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Article

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The Estimation and Relationship of Domestic Electricity Consumption and Appliances Ownership in Malaysia's Intermediate City

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ABSTRACT

The growing trend of energy consumption in urban area has created negative impacts to the urban environment because the issues related to energy use and urban developments are largely dependent on human aspects and mobilized by the inhabitants of the city itself. This study aims to estimating the electricity consumption with regards to electrical appliances usage and carbon emissions in domestic sector of urban area. The study revealed that average electricity power consumption was 648.31 kWh. Meanwhile, refrigerator and air conditioning recorded as the highest electricity consumption appliances compared to other appliances. In terms of type of house, household from bungalow house consumed more electricity power and resulted to high carbon emissions compared to other households. The study suggested that the level of knowledge, awareness, commitment, attitude and behavior of electricity consumption among household should be intensified. Besides, the number of energy saving appliances also needs to be improved and encourage smart energy consumption that led to the sustainable urban development.

Keywords: Electricity Consumption, Appliances, Carbon Emissions
JEL Classifications: Q40; R20

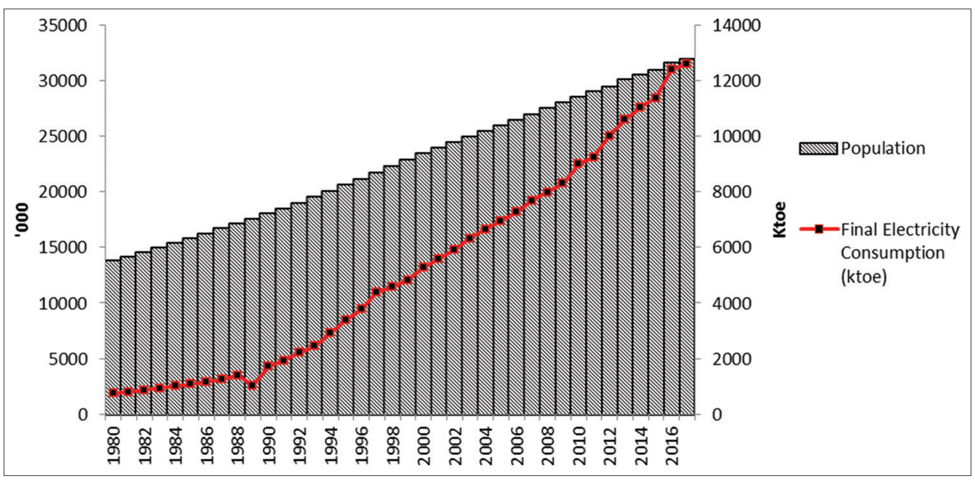
1. INTRODUCTION

Energy is one of the most required resources for economic development especially in a developing country like Malaysia. As urban continue to grow and more human populated in the urban area, energy resources becoming very crucial in order to fulfill human needs. In the context of electricity power, domestic sector remains as one of the major electricity consumption in line with the industrial and commercial sector (Tan et al., 2013). The previous study proved that human factors such as socioeconomic, housing, appliances, attitudes and behavior contributed significant impact on electricity consumption (Wahlström and Hårsman, 2015; Jalalkamali and Abbas, 2014). This is because the issues related to energy use and urban developments are largely dependent on human aspects and mobilized by the inhabitants of the city itself. Therefore, it's essential to understand electricity consumption in the domestic sector since the demand from that sector continues growing significantly.

Coal remains as main resources for electricity generation mix contributed about 51.25% followed by natural gas (49.24%) and hydro (3.11%). Meanwhile, total installed capacity also increased from 20,710 megawatt (MW) in 2015 to 22,910.55 MW in 2016 as a result of high energy demand and newly operated power stations (Suruhanjaya Tenaga, 2016). Electricity demand for building sector is projected to grow 2.9% from about 10 Million ton of equivalent (Mtoe) in 2013 to 22 Mtoe in 2040 whereby electricity power dominates the energy demand from building sector consisting 68% in 2040 (APEC, 2016). Meanwhile, the domestic users remain as the main electricity consumer in 2016 with total around 7 million users, commercial 1.5 million users and industrial 28 thousand users in Peninsular Malaysia (Suruhanjaya Tenaga, 2016). As population increased, the electricity consumption in Malaysia has risen significantly. Figure 1 explained the growing trend of electricity consumption were in line with increasing population. On the other hand, the urban population in Malaysia continue to increase from 13.7 million in 2000, increased to settled at 20.1 Million in 2010 and hit a peak at 23.7 Million in 2016 (Department of Statistics Malaysia, 2017). As illustrated in Figure 2, the urban population has skyrocketed particularly where the main urban area was located such as in Selangor, Johor, Sabah, Perak and Kuala Lumpur.

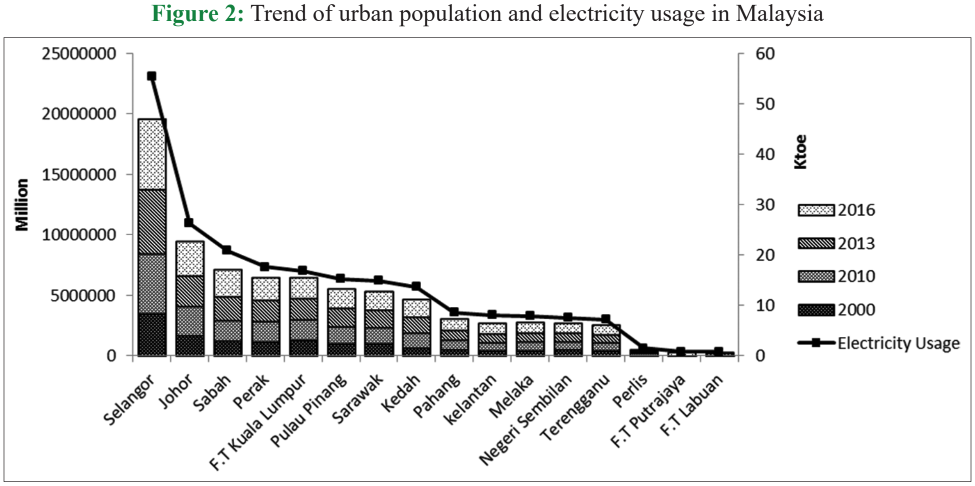
Malaysia government was very committed to reduce the energy consumption and greenhouse gases emissions especially from the domestic sector. In 2011, Sustainability Achieved via Energy Efficiency Program (SAVE) was designed by Malaysian Government Economic Transformation Program (ETP) for funding cash rebates for the purchase of energy efficient appliances such as refrigerators, air conditioning and chillers (Kementerian and Teknologi, 2015). The Small Renewable Energy Power Program (SREP) was a program aimed at encouraging and intensifying the utilization of renewable energy in power generation (Mustapa et al., 2010). Under this program, permission is given to small power producers (<10 MW), including solar, mini-hydro power, biomass, biogas, wind, and municipal waste to sell their generated electricity to the grid under the Renewable Energy Power Purchase Agreement (REPPA) at a ceiling price. However, this was only limited to 219 MW in 2011. In order to encourage households and industry players to install PV systems, the Malaysian Building Integrated Photovoltaic (MBPIV) Project was introduced for electricity generation and is expected to reduce carbon emissions by reducing the long-term costs of BIPV technology via the development of a sustainable BIPV market. In 2009, the cumulative connected PV increased from 468 kWp in 2005 to 1416 kWp in 2009 under the MBIPV project. In addition, a total of 1070 tons of CO_2 equivalent GHG emissions were avoided (Mustapa et al., 2010). After that, Feed-in Tariff (FiT) was introduced by the Sustainable Energy Development Authority of Malaysia (SEDA) in 2011. Under this tariff, 1% of the electricity tariff from consumers is used to support the development of renewable energy, except for low-income consumers with an average monthly electricity consumption of

Figure 1: Trend of electricity consumption and population in Malaysia (1980-2017)



Source: Suruhanjaya Tenaga, 2017

Figure 2: Trend of urban population and electricity usage in Malaysia



Source: Department of Statistics Malaysia, 2017

<200 kWh (Mekhilef et al., 2014). The implementation of FiT has led to an increase in the CO2 reduction from 2012 up to the end of 2015.

Although the Malaysian government seems very committed to reducing energy consumption by introducing new energy policies and programs to promote the utilization of renewable energy sources, there are obstacles to reducing fossil fuel consumption in Malaysia. As mentioned by Sukarno et al. (2015), urban energy consumption was differing due to climatic conditions, socioeconomic structure, population and physical environment. Appliances ownership is one of the important indicators to determine the electricity consumption in urban area. Hence, the identification of the underlying factors that contributes to the high electricity consumption able to help energy consumption reduction. Therefore, in order to reduce the electricity consumption and its impact, we need to understand how the electricity power is consumed. Therefore, we focused on electricity consumption and relationship with regards to appliances ownership in domestic sector. The indirect greenhouse gases emissions also will take consideration to provide additional data for electricity consumption in domestic sector towards sustainable urban development in Malaysia.

2. METHODOLOGY

2.1. Sample Selection and Study Area

The study was conducted in Seremban. As our sample was households, we used number of house to represent the household population in Seremban. Total housing units is 107755 units. In order to select sample of the population, we classified the housing land use into several strata according to the type of houses such as traditional/village house, single story terrace, double story terrace and above, detached terrace, bungalow and flat/apartment/condominium. The stratification was based on Seremban Municipality Council classification (Majlis Perbandaran Seremban, 2015). In terms of sample size, we applied methodology by Creative Research System (2012) by using proportionated stratified random sampling technique. This technique able to avoid human bias and highly representative of the population studied (Laerd Dissertation, 2014). The sufficient sample is 383. According to Sekaran (2003), the appropriate sample size for a research was larger than 30 and <500. Before the real survey, we conducted a pilot test on 30 households to test the reliability and validity of the questionnaires. We also want to make sure that respondent understand the questions given. We then distributed the questionnaire to 620 households and after the data cleaning only 400 samples were used for further analysis. Seremban was selected due to as one of the city that experiencing rapid development due to its location in the Kuala Lumpur Corridor (KLK) and the role played by Seremban itself is similar with other mega cities.

2.2. Appliances Selection and Power Rating

We used the questionnaire as a survey instrument to obtain the socioeconomic profile of households and type of electrical appliances usage including the unit of appliances and duration of the operation. We listed 23 appliances in the survey however only 11 appliances were used in data analysis. The power rating was estimated according to Tenaga National Berhad energy services (TNBES) and several from previous studies. The appliances were selected based on the most frequent used equipment among households in Seremban. The summary of the power rating can be referred to in Table 1.

2.3. Estimating Electricity Consumption

In the context of this study, the total electricity consumption is identified based on the methodology used by Olaniyan et al.

Table 1: Summary of power rating

Appliances	Average power for each electrical appliances (watt)				Power rating for this study
	Saidur et al. (2007)	TNBES (2015)	CETDEM (2011)	Ponniran et al. (2007)	
Refrigerator	196	400	-	500	400
Kettle	2125	-	1200-2400	2000-2200	-
Microwave	1125	1500	1050-2100	1100-1200	1500
Washing machine	1005	425	210-450	240-700	425
Blender	300	-	400	-	-
Toaster	800	1100	1200	700	-
Water heater	2000	-	1000	-	-
Rice cooker	905	730	260-1550	600-700	730
Shower heater	-	-	-	3600	-
Computer	100	50	-	65	-
Radio (stereo)		235	-	-	-
Television	80	150	80-175	75	150
Charger	30	-	-	-	-
Fluorescent lamp	30	-	-	36	30
Bulb	70	-	-	-	36
CFL/LED	-	-	-	-	-
Air conditioning	1385	750	1000	1200	750
Ceiling fan	-	100	71-95	100	100
Stand fan	60	75	-	50-60	75
Vacuum	1200	1220	800-1600	1200-1600	1220
Iron	1200	1000	950-1450	1200-1400	-
Water filter	150	-	-	-	-
Hair dryer	1125	1500	750-1500	1200	-

(2018) through selected electrical appliances ownership using the equation below:

$$E_{ha} = \frac{\sum_{i-1}^{n}(R_i \times H_i \times Q_i)}{1000} \quad (1)$$

Where E_{ha} is total electricity consumption by each household in kilowatts per hour (kWh/month), R is the power rating of each used appliances, H is the length of each appliance's operation and Q is the number of appliances. All the daily consumption data is converted to monthly usage (30 days).

2.4. GHG Emissions Estimation from Electricity Consumption

Next, in order to estimate GHG emissions, we applied a methodology from IPCC (Parry et al, 2007). The emissions factor will multiply with activity data (Khan and Siddiqui, 2017). The estimation of GHG emissions can be calculated according to the equation below:

$$Ei = \Sigma A \times EF \quad (2)$$

Where Ei is total GHG emissions, A is activity data, and EF is the emissions factor. The GHG emissions will be converted in CO_2e by multiplying it with global warming potential (GWP) as shown in Table 2.

Table 3 shows the emissions factor for Malaysia. The GHG emission from electricity consumption was defined as indirect emissions. In order to determine the GHG emissions from electricity consumption in Seremban, we calculated activity data with the emissions factor according to the equation below:

$$E_E = E_c \times EF_c \quad (3)$$

Where, E_E refers to the total greenhouse gases emissions from electricity consumption per month, E_C is total electricity consumption (kWh/month), and EF_C is the emissions factor for Malaysia.

2.5. Measuring Relationship

Pearson correlation was used to evaluate the linear relationship between independent variables (electrical appliances consumption) and the dependent variable (total electricity consumption). The analysis resulted in a Pearson correlation coefficient *(r),* and if the correlation coefficient is between (−1) and (1), it shows a strong correlation, but if the value is close to (0), there is no or weak correlation (Rosenthal, 2001). The correlation equation can be referred to as follows.

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{\left[n\left(\sum x^2\right) - \left(\sum x\right)^2\right]\left[n\left(\sum y^2\right) - \left(\sum y\right)^2\right]}} \quad (4)$$

Table 2: Global warming potential

Greenhouse gases	Chemical formula	GWP value
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298

Source: Parry et al. (2007); Khan and Siddiqui (2017)

Table 3: Emissions factor

Consumption category	$kgCO_2$/kWh	$kgCH_4$/kWh	kgN_2O/kWh
Electricity (Generation)	0.74884244	0.00001099853	0.00000675290
Electricity (Usage)	0.770701108	0.00001131957	0.00000695002

Source: Brander et al. (2011); Eggleston et al. (2006)

3. RESULTS AND DISCUSSION

3.1. Household Electricity Consumption

The overall electricity consumption in Seremban can be referred to Table 4. The average electricity consumption in Seremban was 648.31 kWh/month and average monthly cost about RM141.85 or $34.31. The survey revealed that the electricity consumption in Seremban ranged from 78.45 kWh to 2193.93 kWh/month. As indicated in Table 4, majority of the respondents consumed about 401-800 kWh/month (72.25%) of electricity, 49 households or 12.25% consumed around 801-1200 kWh/month, 44 (11%) respondents consumed below 400 kWh/month, 1.5% respondents roughly consumed 1601-2000 kWh/month and 0.25% of the respondents utilized around 2001-2400 kWh/month.

We also investigated the electricity consumption based on type of house, monthly cost and estimated potential of greenhouse gases emissions (GHG) ($kgCO_{2e}$/kWh). According to Table 5, study revealed that a bungalow house consumed the highest electricity per month with average consumption of 885.92 kWh/month followed by a detached house (717.76 kWh/month), double story terrace (690.64 kWh/month), single story terrace (583.52 kWh/month), traditional/village house (560.07 kWh/month) and flat (460.16 kWh/month). This might be influenced by a larger house with more rooms for heating and cooling. Previous studies proved that the size of a house is a predicting factor influencing electricity consumption in urban areas (Ponniran et al., 2012; Chen et al., 2013; Aldossary

Table 4: Overall consumption (kWh) in Seremban

Consumption (kWh)	Number of house	%
0-400	44	11
401-800	289	72.25
801-1200	49	12.25
1201-1600	11	2.75
1601-2000	6	1.5
2001-2400	1	0.25

Table 5: Average electricity consumption, cost estimation and emissions

Housing types	Usage/ household	Monthly cost (RM)	$kgCO_{2e}$/kWh
Traditional/village	560.07	122.54	431.77
Single story terrace	583.52	127.67	451.09
Double story terrace	690.64	151.11	533.90
Detached house	717.76	157.04	554.28
Bungalow	885.92	193.83	684.86
Flat	460.16	100.68	355.72

et al., 2015). Another study found that detached houses used more electrical power compared to other types of house in London. This is because bungalow houses were commonly resided by adult households that portray low electricity usage compared to family households (Ponniran et al., 2012). The result of this study is similar with the study by Ahmed et al. (2017) that found that bungalows consumed high electricity power compared to other types of houses such as double story terrace, detached house, single story terrace and flats in Kajang and Putrajaya located in the KLK region as well. Meanwhile, McLoughlin et al. (2012) found that flats consumed less electricity. This is probably because this type of house is normally resided by small-sized households and has a limited number of rooms. Accordingly, the type of house plays a vital role in determining the electricity consumption. Hu et al. (2017) explained that a bigger house tends to consume more electricity mainly for cooling and heating. Also, high class households used more electricity compared to other households (Ponniran et al., 2012). This is because more spacious houses reflected higher income earners and leads to greater electricity usage (Yohanis et al., 2008).

In the context of electricity cost, we estimated monthly electricity cost by multiplying the total electricity consumption (kWh) and current electricity tariff in Malaysia as provided by TNB (Suruhanjaya Tenaga, 2016). Bungalows spent roughly RM193.83/month while flats spent about RM100.68/month. This study also found that detached houses spent around RM157.04/month on electricity cost while double story households spent around RM151.11/month. The monthly cost for single story terrace and traditional/village house was RM127.67 and RM122.54 respectively. We also analyzed the potential of greenhouse gases emissions as it has been classified as indirect emissions by IPCC (Eggleston et al., 2006). We found that the total GHG emissions were synchronized with electricity consumption in Seremban. The highest average GHG emissions was released by bungalows (684.86 $kgCO_{2e}$/kWh) followed by detached house (554.28 $kgCO_{2e}$/kWh), double story terrace (533.90 $kgCO_{2e}$/kWh), single story terrace (451.09 $kgCO_{2e}$/kWh), traditional/village house (431.77 $kgCO_{2e}$/kWh) and flats (355.72 $kgCO_{2e}$/kWh). The high GHG emission in Seremban is probably due to high electricity demand from the domestic sector. Similarly, the highest GHG emission from the building sector in Kuala Lumpur was due to public housing (64%). Thus, a strategic framework in order to reduce electricity consumption is urgent since electricity consumption contributed significantly to the high GHG emissions in urban areas.

3.2. Electrical Appliances Ownership

We identified the level of electrical appliances ownership and its consumption among urban households in Seremban with consideration to the 11 appliances. More than 90% of appliances ownership was refrigerators, washing machines, rice cookers, televisions, and ceiling fans as detailed in Table 6. A big portion of electricity was used for cooling and lighting. The highest electricity consumption among households in Seremban was refrigerators with an average usage about 308.41 kWh/monthly followed by air conditioning (206.63 kWh/monthly), ceiling fan (80.96 kWh/monthly), fluorescent lamp (47.70 kWh/monthly) and light bulbs (34.68 kWh/monthly). The result was similar with study conducted by Santosa et al. (2019). Accordingly, we assume that these appliances are commonly used and owned by households while other appliances are not as important or rarely used such as microwaves and vacuums (Ponniran et al., 2012). The result of this study is similar with Kubota et al. (2011) that revealed the highest percentage of appliances ownership in Johor Baharu were refrigerators, washing machines, rice cookers, televisions and ceiling fans. This is might be respondent sharing similar socioeconomic characteristic between households in Johor Baharu and Seremban.

We estimated the monthly cost of electricity by multiply with the current electric tariff. Our findings revealed that if the refrigerator is used for 24-h, the daily consumption for a refrigerator is 9.6 kWh and it will cost about RM63/month as shown in Table 7. Similarly, if air conditioning is used for 6 h, the average usage is 4.5 kWh/day and will cost around RM29.53/month. In contrast, the refrigerator consumption in Brunei was recorded only for a small portion of the monthly consumption while air conditioning recorded the highest electricity consumption with an average consumption of 403.2 kWh (Ahmad, 2015). This is because of the hot weather condition in Seremban and Brunei that required users to use cooling appliances. Apart from that, our study also identified that microwaves and stand fans used the smallest portion of electricity compared to other appliances. Daily average usage for both appliances was 0.37 kWh and 0.3 kWh respectively. In the context of monthly cost, the 5 min consumption of a microwave will cost around RM2.46/month. The monthly cost for 4 h of a

Table 6: Ownership of electrical appliances

Appliances	Number of equipment	Ownership (%)	Average consumption (kWh/month)
Refrigerator	395	99	308.41
Microwave	177	44.25	15.07
Washing machine	382	95.5	16.71
Rice cooker	380	95	20.95
TV	372	93.75	29.43
Fluorescent lamp	292	73	47.70
Bulb	179	44.75	34.68
Air conditioning	237	59.25	206.63
Ceiling fan	378	94.5	80.96
Stand fan	229	57.25	25.35
Vacuum	220	55	12.39

Table 7: Average electricity cost for each appliance

Appliances	Average power (watt)	Average operating (hours/day)	Average usage (kWh)	Average cost (RM/month)
Refrigerator	400	24	9.6	63
Microwave	1500	0.25	0.37	2.46
Washing Machine	425	2	0.85	5.57
Rice cooker	730	1	0.73	4.79
Television	150	5	0.75	4.90
Fluorescent lamp	30	5	0.15	0.98
Bulb	36	3	0.10	0.70
Air conditioning	750	6	4.5	29.53
Ceiling fan	100	6	0.6	3.93
Stand fan	75	4	0.3	1.96
Vacuum	1220	1	1.22	8.00

Table 8: Relationship between selected electricity appliances and electricity consumption

	Total consumption	Refrigerator	Microwave	Washing machine	Rice cooker	TV
Total consumption	1					
Refrigerator	0.492**	1				
Microwave	0.094	−0.014	1			
Washing machine	0.302**	0.026	0.201**	1		
Rice cooker	0.138**	−0.019	0.124	0.301**	1	
TV	0.389**	0.170**	0.121	0.192**	0.111**	1

**Significant level at 0.01, *Significant level at 0.05

Table 9: Relationship between selected electricity appliances and electricity consumption

	Total consumption	Fluorescent lamp	Bulb	Air conditioning	Ceiling fan	Stand fan	Vacuum
Total consumption	1						
Fluorescent lamp	0.458**	1					
Bulb	0.317**	0.193*	1				
Air conditioning	0.807**	0.295**	0.120	1			
Ceiling fan	0.460**	0.381**	0.115	0.204**	1		
Stand fan	0.154*	0.159*	0.255**	0.048	0.247**	1	
Vacuum	0.262**	0.235**	0.142	0.135	0.169*	0.145	1

**Significance level at 0.01, *Significance level at 0.0

stand fan will cost RM1.96/month. This is because both appliances were not used frequently in Seremban and there is an option for households to use or not to use those appliances.

3.3. The Relationship between Appliances and Total Electricity Consumption

The study revealed the relationship between electrical appliances and total electricity consumption as shown in Tables 8 and 9. Pearson correlation indicated a significant relationship between total electricity consumption (kWh/month) and refrigerator ($r = 0.492$), washing machine ($r = 0.302$), rice cooker ($r = 0.138$), television ($r = 0.389$), fluorescent lamp ($r = 0.458$), bulb ($r = 0.317$), and vacuum ($r = 0.262$) at the significance level of 0.01. The study also revealed strong correlation between cooling appliances and total electricity consumption such as air conditioning ($r = 0.807$) and ceiling fan ($r = 0.460$) at significance level of 0.01 and a significant relationship between total electricity consumption (kWh/month) and stand fan is $r = 0.154$ at significance level of 0.05. The significant also found in Hangzhou, Saudi Arabia, Brunei and Taiwan (Chen et al., 2013; Aldossary et al., 2015; Ahmad, 2015; Chen, 2017).

Most of the electricity consumption data at the city level are very limited or absent especially for cities and suburban scale in developing and third world countries (Eggleston et al., 2006). Thus, this work has contributed to the data at a city level and is beneficial for urban planners and the government to better plan towards sustainable urban development.

4. CONCLUSION

This work has demonstrated electricity consumption and its relationship with electrical appliances ownership. It is undeniable that human factors contributed to the high electricity consumption in urban areas through the use of inefficient electrical appliances and a lack of knowledge and awareness of electricity consumption. In order to minimize the usage of electricity, this study suggests that electricity consumption for heating and cooling should be reduced because the major electricity consumption globally is dominated by heating and cooling appliances. We believe that using more energy-saving appliances and changing energy consumption behavior could reduce energy consumption. Therefore, energy consumption should be monitored and managed wisely to achieve sustainable development goals in urban areas. Energy efficiency labeling is one of the important tools to educate and enhance awareness level among users about electrical appliances consumption. However, only 4 appliances (refrigerator, television, domestic fan and air conditioner) were categorized under this scheme. Therefore, government also should consider other products as well especially appliances with high power watt because these appliances consume more electricity compared to other appliances. We also suggest that campaign or seminar on sustainable energy consumption should be intensified in order to gaining the knowledge and awareness among user. Although there are a few programs and incentive from the government, it would not successful if there is no involvement and support from the people. Hence, the user should consider reducing the electricity consumption and changing the behavior and lifestyle in order to minimizing carbon emissions in urban area towards sustainable urban development in Malaysia.

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