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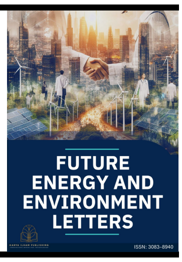

A Comparative Analysis of Electrical Consumption in Urban and Rural Households: A Case Study of Muar

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ABSTRACT

Urban areas, with dense populations and fast-paced lifestyles, have higher and more varied energy needs, while rural areas consume less due to lower density and simpler economies. This study investigates the differences in electricity consumption between urban (Bandar Maharani) and rural (Ayer Hitam) households in Muar, Johor, emphasizing key factors such as income, household size, type of housing, the number of electrical appliances, total daily usage for minor appliances, total daily usage for major appliances and residential area (urban/rural) that influence the electric consumption and region-specific energy sustainability approaches. Using a quantitative approach, data were collected via structured questionnaires from 300 households, selected through stratified and random sampling methods. Statistical analysis, including multiple linear regression, was conducted to determine the relationship between monthly kWh bill and several independent variables. The result indicates that urban households consume significantly more electricity than rural ones, with an average difference of 202.86 kWh per month ($p < 0.001$, Cohen's $d = 0.488$), indicating a moderate effect size. Among all variables, the key factor found to influence electricity consumption most significantly is income level, which exhibited the highest standardized regression coefficient ($\beta = 0.250$, $p < 0.001$), confirming its strong and statistically significant impact. Most households with 42% choose that they save energy by using energy-efficient appliances and respondents strongly agree that energy efficiency is important for the environment with mean = 4.55. In summary, electricity consumption is influenced by both usage behaviour and socio-economic conditions. Addressing these through education, policy, and technology is key to promoting sustainable energy practices.

1. Introduction

Electricity is an essential part of modern life, powering residential, commercial, and industrial activities. In Malaysia, the demand for electricity continues to grow, driven by increased appliance ownership, urbanization, and evolving lifestyles. According to Tho Pesch *et al.,* [10], when energy demand continues to rise globally, understanding the pattern of electrical usage across different

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region becomes very crucial. However, electricity usage patterns vary significantly between urban and rural areas due to differences in socioeconomic status, housing types, and access to infrastructure.

Recent reports in Malaysia have highlighted public dissatisfaction over rising electricity bills, with government officials receiving numerous complaints via digital platforms. This concern reflects broader challenges, such as bill arrears and financial constraints, especially in middle- and lower-income households. Although urban areas are known for higher electricity usage due to dense populations and more devices, rural areas face their own limitations, such as infrastructure and income constraints. Despite this, there is still a lack of empirical studies comparing electricity consumption patterns between rural and urban households within specific regions like Muar.

Previous studies have shown that electricity consumption is shaped by factors such as household characteristics, demographics, behavior, technology, accessibility, lifestyle, and occupation. Halkos *et al.,* [11] also mentioned that electric consumption patterns are often linked to economic activities and income levels. So that income and housing type play a major role. According to Mustapa *et al.,* [1], appliance usage increased during the MCO period, reflecting the influence of lifestyle change and policy impacts. Finding by Ali *et al.,* [2] and Zhang *et al.,* [3] indicate that marital status and socioeconomic background also influence usage whereas Sena *et al.,* [4] suggest that occupant behavior may exert an even stronger influence. In Becket *et al*., [5] urban areas show higher appliance usage due to income elasticity and aspects like dwelling size, occupancy, and seasonal changes further affect consumption based on finding by Yohanis *et al*., [6] and Rodes *et al*., [7]. Differences in service access, occupations, and lifestyles between urban and rural areas influence energy consumption and emissions.

Income, household size, appliances, usage patterns, and climate are also key influencers. According to Yohanis *et al*., [6] low-income groups tend to adopt energy-saving measures only when payback is short , while Ali *et al.,* [2] found that high-income households often consume more energy but may use it inefficiently. Due to Ali *et al.,* [2] and Sena *et al.,* [4] larger households and homes with more appliances typically use more electricity, and urban homes may come with built-in appliances stated by Yohanis *et al*., [6]. Other than that, Zhang *et al.,* [3], Sena *et al.,* [4] and Aqilah *et al.,* [8] highlighted that climate change increases the use of cooling systems, particularly in warmer areas . Promoting sustainability involves using energy-efficient appliances, as highlighted by Yohanis et al. [6], supported by awareness campaigns and regulatory measures recommended by Sena et al. [4], along with low-carbon strategies and enhanced energy technologies discussed by Ali *et al*., [2]. Collaboration among stakeholders is essential to reduce consumption and build energy-efficient communities.

While a vast body of research explores household electricity consumption and urban rural disparities, most studies rely on broad national or regional comparisons. This approach often overlooks the nuanced socio-economic and infrastructural variations that exist within a single district. In Johor, there is particularly limited empirical evidence comparing consumption patterns between adjacent urban and rural communities.

Bandar Maharani and Ayer Hitam offer contrasting development contexts within Muar, where divergent income levels, housing types, and lifestyle habits coexist under identical climatic and policy frameworks. By focusing on these two specific areas, this study effectively isolates the impact of urbanization and household characteristics from external factors such as regional weather and tariff structures. The originality of this research lies in its micro-level focus by examining a single district, it provides context specific insights that move beyond generalized assumptions to inform targeted, localized energy-saving strategies.

2. Material and Methods

This study adopts a quantitative research approach to examine the differences in electricity consumption between urban and rural households in the Muar district. The methodology is structured into three main components: data collection, data analysis, and regression modelling.

2.1 Data Collection
2.1.1 Sampling framework

The population of the study is families residing in the Muar district, which comprises 12 administrative mukims. These were stratified into rural and urban strata which specifically within two distinct areas, Bandar Maharani (urban) and Ayer Hitam (rural) as stated in Yeo *et al.,* [9]. The population of Muar is about 314,776, comprising approximately 57.26% urban and 42.74% rural, according to the Department of Statistics Malaysia (2020). A stratified random sampling method was employed to obtain proportional representation. We had calculated the ideal sample size of 400 using Yamane's formula at a 95% confidence level. However, due to logistical constraints, a total of 300 households were selected: 172 urban and 128 rural.

2.1.2 Instrumentation

The primary instrument used in collecting data for this study was a structured questionnaire that was prepared through Google Forms. The questionnaire was well developed to align with the study's objectives as well as collect relevant information from the selected respondents in urban and rural Muar, Johor.

The questionnaire consisted of 12 structured questions grouped under themes such as demographics, housing characteristics, ownership and utilization of appliances, monthly electricity consumption, and knowledge of energy savings. More specifically, the respondents were asked to indicate their residence (urban or rural), household size, monthly income, type of house, number and variety of electric appliances, and average daily utilization of large and small appliances.

Additionally, the survey included an item on the household’s latest monthly electricity consumption (in kWh), which served as the dependent variable for the statistical analysis. To facilitate standardized and comprehensive data collection, the questionnaire employed multiple-choice grids, short-answer questions, and Likert scale items. In particular, Likert-scale statements were used to assess respondents’ energy-saving practices and perceptions of energy efficiency, allowing the study to gauge the level of importance attributed to sustainable electricity usage. This instrument enabled broad-spectrum and reliable data capture from diverse households.

2.1.3 Variables

Table 1 are dependent variable and independent variables that are expected to influence household electricity consumption. The dependent variable is the monthly electricity consumption, measured in kilowatt-hours (kWh), which reflects the total amount of electricity used by a household within one month. The independent variables include household size, which refers to the number of occupants in the home, and household income, which indicates the total monthly earnings of the household. Another important variable is the number of electrical appliances owned by the household, as well as the average daily usage of those appliances, which estimates how long the appliances are used each day. The type of housing is also considered, covering categories such as terrace houses, apartments, or bungalows, as housing design can affect electricity usage, especially cooling. Lastly, the residential area, classified as either urban or rural, is included to capture location-based differences in infrastructure and energy access. These variables are measured using ordinal and nominal scales and were collected through responses to structured survey questions.

Table 1
Description of variables

Variable Type	Variables
Independent (X)	Household size, income, total number of appliances, total daily usage for minor appliances, total daily usage for major appliances, type of housing, residential area (urban/rural)
Dependent (Y)	Monthly electricity consumption (kWh)

2.2 Data Analysis

All collected data were analyzed using the Statistical Package for the Social Sciences (SPSS) to household electricity consumption patterns and identify significant predictors. Before analysis, a comprehensive data cleaning procedure was performed to ensure accuracy and consistency by removing incomplete, inconsistent, or duplicate responses.

Descriptive statistics, including mean, standard deviation, and range, were used to summarize continuous variables such as household income, household size, number of electrical appliances, and average daily usage. Frequency analysis was applied to categorical variables like residential area, housing type, and energy-saving practices to assess distribution trends across categories.

To compare mean electricity consumption between urban and rural households, an independent samples t-test was conducted to assess whether the observed differences were statistically significant. Likert-scale responses related to energy efficiency awareness and behaviour were analysed using mean scores to evaluate respondents' overall perception and practice.

Finally, multiple linear regression analysis was performed to determine the impact of independent variables—including income level, household size, type of housing, and appliance usage—on monthly electricity consumption (kWh). The model generated unstandardized coefficients, standardized Beta values, and p-values to measure the strength and statistical significance of each predictor.

2.3 Multiple Linear Regression Analysis

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \epsilon \quad (1)$$

- Y = monthly electrical consumption (kWh) (DV)
- β_0 = intercept
- $X_1, X_2, X_3, X_4, X_5, X_6, X_7 =$ Independent variables (e.g., household size, total number of appliances, total daily usage for minor appliances, total daily usage for major appliances, type of housing, income, and areas (rural/urban))

- $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$ = Coefficients to estimate
- $\epsilon =$ Error term

The Eq. (1) is a multiple linear regression model used to determine the factors that influence electricity consumption. It includes seven independent variables: total daily usage for major appliances and total daily usage for minor appliances, type of housing, number of appliances, income, household size, and areas (urban and rural). This method helps in understanding how these factors are related to electricity consumption and identify key contributors.

3. Results and Discussion

3.1 Comparison of Electrical Consumption Patterns between Rural and Urban Households

Table 2 presents the results of an independent-samples t-test comparing electricity consumption between urban and rural households. The analysis shows that there is a statistically significant difference ($p < 0.001$) in which urban households (M = 636.77, SD = 462.724) consume significantly more electricity than rural households (M = 433.91, SD = 342.388). The mean difference was 202.86 kWh/month with a moderate effect size (Cohen's d = 0.488). Therefore, living in an urban area is associated with higher electricity consumption. This outcome implies that urban households, likely due to greater access to appliances, higher standards of living, and more frequent use of electronic devices, tend to consume significantly more electricity than their rural counterparts. The results of the independent samples t-test indicate a statistically significant difference in electricity consumption between urban and rural households ($p < 0.001$).

Table 2
Comparison of monthly electrical consumption between rural and urban

				t-test for Equality of Means		95% Confidence Interval of the Difference	
	N	**Mean (kWh)**	**Std. Deviation**	**Mean Difference**	**Std. Error Difference**	**Lower**	**Higher**
Area 1 (Urban)	172	636.77	462.724	202.861	48.528	107.360	298.362
Area 2 (Rural)	4.364	297.994	<0.001	202.681	46.483	111.384	294.338
Area 2 (Rural)	128	433.91	342.388				

3.2 Factors Influencing Electricity Consumption

To further understand the determinants of electricity consumption, multiple linear regression analysis was conducted to identify the influence of socio-demographic and appliance usage factors on monthly household electricity consumption based on different types of variables such as total appliances, area, income, housing type, total daily usage of minor and major appliances.

Table 3 shows the results of multiple linear regression analysis to examine the factors affecting household electricity consumption. Among the seven independent variables, income level was the strongest positive predictor ($\beta = 0.250$, $p < 0.001$), indicating that households with higher income tend to consume more electricity. This is likely due to increased appliance ownership and more frequent usage.

Household size also had a significant positive effect ($\beta = 0.167$, $p = 0.004$), suggesting that larger households generally use more electricity. In addition, minor appliance use was positively associated with consumption (β = 0.136, p = 0.028), suggesting that frequent use of smaller devices is associated with higher overall electricity use.

Otherwise, area (urban vs. rural) was a significant negative predictor (β = –0.198, p < 0.001), with urban households consuming more electricity than rural households. Interestingly, major appliance usage showed a significant negative relationship (β = –0.284, p < 0.001), which may indicate behavioral differences, such as limited usage despite ownership, or multicollinearity effects. Meanwhile, the total number of appliances (p = 0.432) and type of housing (p = 0.639) were not statistically significant, suggesting that these factors do not meaningfully predict electricity usage when other variables are considered. Overall, the model highlights that socioeconomic characteristics and specific appliance usage behaviors are key determinants of household electricity consumption. Mathematically, the regression equation will eventually become

$$\begin{aligned} Electrical\ Consumption\ (kWh) &= -170.867\ (Area) + 100.008\ (Income) + 9.392\ (Housing\ type) \\ &+ 26.514\ (Total\ daily\ usage\ for\ minor\ appliances) \\ &- 38.123\ (Total\ daily\ usage\ for\ major\ appliance) + 36.627\ (Household\ size) \end{aligned}$$

Table 3
Electrical consumption model

	Unstandardized B	Coefficients Standard Deviation	Standardised Coefficients Beta	p
(Constant)	449.235	154.107		0.004
Total appliances	3.160	4.019	0.056	0.432
Area	-170.867	47.559	-0.198	<0.001
Income	100.008	24.091	0.250	<0.001
Housing type	9.392	20.010	0.026	0.639
Sum minor use	26.514	12.012	0.136	0.028
Sum major use	-38.123	9.294	-0.284	<0.001
Household size	34.627	11.813	0.167	0.004

3.3 Recommend energy-saving practices

Figure 1 show the percentage of energy-savings practice of respondents. Most respondents, 42 percent reported using electrical appliances with energy-efficient labels as their main energy-saving practice. This is followed by unplugging devices 20 percent and air-drying clothing 17 percent. Meanwhile, 12 percent of respondents use solar panels, and only 9 percent reported using LED bulbs. These results indicate that most households prioritize appliance efficiency over other energy-saving methods.

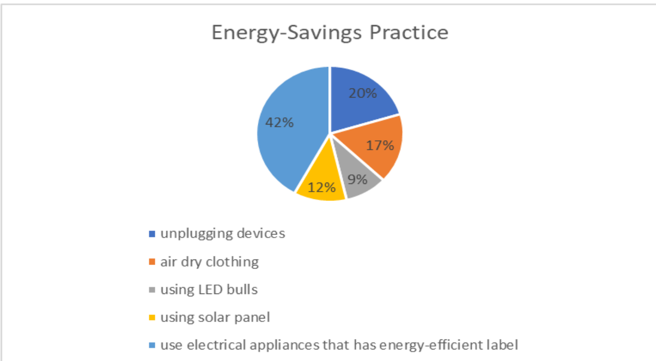

Fig. 1. Pie chart of energy-savings practice

Table 4 shows the descriptive statistics of respondents' perceptions of energy efficiency. The results indicate a high level of agreement across all three statements on the importance of energy efficiency. The highest mean score was 4.55, where respondents agreed that energy efficiency is important for environmental impact. This is followed by a mean of 4.45 for the statement that energy efficiency should be a priority in government policy, and 4.40 for the statement that energy efficiency can reduce energy consumption. These findings suggest that most respondents are aware of the role of energy efficiency not only in reducing electricity usage but also in supporting environmental sustainability and informing public policy.

Table 4
Energy efficiency

	N	Minimum	Maximum	Mean
Energy efficiency is an important in environmental impact	300	2	5	4.55
Energy efficiency can reduce energy consumption	300	2	5	4.40
Energy efficiency should be a priority for government policy	300	2	5	4.45

4. Conclusions

This study examined household electricity consumption through three primary lenses: a comparison of urban and rural usage, an identification of key influencing factors, and the formulation of targeted energy-saving strategies. The results indicate a significant disparity in consumption, with urban households using an average of 202.86 kWh more than their rural counterparts—a reflection of divergent lifestyles, income levels, and appliance ownership.

Statistical analysis revealed that major appliances, particularly air conditioners, are the strongest predictors of high electricity demand. In contrast, the use of fans and fluorescent lighting was associated with lower consumption levels, while smaller electronics like laptops and vacuums played a minor but notable role. Among socio-demographic variables, income and household size emerged as significant drivers of usage, whereas housing type had no measurable impact.

Public sentiment gathered during the survey suggests a strong foundation for future initiatives, respondents broadly recognized the importance of energy efficiency for environmental protection and its alignment with government policy. However, to be effective, these findings suggest that energy strategies must be tailored to specific community profiles. In urban centers like Bandar Maharani, where income and appliance density are higher, policies should prioritize high-efficiency cooling systems, smart energy management, and "time-of-use" awareness programs. Providing incentives for inverter-based air conditioning and energy-efficient refrigeration would be particularly impactful here. Conversely, rural communities like Ayer Hitam would benefit more from financial support mechanisms, such as subsidies for efficient appliances, expanded access to rooftop solar, and community-led education programs.

It is important to acknowledge certain limitations of this research. The data relies on self-reported survey responses, which may be susceptible to recall bias. Furthermore, the cross-sectional design captures usage at a single point in time, meaning it does not account for seasonal fluctuations or long-term behavioral shifts. Finally, as the study focuses specifically on two areas within the Muar district, the results may not be directly generalizable to regions with different infrastructural or socio-economic profiles. Nevertheless, these findings provide a vital localized framework for understanding urban–rural energy dynamics and suggest that targeted, socio-economic interventions are essential for achieving equitable energy sustainability.

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