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RESEARCH ARTICLE

Forecasting electricity consumption of Malaysia's residential sector: Evidence from an exponential smoothing model

[version 1; peer review: 1 approved with reservations]

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<https://doi.org/10.12688/f1000research.74877.1>Latest published: 17 Jan 2022, 11:54
<https://doi.org/10.12688/f1000research.74877.1>

Abstract

Background: In Malaysia, residential electricity consumption has shown a steady upward trend year by year. Due to this increase in energy consumption, it is important to forecast the value of electricity consumption until the year 2032 to accommodate the electricity demand.

Methods: Three exponential smoothing models were compared to identify the most appropriate model in forecasting electricity consumption. The three exponential smoothing models are Simple, Holt, and Brown exponential smoothing. To identify the most appropriate model, a mean absolute percentage (MAPE) was chosen.

Results: The results show that Holt's exponential smoothing has the best performance with the lowest MAPE score of 2.299.

Conclusions: Consequently, it was found that electricity consumption would substantially increase from 2647 ktoe (kilotonne of oil equivalent) to 3873 ktoe within the period of 2019 to 2032.

Keywords

forecasting, electricity consumption, exponential smoothing, time series

Open Peer Review

Approval Status ?

1

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1. **Azer Dilanchiev** , International Black Sea University, Tbilisi, Georgia

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Author roles: **Ishak I:** Conceptualization, Formal Analysis, Investigation, Methodology, Resources, Software, Visualization, Writing – Original Draft Preparation; **Othman NS:** Data Curation, Project Administration, Validation, Writing – Review & Editing; **Harun NH:** Data Curation, Project Administration, Supervision, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: This study was funded by TNB Seed Fund 2020 (U-TR-RD-20-01). We would like to thank UNITEN R&D for the financial support of this project entitled Domestic Electricity Demand Model for TNB Regulation Strategy.

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How to cite this article: Ishak I, Othman NS and Harun NH. **Forecasting electricity consumption of Malaysia's residential sector:**

Evidence from an exponential smoothing model [version 1; peer review: 1 approved with reservations] F1000Research 2022, 11:54 <https://doi.org/10.12688/f1000research.74877.1>

First published: 17 Jan 2022, 11:54 <https://doi.org/10.12688/f1000research.74877.1>

Introduction

In Malaysia, energy is no longer viewed as a luxury as it is becoming a necessity in our everyday activities such as in transportation, production, commercial activities, and residential anthropogenic activities.¹ Energy consumption in residential sectors grew up to 7% within the period 1978 to 2015.² As one of the countries with the highest recorded energy per capita and energy intensity over the years, electricity is considered as an important form of energy which drives Malaysia's economic development.^{3,4} The Malaysia Energy Information Hub (MEIH) revealed that electricity consumption for the residential sector in 2018 was 2553 ktoe (kilotonne of oil equivalent), which is a slight decrease from 2017 with 2610 ktoe. However, in 2017 the World Energy Markets Observatory (WEMO) reported that electricity consumption is projected to increase by 4.8% annually up to 2030.

Thus, it is important to conduct a forecast of electricity consumption as it is significant for economic development as well as policy improvement.^{5,6} As a reliable and an important tool for making decisions, there are several forecasting techniques that can be used. In fact, the accuracy of forecasting can be observed to obtain significant results in the projection of electricity consumption.⁵ In this study, three different exponential smoothing models were utilised to forecast electricity consumption: simple, Holt, and Brown's exponential smoothing.

This aim of this research was to conduct a study in order to forecast electricity consumption in Malaysia until the year 2032. This research also attempts to identify the most appropriate exponential smoothing model in forecasting electricity consumption.

Literature review

Lee *et al.*,⁷ conducted a study involving six different forecasting methods, which were used to predict electricity consumption in Universiti Tun Hussein Onn Malaysia (UTHM), Malaysia. The study selected a mean absolute percentage error (MAPE) as the measurement of error. Historical data were obtained monthly from 2011 until 2017 which generated a projection up until December 2018. From the six forecasting models, Holt-Winters' exponential smoothing was found to be the best technique implemented due to having the lowest MAPE. Similarly, Nazim and Afthanorhan⁸ also found that Holt's exponential smoothing was the best method to predict Malaysia's population from 2004 to 2020. The study selected a mean square error (MSE) as a criterion to determine the best model. There were four different techniques used which were single exponential smoothing (SES), double exponential smoothing (DES), Holt's exponential smoothing, and adaptive response rate exponential smoothing (ARRES). Lima *et al.*,⁹ claimed that economic data could be forecasted using Holt-Winters' exponential smoothing, which involves comparing additive and multiplicative practices. The results showed that multiplicative exhibited the best forecasting performance. Maçaira *et al.*,¹⁰ forecasted the best yearly projection for residential electricity consumption in Brazil by applying exponential smoothing. All the studies mentioned above provided economic projection values together with consumption growth and were validated by the accuracy of the forecast.

In contrast, Popeangă and Lungu¹¹ found that the double moving average was the best technique in forecasting energy consumption in Romania from quarter one until quarter four of 2014. The study used two different moving average practices. Suresh¹² used an autoregressive integrated moving average model (ARIMA) to analyse and forecast electricity consumption in India. The proposed ARIMA with the neural network (NN) model provided the best future time-series forecasting. A data set of 40 years of electricity consumption was analysed by Mahia *et al.*,¹³ using ARIMA methods. Several steps were conducted, and the best model was selected based on the lowest Akaike Information Criterion (AIC). Notably, the literature has specific reasons to conduct a moving average when the data set performs seasonally, particularly throughout the study period.

From a business perspective, exponential smoothing is used in projecting sales. For example, Sidqi and Sumitra¹⁴ applied the single and double exponential smoothing in a study with MAPE as the criterion to determine the accuracy of the forecast model. As a result, the single exponential smoothing exhibited the lowest MAPE. In the agricultural sector, Talwar and Goyal¹⁵ analysed and compared coriander prices in India using several exponential smoothing methods. The results showed that the Holt-Winters' trend adjusted model provided the best model with the lowest error measurement in MSE. A study by Booranawong and Booranawong¹⁶ in Thailand showed that the double exponential smoothing method provided better performance in predicting Thai chilli and lemongrass prices. The study utilised MAPE to determine the minimum error measurement from other methods such as multiplicative Holt-Winters' (MHW) and additive Holt-Winters' (AHW). The forecasted prices of the agricultural products were from October 2016 to December 2019. Regardless of the sector, exponential smoothing is very suitable to conduct forecasting together with the least error of measurement, such as MAPE.

Based on previous literature, exponential smoothing has been widely used, and this technique captures the time series that may change its behaviour, and the model parameters should adapt to that change in behaviour as well.¹⁷ Currently, studies that provide exponential smoothing as a mechanism to predict the electricity consumption of the residential sector are limited. Therefore, this study selected this method as it is considered an appropriate technique to conduct a forecasting of the residential electricity consumption in Malaysia.

Methods

Three exponential smoothing models were used to forecast electricity consumption in this study: simple exponential smoothing, Holt's exponential smoothing, and Brown's exponential smoothing. Yearly data from 1997 to 2018 was obtained from the Malaysia Energy Information Hub (MEIH). The forecasting period started from the year 2019 until 2032. Details on the function and formula of the simple exponential smoothing, Holt's exponential smoothing, and Brown's exponential smoothing are explained in the following sections.

Simple exponential smoothing

Simple exponential smoothing is the most widely used model in forecasting if there are no cyclic variation patterns or consistent growing patterns involved.¹⁴ The formula for this method is as follows¹⁸:

$$F_{t+m} = \alpha y_t + (1 - \alpha)F_t \quad (1)$$

where:

F_{t+m} : simple exponentially forecast value in period m , for $m = 1, 2, 3, \dots, t$; y_t : actual value in time t ;

α : unknown smoothing constant to be determined for value between 0 and 1;

F_t : forecast value at period t .

Holt's exponential smoothing

Holt's exponential smoothing can be used in forecasting when there is a linear trend in the historical data of the forecast. According to Alias,¹⁹ this method requires three equations which are exponential smoothed series, trend estimate, and forecast.

Exponential smoothed series:

$$S_t = \alpha y_t + (1 - \alpha)(S_{t-1} + T_{t-1}) \quad (2)$$

Trend estimate:

$$T_t = \beta(S_t - S_{t-1}) + (1 - \beta)T_{t-1} \quad (3)$$

Forecast for m period:

$$F_{t+m} = S_t + T_t \times m \quad (4)$$

where:

S_t : exponential smoothed series;

T_t : trend estimates;

F_{t+m} : forecast for m -step-ahead period.

Brown's exponential smoothing

This method is also known as the double exponential smoothing and can be used if there is a linear trend in the data. The trend is a smoothed estimate of average growth at the end of each period.¹⁷ The formula for Brown's exponential smoothing is as follows:

$$F_{t+m} = \alpha y_t + (1 - \alpha)F_t \quad (5)$$

$$a_t = 2S_t - S'_t \quad (6)$$

$$b_t = \frac{\alpha}{1 - \alpha}(S_t - S'_t) \quad (7)$$

$$S_t = \alpha y_t + (1 - \alpha)S_{t-1} \quad (8)$$

$$S'_t = \alpha S_t + (1 - \alpha)S'_{t-1} \quad (9)$$

where:

S_t : exponentially smoothed value of y_t at time t ;

S'_t : double exponentially smoothed value of y_t at time t ;

a_t : computes the difference between the exponentially smoothed values;

b_t : computes the adjustment factor;

F_{t+m} : forecast for m -step-ahead period.

Accuracy of forecast

According to Kalekar,¹⁷ the forecasting model should be validated. Here, an error measurement such as mean absolute percentage error (MAPE), relative mean square error (RMSE), or mean absolute error (MAE) is needed. The selection of an error measurement has a significant effect in determining the most accurate forecasting method. In this study, MAPE was selected to verify the model because it is the most suitable measurement to compare the accuracy of the forecasting methods, as it measures relative performance.^{7,14,20} A low MAPE score indicates that the forecasting model has a good performance.²¹ The range of the MAPE score is shown in Table 1.

Results

An analysis of the historical data was conducted to examine the pattern of electricity consumption trend (kilotonne of oil equivalent, ktoe) from 1997 until 2018 for the residential sector in Malaysia.

Based on Figure 1, the trend pattern in this time series is linear and no seasonality is involved. In addition, the graph shows a constant increase in the pattern. In 2016, a total of 2679 ktoe of electricity was consumed as the highest value. The consumption value gradually decreased from 2017 to 2018 with values of 2610 ktoe and 2553 ktoe respectively as shown in Table 2. Thus, all three exponential smoothing methods, namely simple, Holt's and Brown exponential smoothing were capable of forecasting electricity consumption. The lowest MAPE was compared to identify the most appropriate exponential smoothing model.

Simple exponential smoothing

The simple exponential smoothing was analysed using SPSS version 26 (IBM SPSS Statistics, RRID:SCR_019096) starting from the year 2019. Referring to Figure 2, the three lines represent the limit of the forecast values for the forecast year: yellow indicates the upper limit of electricity consumption, purple indicates the best prediction of electricity consumption, and brown indicates the lower limit of electricity consumption at a particular year. This means that the expected electricity consumption could fall between the green and brown dotted lines.

Table 1. Significance of MAPE score.

MAPE	Significance
<10%	Excellent forecasting ability
10-20%	Good forecasting ability
20-50%	Reasonable forecasting ability
>50%	Bad forecasting ability

Figure 1. Electricity consumption (ktoe) residential increases over time. (Source: Malaysia Energy Information Hub, <https://meih.st.gov.my/statistics>.)

Table 2. Electricity consumption (ktoe) residential increases over time.

Year	Final electricity consumption (ktoe)
	Residential
1997	770
1998	874
1999	885
2000	975
2001	1,081
2002	1,161
2003	1,248
2004	1,319
2005	1,395
2006	1,514
2007	1,598
2008	1,668
2009	1,792
2010	1,937
2011	1,974
2012	2,126
2013	2,262
2014	2,346
2015	2,471
2016	2,679
2017	2,610
2018	2,553

Figure 2. Simple exponential smoothing. UCL: upper confidence level (upper limit); LCL: lower confidence level (lower limit).

Based on Table 3, the year 2019 recorded the best forecasted electricity consumption, which is 2553 ktoe; the consumption maintains this value until 2032. However, this method also predicted a wide range of possible values until 2032. For example, the electricity consumption in 2032 is predicted to be between 3345 ktoe as the upper limit and 1760 ktoe as the lower limit, but the best value generated is 2553 ktoe.

Table 3. Forecasting result: simple exponential smoothing.

Year	Forecast value (ktoe)	Upper limit (ktoe)	Lower limit (ktoe)
2019	2553	2773	2333
2020	2553	2864	2242
2021	2553	2934	2172
2022	2553	2993	2113
2023	2553	3044	2062
2024	2553	3091	2015
2025	2553	3134	1972
2026	2553	3175	1931
2027	2553	3212	1894
2028	2553	3248	1858
2029	2553	3282	1824
2030	2553	3314	1792
2031	2553	3345	1761
2032	2553	3345	1761

Table 4. Model fit statistics for simple exponential smoothing.

Error measurement	Score
RMSE	105.677
MAPE	5.678
MAE	92.504

The accuracy of the forecasting value was measured via model fit statistics. As shown in [Table 4](#), there are three error measurement scores generated by SPSS version 26: relative mean square error (RMSE), mean absolute percentage error (MAPE), and mean absolute error (MAE). For simple exponential MAPE, the score is 5.678.

Holt's exponential smoothing

[Figure 3](#) shows Holt's exponential smoothing method, which was conducted. It is expected that the electricity consumption value would fall between the pink and brown dotted lines for the forecast year, but the width is narrower compared to the previous method. It can be observed that the forecast has a considerable upward trend from 2019 until 2032.

The value of the best forecasted electricity consumption was 2647 ktoe for 2019 and 3873 ktoe for 2032 as shown in [Table 5](#). In 2032, the predicted electricity consumption value would be between 3360 and 4386 ktoe whereas the

Figure 3. Holt's exponential smoothing. UCL: upper confidence level (upper limit); LCL lower confidence level (lower limit).

Table 5. Forecasting result: Holt's exponential smoothing.

Year	Forecast value (ktoe)	Upper limit (ktoe)	Lower limit (ktoe)
2019	2647	2783	2511
2020	2742	2934	2549
2021	2836	3072	2600
2022	2930	3203	2658
2023	3024	3329	2720
2024	3119	3453	2785
2025	3213	3574	2852
2026	3307	3694	2921
2027	3402	3812	2992
2028	3496	3929	3063
2029	3590	4044	3136
2030	3685	4159	3210
2031	3779	4273	3285
2032	3873	4386	3360

Table 6. Model fit statistics for Holt's exponential smoothing.

Error measurement	Score
RMSE	65.235
MAPE	2.299
MAE	42.664

Figure 4. Brown's exponential smoothing. UCL: upper confidence level (upper limit); LCL: lower confidence level (lower limit).

best projected value is 3873 ktoe. Table 6 shows the accuracy of the forecasting where the score measured by MAPE is 2.299.

Brown's exponential smoothing

The last forecasting method is Brown's exponential smoothing (Figure 4). This method enjoys a very wide range of forecasting values where the upper and lower limit values experienced a steep trend. In 2019, the forecasted electricity consumption value is 2402 ktoe. However, the value gradually decreases year by year until 2032 with a consumption value of 2399 ktoe as presented in Table 7. In 2032, the predicted electricity consumption value would be within 4967 ktoe as the maximum value and 90 ktoe as the minimum value; the best projected value is 2399 ktoe. Table 8 shows the MAPE score for Brown's exponential smoothing, which is 3.125. The lower the MAPE score, the higher the accuracy of the forecast.

Discussion

Table 9 shows the summary of all smoothing methods using MAPE as the measurement. Holt's exponential smoothing is the most suitable method to predict the electricity consumption of the residential sector in Malaysia. This is because this method has the lowest MAPE score which is 2.299 compared to the other two methods. The result is consistent with Omer *et al.*²² where they used MAPE to identify the most appropriate prediction model. Therefore, in this study, Holt's exponential smoothing is the best method to forecast future electricity consumption in Malaysia.

Table 5 lists the forecasting values from 2019 until 2032 generated by Holt's exponential smoothing. In 2032, the maximum electricity consumption is 4386 ktoe and the minimum consumption is 3360 ktoe. However, the best predicted value is 3873 ktoe.

Table 7. Forecasting result: Brown exponential smoothing.

Year	Forecast value (ktoe)	Upper limit (ktoe)	Lower limit (ktoe)
2019	2553	2702	2403
2020	2541	2799	2282
2021	2529	2914	2144
2022	2517	3043	1991
2023	2505	3187	1824
2024	2494	3343	1645
2025	2482	3511	1453
2026	2470	3690	1251
2027	2458	3879	1038
2028	2447	4079	815
2029	2435	4288	582
2030	2423	4506	341
2031	2411	4733	90
2032	2400	4968	-169

Table 8. Model fit statistics for Brown's exponential smoothing.

Error measurement	Score
RMSE	72.041
MAPE	3.125
MAE	51.085

Table 9. Summary of the results of the exponential smoothing models.

Method	MAPE
Simple exponential smoothing	5.678
Holt's exponential smoothing	2.299
Brown exponential smoothing	3.125

Conclusion

The aim of the study was to forecast the total electricity consumption in Malaysia until the year 2032 and to identify the most appropriate exponential smoothing model to predict this consumption. Based on the results and discussion, Holt's exponential smoothing was found to be the most appropriate model in forecasting electricity consumption in Malaysia. Generally, electricity consumption in residential sectors comes from electrical appliances. Hence, based on the predicted consumption growth, energy efficiency regulations by electrical manufacturers should be revised. Campaigns for less energy demand in households should also be implemented. This can benefit both parties by maximising energy efficiency and minimising electricity consumption. As a suggestion for further study, moving average methods can also be applied to predict electricity consumption. There are various types of moving average method including the integrated model such as autoregressive–moving-average (ARMA), autoregressive integrated moving average (ARIMA), autoregressive integrated moving average- neural network (ARIMA-NN), or the hybrid model. These methods can be used by future researchers to further expand on this study.

Data availability

All data underlying the results are available as part of the article and no additional source data are required.

Acknowledgments

This study was funded by TNB Seed Fund 2020 (U-TR-RD-20-01). We would like to thank UNITEN R&D for the financial support of this project entitled Domestic Electricity Demand Model for TNB Regulation Strategy.

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<https://doi.org/10.5256/f1000research.78678.r143421>

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Azer Dilanchiev

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To begin with, it was a pleasure for me to review this engaging paper. In my perspective, the paper is valid. Throughout the investigation, the authors created a well-written, well-structured manuscript while adhering to rigorous research procedures. I'd like to encourage the authors to apply the following tips to revise and improve their writing:

1. The introduction gave useful information on the desired topic, but it needs to be changed to be relevant. There are several gaps in the introduction. The introduction section, in particular, failed to clarify the earlier research contribution, limits, and novelty of this study to the literature and practice. It is also suggested that a paragraph at the end of this section explain the study structure. It is recommended to enlarge the introduction part in general.
2. The authors should use a consistent referencing style throughout the manuscript. The literature review has to be reviewed and rebuilt once more. Cite current and relevant references from well-reputed journals. I am the coauthor of the first and second papers listed below. The first paper considers the case of Pakistan the role of Technological Innovations: A Pathway for Addressing Energy Sustainability which can be incorporated and compared with the case of Malaysia's electricity consumption. While the second paper deals with the case of China, again the role of renewable energy is highlighted. I think taking into account these two papers the authors can compare the case of Malaysias and the cases of China and Pakistan, in relation to the issue of energy sustainability and renewable energy.

https://www.frontiersin.org/articles/10.3389/fenvs.2022.888080/full?utm_source=F-NTF&utm_medium=EMLX&utm_campaign=PRD_FEOPS_20170000_ARTICL - <https://doi.org/10.3389/fenvs.2022.888080>¹

<https://www.sciencedirect.com/science/article/abs/pii/S096014812200628> - <https://doi.org/10.1016/j.renene.2022.04.162>²

<https://www.sciencedirect.com/science/article/abs/pii/S036054422201659> - <https://doi.org/10.1016/j.energy.2022.124756>³

3. The methodology is OK but cite the most relevant and current references. The methodology of the article is clear and justified by the literature. Better to cite the latest and relevant studies on similar topics.
4. The discussion part is very small, It needs to be enlarged.
5. The robustness of the empirical investigation is missing; please include it.
6. In conclusion, indicate whether your findings follow or oppose the previous works.
7. Please indicate in conclusion policy recommendations, limitations and recommendations for future work.
8. Generally, the paper needs major revision and professional English editing. However, some tables and graphs can be transferred to the appendix. In addition, the paper needs to be enlarged.

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Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

No

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: ReneRenewable energy, poverty, regional economics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

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