The Impact of Economic Growth, Trade and Urbanization on Electricity Consumption in Malaysia

HAFIDA YAKUB, MOHD KHAIRUL HISYAM HASSAN, JEROME KUEH SWEE HUI
Faculty of Economics and Business,
Universiti Malaysia Sarawak,
MALAYSIA

Abstract: - This study aimed to examine the effects of economic growth, trade, and urbanization on electricity consumption in Malaysia from 1990 to 2022. The research employed the ARDL-ECM methodology and determined that all factors were significant. Unit root tests (ADF, PP, and KPSS) indicate mixed cointegration at both levels and initial differences for the variables in the equation. Then, it is appropriate to utilize the Autoregressive Distributed Lag (ARDL) method test. The study found that ARDL (3, 3, 3, 4) was the best ARDL model to use. Urbanization had a favorable effect on energy use over the long run, but economic expansion and commerce had a negative effect. In the near run, though, economic expansion and urbanization had a good effect on power use, while trade had a bad effect. The speed of adjustment, ECT(-1), also had a big effect on how much electricity was used. Because of this, Malaysia's energy policies are not likely to hurt economic growth.

Key-Words: - electricity consumption, trade, urbanization, economic growth, ARDL-ECM.

Received: July 27, 2025. Revised: October 29, 2025. Accepted: November 13, 2025. Published: December 22, 2025.

1 Introduction

Since energy resources are vital to the economic development of both developed and developing countries, including those in the ASEAN region, they are important in today's world. They are essential to achieving all-encompassing progress and ensuring long-term sustainability. Once considered a luxury, energy is now a vital necessity in our daily lives. Most economic activity, including those in the manufacturing, production, commercial, and residential sectors, is heavily reliant on energy. The International Energy Agency (IEA) predicts a major 53% rise in energy consumption by 2030, with developing nations, including Malaysia, expected to contribute 70% of this increase, [1].

In recent years, Malaysia, like other developing countries, has experienced a substantial surge in its energy consumption. Between 1990 and 2010, Malaysia's ultimate energy consumption increased threefold, with an average annual growth rate of 6%, [2]. Electricity is categorized as a secondary form of energy due to its production from primary sources. Due to the rapid increase in our country's electricity demand, there was a corresponding exponential growth in the requirement for power, which prompted further developments in the energy sector. Having grown at an exponential rate over the past decade, electricity is now plainly a major player in the energy sector. This is because almost every part of our everyday life is dependent on electricity for successful operation. It is also necessary for a lot of different applications because it lets energy change into heat, light, sound, and mechanical energy, among other things [3].

The demand for electricity has increased over time at a significantly faster rate than the total amount of energy consumed. With the world's electricity consumption having significantly increased in recent years, this trend has been especially noticeable since the turn of the century. Nearly half of the world's electricity consumption, or roughly 47%, came from the Asia Pacific region alone as of 2019.

Since its initial introduction in Malaysia in the early 1990s, electricity has been essential to the nation's economic growth. Electricity has become increasingly important for Malaysia's continued growth as it has developed into a thriving economic hub. Malaysia has emerged as one of the top countries in recent years for per capita energy consumption, especially for electricity. The nation's remarkable economic growth, which has been fueled by an increase in demand for electricity, is what has allowed it to receive this recognition. This demand has been fuelled by the rapid growth of industrialization, urbanization, and population increase experienced by Malaysia.

The purpose of this study is to shed more light on Malaysia's electricity usage. When looking for new resources or renewable energy solutions, understanding electricity consumption may hold the key to resolving such problems. Given this, the makeup of electricity consumption has an impact on economic growth, and vice versa. In order to determine whether trade, urbanization, and economic growth have a significant impact on electricity consumption, their effects are examined.

2 Literature Review

It is widely recognized that electricity consumption is crucial for economic development, influencing factors such as GDP growth, trade patterns, and urbanization. Since the 1970s, a lot of research has been done on how these variables are related to each other in complicated ways. Different countries and regions can have both repeating patterns and different results. Early research like [4] laid the groundwork by showing that there is a positive link between energy use, such as electricity, and economic growth in the US. This groundbreaking study set a new standard by showing how higher energy use could lead to economic growth. Subsequent research expanded this analysis to additional contexts, with [5] revealing similar results in Jamaica, indicating that electricity consumption positively influenced economic growth during specific periods. In a comprehensive study across multiple countries, [6] identified a significant positive correlation and unidirectional causality between income levels and electricity consumption. Their research showed that using more electricity helped the economy grow instead of slowing it down. Further research in Taiwan by [7] corroborated these findings, demonstrating a positive correlation between economic activity and electricity consumption, thus validating the notion that energy consumption fosters economic growth. Numerous studies have identified bidirectional relationships between economic indicators and electricity consumption, contrasting with earlier unidirectional perspectives. Studies [8] in Indonesia and [9] in the United Arab Emirates identified evidence of a reciprocal causal relationship between economic growth and electricity consumption, indicating that, over time, economic activity and energy consumption influence each other. Moreover, [10] examined multivariate relationships in China and discovered that urbanization, economic growth, and electricity consumption are causally interconnected in both directions, suggesting that these factors amplify each other's impacts on economic output and energy demand.

Research conducted in a variety of geographical areas offered complex insights into the connection. [11] in Nigeria and [12] in Iceland demonstrated how urbanization, trade openness, and economic growth all had a positive effect on electricity consumption, reflecting local economic structures and dynamics. These studies demonstrated how local contexts and policy environments impact the intricate relationship between economic development and energy demand.

Despite widespread agreement on the positive correlation, studies such as [13] and [14] pointed out inconsistencies in causal relationships between electricity consumption and economic growth. Previous research has primarily examined the connections between electricity consumption, economic growth, and urbanization, but there has been a notable absence of studies incorporating trade dynamics into this analysis, especially in Malaysia, [15]. By utilizing a comprehensive dataset spanning from 1990 to 2022, the study seeks to enhance the reliability and depth of empirical evidence concerning these interrelationships.

[16] examined the influence of electric power usage on economic growth in 41 high-income nations utilizing a heterodox growth model. Their findings indicate a statistically significant positive correlation between power usage and GDP per employed individual, in both the short and long term. Human capital and total factor productivity indicate that economic capacities and structure are essential intermediaries in the energy-growth relationship. [17] examined the impact on home energy usage by utilizing panel data from 30 provinces from 2000 to 2020. The study seeks to ascertain a U-shaped relationship between urbanization and direct energy consumption. At first, urbanization lowers energy use because it makes things more efficient. But if a certain level is crossed, it increases consumption because of changes in lifestyle and the building of infrastructure. Their findings underscored the necessity to distinguish between direct and indirect energy consumption in policy development. [18] examine the triangular relationship between energy consumption, trade liberalization, and economic development in 45 countries. By using dynamic seemingly unrelated regression (DSUR), they show that all three variables are related to each other in both directions. Economic growth has the biggest effect on trade openness, but energy use has a bigger effect on growth than trade does. Their findings underscore the necessity for cohesive energy and

trade policies to foster sustainable growth. These studies show how complicated the link between energy and growth is. [17] focus on spatial and behavioral dynamics, [16] focus on structural and capability-based aspects, and [18] include commerce as an important third dimension. They all point to the fact that energy policy needs to be flexible and take into account things like income levels, stages of urbanization, and the way international trade works.

Electricity consumption and economic growth have been studied using many methods. [12], [19], and [20] use time series analyses like ARDL, ECM, and cointegration to study how electricity consumption and economic growth interact over time in individual countries. However, panel data approaches have become popular for their capacity to account for cross-country variability and strengthen empirical conclusions. [16] analyze high-income countries using a heterodox growth model with dynamic panel estimators, while [17] and [18] examine urbanization, trade, and energy consumption across regions using panel data models like fixed/random effects and dynamic seemingly unrelated regression (DSUR). [6], [7], and [8] use causality testing frameworks like Granger causality and VECM to determine whether electricity consumption drives economic growth, vice versa, or if feedback effects exist.

Research on the relationship between economic growth and electricity use varies. The notion that energy propels economic growth was confirmed by [4], [6], and [7], which discovered unidirectional causality between electricity use and economic growth. Nonetheless, recent research such as [8], [9], and [10] demonstrates bidirectional causality, suggesting a reciprocal relationship between economic expansion and electricity use. [18] confirm this interdependence. [13] and [14] propose that the link may be context-dependent and shaped by structural or policy changes among countries and times.

3 Methodology

3.1 Data

The multivariate framework includes the electric power in kWh per capita and real GDP per capita (in constant 2010 US$); urbanization is measured by urban population and trade openness as a percentage of GDP. The data series is from the period 1990-2022. Data for real GDP per capita, trade, and urbanization were collected from World Bank Data (2020), while data for electricity consumption were collected from National Energy Balance 2020 & Malaysia Energy Statistics 2020. This study employs EViews software to analyze all the variables under discussion.

3.2 Statement of Hypothesis

In this study, the hypothesis will analyze how Malaysia's electricity consumption, economic growth, trade, and urbanization are related. Thus, the hypothesis of the study is as follows:

Economic Growth

H_0: Economic growth is significantly impacted by electricity consumption.
H_1: Economic electricity consumption is significantly impacted by economic growth.

Trade

H_0: Trade has a significant effect on electricity consumption.
H_1: Electricity consumption has a significant effect on trade.

Urbanization

H_0: Urbanization has a significant effect on electricity consumption.
H_1: Electricity consumption has a significant effect on electricity consumption.

3.3 Estimation Methodology

3.3.1 Unit Root Tests

This study adopts the Augmented Dickey Fuller (ADF) test and the Phillips-Perron (PP) test to examine the existence of unit roots in the selected variables. Additionally, this study also uses the Kwiatkowski-Philips-Schmidt-Shin (KPSS) unit root test, which confirms the integration of the series.

When analyzing the stationarity of time series data, the ADF unit root test is employed. Three different forms of null hypotheses can be used in the ADF test. The following equations, for example, can be used to express the null hypothesis for LEK:

$$\Delta LEK_t = \rho LEK_{t-1} + \sum_{i=1}^{m} \alpha_t LEK_{t-i} + \varepsilon_t \, , \quad (1)$$

$$\Delta LEK_t = \beta_1 + \rho LEK_{t-1} + \sum_{i=1}^{m} \alpha_t LEK_{t-i} + \varepsilon_t , \quad (2)$$

$$\Delta LEK_t = \beta_1 + \beta_2 + \rho LEK_{t-1} \sum_{i=1}^{m} \alpha_t LEK_{t-i} + \varepsilon_t \quad (3)$$

where t is the time series trend, m is the number of lagged terms, εt is the error term, and β_1 is the intercept. The series of logarithms of electricity power consumption per capita is represented by the differencing operator, ΔLEK_t. Model (1) is completely random, Model (2) contains an intercept, and Model (3) contains both an intercept and a trend.

The PP test equation is as follows:

$$Y= \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 (t - \frac{T}{2}) + \mu_t \quad (4)$$

where the time series Yt is represented as μt, which is defined as the innovation term. The variable t represents the number of observations that are similar to the ADF test.

Trend stationary time series can be tested using the KPSS test. The KPSS test model is as follows:

$$Y_t = X_t + \varepsilon_t \text{ and thus, } X_t = X_{t-1} + u_t \quad (5)$$

The hypothesis is tested for ut in the model mentioned below:
H_0: α=0 (The time series is trend stationary)
H_a: α<0 (The time series is not trend stationary)

The null hypothesis indicates that the time series is trend stationary. Conversely, it is implied by the null hypothesis that the series is not trend stationary.

3.3.2 ARDL Bound Tests

This method is recommended in [21] as it is the most appropriate method for assessing the relationship between electricity consumption and economic growth, trade, and urbanization. This is because it is more effective with a small sample size, which is appropriate for this study. Using this method, the estimated parameters and standard errors are efficient and unbiased. In addition, the ratios can be estimated in the long and short term using sequential estimation. The advantage of using the ARDL approach is that it is easier to interpret and implement, and different types of variables may have different lag lengths due to the small sample size.

The basic form of the ARDL model is as follows:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_p Y_{t-p} + \alpha_0 X_t + \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \alpha_q X_{t-q} + \varepsilon_t \quad (6)$$

To test for the presence of a long-run relationship through cointegration, an Unrestricted Error Correction Model is being developed in the following manner:

$$\Delta LEK_t = \theta_1 + \sum_{i=1}^{k1} \gamma 1i\, \Delta LEK_{t-1} + \sum_{i=2}^{k2} \gamma 2i\, \Delta LRGDP_{t-2} + \sum_{i=3}^{k3} \gamma 3i\, \Delta LTR_{t-3} + \sum_{i=4}^{k4} \gamma 4i\, \Delta LURB_{t-4} + \beta_0 LEK_{t-1} + \beta_1 LRGDP_{t-1} + \beta_2 LTR_{t-1} + \beta_3 LURB_{t-1} + \varepsilon_t \quad (7)$$

Once the cointegration relationship has been confirmed, the ARDL conditional long-run model can be estimated as:

$$LEK_t = \theta_2 + \sum_{i=1}^{k1} \vartheta_{1i}\, LEK_{t-1} + \sum_{i=0}^{k2} \vartheta_{2i}\, LRGDP_t + \sum_{i=0}^{k3} \vartheta_{3i}\, LTR_t + \sum_{i=0}^{k4} \vartheta_{4i}\, LURB_t \quad (8)$$

Furthermore, when using the ARDL approach, choosing the right lag order is essential, where either the Akaike information criterion (AIC) or the Schwarz Bayesian Criterion (SBC) can be used to identify the best lag..

An Error Correction Model (ECM) will be used in the final step. By establishing the error correction term, which is connected to the long-run estimators, the ECM is utilized to create the short-run model. It is defined as follows:

$$\Delta LEK_t = \theta_3 + \sum_{i=1}^{k1} \varphi_{1i}\, \Delta LEK_{t-1} + \sum_{i=0}^{k2} \varphi_{2i}\, \Delta LRGDP_t + \sum_{i=0}^{k3} \varphi_{3i}\, \Delta LTR_t + \sum_{i=0}^{k4} \varphi_{4i}\, \Delta LURB_t + \delta ecm_{t-1} \quad (9)$$

where, φ_{1i}, φ_{2i}, φ_{3i}, and φ_i are the short-run parameters of the model, and δ is the speed of adjustment. The speed of adjustment indicated the extent of adjustment required to achieve long-term equilibrium.

3.3.3 Diagnostic Tests

Diagnostic tests were performed to determine the robustness of the model. The tests were the serial correlation test, heteroscedasticity test, normality test, and the Ramsey-Reset test. The stability of the model was also tested by using the CUSUM and CUSUMSQ tests.

4 Empirical Results and Discussion

4.1 Result of Unit Root Tests

The study used three different unit root tests (ADF, PP, and KPSS) to check if the time series data were stationary before conducting the Autoregressive Distributed Lag (ARDL) model test. The analysis was carried out at both the level and the first difference. The findings, presented in the table, indicate whether the variables exhibit significance with a trend and a constant at a 5% level. If the trend is not significant, the results are reported with a constant only. Furthermore, if the variable does not exhibit stationarity when estimated with a trend and constant, the next step is to estimate the first differences with a constant. Similarly, if the variable is not stationary with a constant, the next course of action is to estimate the first difference without a constant. The outcomes of the unit root tests are shown in Table 1.

Based on the ADF unit root test results, the null hypothesis for economic growth and trade cannot be rejected when considering the level in constant, but we can reject the null hypothesis for electricity consumption and urbanization with a significance level of 5%. When looking at the trend and constant, the null hypothesis for electricity consumption, economic growth, and trade cannot be rejected, but the null hypothesis for urbanization can be rejected at the 5% level of significance. Additional testing is required to determine if the variables are stationary or non-stationary after being differenced.

The null hypothesis regarding urbanization at first difference remains unchallenged, as the tau-statistics of the change in urbanization are negative and exceed the critical value at a significance level of 5%, as evidenced in Table 1. As indicated in the table, it was observed that electricity consumption, economic growth, and trade are not stationary at the initial level, but become stationary when the first difference is applied to these variables. This suggests that when the first difference is employed, the null hypothesis is rejected for all variables, rendering them stationary at a significant level of 5%. Therefore, all variables exhibit first-order integration, or $I(1)$ integration.

The results of the PP unit root test at the level indicate that the variables show similar results to the ADF test at the level with a constant. We could not rule out the existence of economic growth and trade, as the tau-statistics for both variables exceeded the critical value at a 5% significance level. The PP unit root test, on the other hand, did not reject all variables for both trend and constant at the level, which means that the variables are not stationary. When estimating the first difference, this study found that all variables became stationary, except for urbanization, which remained constant. This means that all of the variables are integrated of order one, $I(1)$.

When tested for both constant and trend, as well as constant at the level, the KPSS unit root test shows that all variables are non-stationary. Trade and economic growth are the only exceptions; they are only non-stationary in constant terms. Economic growth is also non-stationary in trend because tau-statistics are over 5%. However, all variables become stationary at first difference with significance at 5%, except for electricity consumption and urbanization, which remain non-stationary in constant. Additionally, trade is non-stationary in both constant and trend.

Because the variables in the study have a mixed order of cointegration, traditional cointegration tests like the Johansen-Juselius (JJ) test cannot be used. The independent variables are mostly.

Table 1. Unit Root Test Results

	Test Statistics					
	t_m	t_t	t_m	t_t	h_m	h_t
A: Level						
LEK	-5.941 (0)*	-2.950 (0)	-5.994 (3)*	-3.127 (2)	0.740 (4)*	0.178 (4)*
LRGDP	-1.829 (0)	-3.107 (0)	-1.833 (1)	-3.102 (2)	0.767 (4)*	0.074 (2)
LTR	-1.083 (1)	-2.019 (1)	-0.957 (1)	-2.296 (8)	0.379 (5)	0.171 (4)*
LURB	-11.738 (1)*	-7.636 (1)*	-11.978 (2)*	-1.244 (2)	0.652 (5)*	0.203 (4)*
B: First Differences						
DLEK	-3.461 (0)*	-5.157 (0)*	-3.515 (4)*	-5.303 (4)*	0.538 (4)	0.131 (4)*
DLRGDP	-5.187 (0)*	-5.282 (0)*	-5.185 (1)*	-5.274 (2)*	0.202 (0)*	0.072 (1)*
DLTR	-4.047 (0)*	-3.943 (0)*	-4.073 (9)*	-3.856 (12)*	0.336 (1)*	0.185 (3)
DLURB	-0.408 (0)	-5.335 (0)*	-0.478 (1)	-4.997 (4)*	0.681 (4)	0.110 (3)*

Notes: The t, τ, and η statistics are for ADF, Phillips-Perron and KPSS respectively. The subscript μ in the model allows a drift term while τ allows for a drift and deterministic trend. Refer to the main text for the notations. Asterisks (*) indicate statistically significant at 5 percent level. Figures in parentheses are the lag lengths. The asymptotic and finite sample critical values for ADF are obtained from MacKinnon (1996) while the KPSS test critical values are obtained from Kwiatkowski et al. (1992, Table 1. pp. 166). Both the ADF and Phillips-Perron test examine the null hypothesis of a unit root against the stationary alternative. KPSS tests the null hypothesis that the series is stationary against the alternative hypothesis of a unit root. A denotes first difference operator.

Source: Created by the authors

$I(1)$ except for trade and urbanization, which are $I(0)$. Nevertheless, none of the variables in the series are integrated at order 2, and the dependent variable, electricity consumption, is cointegrated at order $I(1)$. Because it can be used whether the series is integrated of order 1 or order 0, the ARDL model is a frequently used technique in this situation. [20]. Consequently, the prerequisites for applying the ARDL approach are satisfied.

Table 2. ARDL Bounds Test Results

Test statistic	Value	Significance (%)	Lower bound I(0)	Upper bound I(1)
F-statistic	13.41294	10%	2.72	3.77
		5%	3.23	4.35
k	3	2.5%	3.69	4.89
		1%	4.29	5.61

Source: Created by the authors

4.2 Result of ARDL Bound Test

Table 3. ARDL based long run estimation

Long run estimation: Dep LEK, ARDL (3, 3, 3, 4)				
Variable	Coefficient	Std. Error	T-statistic	Prob.
LRGDP	-0.209479	0.620572	-0.334334	0.7444
LTR	-0.528321	0.451977	-1.168912	0.2671
LURB	6.363957	2.830026	2.248782	0.0460**
C	-4.309513	2.149001	-2.005357	0.0702

Notes: The asterisks (***, ** and *) indicates significant at 1, 5 and 10 percent level respectively.
Source: Created by the authors

The study investigates whether there is a long-term correlation between electricity consumption and the independent variables of urbanization, trade, and economic growth using the ARDL bound test. A long-term relationship may exist if the F-statistic exceeds the upper critical value. But if the F-statistic is less than the lower critical value, there is no long-term relationship. The results are not clear if the F-statistic is between the upper and lower critical values. The null hypothesis of no cointegration is rejected, and a long-term relationship between the variables is indicated, as the F-statistic of 13.41294 in Table 2 exceeds the upper critical values at various significance levels (1%, 2.5%, 5%, and 10%). The ARDL bound test results confirm that the variables included in the analysis are cointegrated, demonstrating long-term cointegration among the Malaysian economy's urbanization, trade, economic growth, and electricity consumption.

After identifying the presence of the cointegration relationship, the following step involves uncovering the long-term equilibrium relationship between the variables using the ARDL method (3, 3, 3, 4) model. The optimal lag length chosen is 2, determined through the Akaike information criterion selection process. The ARDL (3,3,3,4) specification produced the lowest AIC value among the assessed lag length combinations, signifying the optimal model fit based on this criterion. This method guarantees that the selected model achieves a balance between goodness-of-fit and parsimony, as advocated in the time series econometrics literature. According to the findings presented in Table 3, the analysis reveals the long-term coefficients of the ARDL method for electricity consumption and its associated independent variables, specifically economic growth, trade, and urbanization in Malaysia.

The estimated coefficient for urbanization suggests a positive long-term effect on urbanization, with a p-value of 0.0460 indicating significance at the 5% level. This variable is important in explaining the long-term relationship that exists. This indicates a 1% increase in urbanization. This would result in an increase in the demand for electricity by 2.25%. This result is in line with earlier studies that showed that urbanization raises electricity consumption, as shown in the cases of Tunisia [22], countries in the Organization for Economic Cooperation and Development (OECD) [23], 109 countries [24], the United Arab Emirates (UAE) [25], China [10], Angola [26], and Ireland [12]. With 78.7% of the population living in cities, Malaysia's rising demand for electricity is a result of both urbanization and population growth. This also means Malaysia’s energy demand is reliant on its population, particularly in terms of electricity consumption. Consequently, as cities expand and attract more residents, the need for electricity also grows.

Nevertheless, the findings from both economic growth and trade indicate that the lack of a significant correlation with electricity consumption does not effectively explain the presence of a long-standing relationship. In terms of economic growth, the findings align with a study in [19], which demonstrated negative results in the long term for countries such as Kenya, Cameroon, Togo, Nigeria, and Congo. The negative correlation between economic growth and electricity consumption in this study could be attributed to suboptimal usage and inefficient distribution of electricity, [27]. Additionally, various countries have different models and findings regarding the positive and negative relationships between trade and electricity consumption, [28]. In high-income nations, the identified adverse long-term correlation between economic growth and power consumption can be attributed to enhancements in energy efficiency, structural economic transformations, and technical progress. Investments in advanced technologies and energy-efficient infrastructure have allowed these economies to dissociate economic output from electricity consumption, as technological advancements decrease production costs and encourage the utilization of renewable energy sources, consequently reducing energy intensity, [16]. The shift from energy-intensive manufacturing to service-oriented and knowledge-based sectors has diminished electricity demand, despite ongoing GDP growth, a phenomenon illustrated in heterodox growth models that integrate economic capabilities and productivity metrics, [17]. Technological innovation further advances this trend by integrating smart grids, automation, and digitalization, hence improving energy efficiency in production processes. Investments in research and development (R&D) and human capital enhance productivity improvements that are not directly associated with heightened power consumption, [29].

Table 4. Result of ECM short run estimation

Short run estimation: Dep LEK, ARDL (3, 3, 3, 4)

Variable	Coefficient	Std. Error	T-statistic	Prob.
ΔLRGDP	0.559519	0.094394	9.498392	0.0000**
ΔLRGDP (-1)	0.704984	0.093109	7.468565	0.0000**
ΔLRGDP (-2)	0.665898	0.045690	7.151842	0.0000**
ΔLTR	0.099812	0.044870	2.184534	0.0515*
ΔLTR (-1)	0.069652	0.050801	1.552288	0.1489
ΔLTR (-2)	-0.102529	2.963603	-2.018268	0.0686*
ΔLURB	12.64005	3.388877	4.265095	0.0013**
ΔLURB (-1)	1.399654	3.300672	0.413014	0.6875
ΔLURB (-2)	0.294593	2.836073	0.089252	0.9305
ΔLURB (-3)	14.14969	0.033806	4.989184	0.0004**
C	-4.309513	0.516665	-8.341022	0.0000**
CointEq(-1)	-0.279356			
R-squared	0.952045			
Adjusted R-squared	0.907515			

Notes: The asterisks (***, ** and *) indicates significant at 1, 5 and 10 percent level respectively
Source: Created by the authors

4.3 Result of ARDL-ECM

Table 4 presents the findings of the short-term model analysis, which indicate a positive relationship between economic growth and electricity consumption. A 1% increase in economic growth is associated with a 0.67% increase in electricity consumption, according to the coefficient of 0.665898, which is statistically significant at the 5% level. This finding supports the idea that Malaysia's rapid economic growth leads to higher energy use in the short term. This is in line with earlier studies in Ireland [12], Kenya [30], and the Visegrad countries [20]. Because Malaysia is a developing country that needs more electricity to support its growth and development, this means that an increase in economic activity will have a big and positive effect on the demand for electricity in the near future.

In the short term, the findings revealed a negative correlation between trade and electricity consumption, with a coefficient of -0.1025%. This suggests that as electricity consumption goes up, trade tends to decrease. This relationship was determined to have statistical significance at a 10% level of confidence. These results align with a similar study conducted by [20] in the context of Poland and Hungary, further supporting the notion that trade has a detrimental effect on electricity consumption in the short run.

Urbanization has a short-term positive effect on electricity use. For every 1% increase in urbanization, electricity use goes up by 14.15%. This is shown by a significant coefficient of 14.1496% at a 5% level of significance. This trend is due to Malaysia's growing population, which is causing the demand for electricity to rise. So, urbanization is thought to be a major reason why people use so much electricity. This aligns with previous research conducted in the USA, European Union countries, and countries such as Denmark, Japan, Australia, and Brazil, [31], [32], [33]. As stated in [34], Malaysia has experienced a rapid growth in population, leading to a notable rise in energy consumption. Thus, the rapid urbanization will result in a considerable increase in electricity consumption in the future.

Furthermore, the regression model demonstrates a good fit with an R-squared value of 0.952 and an adjusted R-squared value of 0.907. This suggests that almost all variations in the independent variables can be accounted for by the independent causes. In the short term, it is evident that economic growth and urbanization positively influence electricity consumption, excluding trade. To ensure that short-term discrepancies are corrected in the long run, as suggested by the ECT, the error correction coefficient should be computed.

The estimated coefficient for the error correction term is -0.2793, showing the expected sign and statistical significance even at a 5% level. This describes the speed at which the electricity demand function returns to its stable long-term level after experiencing temporary fluctuations. Within the first year, 27.93% of short-run variations are corrected. The system's ability to return to its equilibrium suggests stability.

The inclusion of an ECT revealed that all independent variables are statistically significant in explaining the short-term relationship between electricity consumption, economic growth, trade, and urbanization, with a p-value of less than 5%. Consequently, the null hypothesis was rejected. The ECT was found to be negative and statistically significant at the 1% level, indicating a shock from the previous year.

4.4 Diagnostic Test

In order to check for heteroscedasticity, the Breusch-Pagan-Godfrey Heteroscedasticity test was utilized in the analysis of the time series data. If the p-value is below 1% significance level, it indicates the presence of heteroscedasticity. According to Table 5, the p-value (0.5054) from the Breusch-Pagan-Godfrey test is greater than the 1% significance level, leading to the conclusion that there is no heteroscedasticity issue in the study.

Following that, the Breusch-Godfrey Serial Correlation LM test was employed to determine if there is an issue of autocorrelation. An autocorrelation issue will arise if the p-value is below the 1% significance level. Based on the findings presented in Table 5, since the p-value exceeds the 1% significance level, it can be concluded that there is no autocorrelation problem.
Then, the Jacque-Bera test, which is a normality test used to check for model specification bias, was conducted. Stability is indicated if the p-value is less than 1% at the significance level and the error term is not normally distributed. The null hypothesis in this instance should not be rejected because the Jacque-Bera test result showed a p-value of 0.8889, which is higher than the 1% significance level. Consequently, this study suggests that the error term is normally distributed.

Table 5. Diagnostic tests results

Diagnostic Testing	Chi-square/ F-statistic	Prob.
ARCH Test	0.823881	0.5054
Serial Correlation LM Test	2.712947	0.1465
Jacque-Bera (Normality Test)	0.235542	0.8889
Ramsey RESET Test (Stability Test)	0.081267	0.7814

Notes: The asterisks (***, ** and *) indicates significant at 1, 5 and 10 percent level respectively.
Source: Created by the authors

Finally, the Ramsey RESET test was conducted to check for model specification bias. A model is viewed unstable if the p-value is less than 1% at the significance level and the error term is not normally distributed. Nevertheless, the null hypothesis should not be rejected because the Ramsey RESET test results showed a p-value of 0.7814, which is higher than the 1% significance level. Thus, the research validates that the model is appropriately defined, guaranteeing the reliability of the t-test and F-test and conformity to the normal distribution.

Figure 1 and Figure 2 demonstrate that the stability of both the short-run and long-run models was assessed using the CUSUM test and the cumulative sum of squares (CUSUM Square) test.

If the graphs of these test statistics remain within the critical boundary of the 5% significance level, the null hypothesis that all coefficients of the regression are stable and cannot be rejected. In this research, the graphs of both the CUSUM and CUSUM Square tests fall within the two boundary lines at the 5% significance level, as shown in Figure 1 and Figure 2 respectively. This confirms the stability of the long-run and short-run coefficients for the chosen period in this study, which ranges from 1990 to 2022, and indicates that they do not experience a structural break in the cumulative sum.

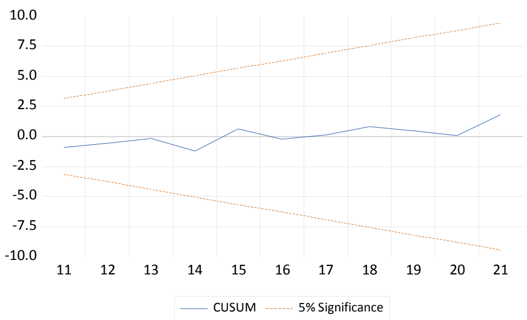

Fig. 1: CUSUM Test
Source: EViews software

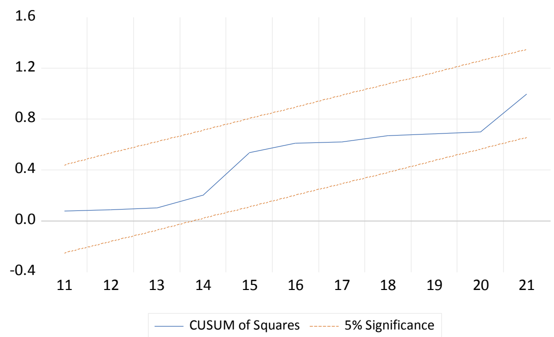

Fig. 2: CUSUM Square Test
Source: EViews software

5 Conclusion

This study is to investigate the impact of the relationships between electricity consumption and its key determinants—economic growth, trade, and urbanization—within the context of Malaysia. To begin with, the unit root tests (specifically ADF, PP, and KPSS) were conducted to analyze the connection between electricity usage and the factors that influence it, including economic growth, trade, and urbanization. The results of these tests indicate that most of the variables are integrated of order $I(1)$ with a significant level of 5%. This suggests that the independent variables exhibit fluctuations around a stable long-term average. However, there is a mixture of cointegrated orders among the variables, with some being integrated of order I(0) and others of order I(1) at both the level and first difference.

Subsequently, the study conducted tests to determine the relationship between electricity consumption, economic growth, trade, and urbanization, which are interconnected and show evidence of cointegration. Through the use of the ARDL specification (3, 3, 3, 4), this study was able to establish the existence of a cointegration relationship and analyze the long-term equilibrium and short-term dynamics among the variables. According to the results, urbanization has a long-term positive impact on electricity consumption, whereas trade and economic growth have a long-term negative impact and no discernible relationship. It was determined that there was an elastic, positive, and statistically significant relationship between urbanization and electricity consumption. Given Malaysia's increasing urban population, this positive correlation is not surprising. It is anticipated that the demand for electricity will rise in tandem with the ongoing urbanization that is driving population growth and migration to cities.

A 1% increase in economic growth leads to a 0.67% increase in electricity consumption, demonstrating the short-term positive relationship between economic growth and electricity consumption. This is important since Malaysia is a developing nation, and the country's development requires more electricity. Because of Malaysia's expanding population, urbanization also has a major short-term effect on electricity consumption; a 1% increase in urbanization results in a 14.15% increase in electricity consumption.

In addition, the negative and significant coefficient of ECM confirms a cointegration relationship between variables in the short-term analysis. The ARDL-ECM estimates show that deviations in electricity consumption levels are corrected by 27.93% annually. The short-term growth of electricity consumption is found to be positively impacted by economic growth, which was not significant in the long-term analysis. Long-term, sustained growth may result from this effect, which takes time to accumulate.

5.1 Policy Implications and Recommendations

According to preliminary analysis, there is a significant short-term relationship between economic growth and electricity consumption. The data specifically demonstrates that Malaysia's economic expansion raises the country's electricity consumption. If a nation's GDP and electricity consumption are directly related, then the country would be wise to implement energy conservation measures. This relationship also suggests that the nation's economic growth is not unduly reliant on energy. Therefore, putting policies in place to cut energy use can help the nation's economy and environment. Basically, a rise in electricity consumption is associated with an increase in real GDP. As the economy grows, a greater percentage of GDP is devoted to electricity use, which encourages further increases in electricity consumption.

The demand for electricity has significantly increased across a number of sectors as nations' economies continue to grow. According to [30], as GDP increases, so does the demand for electricity. In order to meet the increasing demand, this calls for additional investments in the production of electricity as well as the construction of distribution networks to guarantee that electricity is easily accessible to both homes and businesses. Electricity is essential to human life and technological progress in today's modern society. From household use to industrial operations, it is essential to practically every facet of human activity. With higher disposable incomes, households are consuming more electricity than ever before. Economic growth not only drives the growth of industrial and commercial sectors but also increases the demand for electricity as a crucial input. In addition, the construction of new large-scale factories and plants increases electricity consumption to keep up with economic growth. Thus, it makes sense to anticipate that as the economy expands, the nation's electricity consumption will rise.

By stimulating growth and development, it is anticipated that putting into action a plan aimed at boosting investment in the electricity sector will help Malaysia's economy. Policies that promote a decrease in power consumption may impede economic growth if electricity consumption is the primary driver of that growth. On the other hand, attempts to save electricity won't have an impact on the expansion of the economy if economic growth doesn't drive electricity consumption or if rising consumption drives economic growth. Thus, as a long-term development strategy, Malaysia needs to concentrate on raising investments in infrastructure related to the supply of electricity in order to maintain economic growth. The decision-making process for funding infrastructure for the supply of electricity is assured by this study.

However, Malaysia needs to take steps to save energy in order to lessen the strain that constant growth and industrialization are putting on energy resources. Even though urbanization may use a lot of energy, growing rural areas can help slow it down and make sure that all areas have the same access to electricity. Encouraging dispersed growth instead of dense urban development and promoting the efficient use of electricity can help lower energy use. Changing trade rules to cut down on too much energy use can also save the country money on energy in the long run.

It is also very important to be careful when following these suggestions because more research is needed to fully understand which parts of economic growth are best at lowering energy use. Aspects of urbanization and trade that raise energy demand must also be addressed. If we shift our focus from sectors that use a lot of energy to ones that use less, we could see a big drop in energy use. To encourage growth in cities and keep the economy growing, the Malaysian government should put more money into renewable energy sources.

In order to alleviate shortages that arise when the government lacks the resources to meet energy demand, the government can also encourage the private sector to participate in the production, transmission, and distribution of energy sources like electricity. This not only offers a new avenue for investment in energy facilities but also enhances efficiency in the sector. Even though there has been some progress in this area, the government should provide more financial incentives that are currently absent from government organizations in order to promote private sector involvement in electricity generation and guarantee the required redundancies in power generation. These findings imply that the best options for the nation's energy policies are those that concentrate on improving energy infrastructure and raising supply to satisfy high demand.

5.2 Limitations and Future Research

A few restrictions were faced throughout the course of the investigation. The absence of enough data sources was one of the difficulties encountered. The study's main drawback was the limited time series of data that was available. Reassessing the results after a longer time series is available would be advantageous. It is advised that they obtain a large amount of data in order to obtain reliable results from their tests. In every aspect of the study, more precise estimations will be possible with a larger sample size.

Furthermore, obtaining current and accurate secondary data is difficult, particularly when it comes to electricity consumption data, which is only available through 2014, and annual trade data from various sources. By acquiring more recent data and making sure the right units of measurement are used, it is crucial to correct any inaccuracies in the data. Additionally, even in cases where data for specific years is lacking, researchers can investigate alternative methods to find patterns and connections over time across different geographic regions when working with missing annual data.

Lastly, it is important to note that the absence of a thorough theoretical framework for every variable was a significant limitation of this study. The researchers' inability to locate pertinent data or literature to back up their investigation resulted in a lack of review of pertinent theoretical models. In order to enhance their model for future research, it is recommended that future researchers include other variables that are relevant to the study in addition to electricity consumption. This is important because including more relevant variables in research will offer policymakers more essential information. Additionally, further investigation into the connection between economic growth, trade, and urbanization could benefit future research by including additional independent variables to analyze how each variable impacts electricity usage.

Acknowledgement:
The authors would like to express gratitude to Universiti Malaysia Sarawak (UNIMAS) for their support to this research.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

The authors wrote, reviewed and edited the content as needed and verifies that none utilized artificial intelligence (AI) tools were used. The authors take full responsibility for the content of the publication.

References:

[1] Bunnag, T. (2021). The causal relationship between electric power consumption and economic growth in Malaysia and Thailand: ARDL Bound testing approach. *Journal of Hunan University (Natural Sciences)*, *48*(9), 241-247.

[2] Abd Rahman, N. A., Kamaruzzaman, S. N., & Akashah, F. W. (2019). Scenario and strategy towards energy efficiency in Malaysia: A review. *MATEC Web of Conferences,* 266, 1-5.

[3] Lakshmanan, R., Kok, K. H., & Sinnadurai, R. (2015). Wireless power transfer for small scale application. *The Journal of Energy and Development*, *3*(2), 401–403.

[4] Kraft, J., & Kraft, A. (1978). On the relationship between energy and GNP. *2013 IEEE Student Conference on Research and Development (SCOReD),* (pp.31–36), 2013.

[5] Ramcharran, H. (1990). Electricity consumption and economic growth in Jamaica. *Energy Economics*, *12*(1), 65-70.

[6] Masih, A. M. M., & Masih, R. (1996). Energy consumption, real income and temporal causality: results from a multi-country study based on cointegration and error-correction modelling techniques. *Energy Economics*, *18*(3), 165–183.

[7] Cheng, B. S. & Lai, T. W. (1997). An investigation of co-integration and causality between energy consumption and economic activity in Taiwan. *Energy Economics*, 19, 435-444.

[8] Yoo, S. H., & Kim, Y. (2006). Electricity generation and economic growth in Indonesia. Energy, 31(14), 2890-2899.

[9] Alshami, M., & Sabah, A. (2020). The strategic importance of energy consumption to economic growth: Evidence from the UAE. International *Journal of Energy Economics and Policy*, *10*(1), 114-119.

[10] Zhao, Y., & Wang, S. (2015). The relationship between urbanization, economic growth and energy consumption in China: An econometric perspective analysis, *Sustainability*, MDPI, *7*(5), 1-19.

[11] Ogundipe, A. A., & Apata, A. (2013). Electricity consumption and economic growth in Nigeria. *Journal of Business Management and Applied Economics*, *2*(4) 1–14.

[12] Faisal, F., Tursoy, T., Resatoglu, N. G., & Berk, N. (2018). Electricity consumption, economic growth, urbanisation and trade nexus: empirical evidence from Iceland. *Economic Research-Ekonomska Istraživanja*, *31*(1), 664-680.

[13] Ozturk, I. (2010). A literature survey on energy-growth nexus. *Energy Policy*, 38, 340-349. https://doi.org/10.1016/j.enpol.2009.09.024.

[14] Dogan, E. (2014). Energy consumption and economic growth: Evidence from low-income countries in Sub-Saharan African. *International Journal of Energy Economic and Policy*, *4*(2), 154-162.

[15] Halim, H. A., Harun, N. H., Shaari, M. S. & Zainol Abidin, N. (2020). The effects of capital, labor and electricity consumption on economic growth in Malaysia. *International Journal of Energy Economics and Policy*, *10*(6), 305-309.

[16] Özdemir, O., & Bekun, F. V. (2023). Electric power consumption in high-income countries as a catalyst for sustainable development: Empirical evidence from generalized quantile regression. *Energy Efficiency,* *16*(47). https://doi.org/10.1007/s12053-023-10128-2.

[17] Wu, W., & Lin, Y. (2022). The impact of rapid urbanization on residential energy consumption in China. *PLOS ONE, 17*(7), e0270226. https://doi.org/10.1371/journal.pone.0270226.

[18] Bonsu, M. O.-A., & Wang, Y. (2022). The triangular relationship between energy consumption, trade openness and economic growth: New empirical evidence. *Cogent Economics & Finance,* *10*(1), 2140520. https://doi.org/10.1080/23322039.2022.2140520.

[19] Akinlo, A. E. (2008). Energy consumption and economic growth: Evidence from 11 Sub-Sahara African countries. *Energy Economics,* 30(5), 2391-2400. https://doi.org/10.1016/j.eneco.2008.01.008.

[20] Ugurlu, E., & Jindrichovska, I. (2024). The relationship between electricity consumption, trade and GDP and the effect of COVID-19: A panel ARDL approach on the Visegrad countries. *Frontiers in Energy Research*, 11, 01-14.

[21] Pesaran, M., Shin, Y., & Smith, R. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, *16*(3), 289-326.

[22] Shahbaz, M., & Lean, H. H. (2012). Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia. *Energy Policy,* 40(C), 473-479.

[23] Salim, R. A., & Shafiei, S. (2014). Urbanization and renewable and non-renewable energy consumption in OECD countries: An empirical analysis. *Economic Modelling*, 38(C), 581-591.
[24] Liddle, B., & S. Lung. (2014). Might electricity consumption cause urbanization instead? Evidence from heterogeneous panel long-run causality tests. *Global Environmental Change*, 24, 42–51.
[25] Shahbaz, M., Sbia, R., Hamdi, H., & Ozturk, I. (2014). Economic growth, electricity consumption, urbanization and environmental degradation relationship in United Arab Emirates. *Ecological Indicators*, 45, 622-631.
[26] Solarin, S. A., Shahbaz, M., & Shahzad, S. J. H. (2016). Revisiting the electricity consumption-economic growth nexus in Angola: The role of exports, imports and urbanization. International *Journal of Energy Economics and Policy*, *6*(3), 501-512.
[27] Sari, V. K. (2022). Does electricity consumption influence economic growth in Indonesia? *Jurnal Ekonomi dan Pembangunan*, *30*(1), 47-55.
[28] Ghani, G. (2012), The impact of trade liberalisation on the economic performance of OIC member countries. *Journal of Economic Cooperation and Development*, *32*(1), 1-18.
[29] Gozgor, G., Lau, C. K. M., & Lu, Z. (2018). Energy consumption and economic growth: New evidence from the OECD countries. *Energy*, *153*, 27–34. https://doi.org/10.1016/j.energy.2018.03.158.
[30] Njenga, J. K. (2024). Electricity consumption and economic growth in Kenya: An ARDL bound test approach. *Journal of Energy Research and Reviews*, *16*(1), 28-36.
[31] Parshall, L., Gurney, K., Hammer, S. A., Mendoza, D., Zhou, Y., & Geethakumar, S. (2010). Modelling energy consumption and CO2 emissions at the urban scale: Methodological challenges and insights from the United States. *Energy Policy*, *38*(9), 4765-4782.
[32] Kasman, A., & Duman, Y. S. (2015). CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: A panel data analysia. *Economic Modelling*, 44(C), 97-103.
[33] Lenzen, M., Wier, M., Cohen, C., Hayami, H., Pachauri, S., & Schaeffer, R. (2006). A comparative multivariate analysis of households energy requirements in Australia, Brazil, Denmark, India and Japan. *Energy*, *31*(2-3), 181-207.
[34] Abd Aziz, A. J., Baharuddin, N. A., Md. Khalid, R., & Kamarudin, S. K. (2024). Review of the policies and development programs for renewable energy in Malaysia: Progress, achievements and challenges. *Energy Exploration & Exploitation,* 42(4), 1472-1501. https://doi.org/10.1177/01445987241227509.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.