

An Analysis on the Effect of Consumers Behaviour Towards Household Electricity Consumption

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Abstract—In the recent years, the world has witnessed significant surge in energy consumption due to the increasing population. The world's population exceeded 7 billion in 2011 and is predicted to be more than 9.3 billion by 2050. Increase in the population will increase the energy consumption, which will result in a number of negative consequences. Thus, it is crucial to plan, monitor and subsequently manage the energy consumption in order to control and minimise its negative impacts. To do this, it is necessary to first obtain the information on the current practice in energy consumption amongst the domestic consumers. In our study, a survey to obtain the information was performed. Focusing on the electricity consumption, information on the residents ownership of the six identified electrical appliances that were found to contribute the most to the electricity consumption in Malaysia and their behaviour in general and in using the appliances were collected. The behaviour was measured by means of the ten predefined electricity saving behaviour gathered from the literature and previous research work. Analysis results showed that all of the appliances significantly affect the household electricity consumption and four out of the ten electricity saving behaviour is significant to the household electricity consumption. Findings can serve as a basis for energy consumption planning and related areas such as the development of household electrical energy consumption recommendation model.

Index Terms—energy consumption, survey, case study, energy saving, statistics, electrical appliance

I. INTRODUCTION

With the current style of living, it is expected that the electricity consumption in Malaysia will keep on growing, so does the demand for its supply. As such, a number of measures have been taken to ensure its proper planning and management, such as preparing for renewable electricity power supply. In order to increase the success rate of the measures taken, it is important to ensure that they are designed and implemented based on the actual data or information. For this reason, the needed data have to be obtained from the actual targets, who are the households in Malaysia. In order to do that, data collection mechanism such as survey and interview will have to be conducted. In the context of household electricity consumption in Malaysia, the data have to come from the residents, whose houses are supplied with the electricity. Though investigations on this subject can also be seen in a number of the developing countries, data that reveal the detailed profile of household electricity consumption in Malaysia are still lacking. To the

best of our knowledge, none exists thus far. The closest that we could found was the survey done by [1], which focused their study on the use of air conditioning in the residential buildings in Malaysia. The survey, which was done in 2010, covered the residents in one of the cities in Malaysia, which is Johor Bahru.

Although air conditioner was found to be the electrical appliance that contributed the most to the electricity consumption in Malaysia (44.23%) [2], contributions from other appliances cannot be underestimated. In descending order of contribution, the following appliances were found to be at the highest proportions of Malaysia's electricity consumption after air conditioners; refrigerators (21.48%), heating appliances (11.03%), lamps (7.12%) and cooking appliances (4.96%). The remaining proportions include entertainment appliances (4.22%), washing machine (2.47%) and others (4.49%). Thus, it is equally important to obtain the information on the other electrical appliances owned by the households, especially when the household electricity consumption was found to be increasing in parallel with the increased appliances ownership rate [3]. Other than appliances' ownership, consumers behaviour in using the appliances also contributes to the amount of electricity consumed [4]. Thus, information on how they use their appliances need to be obtained too.

Therefore, in our research, a survey was performed to collect detailed information on household electricity consumption in Malaysia with respect to the appliances ownership and consumers behaviour in using the appliances. This survey is part of a larger research on the construction of a big data analytics model for the household electricity consumption and monitoring. With regard to the behaviour, the survey also aimed to identify if there are any significant relationships that exist between appliances usage behaviour and household electricity consumption. Listed below are the research questions addressed by the research.

- RQ1 What is the current state of the household electricity consumption?
- RQ2 What is the current state of ownership of the appliances that contribute the most to the household electricity consumption?

RQ3 What is the consumer behaviour with regard to the electricity saving concerning the appliances?

RQ4 Is there any significant relationship between electricity saving behaviour and electricity consumption?

Additionally, the survey also aimed to validate the following appliances that were found to be contributing significantly to the household electricity consumption in Malaysia [2]. For this reason, the following research hypotheses were added.

H1 There is a significant relationship between the possession of *air conditioners* and household electricity consumption

H2 There is a significant relationship between the possession of *refrigerators* and household electricity consumption

H3 There is a significant relationship between the possession of *water heaters* and household electricity consumption

H4 There is a significant relationship between the possession of *lamps* and household electricity consumption

H5 There is a significant relationship between the possession of *thermos pots* and household electricity consumption

H6 There is a significant relationship between the possession of *irons* and household electricity consumption

The target respondents of the survey were the residents of Putrajaya, Malaysia. Putrajaya residents were chosen as the sample for the study due to a number of reasons, including the systematic planning of the city that enabled more accurate sampling of the respondents to be made. Descriptive statistics and statistical significance tests were used in analysing the returned results. Findings showed that the possession of the appliances under study and four of the ten behaviour included in the study have impact on the household electricity consumption that is statistically significant. The rest of the paper is organized as follows. Section II explains the method applied in conducting the survey. Section III presents the results obtained from the survey, which are analysed and discussed in section IV. Threats to validity of the survey results are briefly mentioned in section V and section VI concludes the paper.

II. METHOD

The survey was accomplished by means of questionnaires distribution. The questionnaire comprised open-ended and close-ended questions, and distribution was using both online and off-line (paper-based) media. Analyses on the results obtained were performed using descriptive statistics and statistical significance tests.

A. Questionnaire Design

The questionnaire was designed using the goal question metric approach [5] to ensure fulfilment of the survey objectives. It comprised three main sections with a total of 28 questions. Twenty seven questions were close-ended and one question was open-ended. The first section contained

ten questions (Q1-Q10) on the background information of the respondents. The unit size of the survey was household. Therefore, one of the questions in the first section asked about the house address of the respondent, which was needed to identify duplication. The second section, which contained 15 questions (Q11-Q25) sought information on the ownership and usage of the appliances included in the study. The electricity saving behaviour was explored by means of the following ten electricity saving behaviour (questions), which were gathered from the literature and previous related work.

- Behaviour 1: On whether or not they unplug from the socket after each usage (Q12)
- Behaviour 2: On whether or not they set the air conditioner timer (Q14)
- Behaviour 3: On whether or not they used to have the fan on together with the air conditioner (Q15)
- Behaviour 4: On whether or not they always fill up their refrigerator with two-third full (Q17)
- Behaviour 5: On whether or not they clean the refrigerator condenser coil at least twice a year (Q18)
- Behaviour 6: On whether or not they use tank water heater at home (Q20)
- Behaviour 7: On whether or not they use energy saving lamps at home (Q21)
- Behaviour 8: On whether or not they switch off the thermos pots when not in use (Q23)
- Behaviour 9: On their ironing habit, whether in batch or in small quantity (Q25)
- Behaviour 10: On their consideration of buying electrical appliances with the smart energy label (Q26)

All of the above questions, except for Q20 and Q21, used five point Likert scale with 1 being never and 5 being all the time. The last section consisted of two close-ended and one open-ended questions (Q26-Q28), which asked about the perception, opinion and recommendation on electricity saving initiatives from the respondents. However, results from this section are not part of the scope of this paper and hence will not be discussed here.

B. Questionnaire Distribution and Sampling

Prior to the actual distribution of the questionnaire, a pilot test was performed on the initial version of the questionnaire involving ten participants to identify the potential problems concerning the clarity of the questions asked. As a result, a number of questions were revised and rephrased. The paper-based questionnaires were distributed to the Putrajaya residents using convenience sampling method. For the online version, calls to participate were sent to the target respondents via several platforms, such as email, Facebook, WhatsApp and Telegram. In total, 413 paper-based questionnaires and an unknown number of online questionnaires were distributed. The online version of the questionnaire contained one additional question (Q0) at the beginning that asked the respondent if he/she is a Putrajaya resident. This was needed because the distribution of the online questionnaire could not be controlled.

TABLE I
RESPONDENTS'S MARITAL STATUS

Marital Status	No. of Respondents
Married	240
Single	39

TABLE II
TOTAL NUMBER OF RESPONDENTS BASED ON HOUSEHOLD MONTHLY INCOME AND MARITAL STATUS

Income Group	Married	Single	Percentage (%)
T20	88	1	31.9
M40	136	12	53.0
B40	16	26	15.1

Therefore, the question served to filter the online results to ensure that the data came from the valid respondents only.

Putrajaya residents were chosen to be the target respondents because Putrajaya is a well-planned city with high density population. Being a well-planned city, the required data on the number of houses in the city could be obtained, which enabled us to determine the minimum number of samples required. A total of 24,600 residential quarters are available in Putrajaya as at 2016 [6]. Furthermore, basic infrastructures and amenities in the city are one of the best to date. With this understanding, it is safe to assume that all of the 24,600 houses in Putrajaya are equipped with the electricity supply. Hence, this figure was taken to be the population size for the survey and therefore, a minimum sample of 267 was needed for the survey. Taking into consideration that 79.1% of the houses in Putrajaya are occupied by the government servants where they mostly have similar working hours and about the same total hours of electricity usage at home, a confidence level of 95% was adopted.

III. RESULTS

When the survey concluded in March 2017, a total of 355 responses were received from both the online and off-line questionnaires. However, only 279 of them were valid and used for the analysis, which exceeded the minimum sample size required. The remaining 76 responses from the online questionnaire were excluded as they came from the non-Putrajaya residents. No duplication was found among the 279 responses.

A. Demography of Respondents

From the results obtained, it was found that the majority of the respondents are married (86%), as shown in Table I. In reporting the household income, the results were grouped into three based on the categorisation used in [7]. These are low income group (B40), middle income group (M40) and high income group (T20). The distribution is shown in Table II, and as can be seen from the table, most of the respondents fall into the M40 group with income range between RM4000 and RM8000. The majority of the B40 group members are single while most of the M40 and T20 group members are married, as shown in Fig. 1.

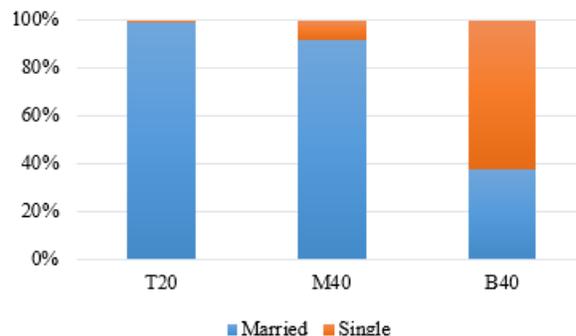


Fig. 1. Percentage of married and single respondents according to income groups.

Five types of houses were covered by this survey, which are apartment, bungalow, flat, semi-detached and terrace. Since house types can be misleading in estimating the house areas due to the various designs, house area information in square feet was also collected and the result is shown in Fig. 2. Out of the 279 respondents, the majority of them are staying in the apartments with the house areas ranging from 1000 square feet to about 1500 square feet. With regard to the number of occupants per household, the majority of houses are accommodating between 5 (18%) and 7 (25%) people as shown in Fig. 3. Figure 4 shows the distribution of the monthly electricity bills amount of the respondents.

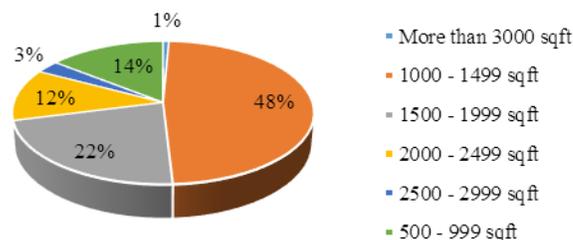


Fig. 2. Distribution of respondents according to house area.

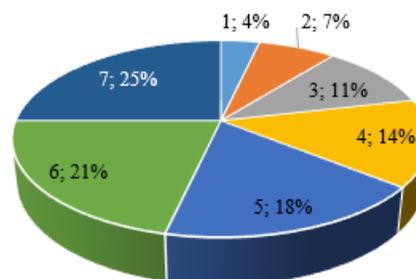


Fig. 3. Number of occupants per household.

With regard to the ownership of the appliances included in the study, all of the respondents at least possess iron and lamps at their houses as shown in Fig. 5. Almost all

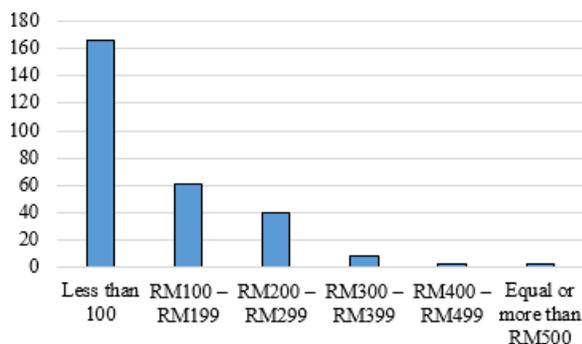


Fig. 4. Monthly electricity bill amount of the respondents.

of them have refrigerators (97%) and the majority of them have thermos pots (63%). Water heaters are owned by only 36% of the respondents. Table III shows the results of the questions that explored respondents' behaviour towards the usage of the appliances (Q12, Q14-Q15, Q17-Q18, Q23 and Q25-Q26); their median, mean and standard deviation values. For questions Q20 and Q21, the results are shown in Table IV.

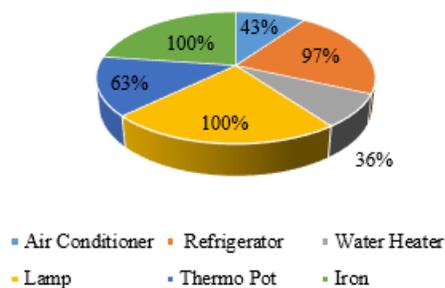


Fig. 5. Percentage of respondents electrical appliances ownership.

TABLE III
QUESTIONS ON ENERGY SAVING BEHAVIOUR

Question Item	Median	Mean	Standard Deviation
Q12 (Behaviour 1)	3.0	2.939	1.15
Q14 (Behaviour 2)	2.0	2.451	1.46
Q15 (Behaviour 3)	4.0	3.524	1.22
Q17 (Behaviour 4)	4.0	3.867	0.88
Q18 (Behaviour 5)	1.0	1.647	0.96
Q23 (Behaviour 8)	2.0	2.210	1.31
Q25 (Behaviour 9)	3.0	2.939	1.11
Q26 (Behaviour 10)	3.0	3.215	1.20

IV. ANALYSIS AND DISCUSSION

In this section, the results presented earlier are analysed and discussed to answer the research questions and test the

TABLE IV
RESPONSES TO Q20 AND Q21

Question Item	Yes	No
Q20 (Behaviour 6)	4	97
Q21 (Behaviour 7)	274	5

hypotheses stated in section I.

A. Current State of Electricity Consumption

In this study, electricity consumption is measured by means of the monthly electricity bill amount, which was shown earlier in Fig. 4. Figure 6 shows the bubble chart of the household electricity consumption versus house area and Fig. 7 shows the bubble chart of the household electricity consumption versus monthly household income. From Fig. 6, the positive correlation between the house area and the household electricity consumption can be seen. Statistical analysis performed using Spearman Rho method showed that it is statistically significant with $r_s = 0.48601$ and $p = 0$. However, the correlation between the household electricity consumption and the monthly household income is a bit less straightforward, though it can be generally seen that most bills are below RM300 across all income range. Nevertheless, statistical analysis performed also showed positive correlation that is statistically significant with $r_s = 0.39506$ and $p = 0$. These explain the current state of electricity consumption, which answer the first research question, RQ1.

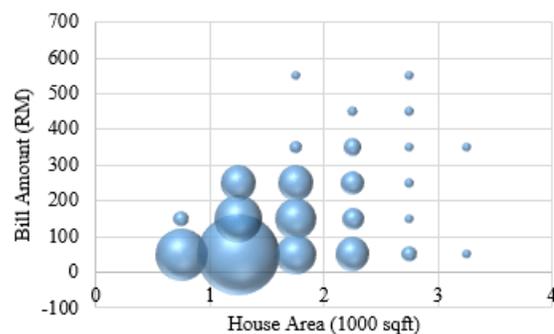


Fig. 6. House area versus monthly electricity bill amount.

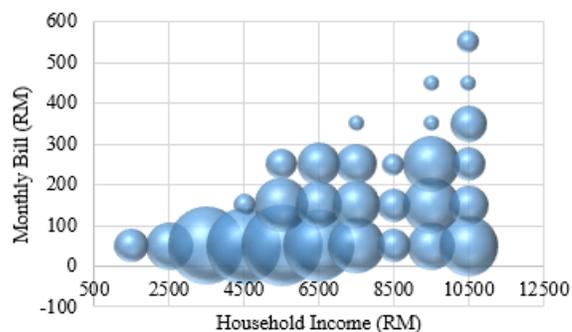


Fig. 7. Monthly household income versus monthly electricity bill amount.

B. Appliances Ownership

With regard to the second research question (RQ2), based on the data collected from the survey as shown in Fig. 5, lamps and irons are owned by everyone who participated in the survey, regardless of their marital status and household income. Possession rate of the refrigerators is also high at 97%. In the married households refrigerators are regarded as a necessity with 100% possession rate (Fig. 8). Possession

rate of the thermos pots in married households is twice the single households'. Air conditioners and water heaters ownership rate in married households is around 40%, while in the single households, they hardly exist. These differences can be attributed to the different lifestyles of the married, often with small children, and the single households. A deeper look at the rate of appliances ownership across the income groups confirms the necessity of lamps, irons and refrigerators. These appliances are found in all M40 and T20 households while close to 80% of the B40 households own refrigerators. Air conditioners and water heaters remain the 'nice to have' appliances that are not found in the B40 households. This finding is consistent with the earlier finding because most of the respondents in the B40 groups were also single as shown earlier in Table I. It is thus interesting to know that these two appliances contributed the most to the overall electricity consumption in Malaysia [2] despite their low possession rate, which confirms their high power consumption.

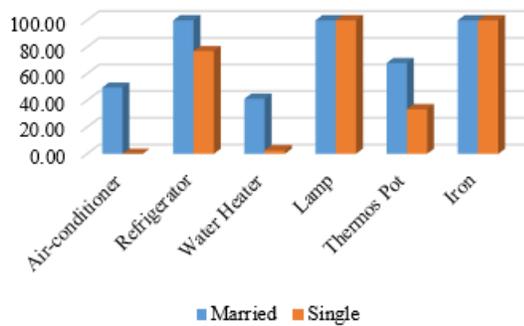


Fig. 8. Percentage of electrical appliances ownership versus marital status.

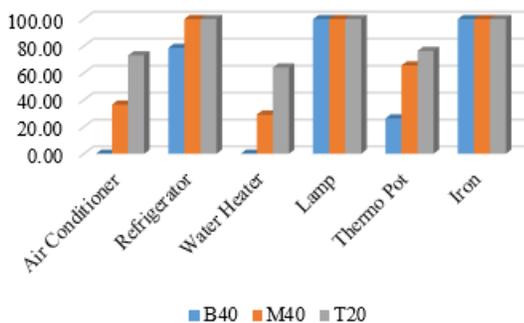


Fig. 9. Percentage of electrical appliances ownership versus income group.

In answering the third research question (RQ3), it can be seen from Table III that the respondents switch on the fan and air conditioner together, and have the refrigerators two-third full, most of the time. Cleaning the refrigerator's condenser coil is not performed by almost all respondents. Reliability analysis performed using Cronbach's Alpha method on the results yielded an α value of 0.781, which confirms the consistency of the questions. With regard to the hypotheses listed in section I, results of the statistical tests performed are shown in Table V. As can be seen from the table, they are all statistically significant. However, statistical significance tests

between household consumption and the possession of irons (H4) and lamps (H6) could not be performed because as can be seen from Fig. 5, all of the respondents who participated in the survey own them.

TABLE V
HYPOTHESIS TESTING RESULTS

Hypothesis	t-value	p-value
H1	11.49110	< 0.00001
H2	2.10146	= 0.01825
H3	8.72965	< 0.00001
H5	5.22602	< 0.00001

C. Consumers Behaviour

Finally, statistical analyses using Spearman Rho and t -test were also performed to identify the relationship between the current practice in electricity saving behaviour of the respondents and their household electricity consumption (RQ4). Results of the statistical analyses are presented and discussed below.

- Behaviour 1: Unplugging from the socket after each usage is believed to and used as an indicator of electricity saving behaviour in a number of related research on electricity consumption [8]. For this behaviour, a median of 3.0 was obtained from the survey as shown earlier in Table III. This indicates a moderate level of practice amongst the respondents with regard to this behaviour. Statistical analysis using Spearman Rho showed that they are negatively correlated ($r_s = -0.0942$). However, the relationship is not significant statistically ($p = 0.11644$).
- Behaviour 2: Utilising the timer setting feature of the air conditioner would be able to reduce the amount of time it is being used, hence reducing the electricity consumption. Statistical analysis performed showed that this behaviour significantly affect the household electricity consumption ($r_s = -0.29761$, $p = 0.00087$). Basically, the more often air conditioner's timer is used, the lower the monthly electricity bill amount would be.
- Behaviour 3: Turning on both air conditioner and fan at the same time obviously increases the electricity consumption as the cooling process that can be done by either appliance are now done by both. However, this seems to be the habit of most respondents who have air conditioners at home with 94% admitted to do that and quite often (median=4.0). However, statistical analysis performed found that this behaviour, which was found to be negatively correlated with the household electricity consumption ($r_s = -0.02888$) is not statistically significant ($p = 0.75014$).
- Behaviour 4: Filling up the refrigerator two-third full allows sufficient space in the fridge for air circulation that optimises its efficiency. The survey results found that most respondents did this most of the time (median=4.0), which is good. Furthermore, there is a positive correlation between this behaviour and the household energy consumption with r_s equals to 0.206 and p equals to 0.00066, which is statistically significant.

- Behaviour 5: Cleaning the refrigerator condenser coil is by far the electricity saving behaviour that most respondents did not do at all (median=1.0), let alone to do it twice a year. This could be due to the fact that the condenser is located at the back of the refrigerator and in most modern design, it is covered. Thus, the users are not aware of its current state. However, the statistical analysis performed showed a positive correlation between this behaviour and energy consumption ($r_s=0.17333$) that is statistically significant ($p=0.00435$).
- Behaviour 6: Using tank water heater is said to be using more power due to the heating that is done in large volume. It can be seen from the survey results that only four out of the 97 respondents (3.96%) used tank water heater. Apart from higher energy consumption, this could be attributed to the installation cost that is higher and more demanding for tank water heater compared to the instant one. However, the type of water heater was found to be not statistically significant to the household electricity consumption ($t = 0.4518$, $p = 0.326202$).
- Behaviour 7: The types of lamp used was also found to be not statistically significant to the household electricity consumption, although positive correlation can be seen ($t = 0.33894$, $p = 0.367456$).
- Behaviour 8: With regard to this behaviour, it is found that most respondents rarely switch off their thermos pots when not in use (median=2.0). This is not surprising, considering that the purpose of having the thermos pot is to be able to have the hot water instantly. If it is switched off, the water will take some time to reach boiling temperature when it is switched on again. In our study, this behaviour was found to be negatively correlated with the household electricity consumption ($r_s=-0.27619$) that is statistically significant ($p=0.00021$).
- Behaviour 9: Ironing the clothes in large batch at a time is also one the behaviours that is said to be able to reduce the electricity consumption due to frequent (re)heating of the iron. However, this behaviour is only moderately practiced by most respondents (median=3.0). Statistical analysis performed found a negative correlation between this behaviour and the household energy consumption ($r_s=-0.00986$). However, this is statistically insignificant ($p=0.8698$).
- Behaviour 10: In Malaysia, there is a star rating scheme given by the Energy Commission to the electrical appliances manufactured based on their estimated energy consumption when in use. The number of stars represents the appliance's performance with regard to the energy consumption. Higher number of stars means more efficient in terms of energy consumption. Statistical analysis performed on the relationship between this behaviour and electricity consumption yielded a negative r_s value of -0.00526 that is not statistically significant ($p=0.93024$).

In summary, from the analyses performed, it is found that the six electrical appliances included in the survey have

significant impact on the household electricity consumption. This confirms the finding of an earlier study that put these appliances in the top five main contributors to the household energy consumption. However, from the ten electricity saving behaviour studied, only four of them was found to have significant effect on the household electricity consumption. However, only two was found to be able to reduce household electricity consumption if practiced often, which are setting the air conditioner timer and switching off the thermos pot when not in use.

V. THREAT TO VALIDITY

The survey had been carefully designed to ensure its validity as much as possible. On generalisability, the survey had covered both marital status and all income groups. On construct validity, pilot test had been performed and photos of the appliances were included in the survey form to avoid misunderstanding. Household electricity consumption may also be affected by other factors such as the number of appliances, which was not collected in this survey because the focus of the survey was to verify the top six appliances and on the effect of consumers behaviour towards household electricity consumption. This is perhaps the limitation of the study.

VI. CONCLUSION

This article presents the results of a survey on household electricity consumption as one of the means for energy consumption planning and monitoring. Findings from the analyses confirms an earlier finding on the top five proportions of electricity appliances that contributed to the household electricity consumption in Malaysia. It also investigated the relationship between the ten electricity saving behaviour and the household electricity consumption where four of them was found to have significant impact. Findings from this survey allow us to be more focused and to make informed decision when deciding on electricity saving initiatives to embark on. It would be interesting to explore the behaviour against marital status and income group. But due to the space constraint, it is not discussed here. We leave that for future work.

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