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AWARENESS ON ENERGY MANAGEMENT IN RESIDENTIAL BUILDINGS: A CASE STUDY IN KAJANG AND PUTRAJAYA

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Abstract

This paper presents a case study on a survey and measurement being carried out for the purpose of determining residential electric power consumption and awareness toward smart energy management system in the areas of Putrajaya and Kajang, Malaysia. Questionnaires were developed with 37 questions grouped in 5 different sections related to home appliance information. Data was collected from a sample size of 384 respondents with confidence level of 95%. The accuracy of the percentage energy usage data were analysed by applying the SPSS software. Actual residential electric power consumption was measured by using a power quality analyser to determine the total power consumption at weekday and weekend and power consumption of each electrical appliance. The measurement results showed that the average energy consumption is 25.8 kWh/day during weekend and 21.9 kWh/day during weekdays with 11.5 kWh/day for the air conditioner only. The survey results revealed that 89.06% of the respondents expressed awareness toward household power consumption and that they are willing to install home automation system to reducing their electricity bill.

Keywords: Energy consumption level, Home appliances, Home energy management, Feed in tariff, Energy saving, Energy policy.

1. Introduction

The use of electrical energy has increased in recent years and the demand for electrical energy in developing countries, in particular, is expected to increase

Abbreviations	
DR	Demand Response
HEMS	Home Energy Management System
KWH	Kilowatt hour
RE	Renewable Energy
TNB	Tenaga Nasional Berhad

rapidly in line with economic and population growth [1]. In the developed countries such as the UK and US, the power consumption for households are 30% and 25% respectively, of the total energy consumption[2]. In Malaysia, electric power consumption by the residential sector has increased significantly over the year, which has caused high demand in electricity to meet increasing social and economic activities [3]. In addition, carbon dioxide (CO_2) and greenhouse gas (GHG) emission problems have emerged and thus motivated many governments and researchers to focus on the development of smart buildings and home energy management systems (HEMSs) utilizing renewable energy (RE) sources [4]. The combustion of fossil fuel affects climate change, contributes to global warming, and is regarded as one of the main sources of atmospheric CO_2 production [5]. The Economic Planning Unit reports indicate that Malaysia has become the 26th largest GHG emitter in the world [6]. It was predicted that the GHG emissions in Malaysia will increase from 43 Mt in 2005 to 110 Mt in 2020 [7]. Hence, due to climate variability, the temperature will rise from 0.5℃ to 1℃ in East Malaysia and from 0.5℃ to 1.5 ℃ in Peninsular Malaysia [8].

To address the problem of increased environmental pollution, the Malaysian authorities has included in the 8th Malaysian Plan (2001–2005) the goal to make RE source as 5% of the total energy generated in the country [9]. However, the share of RE in the total energy generated in Malaysia is currently less than 0.5% [10]. Studies showed that presently the efficiency of solar energy has reached 40%, which is higher than its efficiency level in the past [11]. The RE strategy, as required by Malaysia 2020, aims to start the move toward sustainable energy development. The aims of this strategy are to reduce the use of conventional energy and decrease the amount of CO_2 emissions by 40% in 2020 [12]. In Malaysia, the total electrical energy consumptions in 2010 and 2013 were 104.59 and 123.16 GWh, respectively, whereas the total energy generations were 113.86 GWh in 2010 and 140.18 GWh in 2013 [13]. Furthermore, Malaysia targets to increase the installed capacity for its RE from 217 MW in 2011 to 11.5 GW by 2050 [14]. In 2012, the electricity in Malaysia was generated from power plants that use fuel in the form of coal (48%), natural gas (40%), hydropower (7%), diesel (3%), fuel oil (2%), and RE (0.2%). The main electricity generators in Malaysia are co-generators (4%), hydropower (7%), and thermal (89%) power plants [15]. The residential sector in Peninsular Malaysia in 2012 was responsible for 21% of the total power consumption, which was utilized for cooling systems and other household appliances [16]. The CO_2 emission by the Malaysian residential sector in 2008 was 2,347,538 T and is expected to increase up to 11,689,308 T by 2020 [17]. The electricity consumption of the residential sector is also estimated to increase from 29.02 GWh in 2008 to 51.14 GWh in 2020 [18]. Thus, the residential sector has a high potential in helping to reduce electricity consumption [19]. Due to increase in tariff rates, which were imposed on January 1, 2014, residential customers face an average increase of 10.6% in electricity consumption [20]. The electricity tariff rates and costs of electricity generation in Malaysia have increased in the last decade. In this regard, RE resources have become a good solution to achieve sustainable energy development in Malaysia [21].

Smart buildings can be supported by RE sources and active communication technology managed via the internet through smartphones or computers [22]. Through communication technology, power consumption of household appliances can be monitored for optimal and efficient usage [23]. Smart buildings with HEMSs can reduce the peak demand and electric bill of consumers [24]. HEMS can assist in reducing overall energy consumption by means of optimal residential load scheduling of appliances and allowing achieving various goals and functions inside the homes such as automatic control, and shifting or curtailing the demand consumption [25, 26]. Consequently, with reduced demand during peak hours, the electricity generated by power plants and thus GHG emissions are also reduced. These emissions are regarded as a major driver of climate change and environmental pollution [27, 28]. In order to consider customers limitations and preferences and to get the benefits of reduced power consumption, a survey on household power consumption usage is required.

In the interest of power consumers in both residential and commercial sectors, power usage reduction is promoted in Malaysia. In this study, a survey and measurement related to power consumption are carried out by considering two objectives. The first objective is to estimate the daily household power consumption usage and the electrical appliances used in homes through collection of data from various residential buildings such as apartments, terrace houses, semi-D homes, and bungalows in the areas of Putrajaya and Kajang, Selangor. The second objective is to investigate resident's willingness toward the use of common electrical appliances and awareness toward smart HEMS for reducing electricity consumption.

2. Questionnaires and Data Collection

The questionnaires used as the survey instrument, consist of 37 questions grouped into 5 different sections, i.e., information about house, use of electrical appliances, awareness on energy consumption and RE, awareness on new technology for homes and personal information. Both Malay and English languages were used in the questionnaires. The participants considered in the study were residents of Putrajaya and Kajang and of age more than 18 years. Putrajaya is a planned city located 25 km south of Kuala Lumpur, which serves as the federal government center of Malaysia. Putrajaya has a total population of 72,413 and has a total land area of 49 km^2, whereas Kajang is a town in the eastern part of Selangor with a total area of 787.6 km^2 and a population of 342,657 [29, 30]. The data collection for this study focused on the types of appliances used by the respondents, the characteristics of household appliances, electricity consumption, customer behavior, and factors that can affect household electricity consumption. A sample of the questionnaire can be found at http://goo.gl/forms/oKaf10bCmUVzk5bp1.

The survey was circulated through a mailing list and interview that included various participants, such as lecturers, students, and employees living in these two regions, to ensure a wide and balanced distribution of the respondents. After gathering all data from the survey, the dataset was screened carefully and all data anomalies were removed to have accurate data analysis. Particular attention was also given while entering the data manually. An efficient method was needed to obtain the data sample because the sample played an important role in validating the study. In addition, the sample size depends on many factors, such as the population sample size, the accepted sampling error, the study limitations, and the aims of the study. The required sample volume size (Sm) is given by [31, 32]:

$$Sm = x^2 \frac{N(P-P^2)}{d^2(N-1)+x^2(P-P^2)} \tag{1}$$

where Sm, x^2, N, P, and d^2 are the required sample size, the table value of chi-square for the desired confidence level (3.84=0.5), the population size, the population proportion (assumed to be 0.50 because this will provide the maximum sample size), and the degree of accuracy expressed as a proportion (0.05), respectively.

Referring to [32], we derive a table that determines the sampling size for the population using Eq. (1). Based on the table, the sample size that represents a population of more than 415,070 is 384, with a confidence level of 95% for the total inhabitants, as in our case study. Our data analysis process shows that the inhabitants in the areas of Kajang outnumber those of Putrajaya. An important concern in this survey is that the sample size has a low marginal error and a high confidence level.

In this paper, we estimate the daily household energy consumption by collecting data from the homes in Putrajaya and Kajang, investigating the reaction of the respondents toward the use of common electrical appliances, and exploring the reasons that may cause inefficient energy management by homeowners. Table 1 shows the specific questions used to explore the two research questions.

Table 1. Survey questions used to explore the research questions.

Research questions Q1	Research questions Q2
1- Appliances used in the kitchen, e.g., dishwasher, refrigerator and oven	1-Information about smart homes
2- Laundry times per week and appliances used, i.e., laundry, washing machine, dryer	2-Owner's willingness to use a home automation system
3-Presence of water heaters in the building	3- Awareness of means to reduce energy
4-Presence of air conditioners in the building	4- Using devices with low energy and price
5-Use of electric water heater per day	5-Switching off bulbs to reduce energy consumption
6-Electricity bill per month	6-Using appliances that considerably affect the electric bill
7-Habit of leaving devices on standby	7-Replacing old devices with new ones
8-Number of water heaters	8-Leaving the lights on although no one is in the room/at home
9- Presence of electronic devices	9-Using a photovoltaic renewable energy system

Therefore, the following research questions are formulated:

Question1: What is the level of energy consumption of Putrajaya and Kajang, Selangor customers?

Question2: What is reaction of the residents of Putrajaya and Kajang, Selangor toward energy consumption, RE, and new technology for homes?

3. Measurement and Survey Results

The data were obtained from 403 respondents in the two areas in Malaysia; Putrajaya and Kajang. The data were arranged in such a way that anomalies and contradictions could be addressed. Valid responses, i.e., 384 samples from 403, were obtained, with a completion rate of 95%. The respondents from the Kajang area were 227 (59.1%), whereas those from the Putrajaya area were 157 (40.9%). Furthermore, 210 respondents were males, and 174 respondents were female. The collected data was analysed by using the SPSS software. The employment status of the participants in the survey is shown in Fig. 1. A similar survey that analysed and investigated the electricity profile in Malaysia has been conducted by Ponniran et al. [33]. The investigation was conducted through monitoring of several appliances that consumed high power in residential sectors such as air conditioner.

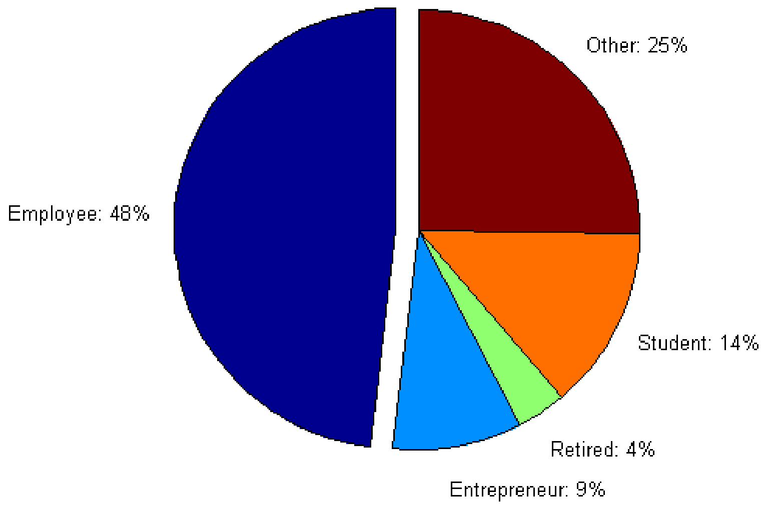


Fig. 1. Employment status of the participants.

Table 2 shows the level of education of the participants, i.e., primary school, bachelor’s degree, diploma, junior high school, high school, master’s degree, PhD and others.

In our survey, questionnaires were also used to collect data from the respondents concerning the appliances that consumed high and low power so as to estimate the household power consumption usage, the amount of electricity bill per month and the daily electrical appliances used in homes from the different residential buildings in Malaysia. The characteristics of every load were analysed, and the potential energy saved was compared with that obtained from the use of efficient electrical appliances to determine the effective energy consumption.

Table 2. Demographic analysis of the conducted survey.

Gender	**Respondent**	**Percentage**
Female	174	45.3%
Male	210	54.7%
Participants' age		
18–35 years old	97	25.3%
36–45 years old	195	50.8%
46–65 years old	80	20.8%
More than 65 years old	12	3.1%
Level of education		
Primary school	62	16.1%
Bachelor's degree or diploma	67	17.4%
High school	46	12%
Junior high school	34	8.9%
Master's degree	51	13.3%
PhD	54	14.1%
Others	70	18.2%

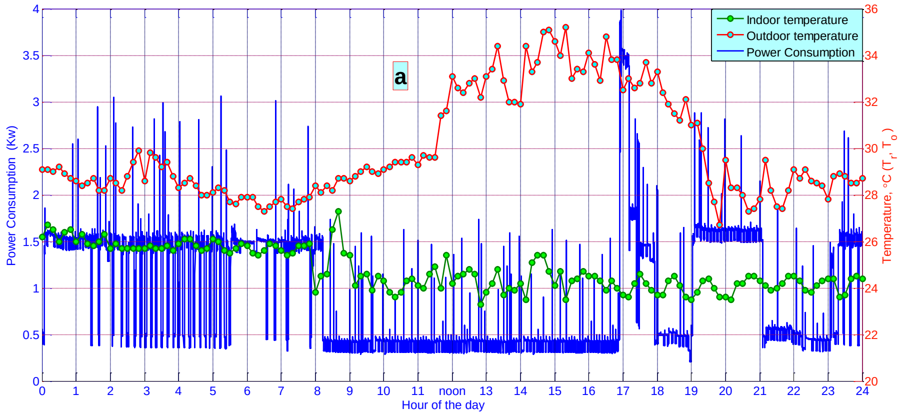
Measurement of total electricity consumption of appliances at weekdays and weekends with the use of a power quality

Measured data were obtained in May 2015 by using a power quality analyser to measure the total power consumption of a sample apartment house in the Kajang area during weekday and weekend. The power consumption data were measured in 1 second interval for 24 hours. The results of the 24 h measured data are shown in Fig. 2. As shown in Fig. 2(a), the household power consumption during a weekday morning (7AM to 8:15 AM) was about 2 kW. The electricity consumed by heating appliances, such as electric iron, water heater, microwave, and refrigerator, from 8:15 AM to 4 PM was only about 0.5 kW because the users were not at home, and only the refrigerator, fan and TM system were working. In the evening, from 4 PM to 11 PM, the power consumption increased to 4 kW because the users were at home and using their electric appliances. As shown in Fig. 2(b), the users were at home during weekend and were using many electric appliances, thus resulting in high electricity consumption. The two figures show that the two peak periods of electricity consumption in Malaysia during weekday from 4 PM to 11 PM and weekend at different time of the day.

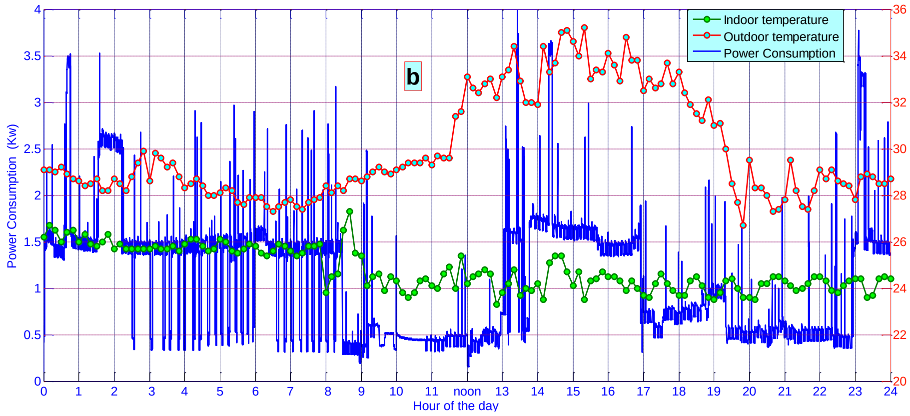
The powers consumed by the common electric appliances used by the respondents were also measured with daily average usage for each device shown in Table 3.

According to the collected data from various homes in Putrajaya and Kajang, the respondents were asked about the common electrical appliances used in their house so as to estimate the daily household energy consumption.

Figure 3 shows the measured energy consumptions during weekend and weekday which were 25.8 kWh/day and 21.9 kWh/day, respectively. The data shown in Table 3 indicated that the air conditioner, water heater and electric kettle consumed high electricity usage compared to all the other appliances.



(a) Weekday power consumption pattern.



(b) Weekend power consumption pattern.

Fig. 2. Total power consumption pattern of households during weekday and weekend.

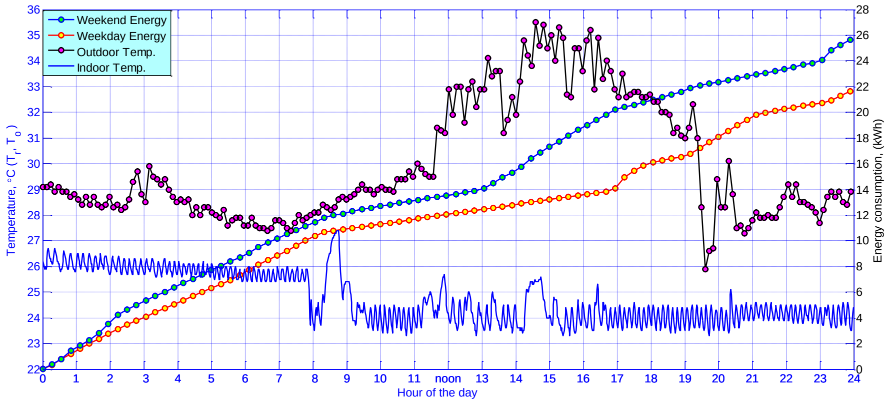


Fig. 3. Energy consumption pattern of households with outdoor and indoor temperature during weekdays and weekends.

Table 3. Common appliances used in households based on survey results.

NO	Appliance	Measured Power in (kW)	Weekday Energy (kWh/day)	Weekend Energy (kWh/day)
1	**Air conditioner**	1.2	6.06	9.69
2	**Water heater**	2	0.32	3
3	**Electric kettle (5 L)**	2–2.2	1.056	0.968
4	**Electric Iron**	1.4	0.742	0.644
5	**Hair dryer**	1.2	0.12	0.06
6	**Microwave**	1–1.1	0.198	0.187
7	**Washing machine (5 kg)**	0.85	0.884	0.884
8	**Rice cooker**	0.7–0.8	0.576	0.584
9	**Computer**	0.75	1.4775	1.365
10	**Fridge**	0.5	2.5	4
11	**Exhaust hood**	0.212	0.00424	0.0212
12	**Blinder**	0.205	0.0546	0.03895
13	**Laptop**	0.1	0.287	0.382
14	**Fan (ceiling)**	0.1	1.155	1.8
15	**Television**	0.08	0.456	0.652
16	**Printer**	0.05	0.001	0.0045
17	**Florescent light**	0.04	0.4	0.52
18	**TM system (receiver + phone + wireless**	0.03	0.57	0.72

In general, the power consumption depends on the frequency of usage of the appliances involved. For instance, appliances, such as oven, microwave, exhaust hood, and electric kettle are assumed to be operated in the morning and during dinnertime while the freezer and refrigerator are assumed to be operated continuously. Other appliances, such as electronic appliances, air conditioner, iron, rice cooker, washing machine, and water heater are assumed to be operated at various times during the day.

4. Residential Energy Consumption of Putrajaya and Kajang

To address the survey questions shown in Table 1, we asked the respondents about 9 issues. The respondents were asked to provide information about their electrical appliances and the number of air conditioners and water heaters used in their homes. Table 4 shows the survey results in terms of energy usage of water heater and air conditioner. The results show that water heater and air conditioner appliances consumed most of the energy in their buildings. Some of the respondents used two or more types of devices or even more energy sources for air conditioning and water heating. Furthermore, 81.3% of the respondents use electric water heaters, whereas 3.1% say that they do not have a water heater at home. Only 14.3% use solar water heaters and 1.3% use gas water heaters. The respondents were also asked about the availability of air conditioners in their buildings, as well as to provide information about the frequency of their usage of these devices.

In Table 4, 93% of the respondents say that they have air conditioners in their houses, and 63% say that they have more than one air conditioner at home; 55.5% say that they use their air conditioning units for more than 2h per day. To estimate the power consumption of home appliances in each residential building, the respondents were asked the about appliances that they own. The home appliances are as listed in Table 5.

Table 4. Energy usage of water heater and air conditioner.

Water heater	Percentage %	Air conditioner	Percentage %
None	3.1%	Those who do not have	7%
Electric water heater	81.3%	Those who have	93%
Solar water heater	14.3%	**Operation time**	
Gas water heater	1.3%	Less than 2 h per day	22.9%
Number of water heaters		Occasionally, not every day	14.6%
None	3.1%	More than 2 h per day	55.5%
1–2	70.3%	**Number of air conditioners**	
More than 2	26.6%	None	7%
		1–2	63%
		More than 2	30%

The percentages of energy usage data were obtained by applying the SPSS software on the survey questions. According to Tenaga Nasional Berhad (TNB) [20, 34], the latest adjustment to electricity tariff rates was implemented on January 1, 2014 as shown in Table 6. The Malaysian government also announced that goods and services tax (GST) of 6% will be charged on the electricity unit consumed monthly by the residential sector beginning April 1, 2015 [35]. The GST will certainly increase consumers' electricity bill and therefore consumers are encouraged to save electricity. From the survey, the respondents were also asked about their power consumption per month and the average monthly electricity bill for different types of houses. From this information and considering the electricity tariff rates in Malaysia, the monthly bill and electricity consumption of the home appliances devices were calculated as shown in Table 7.

Considering the TNB residential tariff, the electricity bill per month for a bungalow house consuming 985 kWh/month can be calculated as; 200 kWh * 21.8 sen + 100 kWh * 33.40 sen + 300 kWh * 51.60 sen + 300 kWh * 54.60 sen + 85 kWh * 57.10 sen = 44413.5 sen/month.

The final total electricity bill/month for a bungalow house = 444.135+ 26.648 (GST %) + 3(additional tax) = 473.783 RM.

The actual data measured in the residential buildings during weekday and weekend as shown in Figs. 2 and 3 were compared with the survey data shown in Tables 5 and 7. The daily load demand consumption and the daily electricity bill are calculated for various types of buildings in Malaysia. According to the survey the air conditioner unit consumed most of the energy in the buildings. Figure 4 shows the real data for air conditioner power consumption of households within 1 second interval for 24 hours with the measured indoor and outdoor temperatures according to the weather in Malaysia.

From Fig. 4, at 3:00 p.m. 10 June 2015, the temperature of room was quite high; however, when the air conditioner was turned on, the temperature started to decrease until it reached the set point temperature of 24℃. As shown in Fig. 5, the energy consumption was 11.5 kWh/day for the air conditioner only. Based on Fig. 5, energy consumption was 345 kWh per month and also its electricity bill was RM80.642 monthly.

From the survey, the appliances that consumed high electricity were the air conditioner, water heater, oven, microwave, refrigerator, rice cooker, and flat iron. The daily power consumption was found to be 20 kWh/day.

Table 5. Percentage of household energy usage.

Devices	Number of Respondents	Percentage %
Exhaust hood	171	44.5%
Dishwasher	99	25.8%
Rice cooker	337	87.8%
Oven	365	95.1%
Microwave	287	74.7%
Refrigerator	382	99.5%
Freezer	249	64.8%
Electric kettle	345	89.8%
Washing machine	336	87.5%
Iron	359	94%
Blender	281	73.2%
TV	367	95.6%
DVD/Blue Ray	128	33.3%
Home theater	69	18%
Console(Wii, PlayStation)	112	29.2%
Stereo HiFi	62	16.1%
TM Unifi system	350	91.1%
Computer	340	88.5%
Printer and/or scanner	274	71.4%
Astro	317	82.6%

Table 6. Domestic tariff rates class A.

Tariff rates	Price in RM
First 200 kWh	21.80 sen/kWh
201–300 kWh	33.40 sen/kWh
301–600 kWh	51.60 sen/kWh
601–900 kWh	54.60 sen/kWh
next 901 kWh	57.10 sen/kWh

Table 7. Electricity energy consumption for different types of residential buildings in Malaysia.

Type of house	Average consumption (kWh)	Electricity bill in Ringgit
Condominium/apartment/flats	451	167.21
Two-storey terrace house	920	434.45
Single-storey terrace house	715	315.27
Semi-D house	735	326.85
Bungalow house	985	470.78

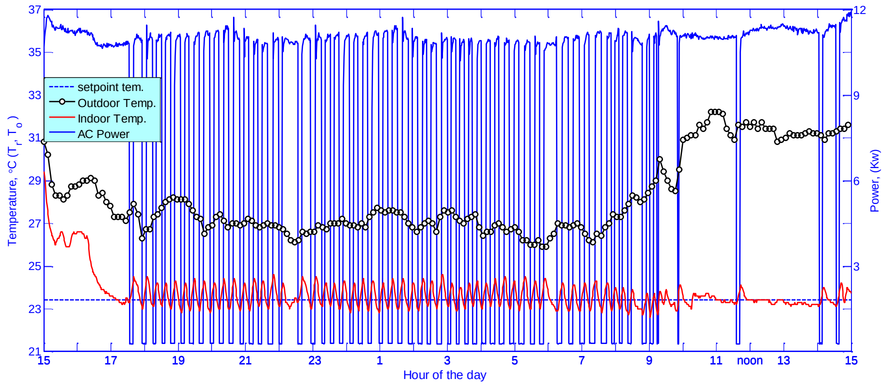


Fig. 4. Real temperature and power consumption for AC load.

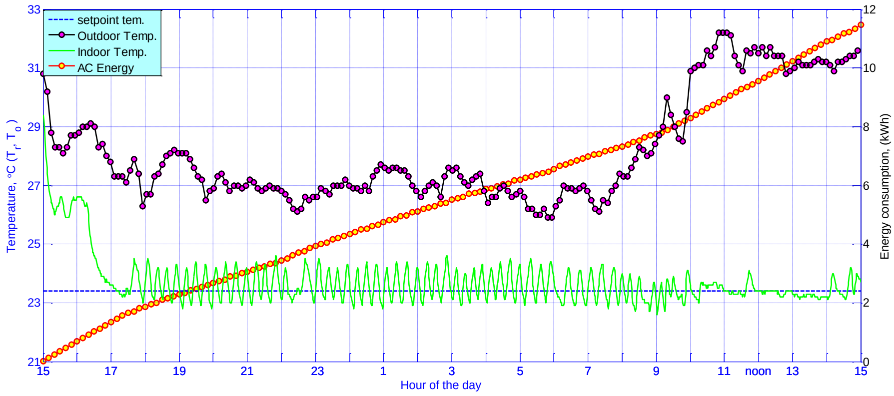


Fig. 5. Energy consumption of AC with outdoor and indoor temperature.

The collected data from the respondents can be used to determine their daily power consumption and load demand. The survey data was applied in [24] to develop home appliance models for HEMS with demand response (DR) for residential buildings in Malaysia. DR application is designed to reduce peak demand, increase power system stability, and improve efficiency of electricity usage with the availability of RE. Moreover, DR enabled load models at residential sectors encourage end users to reduce their electric bill with the use of intelligent HEMS that can control household loads with smart meters and smart appliances [24]. With HEMS, home appliances can be controlled, and power consumption by end users can be monitored. HEMS enables scheduling of the switching on/off of home appliances so as to reduce electric bills and improve customer comfort [36]. The scheduling algorithm considers household loads according to comfort level and customer preference setting, and appliance use can be managed at a given time.

5. Survey Results on the Attitude of Residents Toward Home Automation System

In this part of the survey, the respondents were asked about their reaction toward energy consumption and RE. The respondents from Kajang and Putrajaya expressed that they were interested in the home automation system in their homes.

The appliances that significantly affect the respondents' electricity bill in both regions were air conditioner (93%), water heater (82.8%), oven (71.9%), dryer (71.4%), microwave oven (62.8%), washing machine (60.9%), lighting (42.7%), and other devices that consume less than 40% of their total household energy use, such as flat iron, exhaust hood, computer, and vacuum cleaner. The electrical devices that the owners agreed to discontinue using to reduce energy consumption were lights (94.5%), air conditioner (91.4%), television (89.8%), water heater (75.3%), and flat iron (51.8%). Moreover, the respondents were asked about their willingness to have a home automation system. The results of the survey data indicates that 89.06% of the respondents were willing to install such a system in their homes to reduce their electric bill and only 10.94% are unwilling to install as shown in Fig. 6. However, 59.38% of the respondents have no idea about automation systems and smart homes and the number of RE devices installed in homes was low, with only 6.5% for a photovoltaic system and 2.6% for a solar thermal system. As previously mentioned, this survey shows that most residents of Kajang and Putrajaya expressed interest on energy management in their households to reduce their electricity bill, but most of them are not aware about smart homes and automation systems.

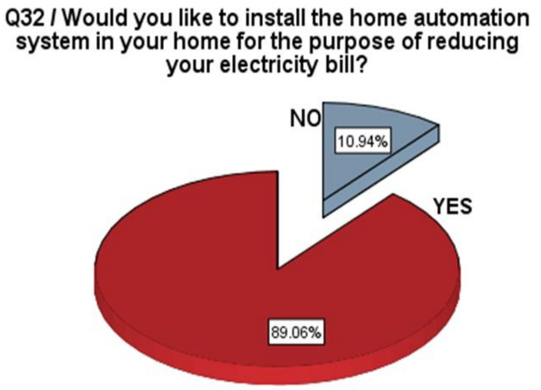


Fig. 6. Awareness about home automation systems for smart homes.

From the aforementioned results, it is clear that there is low awareness on home automation system. Lack of awareness can prevent customers from investing in new energy efficient technologies. The current policy of applying high discount rates to make trade-offs between savings and initial investment also prevents customers from any investment in energy efficient technologies. Moreover, the lack of new technology development is considered as a structural barrier that prevents customers from investing on smart technologies. Therefore, government should implement policies that encourage energy efficiency by introducing smart technologies in residential buildings such as home automation system or intelligent HEMS which can be used to control the controllable loads that consume high energy consumption such as air conditioner, water heater, washing machine, and refrigerator in order to reduce the energy consumption and electricity bill. With the use of intelligent HEMS with demand response (DR), home appliances can be controlled, and power consumption by end users can be monitored. HEMS enables scheduling of the switching on/off of home appliances so as to reduce electric bills and improve customer comfort [37]. Moreover, DR enabled loads at residential sectors encourage end users to reduce their electric bill. The scheduling algorithm in the HEMS should consider household loads according to comfort level and customer preference setting, so that electrical appliance use can be managed at a given time.

6. Conclusions

A survey and power measurement were conducted to determine electricity power consumption in the two residential areas of Kajang and Putrajaya and to evaluate respondent awareness toward smart home energy management system. Actual data of the total household power consumption during weekday and weekend and the power consumption of each household appliance were measured by using a power quality analyser. The measurement results showed that the two peak periods in Malaysia during weekday were from 7 AM to 8:15 AM and from 4 PM to 11 PM and the power consumption were 25.8 kWh/day and 21.9 kWh/day during weekend and weekday, respectively. The household electrical appliance measured results showed that the air conditioner consumes 11 kWh/day and that to reduce this power consumption, the idea of DR program as a new policy in Malaysia can be introduced. The survey results revealed that 89.06% of the respondents expressed that they are aware of their household power consumption and that they are willing to install home automation system to reduce their electricity bill. Survey results can be used to produce representative load profiles of a typical Malaysian single-family home both for weekend and weekday and also allows understanding of usage profiles of the considered power-intensive loads. Finally, human factors and awareness have a significant influence on reducing electricity consumption

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