumption
g = Economic growth (GDP)

4) Customer Factor

The customer factor is a comparison between the number of customers and the economic growth of a region, where the customer factor can be calculated through the following equation:

$$CF = \frac{pP}{g} \quad (6)$$

Information:
CF = Customer factors
Pp = Growth in the number of customers
g = Economic growth (GDP)

F. Load Factor

The load factor is a comparison between the average load and the peak load, where the load factor can be calculated starting from the daily, monthly, or annual period. The load factor has an important role in determining the loading characteristics for the future period or in determining the effect of the loading on the overall system capacity [11]. The load factor can be calculated through the following equation:

$$Faktor\ beban = \frac{beban\ rata - rata}{beban\ puncak} \quad (7)$$

III. RESEARCH METHOD

A. Energy Demand and Modeling Framework

In this study, modeling was carried out from the beginning of 2024 to 2045. This refers to the Province of Bali which has set an earlier target to support *Net Zero Emission* in 2045, which is 21 years faster than the national target in 2060. Thus, it is necessary to project the demand for electrical energy consumption in Bali from the beginning of 2024 to the end of the modeling period in 2045.

The energy demand framework in this study uses an econometric method to project the demand for electrical energy in Bali. This projection includes historical data from electricity sales and annual GDP of Bali from 2011 – 2019.

B. Data Grouping

In this study, data was grouped on the annual GDP data of Bali on the basis of constant prices according to business fields. This data grouping is carried out to make annual GDP data consistent on the basis of constant prices according to business fields with electricity sales data in Bali.

TABLE II
CLASSIFICATION OF BALI ANNUAL GDP DATA

It	Business Field	Sector
1	Agriculture, Livestock, Forestry, and Fisheries	Household
2	Mining and Quarrying	Industry
	Processing Industry	
	Electricity and gas procurement	
	Water Procurement, Waste Treatment, Waste and Recycling	
	Construction	
3	Wholesale and Retail Trade, Car and Motorcycle Repair	Commercial
	Transportation and Warehousing	
	Food and Drink Accommodation Providers	
	Information and Communication	
	Financial Services and Insurance	
	Real Estate	
	Corporate Services	
4	Government, Defense and Compulsory Social Security Administration	Public
	Educational Services	
	Health Services and Social Activities	
	Other Services	

Based on table II, the annual GDP of Bali on the basis of constant prices according to business fields is classified into 17 business fields [14], then grouped into 4 sectors out of 17 existing business fields, namely household, industry, commercial, and public.

TABLE III
BALI ANNUAL GDP DATA (MILLION RUPIAH)

Year	Sector			
	Household	Commercial	Public	Industry
2011	16,258,738.62	51,433,832.92	15,088,713.00	17,210,347.37
2012	16,969,879.77	55,099,010.38	15,381,467.41	19,501,107.41
2013	17,343,285.02	59,489,974.74	16,397,408.34	20,872,912.63
2014	18,151,208.59	63,720,372.13	18,136,380.18	21,779,613.82
2015	18,637,347.47	67,983,745.61	19,677,077.70	22,828,391.45
2016	19,295,696.59	72,756,037.12	21,145,429.28	24,099,282.22
2017	19,821,713.92	77,952,172.65	21,970,048.43	25,189,377.03
2018	20,760,222.17	82,876,393.95	23,394,045.54	27,042,000.92
2019	21,479,547.23	87,836,980.79	24,611,430.93	28,765,398.36

Based on table II, it shows the annual GDP data of Bali on the basis of constant prices according to business fields which have been grouped into 4 sectors from 17 existing business fields, namely households, industry, commercial, and public in units of Million Rupiah.

Furthermore, after grouping the data on the annual GDP of Bali to be consistent with the data on the realization of electricity sales in Bali, it is continued by determining other assumptions before modeling the scenario.

TABLE IV
BALI ELECTRICITY SALES REALIZATION DATA (GWH)

Year	Sector			
	Household	Commercial	Public	Industry
2011	1,420	1.482	206	116
2012	1,548	1.645	228	126
2013	1,661	1.860	245	148
2014	1,847	2.059	269	160
2015	1,918	2.226	282	168
2016	2,105	2.510	305	179
2017	2,059	2.527	310	174
2018	2,154	2.629	332	188
2019	2,345	2.800	359	203

Based on table IV, it shows data on the realization of electricity sales in Bali. The data was obtained in the Electricity Provider Business Plan (RUPTL) document in 2021.

C. *Assumption*

Some of the assumptions required in this study include transmission and distribution losses in 2024 of 5.30% with a target transmission and distribution loss at the end of the modeling period of 4% [15]. The reserve margin used in this study is 30%, based on the analysis conducted by IESR which states that the limit remains at the ideal limit of PLN [16].

Other assumptions in this study include the load curve used in determining the load factor experienced in Bali. In this study, data on the peak load curve that occurred in Bali in 2023 will be used. Based on data obtained from PLN UP2D Bali, it is stated that Bali experienced the highest peak load in 2023 in December with a total distribution of 1,075.4 MW. The peak load curve experienced in Bali can be seen in figure 1.

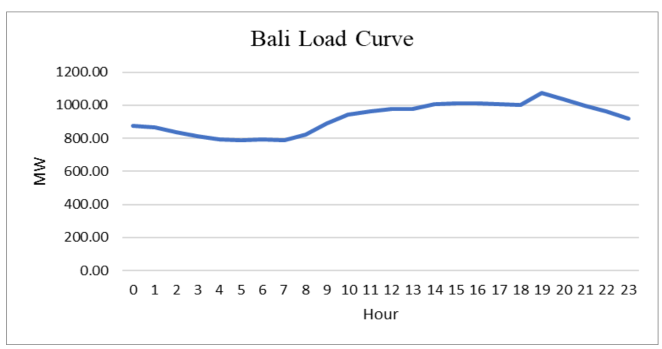

Figure 1. Bali Load Curve

D. *Scenario Modeling*

In this study, the author will make 3 scenario modeling, namely optimistic, moderate, and pessimistic scenarios.

This optimistic scenario is based on the highest economic growth that occurred in Bali. Based on the Kerthi Bali Economic document, it is stated that Bali's economic growth target in 2028 is 7.5%, increasing to 7.7% in 2045 [17].

This moderate scenario describes more realistic conditions that may occur in the future of an event. In this scenario, it is based on the average economic growth that occurs in Bali.

This pessimistic scenario describes the lowest possible conditions in the future of an event. In this scenario, it is based on the lowest economic growth that occurs in Bali.

IV. RESULT AND DISCUSSION

A. *Projected Sales of Electrical Energy*

The projection of electrical energy sales in Bali using the econometric method aims to determine the sales of electrical energy in Bali during the modeling period based on an economic approach, starting from 2024 to 2045.

In an optimistic scenario, the average growth in electrical energy sales is 8.99% with an average economic growth of 7.5%. In a moderate scenario, the average growth in sales of electric energy is 6.98% with an average economic growth of 5.9%. In the pessimistic scenario, the average growth in electrical energy sales is 5.44% with economic growth that occurs in the pessimistic scenario of 4.6%.

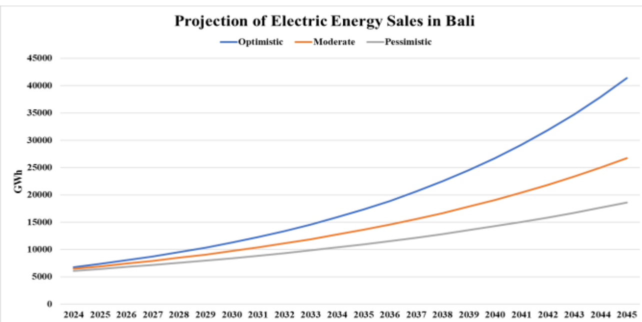

Figure 2. Projection of Electric Energy Sales in Bali

Based on Figure 2, in the optimistic scenario, there will be an increase in electrical energy sales at the beginning of 2024 by 6,786.75 GWh to 41,396.48 GWh. In the moderate scenario, there will be an increase in electrical energy sales at the beginning of the year by 6,478.73 GWh to 26,728.65 GWh. In the pessimistic scenario, there will be an increase in electrical energy sales at the beginning of the year by 6,113.63 GWh to 18,600.89 GWh.

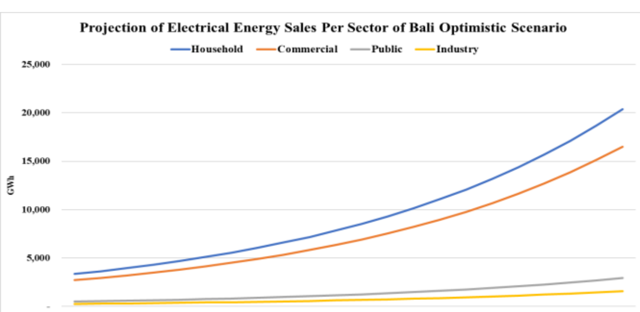

Figure 3. Projection of Electrical Energy Sales Per Sector of Bali Optimistic Scenario

Based on figure 3, showing a graph of projected sales of electrical energy per sector of Bali in an optimistic scenario. At the beginning of 2024, the optimistic scenario is to experience electrical energy sales of 6,786.75 GWh with details, the household sector is 3,340 GWh, the commercial sector is 2,706 GWh, the public sector is 482 GWh, and the industrial sector is 259 GWh. The optimistic scenario is to experience an average growth in electrical energy sales of 8.99% with an increase in electrical energy sales at the end of the modeling period to 41,396.48 GWh. By the end of 2045, The optimistic scenario is to experience electrical energy sales of 41,396.48 GWh with details, the household sector is 20,372 GWh, the commercial sector is 16,505 GWh, the public sector is 2,938 GWh, and the industrial sector is 1,582 GWh

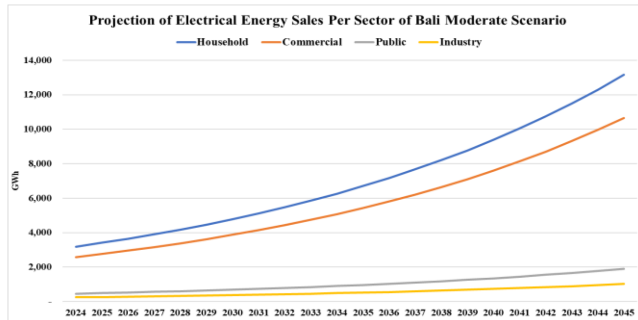

Figure 4. Projection of Electrical Energy Sales Per Sector of Bali Moderate Scenario

Based on figure 4, showing a graph of projected electrical energy sales per sector of Bali in an optimistic scenario. At the beginning of 2024, the optimistic scenario is to experience electrical energy sales of 6,786.75 GWh with details, the household sector is 3,340 GWh, the commercial sector is 2,706 GWh, the public sector is 482 GWh, and the industrial sector is 259 GWh. The optimistic scenario is to experience an increase in electrical energy sales at the end of the modeling period to 41,396.48 GWh. As for the details of electrical energy sales in the moderate scenario, namely the household sector of 20,372 GWh, the commercial sector of 16,505 GWh, the public sector of 2,938 GWh, and the industrial sector of 1,582 GWh.

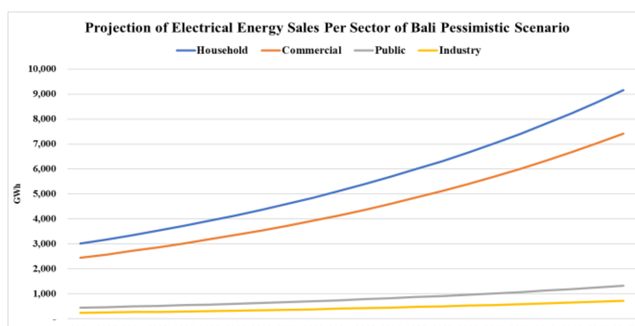

Figure 5. Projection of Electrical Energy Sales Per Sector of Bali Pessimistic Scenario

Based on figure 5, showing a graph of projected electrical energy sales per sector of Bali in an optimistic scenario. At the beginning of 2024, the optimistic scenario is to experience electrical energy sales of 6,786.75 GWh with details, the household sector is 3,340 GWh, the commercial sector is 2,706 GWh, the public sector is 482 GWh, and the industrial sector is 259 GWh. The optimistic scenario is to experience an increase in electrical energy sales at the end of the modeling period to 41,396.48 GWh. namely the household sector of 20,372 GWh, the commercial sector of 16,505 GWh, the public sector of 2,938 GWh, and the industrial sector of 1,582 GWh.

B. Energy Projections per Capita

The per capita projection of electrical energy shows the average electricity consumption of each population, where this figure is obtained from the total amount of electrical energy used in an area divided by the number of people in a certain period [12]. Based on the population projection conducted by the population census, Bali experienced an average population growth of 0.35% [13]. In 2024, Bali will experience population growth of 4.4 million people to 4.8 million people. The projected population growth in Bali can be seen in figure 6.

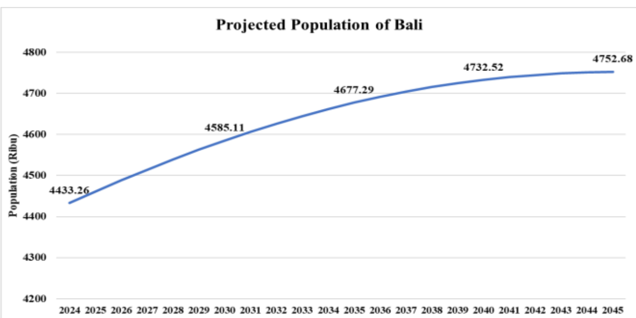

Figure 6. Projected Population of Bali

In the optimistic scenario, there will be an increase in per capita energy at the beginning of 2024 by 1,530.87 kWh/capita to 8,710.13 with an average electricity consumption of 8.46% per population. In a moderate scenario, the per capita energy increase at the beginning of 2024 is 1,461.39 kWh/capita to 5,623.91 with an average electricity consumption of 6.61% per population. In the pessimistic scenario, the per capita energy increase at the beginning of 2024 is 1,379.04 kWh/capita to 3,913.77 with an average electricity consumption of 5.08% per population. The projection of energy consumption per capita in Bali can be seen in figure 8.

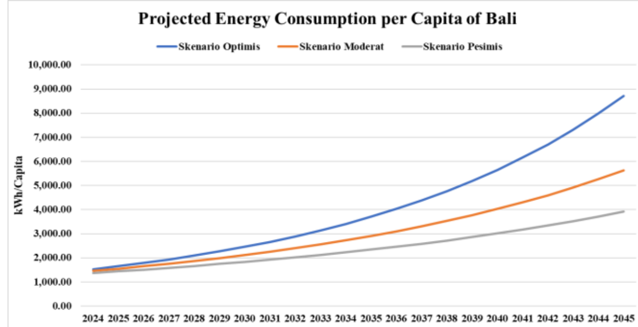

Figure 7. Projected Energy Consumption per Capita of Bali

C. Projection of Electrical Energy Production

Electrical energy production is a large amount of electrical energy from various sources of electrical energy available to meet the required electrical energy consumption [12]. In this modeling, it is modeled that transmission and production losses in the electricity system in Bali will be 5.30% in 2024, decreasing until the end of the modeling period in 2045 by 4%. Transmission and distribution losses in the electricity system in Bali can be seen in figure 8.

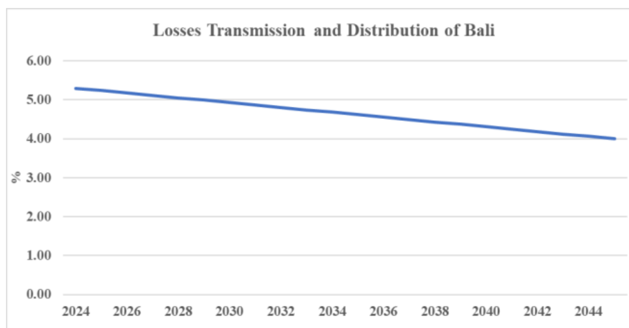

Figure 8. Losses Transmission and Distribution of Bali

Based on the transmission and distribution losses in the electricity system in Bali in Figure 8, the optimistic scenario is to experience an increase in electrical energy production by 7,146.45 GWh to 43,051.51 GWh with an average growth of electrical energy production in Bali of 8.91%. In a moderate scenario, there was an increase in electrical energy production by 6,822.10 GWh to 27,797.26 GWh with an average growth of 6.92% in electrical energy production in Bali. In a pessimistic scenario, there was an increase in electrical energy production by 6,437.65 GWh to 19,344.55 GWh with an average growth of electrical energy production in Bali of 5.38%. The projection of electrical energy production in Bali can be seen in figure 9.

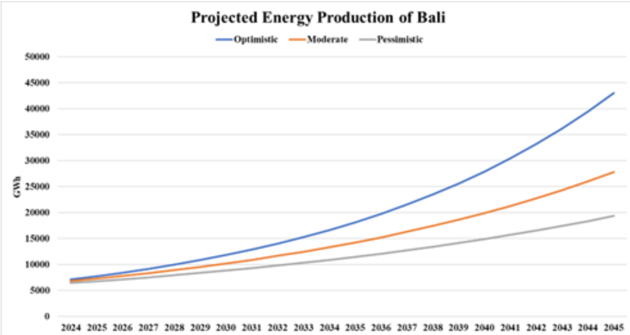

Figure 9. Projected Energy Production of Bali

D. Peak Load Projection

Based on figure 3, it shows the load curve of Bali with a load factor of 85.86%. The value of the load factor can be calculated through equation 7, with the average load occurring in Bali of 923.37 MW and the peak load of 1,075.40 MW. This parameter has an important role in determining the characteristics of the body in the next period in Bali.

In figure 10, it shows the projection of peak load based on the projection of electrical energy demand in Bali. In 2024, the optimistic scenario results in the loading of the electricity system of 950.16 MW with an electrical energy requirement of 7,146.45 GWh. Towards the end of the modeling period, in 2045 it will result in the loading of the electricity system of 5,723.92 MW with an electrical energy requirement of 43,051.51 GWh. In addition, in the optimistic scenario, the average peak load growth is 8.93% with an average required reserve capacity of 802.34 MW.

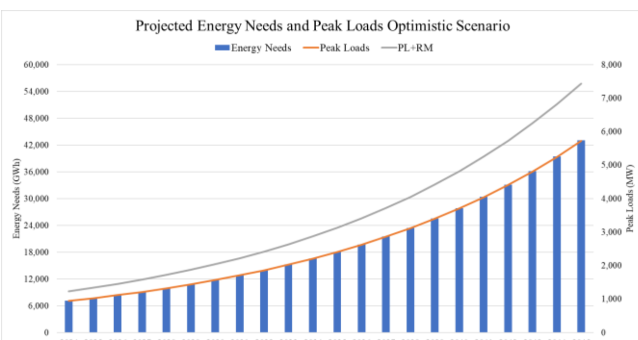

Figure 10. Projected Energy Needs and Peak Loads Optimistic Scenario

In Figure 11, it shows the projection of peak load based on the projection of electrical energy needs in Bali. In 2024, the optimistic scenario results in the loading of the electricity system of 907.03 MW with an electrical energy requirement of 6,822.10 GWh. Towards the end of the modeling period, in 2045 it will result in the loading of the electricity system of 3,695.79 MW with an electrical energy requirement of 27,797.26 GWh. In addition, in the optimistic scenario, the average peak load growth is 6.92% with an average required reserve capacity of 600.09 MW.

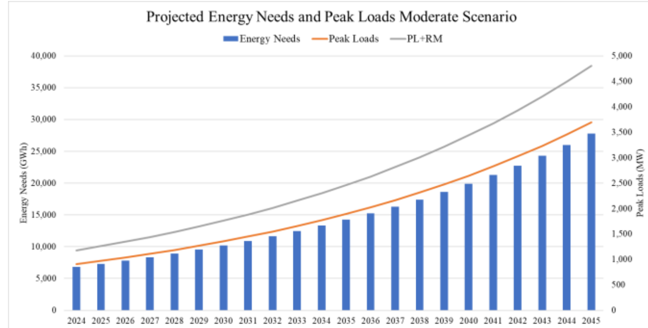

Figure 11. Projected Energy Needs and Peak Loads Moderate Scenario

In Figure 12, it shows the projection of peak load based on the projection of electrical energy demand in Bali. In 2024, the optimistic scenario results in the loading of the electricity system of 855.92 MW with an electrical energy requirement of 6,437.65 GWh. Towards the end of the modeling period, in 2045 it will result in the loading of the electricity system of 2,571.96 MW with an electrical energy requirement of 19,344.55 GWh. In addition, in the optimistic scenario, the average peak load growth is 5.38% with an average required reserve capacity of 470.12 MW.

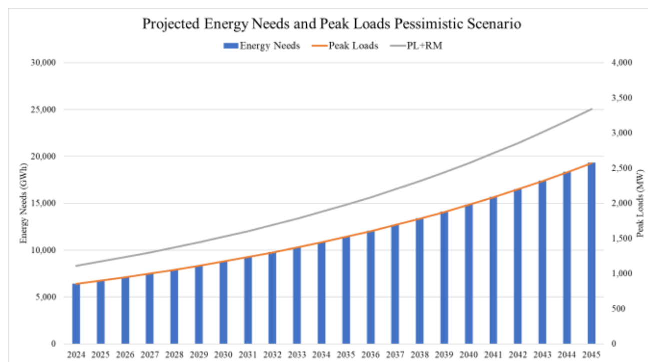

Figure 12. Projected Energy Needs and Peak Loads Pessimistic Scenario

V. CONCLUSION

The results of the research obtained from this study show the demand for the availability of electrical energy in Bali using the econometric method. In an optimistic scenario, the average growth of electrical energy consumption is 8.99% per year with an energy projection per capita is 8,710.13 kWh/capita in 2045. In a moderate scenario, the average energy consumption growth is 6.98% per year with an energy projection per capita is 5,623.91 kWh/capita in 2045. In a pessimistic scenario, the average growth of electrical energy consumption is 5.44% per year with an energy projection per capita is 3,913.77 kWh/capita in 2045.

REFERENCES

[1] R. R. Al Hakim, "Model Energi Indonesia, "Tinjauan Potensi Energy Terbarukan Untuk Ketahanan Energi di Indonesia: Literatur Review," ANDASIH *(Jurnal Pengabdian Kepada Masyaraka)*, vol. 1, no. 1, pp. 1-11, 2020.

[2] I W. A. Winarta, I. A. D. Giriantari, and I W. G. Ariastina, "Studi Emisi Karbon Sistem Pembangkitan Bali," *Majalah Ilmiah Teknologi Elektro*, vol. 13, no. 2, pp. 28-35, 2014.

[3] WRI Indonesia. (2023, August 5). Deklarasi Menuju Bali Emisi Nol Bersih 2045 Pertegas Komitmen Visi Pembangunan Nangun Sat Kerthi Loka Bali [Online]. Available: https://wri-indonesia.org/id/berita/deklarasi-menuju-bali-emisi-nol-bersih-2045-pertegas-komitmen-visi-pembangunan-nangun-sat

[4] G. F. Utami, D. Suhaedi, and E. Kurniati, "Perbandingan Metode Regresi Linier dan Non-Linier Kuadratik pada Peramalan Penjualan Air Minum," *Jurnal Matematika*, vol. 20, no. 2, pp. 33-41, 2021.

[5] Sahrul, Purwoharjono, and R. Gianto, "Peramalan Kebutuhan Energi Listrik Menggunakan Metode Gabungan," JUSTIN *(Jurnal Sistem dan Teknologi Informasi)*, vol. 11, no. 3, pp. 412-418, 2023, doi: 10.26418/justin.v11i3.63821.

[6] M. W. Purnama, "Peramalan Kebutuhan Energi Listrik Jangka Panjang Sektor Rumah Tangga UID Jawa Timur Menggunakan Metode Analysis Time Series: Proyeksi Tren Quadratic dan Regresi Linier Berbasis Software MINITAB V19," *Jurnal Teknik Elektro*, vol. 10, no. 2, pp. 485-495, 2021.

[7] A. A. Diwanda, I N. Setiawan, and W. Setiawan, "Peramalan Kebutuhan Energi Listrik Jangka Panjang di Provinsi Bali Rentang Tahun 2020 – 2030 Menggunakan Neural Network," *Jurnal SPEKTRUM*, vol. 8, no. 2, pp. 99-109, 2021.

[8] I. Nabillah and I. Ranggadara, "Mean Absolute Percentage Error untuk Evaluasi Hasil Prediksi Komoditas Laut," *Journal of Information System*, vol. 5, no. 2, pp. 250-255, 2020, doi: 10.33633/joins.v5i2.3900.

[9] M. Azam, A. Q. Khan, K. Zaman, and M. Ahmad, *"Factors Determining Energy Consumtion : Evidence from Indonesia, Malaysia, and Thailand",* ELSEVIER, vol. 42, pp. 1123-1131, 2014, [online]. Available: https://doi.org/10.1016/j.rser.2014.10.061

[10] R. W. Fridyansyah, O. Erza, and S. Mandai, *"Indentifikasi Determinan Pertumbuhan Ekonomi Provinsi Bali", Jurnal Ekonomi Trisakti*, vol. 3, no.2, pp. 3049-3058, 2023.

[11] F. Arifin and M. T. Tamam, *"Perhitungan Faktor Beban Terhadap Jenis Konsumen Rumah Tangga dan Industri di Wilayah Musi Banyuasin", Jurnal Riset Rekayasa Elektro,* vol. 3, no. 1, pp. 47-52, 2021.

[12] Kementrian Energi dan Sumber Daya Mineral. (2023). Rencana Umum Ketenagalistrikan Nasional [Online]. Available: https://gatrik.esdm.go.id/frontend/download_index/?kode_category=rukn

[13] Badan Pusat Stastistik. (2023). Proyeksi Penduduk Indonesia [online]. Available: https://www.bps.go.id/id

[14] Badan Pusat Statistik Provinsi Bali. (2023). PDRB Tahunan Provinsi Bali [Online]. Available: https://bali.bps.go.id/

[15] PLN. (2021). Rencana Usaha Penyedia Tenaga Listrik (RUPTL) [Online]. Available: https://web.pln.co.id/stakeholder/ruptl

[16] IESR. (2022) Integrasi Energi Terbarukan di RUPTL Dapat Mencapai 129 GW pada 2030 [Online]. Available: https://iesr.or.id/

[17] BAPPENAS. (2021). Transformasi Ekonomi Bali [Online]. Available: https://www.bappenas.go.id/