JMSS Journal of Multidisciplinary in Social Sciences

Journal of Multidisciplinary in Social Sciences
Journal homepage : http://jmss.dusit.ac.th

# Univariate Modelling for Forecasting Residential Electricity Consumption under the Responsibility of the Metropolitan Electricity Authority (MEA)

Saran Kumjinda[a*] & Pattama Kidroub[b]

[a] *72 Nawamin 74 (3-12), Khunnayao/Ramintra, Nawamin Road, Bangkok, 10230 Thailand*
[b] *1635, Mukmontri Road, Nai Mueang Subdistrict, Mueang District, Nakhon Ratchasima, 30000 Thailand*

**Article info**

*Article history:*
Received: 19 March 2021
Revised: 18 June 2021
Accepted: 30 June 2021

*Keywords:*
Residential sector, Forecasting electricity consumption, Univariate modelling, Metropolitan electricity authority (MEA)

**Abstract**

Univariate modelling is employed in this study to forecast the electricity consumption of the residential sector under the responsibility of the Metropolitan Electricity Authority (MEA) over the five-year period from 2021 to 2025 based on time series data and by examining and comparing the effectiveness of three forecasting models. The three models under study are the Holt-Winters' exponential smoothing, Brown exponential smoothing and Damped trend exponential smoothing. The Mean Absolute Percentage Error (MAPE = 2.35) is used to determine the most suitable and effective model, and the comparative results reveal the Damped trend model to be the most suitable for forecasting electricity consumption in the residential sector. Total electricity consumption from 2021 to 2025 for the residential sector is projected to continuously increase. The annual residential electricity capacity of the MEA shows a continuous decrease when compared to total electricity consumption between 2021 and 2025, with the distributed volume being 1,319.06, 1,004.56, 690.16, 375.85, and 61.64 million kWh, respectively. Due to the continuous decrease in electricity sales will significantly impact the management of electricity production and distribution. Consequently, in the future, the MEA may not have sufficient electricity capacity to meet the consumption demand of the residential sector.

## Introduction

Electrical energy is fundamental to the daily lives of the global population and economies. In Thailand, the procurement and distribution of electrical energy require a great deal of investment. The International Energy Agency estimates that from 2011 to 2030, investment in electrical energy for production and distribution in China, India, and the ASEAN countries will increase by up to 32% (International Energy Agency, 2014). As a developing country, it is undeniable that energy plays a critical role in driving Thailand's economic growth and improving competitiveness. It is also important for illumination and cooking. The provision of energy is a critical part of the infrastructure and economic activities of Thailand since it can help to foster growth as well as social and economic development. However, electrical

* Corresponding Author
e-mail: littleyooyee@gmail.com

energy cannot be quarantined, and demand varies at different times. Therefore, the relevant authorities have a key role to play in efficient electrical energy management and the provision of sufficient supplies to meet consumption demand. Such authorities include the Electricity Generating Authority of Thailand (EGAT), the Metropolitan Electricity Authority (MEA), and the Provincial Electricity Authority (PEA). However, the MEA is responsible for providing services to three of the 77 provinces most crucial to Thailand's economy, namely Bangkok, Nonthaburi, and Samut Prakarn. Specifically, in the residential sector, there are about 3,654,363 electrical energy users with the average consumption showing an increase in similar annual proportions. In 2020, the total annual usage was 14,495.32 GWh or 14,495.32 million kWh; an increase of 3.52% from the previous year (Power Economic Department, 2021; Metropolitan Electricity Authority, 2020).

It is clear from the foregoing that electrical energy consumption in the three provinces is continuously increasing. Meanwhile, the investment process and service expansion of the MEA is expected to take at least four to five years per electricity production and distribution station from the start of the construction process (Metropolitan Electricity Authority, 2021). Since current electricity consumption is increasing, these three provinces need to take the necessary steps to ensure the adequate production and distribution of electrical energy. If the current situation is allowed to continue, it could result in an electrical energy crisis.

Therefore, it is necessary to undertake a thorough study of the development or expansion of electrical energy and its availability to meet all economic activity requirements in the residential sector, for which the MEA is responsible. The organisation is under an obligation to purchase electrical energy from EGAT, which produces some of its own electrical energy to cover residential users and the area concerned. Thus, MEA and EGAT play an essential role in electrical energy security of three urban areas and the service extension in remote urban areas has not yet been fully completed. Ultimately, this may lead to insufficient electrical energy being imported to these three provinces to meet the consumption demand of users in the residential sector.

## Objectives

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

1. To compare three forecasting methods to identify the most effective using time series data on the residential sector.
2. To study and forecast the level of electrical energy consumption of MEA in the residential sector for the five years from 2021 to 2025.

## Conceptual framework

This study focuses on the forecasting of electricity consumption in the residential sector under the responsibility of MEA. The forecasting is based on univariate modelling and time series data, by using information relating to the electrical energy consumption of the residential sector. Comparisons are subsequently made between the total predicted electrical energy consumption and total electricity capacity of MEA. In this study, three provinces are examined to forecast the long-term electricity consumption of the residential sector. The framework for forecasting the electricity consumption under the responsibility of MEA is shown in Figure 1.

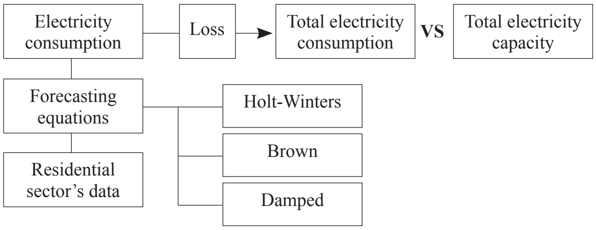


**Figure 1** Conceptual framework

Figure 1 demonstrates the difference between this research and previous studies. The strength of this study is that it forecasts the electricity consumption in the residential sector for three provinces under the responsibility of MEA. The results of the total electricity consumption and total electricity capacity are then compared, and a detailed explanation provided, in contrast to previous studies which only involve forecasting. In addition, this study covers three important areas of Thailand, and the results can be used by MEA in the planning of electricity production and distribution as well as capacity expansion to support electricity consumption in the future.

## Research methodology

This study involves the collection of historical time series data on yearly electricity consumption from the Power Economic Department of the MEA, 2021.

Time series data was collected by using kilowatt hour (kWh) as the variable. For the residential sector, time series data between 2000 and 2020 was investigated under 21 observations as shown in Table 1.

In addition, this study also used the data for the estimation of the historical time series data on the 1electricity capacity of the MEA between 2021 and 2025, which was collected from the Power Economics Department of the MEA in 2021. Moreover, the electricity loss was calculated using a non-technical loss method. Following a review of recent studies, one freehand method to analyze time series data, which is also regarded as the graphic method in the sense that the trend line is determined by inspecting a graph of the series, and three forecasting methods were chosen to predict the electricity consumption of the residential sector under the responsibility of the MEA: Holt-Winters' exponential smoothing, Brown exponential smoothing and damped trend exponential smoothing. The performance of each of these three forecasting methods was compared and evaluated using the MAPE criteria. Details of the time series data analysis are presented as follows:

1 Total electricity capacity of residential sector collected from (Metopolitan Electricity Authority, 2021), there are 21 observations between 2000 and 2020. And predictive in order to find total electricity capacity between 2021 and 2025 by using Holt-Winters' method.

**Table 1** Historical time series data on electricity consumption of residential sector

Unit: Kilowatt hour (kWh)

| Observations | Years | Electricity consumption |
|---|---|---|
| 1 | 2000 | 6,881,908,033.00 |
| 2 | 2001 | 7,295,701,261.00 |
| 3 | 2002 | 7,626,883,090.00 |
| 4 | 2003 | 7,998,774,284.00 |
| 5 | 2004 | 8,334,626,018.00 |
| 6 | 2005 | 8,637,373,070.00 |
| 7 | 2006 | 9,079,156,247.00 |
| 8 | 2007 | 9,230,433,889.00 |
| 9 | 2008 | 9,381,418,282.00 |
| 10 | 2009 | 9,779,260,850.00 |
| 11 | 2010 | 10,713,240,272.00 |
| 12 | 2011 | 10,124,804,736.00 |
| 13 | 2012 | 11,398,924,725.00 |
| 14 | 2013 | 11,420,399,902.00 |
| 15 | 2014 | 11,694,752,582.00 |
| 16 | 2015 | 12,369,389,109.00 |
| 17 | 2016 | 12,998,215,026.00 |
| 18 | 2017 | 13,041,399,249.00 |
| 19 | 2018 | 13,133,862,609.00 |
| 20 | 2019 | 14,296,360,836.00 |
| 21 | 2020 | 15,693,736,927.00 |

Source: The Power Economic Department of the MEA, 2021

1. Freehand method

The freehand method involves time series data analysis and is also referred to as the graphic method in the sense that the trend line is determined by inspecting a graph of the series. In this method, the trend values are determined by drawing a freehand straight line through the time series data judged by the analyst to adequately represent the long-term movement in the series and explain the trend of historical time series data (Srivastava, Shenoy, & Sharma,1989).

2. Holt-Winters' exponential smoothing

This forecasting method is used to fix the problem of the moving average (MA) since exponential smoothing emphasises the importance of current data. Older data is marked as less important, according to its relevant timeframe. The data is altered and adjusted according to the trend, smoothing it for a more accurate result. Another parameter is added to α (alpha) alone, to create α and δ (delta). This helps to reduce the number of random factors or variables as in Equation 1 (Suttichaimethee, 2010).

$$F_{t+m} = F_t + T_t(m) \qquad (1)$$

When: $F_{(t+m)}$ is the forecast for the next period, $F_t$ is the forecast for the current period, $F_t$ is the slope of time series data, and m is the future forecast period.

Where: $F_t$ is $\alpha Y_t + (1-\alpha).\ (F_{t-1} + T_{t-1})$ and $T_t$ is $(F_t - F_{t-1}) + (1 - \delta).\ T_{t-1}$.

3. Brown exponential smoothing

This forecasting method is appropriate for trending time series data. It can correct the deficiencies of the double moving average method, and it can be said that this type of forecast is an extension of the linear exponential smoothing, which can predict turning points well as the trend characteristics of the data are more quadratic than linear. It uses the equations involved in forecasting as seen in Equation 2 (Suttichaimethee, 2010).

$$F_{t-m} = A_t + B_t m + \tfrac{1}{2} C_t m^2 \qquad (2)$$

Where: $F_{(t+m)}$ is the forecast for the next period, $F''_t$ 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 $3F''_t - 3F_t + F'''_t$, $B_t$ 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 in the next period, and $F'''_t$ is always $F''_1 = F_1 = X_1$.

4. Damped trend exponential smoothing

This forecasting method is another appropriate method for trending time series data. It utilizes smoothing with the damped linear trend, which is appropriate for the time series data with a straight-line trend and no seasonal variations and is consistent with Holt-Winters. However, the damped trend has a slower rate of change, including a slope that will also decrease with time, which is forecasted as in Equation 3 (Manmin, 2006).

$$\hat{Y}_{t+m} = a_t = b_t \Sigma_{i=1}^{m} ø^i \quad (3)$$

Where: $\hat{Y}_{t+m}$ is the forecast for the next period, $A_t$ is the intercept, and $B_t$ is an additional adjustment factor.

When: $a_t = \alpha Y_t + (1 - \alpha).(a_{t-1} + øb_{t-1})$ and

$$b_t = \gamma(a_t - a_{t-1}) + (1 - \gamma)øb_{t-1}.$$

5. Modelling Performance Evaluation

The criteria used to determine the effectiveness of the four forecasting methods are designed to establish the most appropriate or closest model to the actual situation. The criteria values for determining the efficiency of the model is the MAPE as equation 4 (Klimberg, Sillup, Boyle, & Tavva, 2010).

$$MAPE = \frac{\Sigma_{t=1}^{n} \frac{|e_t|}{Y_t}}{n} \quad (4)$$

Where: t is the time period, n is the number of periods forecast, $e_t$ is the forecast error in time period t, and $Y_t$ is the forecasting value.

Accordingly, all analysis methods mentioned in this study have been used to forecast electricity consumption in the residential sector and the electricity capacity of the MEA in the residential sector in order to respond to the two objectives of this study. The details of the results and a discussion of the methods are described in the next section.

## Results

This section presents the results and discusses the residential forecasting electricity consumption under the responsibility of the MEA, divided into three sections are analysis of primary historical time series data, the suitable model detail, forecasting the results using the most suitable model, and the results of forecasting electricity consumption in residential sector.

1. Analysis of primary historical time series data

The analysis results for the historical electricity consumption time series data between 2000 and 2020 in the residential sector using freehand reveals that the movement of time series data incorporates the trend component without seasonal influences and with no errors as shown in Figure 2. Therefore, it is possible to use time series data for the residential sector as the default method for further forecasting.

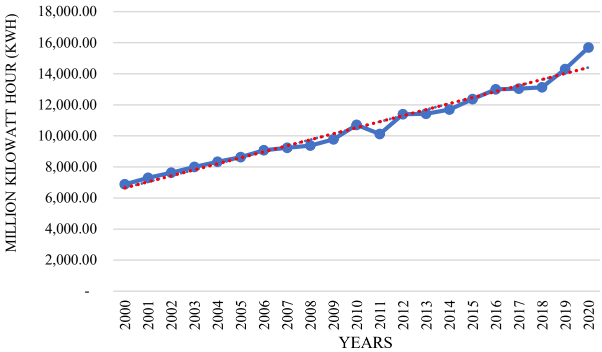


**Figure 2** Analysis of primary historical time series data for residential sector

2. The suitable method details

This section presents the most reliable and effective models for forecasting electricity consumption of residential sector based on MAPE; the details of which is shown in Table 2.

**Table 2** Method performance evaluation of three forecasting methods for residential sector

| Sector | Mean Absolute Percentage Error (MAPE) | | |
|---|---|---|---|
| | Holt-Winters | Brown | Damped trend |
| Residential sector | 2.40 | 3.42 | 2.35* |

Note * is the most reliable and effective forecasting models.
Source: Author's calculation

The results in Table 2 indicate that the most reliable and effective method for forecasting electrical energy consumption in the residential sector is the Damped trend. The details of three forecasting methods are presented in the following section.

2.1 Parameter estimation and diagnostic checking of Holt-Winters, Brown and Damped trend methods

Parameter estimation and diagnostic checking of all three methods for the residential sector are shown in Table 3. Diagnostic checking of the model are based on the Ljung-Box (Q-statistic).

**Table 3** Parameter estimation and diagnostic checking of Holt-Winters, Brown and Damped trend methods

| Methods | Parameter | Estimate | SE | t | P-value | Q-statistic |
|---|---|---|---|---|---|---|
| Holt-Winters | Level (α) | 0.16 | 0.09 | 1.77 | 0.09 | 0.95 |
| | Trend (δ) | 1.00 | 0.60 | 1.70 | 0.11 | |
| Brown | Level (α) | 0.51 | 0.11 | 4.45 | 0.00 | 0.91 |
| Damped trend | Level (α) | 0.17 | 0.11 | 1.44 | 0.17 | 0.92 |
| | Trend (δ) | 0.91 | 0.90 | 1.01 | 0.33 | |
| | Trend damping (ø) | 1.00 | 0.05 | 20.77 | 0.00 | |

Source: Author's calculation

Forecasting equations:

According to, parameter estimation and diagnostic checking can be developed as following equations:

Holt-Winters : $F_{21+5} = [0.16y_t + (1 - 0.16)] + [(1 - 1.00).\ T_{t-1}]$ (5)

Brown : $F_{21+5} = 15{,}597.77 + 109.83(5) + 15.97\frac{1}{2}_t(5)^2$ (6)

Damped trend : $\hat{Y}_{21+5} = (0.140456) + (0.140456)\ \Sigma_{i=1}^{5}\ 1.00^i$ (7)

## 3. Results

According to, equation 5, 6 and 7 are applied to forecasting for electrical energy consumption in residential sector for the next five years and shown in the following Table 4 and Figure 3.

**Table 4** Result of forecasting for electricity consumption in residential sector using Holt-Winters, Brown, Damped trend methods

Unit: Kilowatt hour (kWh)

| Forecasting period | Holt-Winters | Brown | Damped trend |
|---|---|---|---|
| 2021 | 15,331,368,017.79 | 16,204,233,581.11 | 15,330,813,136.78 |
| 2022 | 15,980,765,855.43 | 16,978,831,069.48 | 15,977,755,501.17 |
| 2023 | 16,630,163,693.06 | 17,753,428,557.85 | 16,624,603,910.89 |
| 2024 | 17,279,561,530.70 | 18,528,026,046.21 | 17,271,358,379.60 |
| 2025 | 17,928,959368,34 | 19,302,623,534.58 | 17,918,018,920.92 |
| **Total** | **83,150,818,465.32** | **88,767,142,789.23** | **83,122,549,849.36** |

Source: Author's calculation from equation 5, 6, and 7

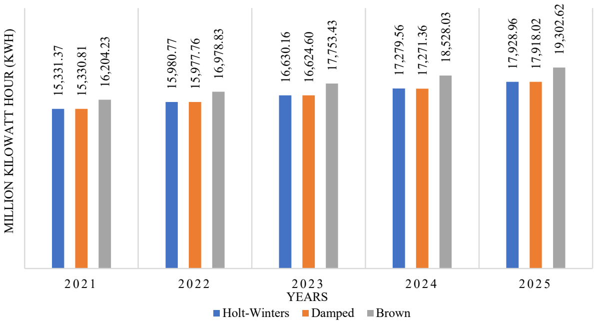


**Figure 3** Result of forecasting for electricity consumption in residential sector using Holt-Winters, Brown and Damped trend methods

Based on the appropriate and effective forecasting equation in residential sector (Damped trend mehtod), when such equation is applied to residential sector for the next five years, the results indicate an increased consumption for electricity from 2021 to 2025. The results are shown in Figure 4.

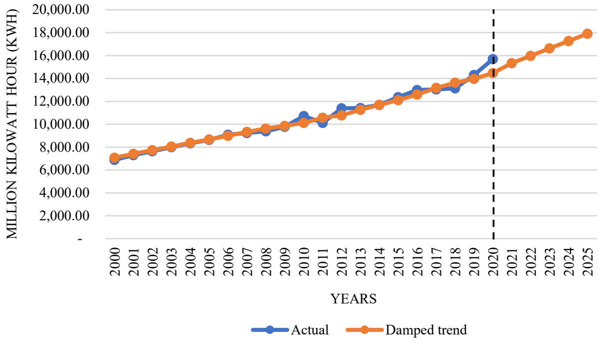


**Figure 4** Forecasting electricity consumption graph for residential sector

After forecasting electricity consumption for residential sector, the results of electricity consumption and [2]electricity loss between 2021 and 2025 are summarised to obtain total forecasting electricity consumption. In other words, total electricity consumption covers loss incurred during distribution to users in residential sector as shown in the following equation:

$$Y = R + Loss \quad (8)$$

Where: Y is total electricity consumption, R is residential electricity consumption, Loss is electricity loss.

The above equation shows that the total forecasting electrical energy consumption also covers electricity loss during the period from 2021 to 2025 and forecasting electricity consumption of residential sector is likely to increase continuously as presented in Table 5.

**Table 5** Summary of the projected total electricity consumption in residential sector

Unit: Kilowatt hour (kWh)

| Forecast periods | Residential Sector | | |
|---|---|---|---|
| | Damped trend | Loss (%) | Total electricity consumption |
| 2021 | 15,330,813,136.78 | 2.40 | 15,698,752,652.06 |
| 2022 | 15,977,755,501.17 | 2.40 | 16,361,221,633.20 |
| 2023 | 16,624,603,910.89 | 2.40 | 17,023,594,404.75 |
| 2024 | 17,271,358,379.60 | 2.40 | 17,685,870,980.71 |
| 2025 | 17,918,018,920.92 | 2.40 | 18,348,051,375.02 |

According to Table 5, when total electricity consumption in the residential sector is compared with total electricity capacity of the MEA between 2021 and 2025 based on economics of electricity supply theory by Attavanich (2014) found that the results can be used to plot the decreasing residential electricity capacity of the MEA as shown in Table 6 and Figure 5.

Electricity loss or loss refers to units lost in electrical energy distribution systems. The two calculation methods for electricity loss are technical loss and non-technical loss (Power Economic Department, 2021). This study uses the non-technical loss calculation in the form of average value and based on economics of electricity supply theory which stated that demand equal to supply by Attavanich (2014).

**Table 6** Comparison of the projected total electricity consumption and total electricity capacity in residential sector under the responsibility of the MEA

Unit: Kilowatt hour (kWh)

| Years | Residential Sector | | |
|---|---|---|---|
| | Total electricity consumption | Total electricity capacity | Excess electricity capacity |
| 2021 | 15,698,752,652.06 | 17,017,816,328.18 | 1,319,063,676.12 |
| 2022 | 16,361,221,633.20 | 17,365,783,922.36 | 1,004,562,289.16 |
| 2023 | 17,023,594,404.75 | 17,713,751,516.54 | 690,157,111.79 |
| 2024 | 17,685,870,980.71 | 18,061,719,110.72 | 375,848,130.01 |
| 2025 | 18,348,051,375.02 | 18,409,686,704.91 | 61,635,329.89 |

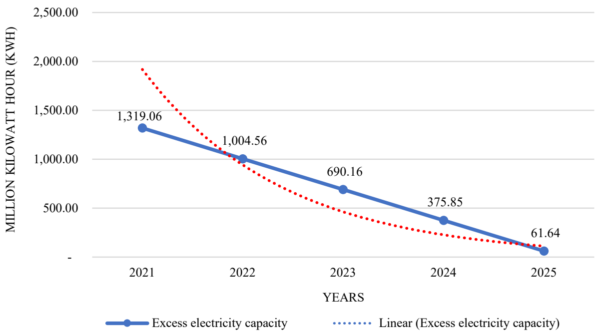


**Figure 5** Annual comparison of the projected total electricity consumption and total electricity capacity in residential sector under the responsibility of the MEA (excess electricity capacity)

Electricity consumption in the residential sector is forecast to increase continuously until it approaches the electricity capacity in residential sector of the MEA, whereas the excess electricity capacity between 2021 and 2025 is equal to 1,319.06, 1,004.56, 690.16, 375.85, and 61.64 million kWh, respectively. Indicating that although there is currently enough for electrical energy to satisfy consumption, the trend indicates that the future consumption is likely to be close to capacity.

However, this situation may affect electricity capacity as consumption catches up and the volume decreases steadily. This may have a direct impact on the electrical energy security of the MEA area in the future. Therefore, forecasting it is necessary in order to provide guidelines for the production and distribution of sufficient and timely electrical energy capacity policy to meet the increased electricity energy consumption in accordance with current and future economic and social changes.

## Discussion

In forecasting electricity consumption under the responsibility of the MEA in residential sector, MAPE models were found to be the most suitable for the residential sector, therefore, the Damped trend model was applied, the results of forecasting electricity consumption for the next five years in residential sector shows an increasing continuous trend from 2021 to 2025. When considering the forecasting electricity consumption results of residential sector from 2021 to 2025, indicating that the total annual electricity consumption is projected to increase.

When the total electricity consumption in residential is compared with the total electricity capacity in residential sector of the MEA, the results indicate consumption may exceed capacity in 2021, 2022, 2023 2024, and 2025 by 1,319.06, 1,004.56, 690.16, 375.85, and 61.64 million kWh, respectively. The results imply that this may affect future electricity security in the area under the responsibility of the MEA. Therefore, it should set the plan or policy in order to support effectively increasing electricity consumption in residential sector in the future. Since the time series data for residential sector in this study contains a low number of observations, this affects the efficiency of some models such as Holt-Winters and Brown where forecasting efficiency is based on the amount of time series data used to create the model structure. If more time series data is available, it can make the forecasting model more accurate. Additional information should be added to the model for further learning. This will affect the efficiency of the forecasting electrical energy consumption model.

For future study, the author's aim to examine the MEA's investment plan and analyse the cost of electricity production and distribution in residential sector of the MEA. This would help to describe the electricity usage amount, the capacity to produce and distribute electrical energy, and the ability to meet the consumption for electricity, due to changes in society and the economy in the future.

**Acknowledgment**

This study focuses on the residential sector to examine electricity consumption under the responsibility of the MEA. The authors would like to extend sincere gratitude to the Power Economic Department of the MEA for allowing access to historical time series data on the electricity consumption and electrical energy capacity of the MEA, including information on energy through related documentation and websites.

## References

Attavanich, W. (2014). *Energy Economics*. Bangkok: Danex Intercorporation Ltd.

International Energy Agency. (2014). *World Outlook Energy 2014*. Retrieved June 20, 2021, from www.iea.org.

Klimberg, R. K., Sillup, G. P., Boyle, K. J., & Tavva, V. (2010). Forecasting Performance Measures-What are their practical meaning. *Advances in Business and Management Forecasting, 7,* 137-147.

Manmin, M. (2006). *Time Series and Forecasting*. Bangkok: Four Printing.

Metropolitan Electricity Authority. (2020). *Classification for Electrical Energy Consumers in the MEA's area*. Retrieved June 20, 2021, from https://www.mea.or.th/

Metropolitan Electricity Authority. (2020). *Time Frame for the Electrical Power Station Construction of the MEA*. Retrieved June 25, 2021, from https://www.mea.or.th/

Metropolitan Electricity Authority. (2021). *Electricity capacity of Residential Sector in the MEA's area*. Retrieved June 25, 2021, from https://mea.or.th/download/127/3393

Power Economic Department. (2021). *Historical Time Series Data on the Electricity Consumption of Residential User Sector*. Bangkok: Metropolitan Electricity Authority.

Srivastava, U. K., Shenoy, G. V., & Sharma, S. C. (1989). *Time Series Analysis, Quantitative Techniques for Managerial Decisions*. New Delhi: New Age International (P) Ltd.

Suttichaimethee, P. (2010). *Applied Econometrics for Research*. Bangkok: Saha Dhammik Co., Ltd.