Innovative Administration Planning for Electricity Consumption in Five Districts of Surin Province, Thailand, Based on Seven Electricity User Sectors

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Abstract

Univariate modelling is employed in this study to forecast the electricity consumption of seven sectors under the responsibility of the Provincial Electricity Authority (PEA) Surin Province, namely residential, small size business, medium size business, industrial, specific business, agricultural, and other sectors. The study covers a five-year period from 2022 to 2026 based on time series data and by examining and comparing the effectiveness of three forecasting methods. The three methods under study are the Holt's linear trend, Brown's linear trend, and Damped trend with the Mean Absolute Percentage Error used to determine the most suitable method. The comparative results reveal Brown's linear trend to be the most suitable for forecasting electricity consumption in the residential, small size business sector, medium size business and other sectors, the Damped trend for industrial and specific business sectors, and Holt's linear trend for the agricultural sector. Total electricity consumption from 2022 to 2026 shows a continuously increasing trend. The annual electricity distribution of the PEA Surin Province shows a continuous increase when compared to the total electricity consumption between 2022 and 2026, with the distributed volume being 2.67, 4.76, 6.47, 7.84, and 8.93 million kWh, respectively. This shows that the PEA Surin Province tends to create a surplus, although at a decreasing rate. Consequently, in the future, the PEA Surin Province may not have sufficient electricity to meet the consumption of all electricity user sectors.

Keywords: Electricity consumption, Electricity distribution, Electricity user sectors, Provincial Electricity Authority Surin Province

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Introduction

Although invisible to the eye, it is generally acknowledged that electricity is fundamental to the daily lives of the global population and economy. It is also a necessity in modern society. By 2021, strong economic growth, combined with colder winters and warmer summers, boosted global electricity consumption demand by more than 6% (IEA, 2022). In 2014, the IEA estimated that during the period from 2001 to 2030, investment in the electricity sector for both production and distribution in developing countries across Asia, including China, India, and the ASEAN, was likely to increase in volume by 32%. As a developing country, Thailand exhibited an increase proportion in electricity demand for 2021 of 12.13% compared to the previous year. It has therefore become necessary for Thailand to buy electricity from abroad and increase its own electricity generation by 13.05% to ensure sufficient electricity distribution to cover the economic activities of all sectors in the country. Moreover, it is undeniable that energy plays a critical role in driving Thailand's economic growth and improving competitiveness. It is also essential to the daily lives of the population for transportation, illumination, and heat for cooking, among other uses. Electricity is a critical part of the infrastructure in all economic activities across Thailand because it can help to foster growth, including both social and economic development. However, electricity cannot be quarantined, and the demand for electricity can vary drastically External Communication Department, EGAT Head Office (2022).

In Thailand, the largest number of electricity users (6,853,770) are located in the Northeast region, followed by the Central, North, and South regions with 5,971,894, 4,365,303, and 3,281,423 users, respectively. The highest level of electricity consumption is exhibited by the Central region at 77,179,160,001 kWh followed by the Northeast, South, and North regions with 22,165,803,137 kWh, 16,265,750,008 kWh, and 16,238,178,248 kWh, respectively. It can be observed that the Northeast region has the highest number of electricity users and the second highest electricity consumption, representing a significant increase during the period under study. When considering the North East region, the following ten provinces exhibited the highest electricity consumption: 1) Nakhon Ratchasima, 2) Khon Kaen, 3) Ubon Ratchathani, 4) Udon Thani, 5) Buriram, 6) Roi Et, 7) Surin, 8) Sisaket, 9) Chaiyaphum, and 10) Maha Sarakham at the level of 6,015,735,151 kWh, 2,440,911,795 kWh, 1,645,061,111 kWh, 1,556,145,874 kWh, 1,237,438,145 kWh, 1,001,140,645 kWh, 956,803,695 kWh, 915,679,550 kWh, 872,714,364 kWh, and 825,125,902 kWh, respectively. Eight provinces show increasing proportions of electricity consumption, namely: Khon Kaen, Ubon Ratchathani, Udon Thani, Buriram, Roi Et, Surin, Sisaket, and Maha Sarakham, at the level of 2.25%, 1.98%, 1.31%, 2.72%, 3.98%, 2.88%, 5.09%, and 2.73%, while Nakhon Ratchasima and Chaiyaphum Provinces exhibit a decreasing proportion of electricity consumption at -2.55% and -0.85% (National Statistical Office, 2022).

According to the aforementioned figures, the provinces with the highest proportion of electricity consumption are Sisaket (5.09%), followed by Roi Et (3.98%), and Surin (2.88%), respectively. Since Surin Province has the highest electricity consumption (956,803,695 kWh), the Provincial Electricity Authority of Surin Province is the main organisation responsible for distributing electricity to users and covers five of the 17 districts in the province, namely: Mueang Surin, Khwao, Lamduan, Sanom, and Chom Phra. These five districts cover most of the area of Surin Province, representing 2,380.85 square kilometres. PEA Surin Province distributes electricity to eight electricity user sectors, namely: 1) residential, 2) small size business, 3) medium size business, 4) industrial, 5) specific business, 6) agricultural, 7) other (or non-profit and temporary) General Accounting Section, PEA Surin Province. (2022).

The electricity consumption in the PEA Surin Province from 2021 to 2025 is estimated to increase by 454,030,083.23 kWh, while the electricity capacity will be capped at 464,926,805.23 kWh. This means that electricity consumption will probably higher than the electricity capacity of the PEA Surin Province in the future (General Accounting Section, PEA Surin Province, 2022). If the current situation is allowed to continue, it may cause electricity consumption to come close to capacity, creating a shortage and potentially resulting in electricity brownout, which is a frequent problem nowadays. Forecasting is therefore necessary to set guidelines for future electricity consumption and capacity. Consequently, it is essential to have as much information as possible on the electricity use of all sectors, namely: 1) residential, 2) small size business, 3) medium size business, 4) industrial, 5) specific business, 6) agricultural, and 7) other. Since the distribution process is likely to take between two and four years per electricity distribution station, from start to finish, sufficient and timely preparation is required to ensure that the capacity to distribute electricity meets the demand for electricity consumption. Therefore, it is essential to forecast the electricity consumption over the next five years starting from 2022 while creating an adequate plan and policy to efficiently accommodate consumption demand within a particular area for use in the future electricity development plans of the PEA Surin Province.

Objectives

Due to the previously mentioned restrictions, the objectives of this study are:

1) To forecast the total electricity consumption based on electricity user sectors over a five-year period from 2022 and 2026.

2) To compare the total electricity consumption with the electricity capacity of PEA Surin Province.

Framework

The literature review and the statement of the problem are used as the study framework, focusing on the forecasting of electricity consumption1 for the PEA Surin Province, covering five of the 11 districts in Surin Province, Thailand. 1) Mueang Surin, 2) Chom Phra, 3) Sanom, 4) Lamduan, and 5) Khwao Sinrin. The forecasting is based on the sectoral approach, using information relating to the electricity consumption of seven electricity user sectors: 1) residential, 2) small size business, 3) medium size business, 4) industrial, 5) specific business, 6) agricultural, and 7) other sectors of the PEA Surin Province, plus electricity loss2. In this study, the total long-term electricity consumption of Surin Province3 is forecast for each of the seven sectors over a five-year period. Comparisons are then made between the total forecasted electricity consumption and total electricity capacity4 of the PEA Surin Province. In this study, five districts in the PEA Surin area are examined to forecast the long-term electricity consumption of seven electricity user sectors under the framework presented in Figure 1.

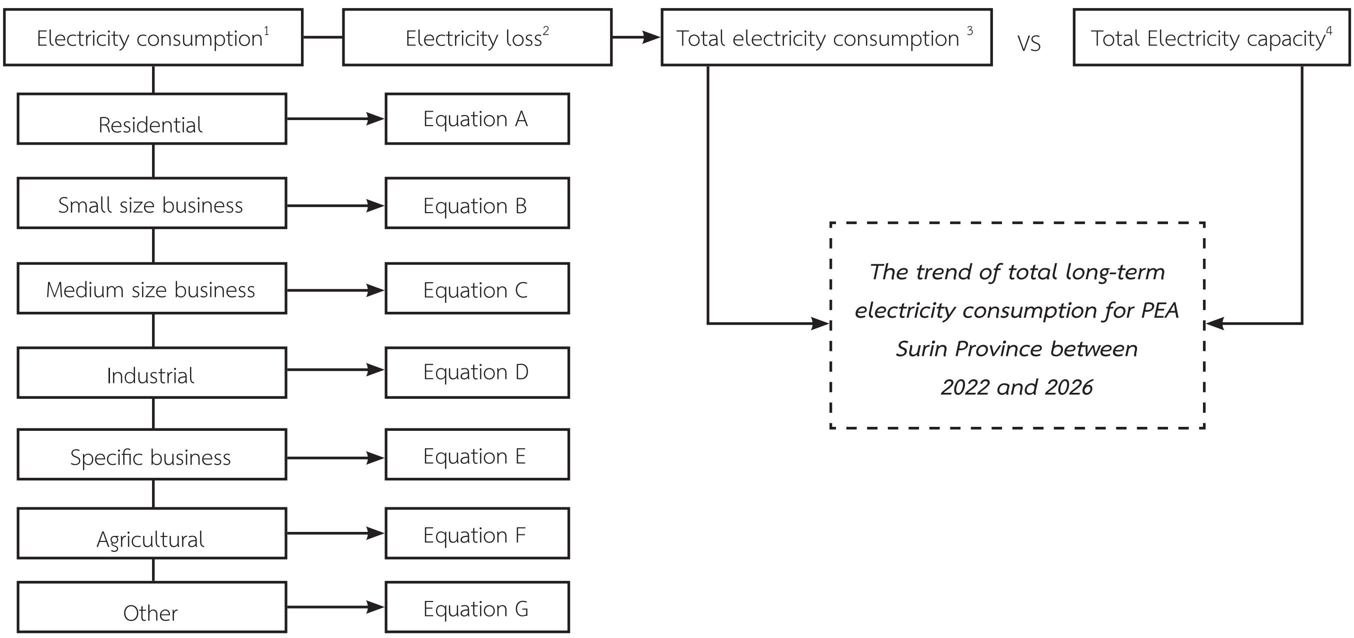

Figure 1. Framework

Source: Adopted from the framework applied by Kumjinda, S. et al. (2019) and Kumjinda, S. (2020)

Methodology

1. Electricity consumption

1.1 Data collection and analysis

Historical time series data on the electricity consumption of seven electricity user sectors was collected from the PEA Surin Province (General Accounting Section, PEA Surin Province, 2022) using kilowatt hours (kWh) as the variable. In each sector, time series data from 2011 to 2021 was investigated under 11 observations to estimate the electricity capacity of PEA Surin Province. The properties of all-time series data sectors were tested using the free hand method proposed by Srivastava et al. (1989). The historical time series data of all sectors was considered by univariate modelling utilising three suitable forecasting methods: 1) Holt's linear trend, 2) Brown's linear exponential smoothing, and 3) the damped trend. The performance of each method was compared and evaluated for suitability using the criterion of mean absolute percent error (MAPE). The electricity loss was calculated using the non-technical loss method, detailed as follows.

1.2 Holt's linear trend

Holt (1957) extended simple exponential smoothing to allow the forecasting of data according to trend. This method involves a forecast equation and two smoothing equations (one for the level and one for the trend):

Forecast equation: $\hat{y}_{t+h|t} = l_t + hb_t$ (1)

Level equation: $l_t = \alpha y_t + (1-\alpha).(l_{t-1} + b_{t-1})$ (2)

Trend equation: $b_t = \beta^*(l_t - l_{t-1}) + (1-\beta^*)b_{t-1}$ (3)

Where: lt denotes the estimated level of the series at time t, α denotes the estimated trend (slope) of the series at time t, α is the smoothing parameter for the level, $0 < \beta^* < 1$, and β^* is the smoothing parameter for the trend, $0 < \beta^* < 1$.

As with simple exponential smoothing, the level equation here shows that l_t is a weighted average of observation y_t with the one-step-ahead training forecast for time t given by $l_{t-1} + b_{t-1}$. The trend equation shows that b_t is the weighted average of the estimated trend at time t based on l_t- l_{t-1} and b_{t-1}, the previous estimate of the trend.

The forecast function is no longer flat but trending. The h-step-ahead forecast is equal to the last estimated level plus h times the last estimated trend value. Hence the forecasts are a linear function of h.

1.3 Brown's linear trend

This forecasting method is appropriate for trending time series data. It can correct the deficiencies of the double moving average method, and considered to be an extension of the linear trend for predicting turning points as well as the trend characteristics of the data, which are more quadratic than linear. It uses the forecasting calculation presented in Equation 4 (Suttichaimethee, 2010).

Forecast equation: $F_{t+m} = A_t + B_t(m) + \frac{1}{2}C_t(m^2)$ (4)

Where: F_{t+m} is the forecast for the next period, is the forecast for the current period, F_t^* is the double exponential smoothing, F_t'' is the triple exponential smoothing, A_t is the intercept, A_t is $3F_t''$-$3F_t$-$3F_t$+F_t'', B_t is an additional adjustment factor, C_t is $\frac{\alpha^2}{(1-\alpha)^2}[F_t - 2F_t'' + F_t'']$, α is the weight, ($0 < \alpha < 1$), m is the time period used to make predictions for the next period, and is always $F_t'' = F_1 + X_1$.

1.4 Damped trend

The damped trend method involves a parameter that "dampens" the trend to a flat line sometime in the future. Methods that include a damped trend have proven to be very successful and are arguably the most popular individual and accurate methods when forecasts are required automatically for many series. In conjunction with the smoothing parameters α and β^* (with values between 0 and 1 as in Holt's method), this method also includes a damping parameter $0 < \emptyset < 1$ (Gardner and McKenzie, 1985).

Forecast equation: $\hat{y}_{t+h|t} = l_t + (\emptyset + \emptyset^2 + \cdots + \emptyset^h)b_t$ (5)

Level equation: $l_t = \alpha y_t + (1-\alpha).(l_{t-1} + \emptyset b_{t-1})$ (6)

Trend equation: $b_t = \beta^*(l_t - l_{t-1}) + (1-\beta^*)\emptyset b_{t-1}$ (7)

If $\emptyset=1$, the method is identical to Holt's linear method. For values between 0 and 1, $\emptyset$ the trend is damped so that it approaches a constant sometime in the future. In fact, the forecasts converge to $l_T + \frac{\emptyset b_T}{(1-\emptyset)}$ as $h \to \infty$ for any value $0 < \emptyset < 1$. This means that short-run forecasts are trended while long-run forecasts are constant.

1.5 Performance evaluation

The criterion used to determine the effectiveness of the four forecasting methods is designed to establish the most appropriate or closest model to the actual situation. The criterion for determining the efficiency of the model is MAPE (Gaynor and Kirkpatrick, 1994).

$$MAPE = \frac{\sum_{t=1}^{n} \frac{e_t}{Y_t}}{n} \quad (8)$$

Where: t is time period; n is the number of periods forecast; e_t is the forecast error in time period t; Y_t is actual value in time period t.

1.6 Electricity loss calculation

This study uses non-technical loss to calculate electricity loss by comparing the discrepancy between electricity units purchased with the level of total forecasting electricity consumption of the PEA Surin Province distribution system, as shown in Equation 9 (Policy and Strategy Department, PEA Head Office. (2018).

$$EL = TPG - ED \quad (9)$$

As a percentage, it can be calculated by Equation 10.

$$EL(\%) = \frac{EL \times 100}{TPG} \quad (10)$$

Where: EL is electricity loss or loss. TPG is units of total electricity purchased by the PEA Surin Province. ED is the forecasted electricity consumption.

Results and Discussion

Suitable forecasting methods

The most suitable method for forecasting the electricity consumption of the seven sectors is based on MAPE, the details of which are shown in Table 1. It can be concluded that the most suitable methods for forecasting electricity consumption in the seven sectors are those presented in Table 2.

Tables 1 and 2 show that the most suitable forecasting method for electricity consumption in each of the residential, small size business, medium size business, and other sectors is Brown's linear trend. Whereas the most suitable forecasting method for the industrial and specific business sectors is the Damped trend. Finally, the most suitable method for forecasting electricity consumption in the agricultural sector is Holt's linear trend. Details of the parameter estimation and diagnostic checking for all three forecasting methods are presented in Table 3.

Table 1. Method performance evaluation of the seven sectors considering MAPE

Sectors	Holt	Brown	Damped
1) Residential	41.696	9.133*	41.799
2) Small size business	8.469	8.466*	18.302
3) Medium size business	10.547	10.526*	18.858
4) Industrial	28.349	31.963	26.273*
5) Specific business	56.313	65.747	55.716*
6) Agricultural	56.190*	77.257	56.240
7) Other	77.871	51.232*	82.733

Note: (*) refers to the most suitable forecasting method. Other refers to the two sectors consisting of government and non-profit and temporary electricity users.

Table 2. The most suitable forecasting methods for the seven sectors

Sectors	Suitable forecasting methods		
	Holt	Brown	Damped
1) Residential		√	
2) Small size business		√	
3) Medium business		√	
4) Industrial			√
5) Specific business			√
6) Agricultural	√		
7) Other		√	

Note: √ is the most effective forecasting method. Other refers to the two sectors consisting of (government and non-profit) and temporary electricity users.

Table 3. Parameter estimation of the three forecasting methods for seven sectors

Sectors	Parameters	Estimate	*SE*	*t*	P-Value
Residential *(Brown's linear trend)*	Level and trend (α)	0.999	0.064	15.668	0.000
Small size business *(Brown's linear trend)*	Level and trend (α)	0.999	0.060	16.719	0.000
Medium size business *(Brown's linear trend)*	Level and trend (α)	0.999	0.063	15.981	0.000
Industrial	Level (α)	0.564	0.338	1.668	0.134
(Damped trend)	Trend (β*)	0.999	1.235	0.809	0.442
	Trend damping factor (∅)	0.891	0.136	6.568	0.000
Specific business	Level (α)	0.300	0.296	1.013	0.341
(Damped trend)	Trend (β*)	0.999	1.855	0.539	0.605
	Trend damping factor (∅)	0.900	0.217	4.147	0.003
Agricultural	Level (α)	0.001	0.487	0.002	0.998
(Holt's linear trend)	Trend (β*)	0.000	209.831	1.101E-6	1.000
Other *(Brown's linear trend)*	Level and trend (α)	0.139	0.092	1.511	0.162

Note: ***SE*** is standard error. ***t*** is ***t***-statistic.

Table 3 presents the parameter estimation and diagnostic checking details of the three forecasting methods for the residential, small size business, medium size business, industrial, specific business, agricultural, and other sectors, which can be developed as equations (A), (B), (C), (D), (E), (F), and (G) respectively.

$$F_{t+5} = A_t + B_t(5) + \frac{1}{2}\left(\frac{0.999^2}{(1-0.999)^2}[F_t - 2F_t^{''} + F_t^{''}]\right)(5^2) \quad (A)$$

$$F_{t+5} = A_t + B_t(5) + \frac{1}{2}\left(\frac{0.999^2}{(1-0.999)^2}[F_t - 2F_t^{''} + F_t^{''}]\right)(5^2) \quad (B)$$

$$F_{t+5} = A_t + B_t(5) + \frac{1}{2}\left(\frac{0.999^2}{(1-0.999)^2}[F_t - 2F_t^{''} + F_t^{''}]\right)(5^2) \quad (C)$$

$$\hat{y}_{t+h|t} = (0.564y_t + (1-0.564).(l_{t-1} + 0.891b_t)) + (0.891 + 0.891 + \cdots + 0.891^h).(0.999(l_t - l_{t-1}) + (1-0.999)0.891b_{t-1}) \quad (D)$$

$$\hat{y}_{t+h|t} = (0.300y_t + (1-0.300).(l_{t-1} + 0.900b_t)) + (0.900 + 0.900 + \cdots + 0.900^h).(0.999(l_t - l_{t-1}) + (1-0.999)0.900b_{t-1}) \quad (E)$$

$$\hat{y}_{t+h|t} = 0.001y_t + (1-0.001).(l_{t-1} + b_{t-1}) + h(0.000(l_t - l_{t-1}) + (1-0.000)b_{t-1}) \quad (F)$$

$$F_{t+5} = A_t + B_t(5) + \frac{1}{2}\left(\frac{0.139^2}{(1-0.139)^2}[F_t - 2F_t^{''} + F_t^{''}]\right)(5^2) \quad (G)$$

When the most effective forecasting method is applied to each of the seven sectors over the next five years, an increase in total electricity consumption excluding loss is indicated from 2022 to 2026, as shown in Table 4 and Figure 2.

Table 4. Electricity consumption forecasting results for the seven sectors

Forecast period	Sectors							Total forecasting electricity consumption excluding loss
	Residential	Small size business	Medium size business	Industrial	Specific business	Agricultural	Other	
2022	217.21	79.41	99.84	57.27	5.46	1.85	2.67	**463.71**
2023	226.50	81.81	102.09	54.71	4.52	1.91	2.43	**473.97**
2024	235.78	84.22	104.34	52.44	3.68	1.97	2.19	**484.62**
2025	245.07	86.62	106.59	50.41	2.92	2.03	1.95	**495.59**
2026	254.36	89.02	108.84	48.61	2.23	2.09	1.71	**506.86**

Note: Unit is million kilowatt hour (kWh)

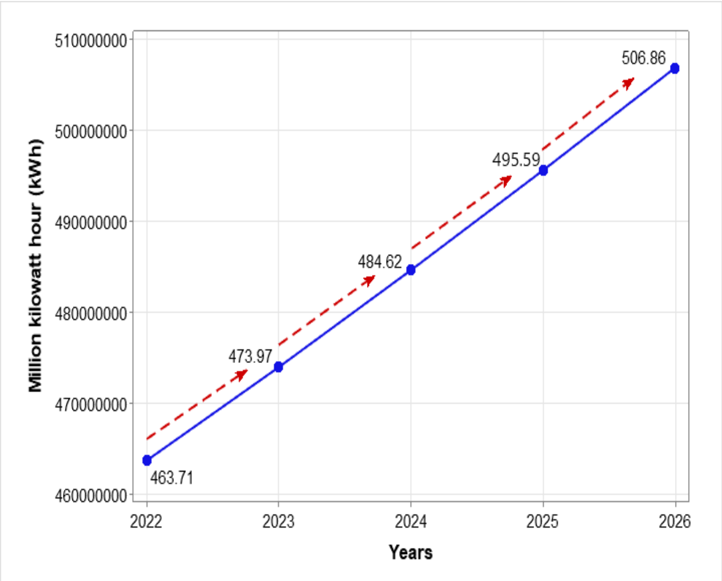

Figure 2. The trend for total forecasting electricity consumption excluding loss

The results for the forecasting of electricity consumption in the seven sectors are shown as graphs in Figures 3, 4, 5, 6, 7, 8, and 9, respectively.

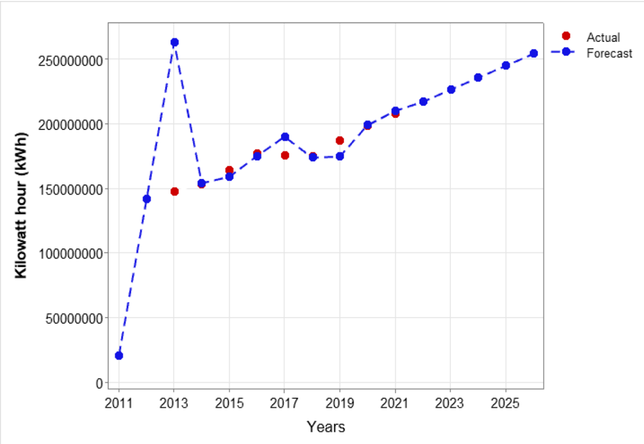

Figure 3. Residential sector

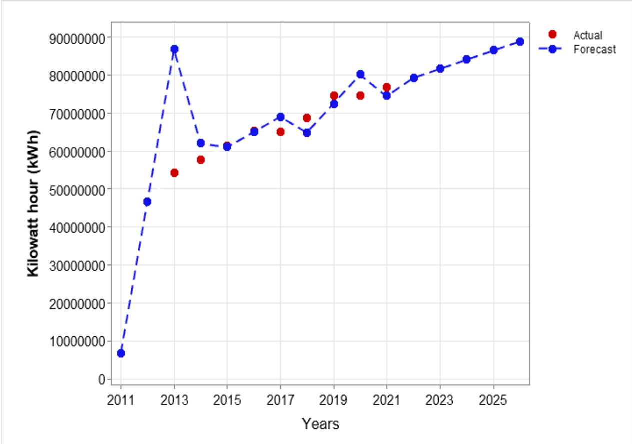

Figure 4. Small size business sector

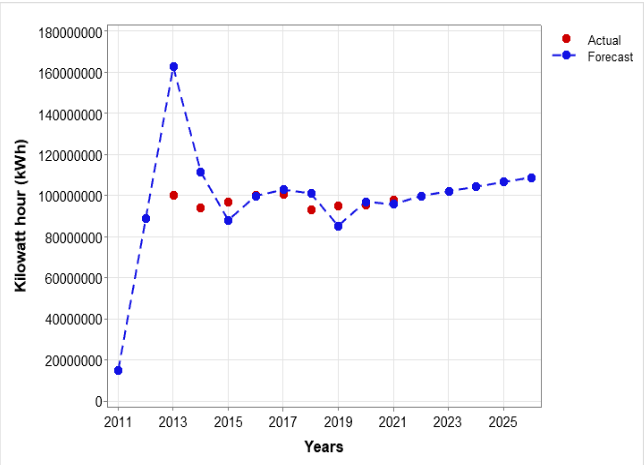

Figure 5. Medium size business sector

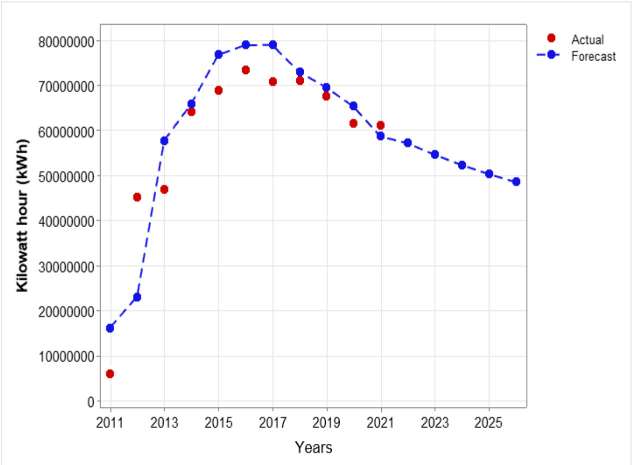

Figure 6. Industrial sector

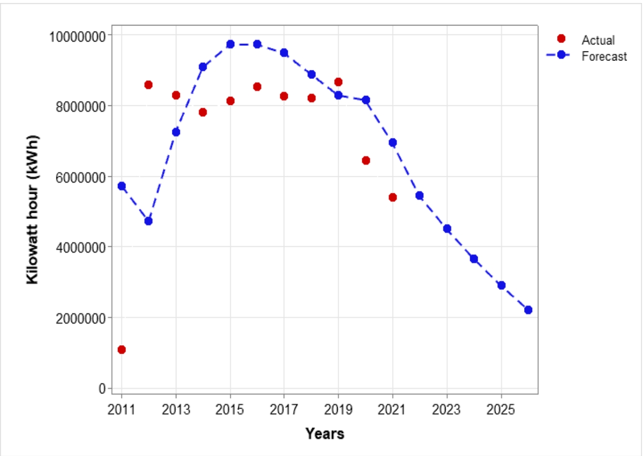

Figure 7. Specific business sector

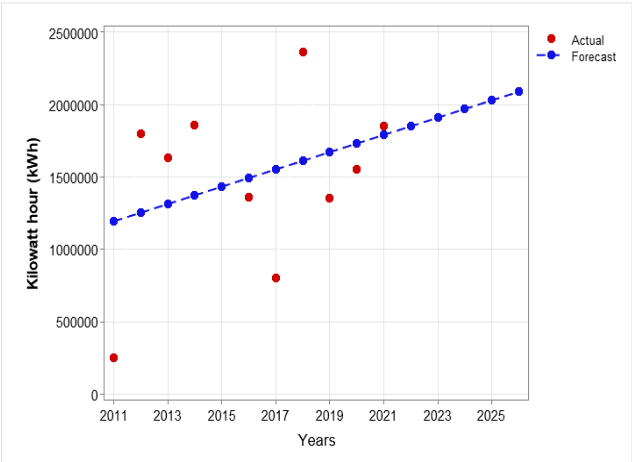

Figure 8. Agricultural sector

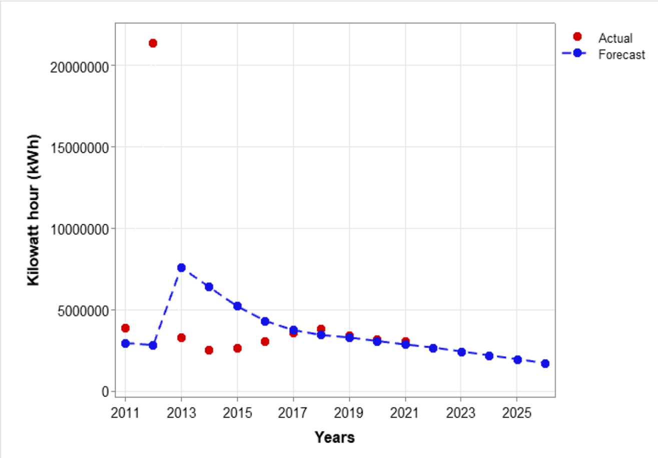

Figure 9: Other sectors

The results of the total forecasted electricity consumption for the seven sectors are presented in Table 4. Electricity loss, is calculated using non-technical loss as shown in Equations 9 and 10; however, no data is available on the number of electricity units purchased. Therefore, the authors applied the economics of electricity supply theory proposed by Attavanich (2014), which states that electricity is non-renewable energy, which it cannot be stored and demand should equal supply. Therefore, this theory has been applied to loss, and calculated loss between 2022 and 2026 and summarised to obtain the total electricity consumption (Y) as shown in the following equation:

$$Y = (R + S + M + I + S + A + O) + L \qquad (10)$$

Where: Y is total electricity consumption, R is the forecasting results of residential sector, S is the forecasting results of small size business sector, M is the forecasting results of medium size business sector, I is the forecasting results of industrial sector, S is the forecasting results of specific business sector, A is the forecasting results of agricultural sector, O is the forecasting results of other sector, and L is the estimated results of electricity loss (non-technical loss).

Equation 10 shows that the total forecasted electricity consumption also covers electricity loss during the period from 2022 to 2026, indicating a continous increase as presented in Table 5.

According to Table 5, the results for the increasing electricity consumption of the PEA Surin Province can be plotted as shown by the graph in Figure 10.

Table 5. Summary of the projected total electricity consumption including loss

Forecast period	Total electricity consumption excluding loss	Loss (%)	Total electricity consumption including loss
2022	463.71	0.57	463.72
2023	473.97	1.00	473.98
2024	484.62	1.32	484.63
2025	495.59	1.56	495.61
2026	506.86	1.74	506.88

Note: Unit is million kilowatt hour (kWh)

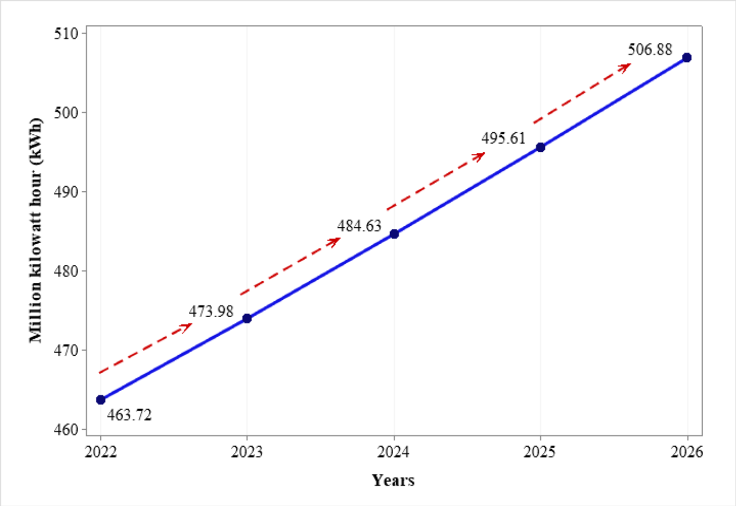

Figure 10. The trend of total forecasted electricity consumption, including loss of the PEA Surin Province

The total electricity consumption of the PEA Surin Province, including loss, is compared with the estimated electricity purchased and generated by the PEA Surin Province. The results indicate that the PEA Surin Province will have a surplus of electricity for distribution, increasing each year from 2022 to 2026 at the rate of 2.67, 4.76, 6.47, 7.84, and 8.93 million kWh, respectively. The PEA Surin Province has a tendency to produce a surplus, although this is at a decreasing rate, as demonstrated in Table 6 and Figure 11.

Table 6. Surplus of electricity for distribution by the PEA Surin Province

Forecast period	Estimated electricity purchased and generated by the PEA Surin Province	Total electricity consumption including loss of the PEA Surin Province	Electricity distribution surplus of the PEA Surin Province
	(1)	(2)	(1) – (2)
2022	466.39	463.72	2.67
2023	478.74	473.98	4.76
2024	491.10	484.63	6.47
2025	503.45	495.61	7.84
2026	515.81	506.88	8.93

Note: Unit is million kilowatt per hour (kWh). The electricity purchased and generated between 2022 and 2026 is estimated using Brown's linear trend.

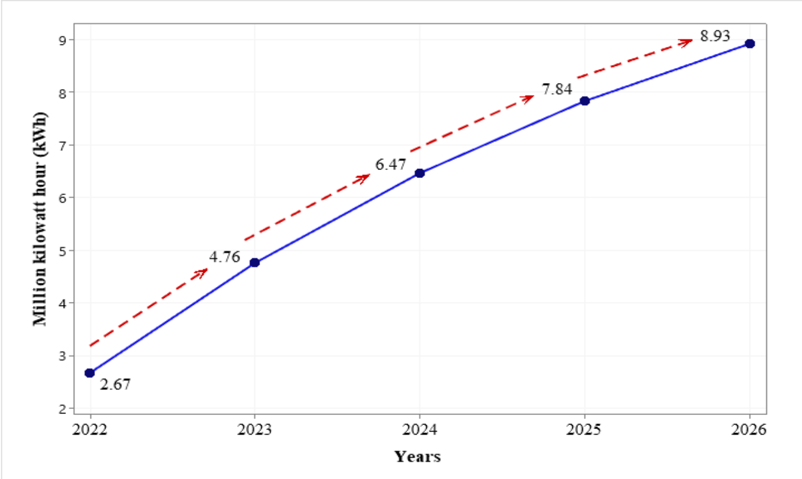

Figure 11. Tendency of the PEA Surin Province to achieve an electricity distribution surplus, although this is at a decreasing rate

Conclusions

Although, at present, the PEA Surin Province has sufficient electricity for distribution to all sectors at the present time, if the current situation is allowed to continue, a shortage of electricity may occur in the future, affecting not only the management and administration of electricity but also the cost of production and distribution. This is because the PEA Surin Province has a tendency to hold a surplus, although electricity consumption, including loss, is likely to catch up with the estimated electricity purchased and generated due to a steady decrease in the surplus volume from 2022 to 2026. This may have a direct impact on the electricity security of the PEA Surin Province in the future. Therefore, it is essential to forecast the electricity consumption of the PEA Surin Province to provide guidelines for timely electricity distribution management and administration planning to support the forecasted increasing trend, including loss by 2026 in accordance with current and future economic and social changes. Accordingly, it can be seen that the electricity distributed must be able to meet the demand for increasing electricity consumption in the future.

Suggestions

The authors aim to analyse the cost of electricity production and distribution of the PEA Surin Province in a future study. This would include planning and describing the level of electricity usage, the capacity to produce and distribute electricity, and the ability of the PEA Surin Province to meet the demand for electricity consumption in 2026 due to changes in society and the economy.

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