© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJIE

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN: 2229-838X e-ISSN: 2600-7916

The International Journal of Integrated Engineering

Energy Consumption Pattern of Residential Buildings: Case Study of Residential Area in Batu Pahat, Johor

Junaidah Jailani[1*], Norsyalifa Mohamad[1], Muhammad Amirul Omar[1], Ali Hauashdh[1], Nor Haslinda Abas[1]

[1]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA

DOI: https://doi.org/10.30880/ijie.2020.12.09.007
Received 24 January 2020; Accepted 07 May 2020; Available online 18 December 2020

Abstract: According to the National Energy Balance report released by the Energy Commission of Malaysia in 2016, the residential sector uses 21.6% of the total energy in Malaysia. Residents waste energy through inefficient energy consumption and a lack of awareness. Building occupants are considered the main factor that influences energy consumption in buildings, and to change energy consumption on an overall scale, it is crucial to change individual behaviour. Therefore, this study focused on analysing the energy consumption pattern and the behaviour of consumers towards energy consumption in their homes in the residential area of Batu Pahat, Johor. A self-administrated questionnaire approach was employed in this study. The findings of this study showed that the excessive use of air conditioners was a significant factor in the increasing electricity bills of homeowners as well as the inefficient use of electrical appliances. Also, this study determined the effect of awareness on consumer behaviour. This study recommends ways to help minimise energy consumption in the residential area.

Keywords: Energy consumption, residential area, saving energy, consumer behaviour

1. Introduction

A residential building needs energy for heating, cooling, lighting and operating appliances. Electricity is an essential element in a building's operating system, since all facilities operate on electricity supply. The absence of electricity can affect household activities and people's needs. Therefore, increasing energy consumption is one of the most relevant concerns that current societies are facing [1]. The inefficient use of electricity can have a negative impact on the environment and on humans. With the increasing consumption of energy, carbon dioxide (CO_2) emissions have increased dramatically. CO_2 emission in Malaysia has increased by 221%, which lists the nation at 26th among the top 30 greenhouse gas emitters in the world [2].

In addition, population growth, ever-increasing personal comfort levels and daily appliance use are driving domestic electricity demand to higher levels. The increase in population leads to the increase of energy consumption and more resources are needed to supply the energy. For this reason, consumer behaviour towards energy consumption is critical. Building occupants are considered the main factor that influences energy consumption, and in order to change energy consumption on an overall scale, it is vital to change individual behaviour [3]. Therefore, this study focused on analysing the energy consumption pattern and the behaviour of occupants towards energy consumption in their homes in the residential area of Batu Pahat, Johor.

2. Energy Consumption

Energy is a fundamental ingredient of modern society and its supply directly impacts the social and economic development of nations. It cannot be created or destroyed, but it can be transformed from one form to another, and the total amount of energy in the universe is always the same. Primary energy sources take many forms including nuclear,

*Corresponding author: junaida@uthm.edu.my

fossil (oil, coal and natural gas) and renewable sources (wind, solar, geothermal and hydropower) [4]. These sources are converted to electricity, a secondary energy source, which flows through power lines and other transmission infrastructure into houses. When electricity is used in homes, electrical power is generated by burning coal, by a natural gas, by a nuclear reaction or by a hydroelectric plant on a river.

Energy generation in Malaysia depends on three primary fossil fuel sources: coal, natural gas and fuel oil. Fossil fuel-based power generation has negative environmental consequences and leads to the depletion of fuel reserves [5]. In Malaysia, electricity is produced by Tenaga Nasional Berhad (TNB) for Peninsular Malaysia, Sabah Electricity Sdn. Bhd. (SESB) for the Sabah area, Sarawak Electricity Supply Corp. (SESCo) for the Sarawak area and Independent Power Producers (IPPs).

Population growth, increasing personal comfort levels and daily appliance use are driving domestic electricity demand to higher levels. Some studies of energy consumption investigate how and why individuals consume energy and how this affects society and the environment [5]. Table 1 shows energy consumption by various sectors in Malaysia according to National Energy Balance, 2016 [6]. The residential sector consumes 21.6% of the total energy with a sum of 31,128 GWh.

Table 1 - Energy Consumption by Various Sectors, GWh in 2016 [6]

Sector	Energy Consumption	
	GWh	%
Industry	67,664	47.0
Commercial	44,349	30.8
Residential	31,128	21.6
Transport	340	0.4
Agriculture	543	0.2
Total	**144,024**	**100**

Electricity consumption has been increasing with growing residential sectors as well as greater dependence on electric appliances such as refrigerators, washing machines, air conditioning, water heaters, lighting and entertainment products. Table 2 shows the distribution of Malaysia's energy consumption by residential sector according to National Energy Balance, 2016. Peninsular Malaysia has the highest percentage of energy consumption (87.1% and 27,119 GWh).

Table 2 - Energy Consumption by Residential Sector, GWh in 2016 [6]

Region	GWh	Energy Consumption%
Peninsular Malaysia	27,119	87.1
Sarawak	2,178	7.0
Sabah	1,831	5.9
Total	**31,128**	**100**

3. Occupant Behaviour Towards Energy Consumption

Over the past years, the assessment of energy demand and usage in buildings has become increasingly acute in response to climate change and rising scientific and political pressure around the world. Occupant behaviour refers to their engagement in activities that affect the energy consumption in their buildings. Activities affecting energy consumption include opening windows, using solar shading and blinds, adjusting air conditioner setpoints, using hot water, etc. [7]. One of the most influential contributions to high rates of energy intensity is how occupants use energy [8]. Therefore, occupant behaviour is a significant factor that influences energy consumption in buildings and should be investigated.

4. Methodology

Research methodology needs to be arranged systematically to achieve the aim of this study. Thus, this study has adopted a self-administrated questionnaire approach to identify the energy consumption of the residential area at Kampung Kenangan Dato Onn 2, Batu Pahat, Johor, Malaysia, as shown in Fig. 1. Kampung Kenangan Dato Onn 2 has been selected as a case study because it is the oldest and biggest arranged residential area in Batu Pahat. There are 85 houses in Kampung Kenangan Dato Onn 2. The houses in the area are old low-cost single-storey terrace house with closed design layout on 23’ x 75’ land. Based on the location and the design of the houses, the typical enegy consumption of most old low cost single-storey house with minimum design in Batu Pahat can be discovered. The questionnaire has

been submitted by hand to all 85 houses representatives. There were a total of 60 respondents response to the questionnaire, each representing one house in the residential area. The questionnaire consisted of demography, ownership level of electrical appliances, household behaviours towards energy consumption, awareness towards the use of electrical energy and knowledge of electricity waste factors. These were the five main categories of questions that were asked and that would cover the aspects meeting the set objectives. It included Likert scale measurement and multiple-choice answers. It was designed in such a way that only concise answers were required. The five sections are described below.

Section A was labelled 'Demographics Information' and listed variables consisting of general information on respondents. Section B was labelled 'Ownership Level of Electrical Appliances' and listed 18 common electrical appliances used at home such as televisions, refrigerators, lamps, fans, air conditioners, etc. Section C was labelled 'Behaviour of Households towards Energy Consumption' and consisted of four questions with multiple-choice answers. This section indicates the time respondents spend at home and their behaviour towards the use of electrical appliances**.** Section D was labelled 'Awareness towards Energy Consumption' and included five items with a Likert scale. Section E was labelled 'Knowledge of Factors that Contribute to Energy Waste'. Ten items were listed with a Likert scale. Behaviour items were measured by the Likert scale as follows: Very frequently = 1, Frequently = 2, Occasionally = 3, Rarely = 4, Very Rarely = 5. Awareness items were measured by the Likert scale as follows: Strongly disagree = 1, Disagree = 2, Slightly agree = 3, Agree = 4 Strongly agree = 5.

Data analysis was conducted in a clear way to understand the results of the questionnaire. Tables, diagrams and charts taken from the Statistical Package for the Social Sciences (SPSS) software were used to analyse and display these results.

Fig. 1 - Location of the Residential Area

4. Results and Discussion

4.1 Demographic Information

The majority household size was four people. From the 60 respondents that completed the questionnaires, 25 are male (41.67%) and 35 are female (58.33%). In terms of home status, 93.33% are owners and 6.67% are tenants. Most of the respondents (40%) have an income of between RM2,001–RM3,000, followed by the income group of RM1,001–RM2,000 (23.33%). The RM1000 income group ranked third with 16.67%. The minority of the respondents have an income of over RM5000 per month (1.67%). This result is considered logical as most of the respondents are above 50 years old and the residential area is considered low-cost.

4.2 Usage of Household Appliances

Fig. 2 indicates the ownership level of electrical appliances surveyed. As shown, 18 types of electrical appliances were analysed during this study: refrigerators, televisions, lamps, fans, mobile chargers, irons, rice cookers, blenders, washing machines, electric kettles, air conditioners, vacuums, toasters, computers, Wi-Fi modems, hairdryers, ovens, and microwaves. Respondents own at least one unit of the first nine items: refrigerator (100%), television (100%), lamp (100%), fan (100%), mobile charger (100%), iron (100%), rice cooker (96.7%), blender (96.7%) and washing machine

(96%). Additionally, 76.7% of households have an electric kettle. The least-owned electrical appliance is a microwave (15%). All respondents have the first six items in their home, as stated in the chart; these items are considered a requirement for their households. The least percentage of ownership level is for microwaves because they are not a necessary home appliance.

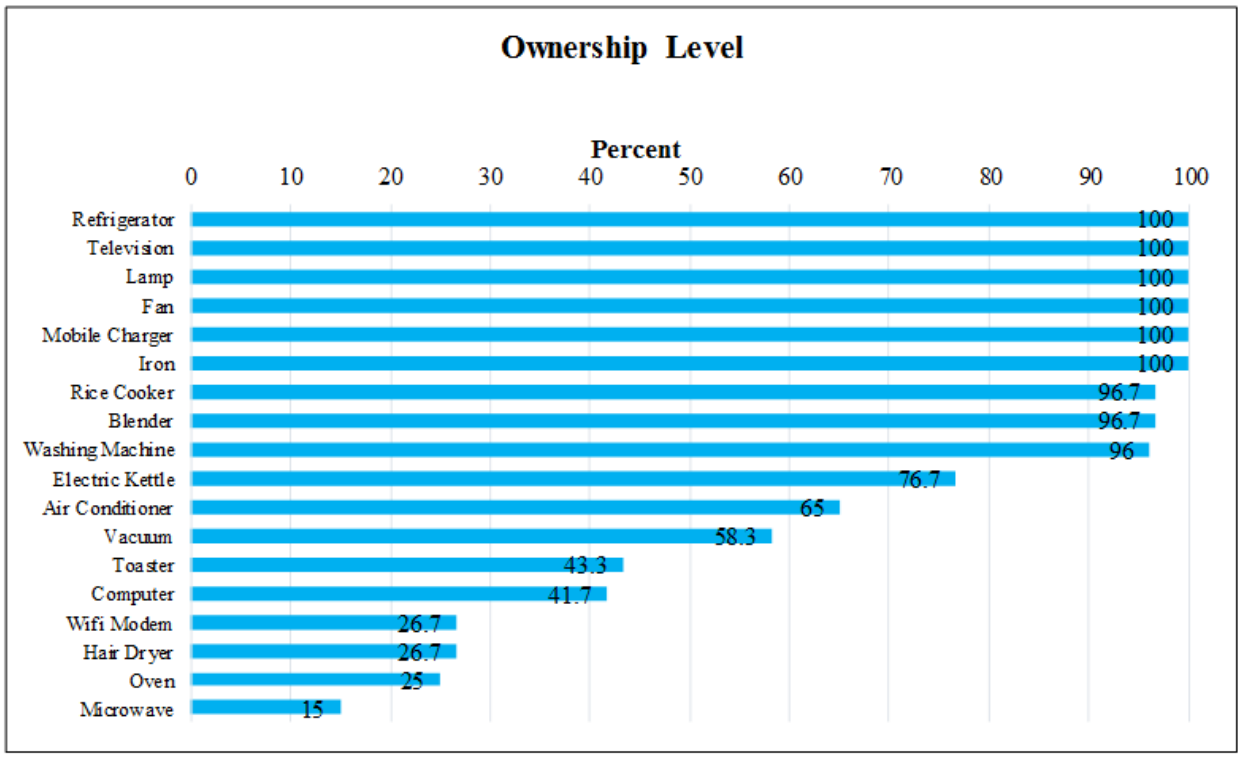

Fig. 2 - Ownership level of electrical appliances

4.3 Electricity Consumption Analysis

The electricity consumption cost per household depends on several variables: the number of occupants, economic background and type of electrical appliances. The measurement of energy consumption can be calculated by multiplying the power (watt) and hours of operation by 30 days [9]. The result is divided by 1000, as given in Eq. (1) below:

$$\text{Electricity Consumption (kWh)} = \frac{\text{Power (Watt)} \times \text{Hours of operation} \times 30 \text{ days}}{1000} \quad (1)$$

Electricity bills from each respondent were collected during the questionnaire distribution. The energy consumption categories for this study were divided into five groups: 1–200 kWh, 201–300 kWh, 301–600 kWh, 601–900 kWh and above 901 kWh. The chart shows that the highest energy consumption per month was 45% for the 201–300 kWh group, followed by 301–600 kWh with 25%, 1–200 kWh with 18.33%, 601–900 kWh with 8.33% and above 901 kWh with 3.33%. Fig. 3 shows the distribution of average energy consumption by group. The highest in energy consumption represented almost half of the total respondents participating in this study, with 27 respondents in the 201–300 kWh group. The lowest was in the group above 901 kWh. Energy consumption depends on the type of electrical appliances used by occupants and the occupants' level of awareness about the efficient use of electricity [7], [8].

4.4 Usage Pattern of Cooling Appliances

In order to analyse the behaviour of respondents towards energy consumption, respondents' actions when they feel uncomfortable at home were studied. Fig. 4 shows the distribution of actions taken by respondents when they feel unconformable with the indoor air quality. Based on the chart below, 29 respondents change the setting of their air conditioner to a temperature they feel comfortable with (39 respondents have at least one air conditioner in their home), followed by 17 respondents that switch on the fan. In summary, the respondents' behaviour shows that they use electrical appliances to comfort themselves. This type of behaviour contributes to an increase in energy consumption and monthly utility bills [7], [8].

According to the data, 21 out of 60 respondents have no air conditioner at home while 39 respondents have at least one. Out of 39 respondents, 19 use the air conditioner for 11–15 hours daily, followed by 20 respondents who use it for 16–20 hours daily. Based on the study, the 39 respondents turn on their air conditioner in the afternoon during a sunny day and at night while they sleep to increase their comfort level. Out of 39 respondents, 9 of them stated that 21ºC is their usual temperature setpoint, followed by 25ºC with 5 respondents. A lower temperature setpoint contributes to an increase in energy consumption; an air conditioner with a setpoint temperature of 16ºC consumes more energy than when its temperature is at 20ºC. Respondents who do not have an air conditioner at home also use electrical appliances (such as a fan) to make themselves comfortable.

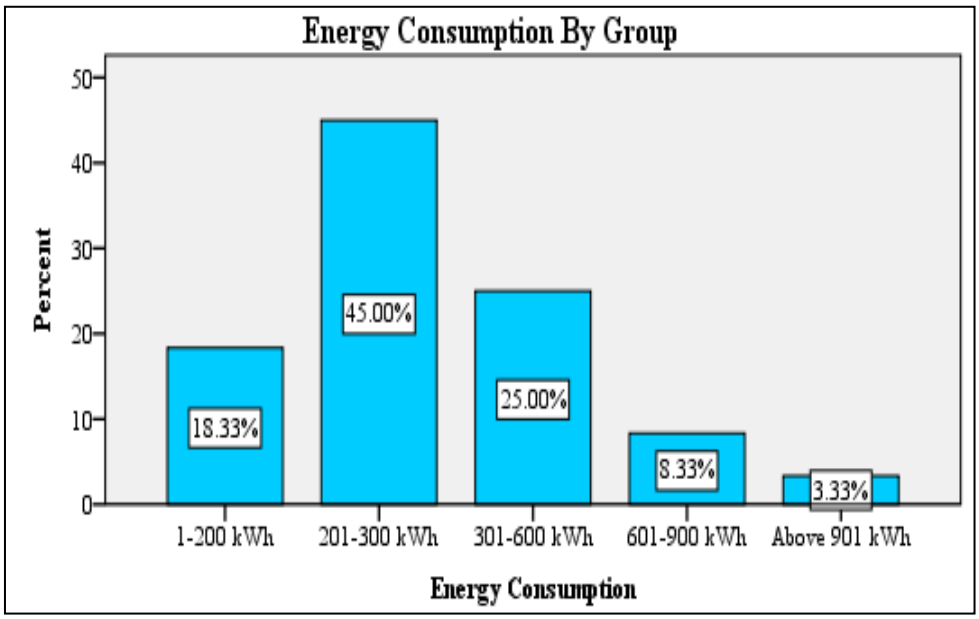

Fig. 3 - Energy consumption by group

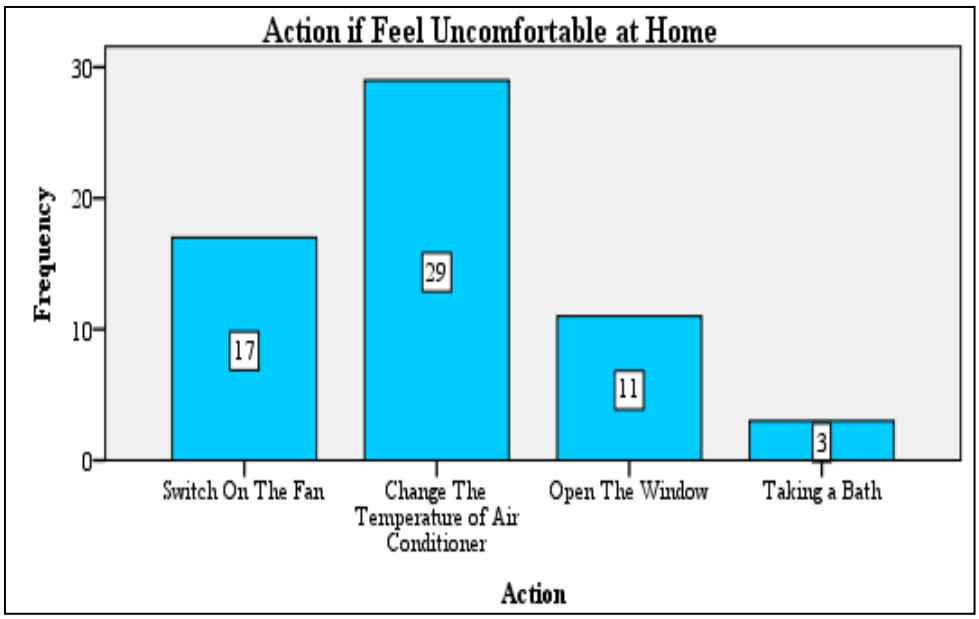

Fig. 4 - Respondents' action with uncomfortable indoor air quality

4.5 Consumer Awareness and Behaviour

Table 3 shows the mean score for the measurement items on respondents' behaviour and awareness towards electricity use in their homes. According to Table 3, the average mean score of behaviour items was between 4.17 to 4.48, which represents occupants' behaviours that contribute to the use of electricity. The findings indicate that the

occupants' behaviours did not contribute to energy waste in their home. The findings of the awareness measurement items were between 3.98–4.18, which indicate that the respondents were aware of the importance of minimising energy consumption. In conclusion, awareness of energy waste affects consumer behaviour, which helps the respondents use energy efficiently [10].

Table 3 - Mean Score for Behaviour and Awareness

	Items	N	Mean
Behaviour	- I do not unplug the socket after use	60	4.48
	- I iron clothes every day	60	4.18
	- I do not turn electrical appliances off after use	60	4.30
	- I wash clothes using the maximum water level	60	4.18
	- I use electrical appliances that do not have a star rating level	60	4.30
	- I leave the light on while sleeping	60	4.25
	- I use an electric kettle to heat the same water repeatedly	60	4.17
	- I turn the lights on during the day	60	4.22
	- I set the air conditioners to cool temperatures at night	60	4.35
	- I let the cell phone charge throughout the whole night	60	4.27
Awareness	- I consider electricity waste a serious problem	60	4.13
	- I intend to begin using electrical appliances with a star rating level	60	4.03
	- I promote awareness of energy efficiency to my children	60	4.13
	- I review the electricity bill every month	60	4.18
	- It is important for me to find out how to calculate energy consumption through billing	60	3.98

A Pearson correlation was used to determine the relationship between consumer behaviour and awareness of factors that contribute to electricity waste in respondents' daily lives. There was a statistically significant positive correlation ($r=0.322$, $n=60$, $p<0.01$), as shown in Table 4. This correlation means that increasing the awareness level among consumers positively affects their behaviour and results in more effective energy consumption and better uses of electrical appliances.

Table 4 - Correlation between Behaviour and Awareness of Electricity Waste Factors

Correlation			
		Behaviour	**Awareness**
Behaviour	Pearson Correlation	1	0.332**
	Sig. (2-tailed)		0.008
	N	60	60
Awareness	Pearson Correlation	0.332**	1
	Sig. (2-tailed)	0.008	
	N	60	60

** Correlation is significant at 0.01 Level (2-tailed)

5. Conclusion

This study focused on the analysis of electricity billing, the use of electrical appliances by occupants and the relationship between consumer awareness and behaviour. This study specifically examined the behaviour of respondents

regarding energy consumption while using cooling appliances such as air conditioners and fans. Overall, the use of air conditioners is one of the main factors that contributes to the increasing monthly electricity bills. Also, most respondents choose to use electrical appliances to increase their comfort level rather than other alternatives that do not need electrical energy. There was a statistically significant positive correlation between awareness and consumer behaviour. Based on the findings of this study, the way to minimise energy consumption in a residential area can be summarised in two fundamental recommendations:

- Motivation among the residents should be promoted to increase their awareness of the uses of electrical appliances.
- An energy management system that helps residents estimate energy consumption by appliance should be developed.

Acknowledgement

This work was supported by Postgraduates Research Grants (GPPS) No. H293, H383 and TIER 1 No. H187 as Graduated Research Assistant (GRA). The authors would like to thank the Faculty of Civil Engineering, Built Environment and Universiti Tun Hussein Onn Malaysia for supporting this study.

References

[1] Pu, Q. and Li, B., 2011, June. Impact factors analysis of residential buildings' energy consumption in Huainan. *In 2011 International Conference on Remote Sensing, Environment and Transportation Engineering*, pp. 1278-1281

[2] Hassan, J.S., Zin, R.M., Majid, M.A., Balubaid, S. and Hainin, M.R., 2014. Building energy consumption in Malaysia: An overview. *Jurnal Teknologi*, 70(7)

[3] Chik, N.A., Rahim, K.A., Radam, A. and Shamsudin, M.N., 2013. CO2 Emissions Induced by Households Lifestyle in Malaysia. *International Journal of Business and Society*, 14(3), p.344

[4] Zhou, Kaile, and Shanlin Yang. "Understanding household energy consumption behavior: The contribution of energy big data analytics." *Renewable and Sustainable Energy Reviews* 56 (2016): 810-819

[5] Samsudina, M. S. N., Rahman, M. M., & Wahidc, M. A, 2016. Power Generation Sources in Malaysia: Status and Prospects for Sustainable Development. *Journal of Advanced Review on Scientific Research*, Vol. 25, No.1. PP, 11-28

[6] National Energy Balance, 2016. [Online, Accessed on 2016]

[7] Delzendeh, E., Wu, S., Lee, A., & Zhou, Y. (2017). The impact of occupants' behaviours on building energy analysis: A research review. *Renewable and Sustainable Energy Reviews*, 80, 1061-1071

[8] Tam, V. W., Almeida, L., & Le, K. (2018). Energy-related occupant behaviour and its implications in energy use: A chronological review. *Sustainability*, 10(8), 2635

[9] Rahman, K. A., A. M. Leman, M. Faris Mubin, M. Z. M. Yusof, Azian Hariri, and M. N. M. Salleh. "Energy Consumption Analysis Based on Energy Efficiency Approach: A Case of Suburban Area." *In MATEC Web of Conferences*, vol. 87, p. 02003. EDP Sciences, 2017

[10] Vassileva, I., & Campillo, J. (2014). Increasing energy efficiency in low-income households through targeting awareness and behavioral change. *Renewable energy*, 67, 59-63