Energy Consumption Analysis Based on Energy Efficiency Approach: A Case of Suburban Area

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Abstract. Sufficient data about electricity consumption over large periods of time was accumulated and analysed in order to develop appropriate electricity-saving measures. An important first step was to analyse and identify electrical appliances that had energy saving potential. Different behavioural consumption profiles were analysed using information from two sources: 1) technical data about electricity consumption (electricity bill) and 2) data about household electrical appliance usage and consumer awareness obtained from a questionnaire survey. The questionnaire consisted of four sections of questions which concerned residents' backgrounds, residential information, consumers' awareness about energy efficiency (EE) and the energy usage of each house. The results showed that the electricity consumption profile of an individual household could be most related to the EE approach. It indicated that consumers' behaviour (awareness and practice) resulted in one of the important factors related to high electricity consumption. Another important conclusion of our questionnaire-based analysis was that the implementation of the EE approach could help the consumer to reduce their monthly energy consumption.

1 Introduction

Energy consumption in the residential sector represents an important part of total electricity demand. Most consumers are not alert about how to use energy efficiently in their daily lives. In other words, consumers use electric energy inefficiently because they use inefficient electrical appliances. Saving electricity requires either conserving or improving efficiency. Conserving means performing fewer activities that use electricity. Improving energy efficiency (EE) is about choosing the right appliances which use less energy for the same tasks. From the questionnaire, it can be seen that consumers did not understand the high power consumption that occurs via their electrical appliances [1]. Based on a 2013 report by the Energy Commission of Malaysia, 20.6% of electricity usage was by domestic users [2]. There are about 7.8 million registered electricity consumers with Tenaga Nasional Berhad (TNB), the largest electricity utility in Malaysia. Effective from 1st January 2014, TNB's tariff remained unchanged at 21.8 cents/kWh for the first 200kWh of consumption per month, therefore there are nearly 50.4% (or 3.25 million) of all domestic users who pay RM43.60 or less monthly [3]. On average, domestic customers will experience an increase of 10.6% (3.03 cent/kWh). Figure 1 shows the distribution of electricity users in Peninsular Malaysia and of the total 7.8 million, 82% are domestic users (6.4 million). The rest of the users are thus divided up: 17 % commercial, 0.4% industrial, and 0.6% other
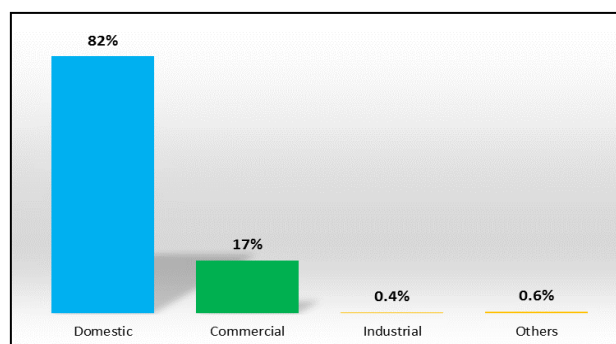
types [4].

Figure 1. Distribution of Electricity Users in Peninsular Malaysia

The increase in the number of residential area development projects has had a great impact on national development, but it has also increased energy demand. By making households more energy efficient, the negative impacts on the environment can be reduced.

The internationally recognized energy star symbol is a simple way for consumers to identify the most energy-efficient electrical products on the market. Devices carrying the energy star service mark, such as computer

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products and peripherals, kitchen appliances, buildings and other products, generally use 20–30% less energy than required by federal standards [5]. In this study, the energy consumption of electrical appliances for a household will be analysed in order to identify the energy consumption pattern for residential area involved. Furthermore, this study aims to identify the relationship between two components of energy awareness: awareness and practice towards the increased energy bill at home. The recommendation and solution will be proposed at the end of this study to help consumers to reduce the energy consumption.

2 Energy Efficiency Standards & Labelling (S&L)

EE standards are a set of procedures and regulations that prescribe the energy performance of manufactured products, sometimes prohibiting the sales of products that are less energy efficient than the minimum standards [6]. This actually means an efficiency level set of standards must be met by the appliance manufacturer in order to sell the products. EE standards can be mandatory or voluntary, which means they can be in the form of a minimum allowable EE or a maximum allowable energy use. Prescriptive standards, minimum energy-performance standards (MEPS), and class-average standards are types of energy standards [7]. Energy labels as shown in Figure 2 are informative labels to describe the manufactured product's energy performance in the form of energy use, efficiency, or energy cost. [8]. The labels properly furnish consumers with the knowledge to buy more efficient appliances. The EE label is meant to be issued by the Energy Commission to manufacturers of electrical appliances who comply with the standards and requirements of the energy performance test for a star rating established by the Energy Commission [9].
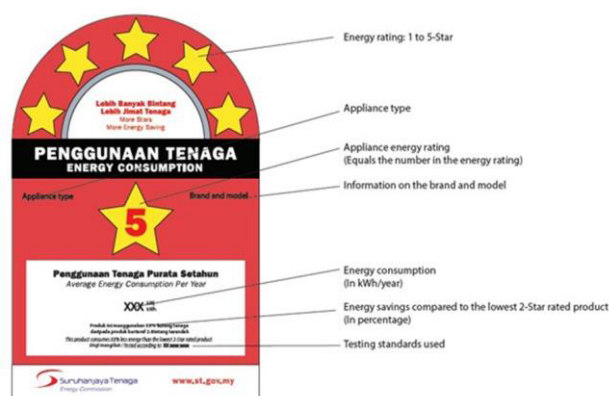

Figure 2. Energy Star Rating in Malaysia

EE labels encourage people to buy more efficient products by helping them to understand and compare how much energy is used. Mahlia [10] highlighted that the purpose of introducing energy star labels is to convince consumers to buy EE appliances. At the same time, it is also to influence manufacturers to produce more EE

products into the market. A label is a mandatory sticker that is affixed to products or their packaging containing information about the EE or EC of the product. The three types of labels that are currently in use in various countries are endorsement, comparison and a combination of both [11,8]. In Malaysia, with the regulations in place, the five domestic appliances (domestic fans, domestic lamps, air-conditioners, refrigerators, and televisions) will be issued with a Certificate of Approval (COA) by the Energy Commission Malaysia. The star rating ranges from 2-star to 5-star, with 2-star representing minimal efficiency and maximum efficiency represented by the 5-star label [8].

2.1 Energy Star Rating

The demand for energy in Malaysia is influenced by many factors such as population and economic growth. Energy consumption usually varies from one sector to another. In the domestic sector, household electrical appliances are one of the biggest energy consumers in Malaysia. Based on the ninth Malaysia Plan, residential and commercial sectors contributed about 12.8% of the total energy demand in 2012 [12], which shows that the authorities are already taking action to reduce energy consumption in this country [12, 13]. Implementing the Energy Star Rating will help consumers to purchase efficient electrical home appliances, which will bring many more advantages to the country, manufacturers, consumers, and environment [14, 15].

The Energy Star Rating is a program that was first developed in 1992 by the US Environmental Protection Agency (EPA) as a method to identify and promote products that are energy efficient. According to TNB [4], the benefits of 5-star appliances include reduced domestic electricity consumption and electricity bills. This will in turn produce increased disposable household income in the long run, which will improve the quality of life. Advantages of using 5-star appliances include:

i. Better savings in the long run.
ii. Reduced carbon footprint from electricity generation.
iii. Improved quality of life with more efficient appliances.

Research and development are still ongoing, as manufacturers strive to deliver low-cost energy efficient products. A major appliance which sports the energy star label is not necessarily a better product than a comparable model, but in order to be rated with an energy star, it must meet very strict energy efficiency guidelines as set out by the program.

Energy guide ratings for appliances will show their typical usage in kWh per year - the lower the energy number, the more cost efficient it is to run. Appliances carrying the Energy Star Rating are typically 10 to 20% more energy efficient than non-rated models [16].

3 Methodology

For this study, the level of energy consumption among the households was found by obtaining electricity bills and distributing a questionnaire. Figure 3 shows the flow chart for this study.
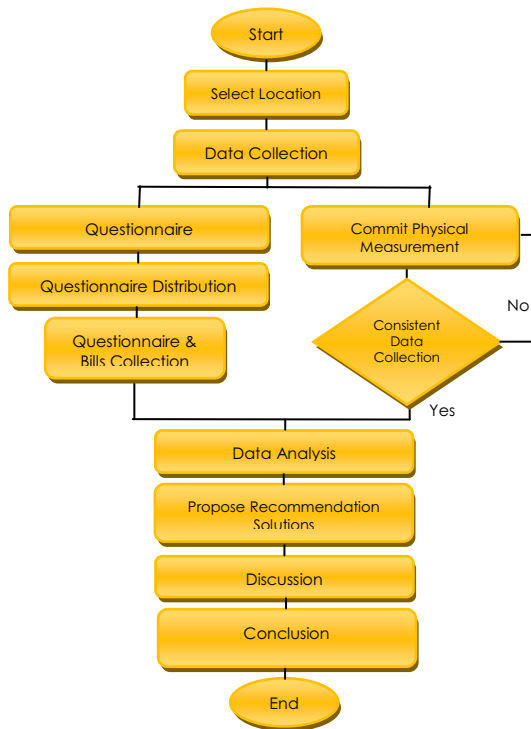

Figure 3. Flowchart of the Study

The process started with location selection, followed by data collection, which was divided into two parts – the distribution of a questionnaire and the collection of three months worth of household electricity bills. The questionnaire was developed. Questions developed based on a literature review and verified by experts. After data collection was successfully carried out, the data were analysed using the SPSS (Statistical Package for Social Science). The next step was the discussion and proposal of a solution. The last part of the study was the final discussion and conclusion.

3.1. Study Case Location

This study was located in Parit Raja, Batu Pahat, Johor which is a suburban area. The purpose of the study was to analyze the level of energy consumption among the residents in the area. The reason a suburban area was selected for this study was to help the residents to manage their energy consumption by using the EE approach. This application will help them to reduce their monthly electricity bills and also raise the environmental awareness level among consumers.

3.2 Questionnaire Survey and Electricity Bills

A questionnaire was distributed to survey the consumers' awareness of EE. Meanwhile, electricity bills were collected to obtain, analyse, compare and classify the total energy consumption of every household studied according to their use of Energy Star Rating appliances. Houses involved were divided into three main groups of energy consumption (kWh). Electricity bills of all houses studied were taken over three continuous months. The Pearson's Correlation and mean score analysis were used to survey consumer awareness of the EE approach.

3.3 Electricity for Domestic Consumers

The voltage used in Malaysia is 230/240 volts - 50 Hz. In Malaysia, most households use a single-phase system rather than a three phase one. Households receive their power supply through a two-wire single-phase 240V from three-phase distribution system provides 415V through the connection at neutral wire and one wire from three wires phases. Figure 4 shows the simple flow of electricity in a domestic household.
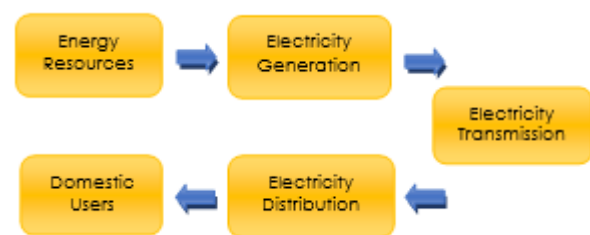

Figure 4. Flow of Electricity in a Domestic Household

3.3.1 Electricity Tariff

The cost of electricity from generation to distribution before reaching the end user will be translated into a tariff. The current tariff for domestic consumers is shown in Table 1 [3]:

Table 1. TNB's Electricity Tariff for Domestic Households

Tariff Category	Unit	Current Rate (1 Jan 2014) (Malaysian Ringgit - MYR)
Tariff A - Domestic Tariff		
For the first 200 kWh (1 - 200 kWh) per month	cent/kWh	21.80
For the next 100 kWh (201 - 300 kWh) per month	cent /kWh	33.40
For the next 300 kWh (301 - 600 kWh) per month	cent /kWh	51.60
For the next 300 kWh (601 - 900 kWh) per month	cent /kWh	54.60
For the next kWh (901 kWh onwards) per month	cent /kWh	57.10
**The minimum monthly charge is MYR3.00		

The monthly electricity usage was based on actual meter readings performed at the households. The average consumption was then multiplied by the billing period

and the applicable tariff rates to determine the total bill amount. Multiply the rate depends on unit of energy use.

3.3.2 Utility Bill Analysis

The electricity consumption cost per household depends on several variables, including family size, economic background, type of housing, number and age of electrical appliances and hours of usage. Customers can calculate the estimated electricity cost for different appliances using the power rating of the electrical appliance and its efficiency, usage by number of hours and the domestic tariff rate per kilowatt hour (kWh) [4].

3.3.3 Measurement of Energy Consumption

The measurement of energy consumption can be calculated by multiplying the power (watt) and hour of operations together with 30 days. The result will be divided by 1000. The equation is as below:

Electricity Consumption (kWh) :

$$\frac{Power\ (Watt)\ x\ Hours\ of\ Operation\ x\ 30\ days}{1000} \qquad (1)$$

** $kW = kilowatt$
$h = Hour$

4 Result and Discussion

4.1 Energy Consumption

Energy consumption categories for this study were divided into three main groups; energy consumption between 0-200 (kWh) (MYR0-MYR43.60), between 201-300 (kWh) (MYR43.90-MYR77), and above 300 (kWh) (above MYR77). Figure 5 shows the distribution of energy consumption by group.
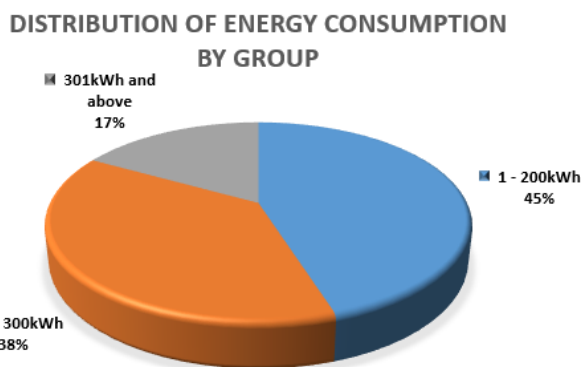

Figure 5. The Distribution of Energy Consumption by Group for All Residents

The graph shows that the energy consumption of 45% (32 respondents) of the 71 respondents was between 1-200kWh per month, followed by 201-300kWh per month

used by 27 respondents, and finally, above 300kWh per month used by 12 respondents.

From the calculations, it was found that the average energy consumed by each household was about 237kWh per month. According to the report by the Association of Water & Energy Research Malaysia (AWER) [17], about 50% of consumers in Malaysia use less than 200 kWh of electricity per month. This statistic has increased in line with the improved economic status of each family. According to the Ministry of Energy, Green Technology and Water (KeTTHA) [18], 75% or 4.4 million domestic consumers used electricity at the rate of 300 kWh per month or less and of the total, 900,000 were low-income earners, while 200,000 comprised the poor population. Therefore, EE could be one of the solutions to help consumers to reduce their energy consumption every month [17]. In this study, the data was analysed by graph to show the energy consumption over three months and the difference in energy consumption between months for each group.
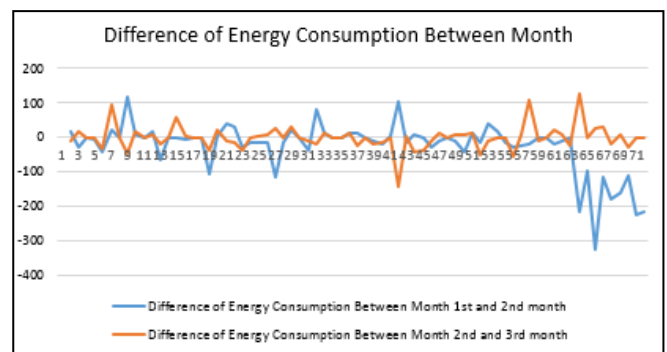

Figure 6. The Difference of Energy Consumption Between Months for All Residents

The graph in Figure 6 shows the difference in energy consumption between months for all participating households. The positive value in this graph means a decrease in energy consumption while the negative value means an increase in energy consumption between months. The results show the highest increase in energy consumption was 325kWh while the highest decrease of energy consumption was 115kWh in between the first and second months. For the second and third months, the results show the highest increase was 143kWh while the highest decrease was 126kWh.

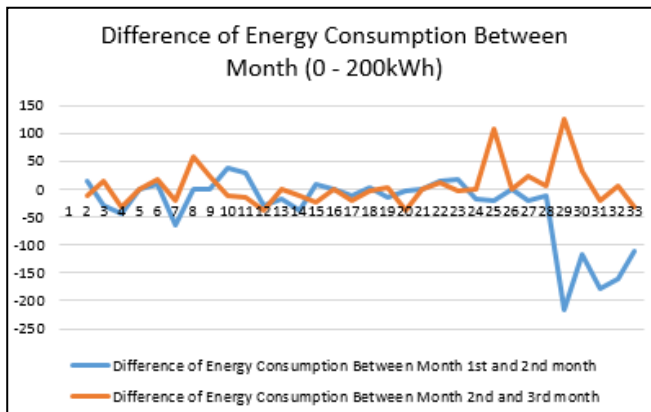### 4.1.1 Group of Energy Consumption 1-200 (kWh)

Figure 7. The Difference in Energy Consumption Between Months for Group of Energy Consumption 1-200 (kWh)

Figure 7 shows 32 residents had a total energy consumption of between 1-200kWh (costing from MYR3 to MYR43.60) This group represented almost half of the total homes participating in this research. Examining the difference in energy consumption between the first and second months, the highest increase was 215kWh while the highest decrease was 38kWh. The highest increase between the second and third months was 38kWh and the highest decrease was 126kWh.

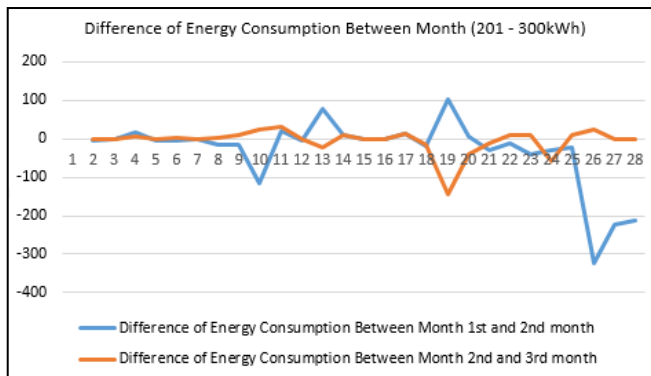### 4.1.2 Group of Energy Consumption 201-300 (kWh)

Figure 8. The Difference of Energy Consumption Between Months for Group of Energy Consumption 201-300 (kWh)

Figure 8 shows the results for the group with the energy consumption of between 200-300 (kWh). 33.8% of the total 71 residents who participated fell into this group. The total energy demand for all residents in this group for three months was 20,328kWh. The highest increase of energy usage in this group was 325kWh. This reading was dramatically increased from the previous bill (65kWh to 390kWh). This situation may be due to the installation of new high energy electrical appliances such as air conditioners or refrigerators. Meanwhile, between the first and second months' energy consumption, the highest decrease amongst respondents was only 18kWh which was the lowest decrease among all the groups. On the other hand, between the second and third months, the

highest increase was 143kWh and the highest decrease was 25kWh, and the lowest energy usage was in this group (3.41%). In this group, three residents did not show a significant change in energy consumption between months. This is because their energy usage was consistent throughout the months.

4.1.3 Group of Energy Consumption 301 (kWh) and above

Figure 9 shows the difference between the energy consumption in the first to second months and the second to third months for households with energy consumption of 301 (kWh) and above. The highest increment from the first to the second month was 105kWh where for the first month the energy usage was 428kWh and in the second month it was 533kWh. For the second to third month, the highest increase was 50kwh while seven residents from this group decreased their energy usage from the previous month with the highest decrease of 95kWh. The lowest energy cost in this group was RM 77.00 and this consumer had to spend more money on their electric bill. In Malaysia, if the energy consumption is more than 300kWh per month, the consumer must include 6% of Goods and Service Tax (GST) [3].
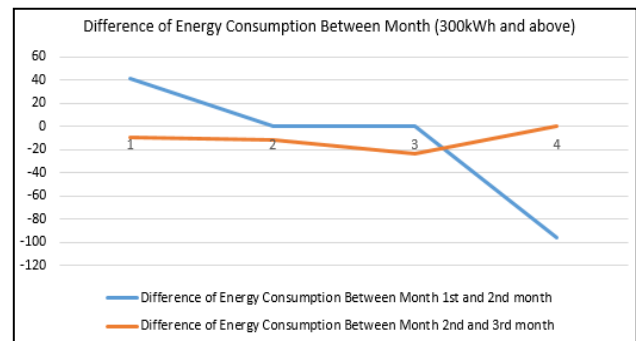

Figure 9 The Difference of Energy Consumption Between Months for Group of Energy Consumption 301 (kWh) and Above

4.1.4 Energy Consumption of Electrical Appliances

This section will discuss the analysis of energy consumption by electrical appliances. Figure 10 shows the most commonly used electrical appliances in households. Of the 20 items listed, lamps (71), fans (71) and refrigerators (70) were the most popular electrical appliances.

Currently in Malaysia, EE Standards and Labelling are only implemented on five types of electrical appliances including refrigerators, air conditioners, televisions, fans, and lamps. The number will increase gradually [19] over the years. Based on the results, the aforementioned electrical appliances had the highest usage compared with the others. Thus, the usage of high EE electrical appliances can help consumers to reduce their monthly energy consumption.
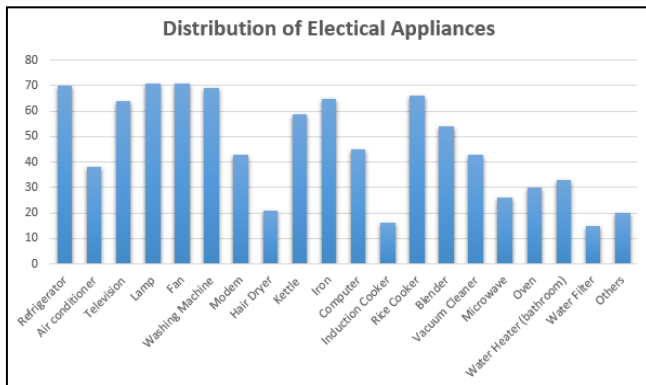
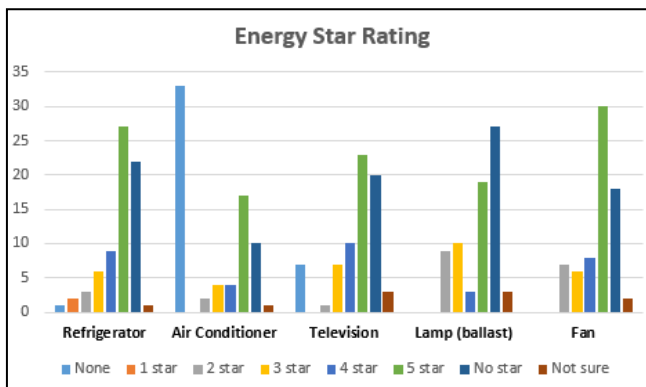**Figure 10.** Distribution of Electrical Appliances

Figure 11. Energy Star Rating of Commonly Used Electrical Appliances

Figure 11 shows the statistic of Energy Star Rating for those five types of electrical appliances. The results show that 33% of consumers were aware of EE as they used 5 star EE products, followed by 10% who used 4 star products, 9% (3 star), and 6% (2 star), compared with 27% of consumers who did not use any energy star rating products. Of the total, about 4% of consumers were not sure about Energy Star Rating products. This was because they had not been exposed to the importance of the EE approach and implementation.

4.2 Consumer Awareness and Practice

A Pearson product-moment correlation or Pearson's r was run to determine the relationship between awareness and the implementation of the energy efficiency approach (practice) in the residents' daily lives.

Table 2. Correlation between Awareness and Practice

Correlations		Practice	Awareness
Practice	Pearson Correlation	1	.316**
	Sig. (2-tailed)		.007
	N	71	71
Awareness	Pearson Correlation	.316**	1
	Sig. (2-tailed)	.007	
	N	71	71

**. Correlation is significant at the 0.01 level (2-tailed).

The data showed no violation of normality and linearity. There was a positive correlation between knowledge and awareness, which was statistically significant ($r = 0.316$, $n = 71$, $p < 0.01$) as shown in Table 2. This correlation means an increase in awareness was increasing the practice and both variables were important for the consumer to implement the energy efficient approach for electrical appliances in residential areas.

Table 3. Mean Score for Awareness

Awareness	Mean	Std. Deviation
Know about energy crisis	3.58	.750
Need energy saving for home	3.92	.368
Electricity consumption can be reduced	3.80	.576
Reducing energy consumption to implement green technology	3.35	.958
Exposure to energy saving by implementation of energy efficiency	3.65	.719
Impact of increasing electricity tariff	3.77	.566
Understands the energy efficiency concept	3.23	.974
Needs guidance, a service advisor, or campaign	3.82	.516
Knows energy saving is important	3.63	.741
Has opportunity to save energy	3.59	.729
Valid N (listwise)		

Table 4 Mean Score for Practice

Practice		
	Mean	Std. Deviation
Uses high energy consumption of electrical appliances	3.56	.788
Unplugs the socket after use	2.94	1.040
Irons clothes every day	3.08	1.052
Electrical appliances help to do work at home	2.55	1.025
Uses high energy efficiency electrical appliances (Energy Efficiency/Energy Star)	2.97	1.000
Shows concern about the electricity consumption of electrical appliances before purchasing	3.42	.936
Washes clothes at the maximum level	3.90	.345
Boils water at the maximum level	3.25	1.010
Switches off the lamp before leaving	3.73	.632
Valid N (listwise)		

Table 3 shows that the average mean value of the awareness was between 3.20 to 3.95. However, the results showed that the average mean value for nine items of practice was between 2.50 to 3.90 as shown in Table 4. Robinson [20] suggested that for the four-point Likert scale, the mean scores should be 1 for very low priority, 2 for low priority, 3 for high priority, and 4 for very high priority. This means that the majority of respondents had a high awareness about EE while consumers held a low priority for a certain item in practice and the rest had already been implementing the EE practice in their daily lives.

In conclusion, awareness and practice can cause the residents to implement energy efficiency, although they place a low priority on practising it. This means that although they know and are aware of EE, they do not practice it, or practice it minimally in their daily lives. Most of the consumers had less awareness about EE at home.

5 Conclusion and Recommendation

Based on the analysis, it can conclude that there is an increase in energy consumption at home by the consumer in three months observation. This scenario caused by many factors, including the use of electrical appliances that are not consistent (time of use), the lack of awareness of the use of efficient energy and the use of electrical appliances that are not energy efficient.

The consumer should use electrical appliances which are high energy efficiency based on the energy star rating to save more energy for their home.

Furthermore, from this study, it has been proven that awareness and practice towards energy efficiency affect the energy consumption of consumers. Consumers had a high awareness about EE but at the same time consumers held a low priority for a certain item in practice and this can increase their energy consumption at home.

Meanwhile, the Energy Standard and Energy Star Rating label help the consumer choose more efficient electrical appliances. Some recommendations would also be useful to improve the study, including benefits, the method of measurements and consultancy in the renovation of homes or new home construction for energy efficiency.

EE approaches such as MEPS and Energy Star Rating can help consumers choose more efficient electrical appliances and start to use energy wisely. The overall result of this study successfully showed that the EE approach is important in energy consumption. In addition, consumers should use electrical appliances which have high EE based on the Energy Star Rating to reduce energy consumption.

In other hands, the findings from this study recommend a number of aspects that should be considered for future works. The recommendation are as follows :

   i. Equipment to create questionnaire and analyse difficult to learn and should be provided with complete instruction so that many types of measurements can be carried out.

   ii. The development of energy management system that can help consumer to estimate the energy consumption (by appliances) easily at home and this can raise their awareness the importance of good energy management.

   iii. To raise awareness and stimulate motivation and the need for action, a broad public campaign may also be necessary. Such a campaign should comprehend the general public, similar to the campaigns of energy suppliers who have created a clear and long-lasting presence in the public.

Acknowledgement

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