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Analysis of Household Carbon Emission and Recommendations of Reduction Methods in Greater Kuala Lumpur

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Abstract

Developing countries including Malaysia are observing a sharp increase of carbon emission due to increasing population, rapid economic growth, and urbanization besides improvements in living standards. This study aims to analyse household energy consumption and appropriate interventions recommendation to reduce carbon emission by changing lifestyles, which will lead to savings. In this study, energy consumption and the carbon dioxide emission model including a household survey is presented. The survey area covers 10 municipalities, governed by local authorities in the Federal Territory of Malaysia and the Selangor State, which reveals that the average household carbon emission is 103±54.6 tonne per month, ranging from 20 to 224 tonne per month. The findings show that 22% of carbon emission could be reduced by each household per month by using energy efficient air-conditioners, fans, refrigerators, bulbs, etc. Hence, each household could save RM 64 per month by reducing energy consumption and changing behaviours, which also offers environmental benefits. Thus, the promotion of energy efficient equipment, behaviour-based approach for conserving energy, promotion of participation in energy conservation, special training for the future generation, comprehensive intervention at the industrial level, and establishment of appropriate databases can decline the potential amount of carbon emission.

Keywords: *household; carbon, emission, consumption, energy, environment*

1. Introduction

Climate change and global warming is the most challenging topic for which the world is fighting nowadays. In the atmosphere, the anthropogenic driver of is the increasing concentration of greenhouse gases (GHG), where carbon dioxide (CO_2) is the most important anthropogenic GHG. Therefore, the global increase in CO_2 absorption is mainly due to the burning of fossil fuel [1,2,3,4].

The world meteorological Organization (WMO), greenhouse gas bulletin showed that worldwide averaged concentrations of CO_2 touched 405.5 parts per million (ppm) in 2017, which has increased from 403.3 ppm in 2016 and 400.1 ppm in 2015, respectively [5]. However, an increment of the environmental concentration of greenhouse gasses causes global warming, which is assumed by the many climatologists since the beginning of the 1980s. Therefore, in 1988, to measure the data for scientific, social, economic, technical which are related to climate change effects and mitigation process due to inhabitant's activities, united nations environmental program (UNEP) and world meteorological organization (WMO) established the intergovernmental panel on climate change

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(IPCC). The most significant increase in energy consumption and CO_2 emissions are taking place in society, where rapidly expanding populations enjoy higher living standards and material affluence. Thus, it is necessary to focus on the lifestyle to deal with the issues of energy consumption and CO_2 emissions. The Stern review and IPCC report mention that lifestyle choice and technology can both help to improve the climate, but it did not go into much detail about how it could be achieved. The carbon emission measures the total amount of emissions directly and indirectly caused by an activity or accumulated over the life stages of a product. The total amount of greenhouse gases is simply measured in mass units (kg or tonne, etc.).

In terms of energy consumption by utilizing electricity and liquid petroleum gas (LPG) also causes the increment of CO_2 emissions from the residential sector. Therefore, reducing CO_2 emissions in the residential sector could be an alternative way of dropping energy consumption. Figure 1 shows that, around 16 to 50% of the total energy is caused due to the excessive use of various household electronic products, where 19 % of this energy consumption is happened by the inhabitants of Malaysia.

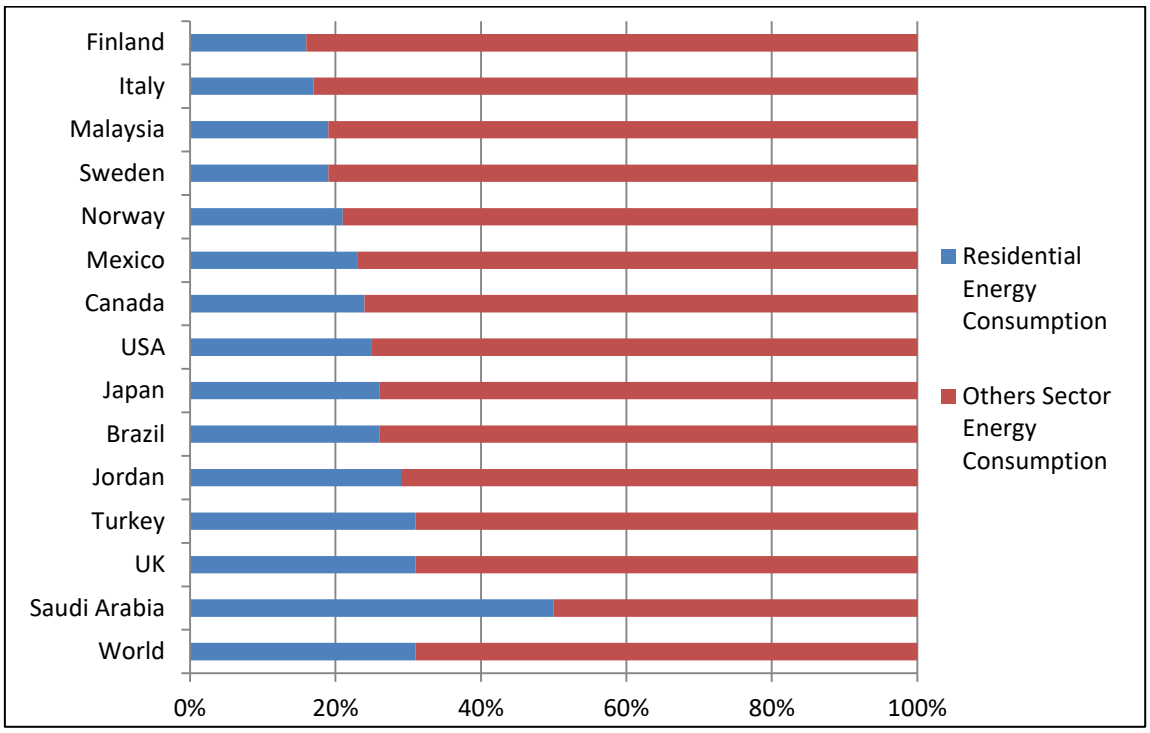

Figure 1. Graphical representation of worldwide domestic energy consumption [6,7,8,9,10,11,12,13].

Figure 2 shows, a cumulative inclination in household electricity dissipation from 1997 to 2016 in Malaysia due to household electricity consumption versus total energy consumption.

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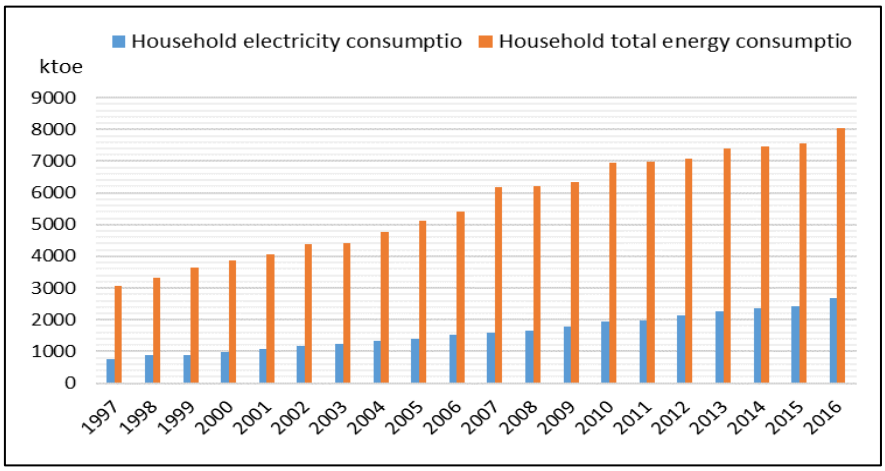

Figure 2. Difference between household total energy and electricity consumption [14].

Studies also show that in Malaysia at least one refrigerator and air conditioners are the second largest energy-consuming electrical appliance [12,15,16]. In addition, household appliances are the significant factors to increase energy consumption such as washing machines, fans, rice cookers, iron, video player, and television etc. Moreover, the use of energy-efficient products in Malaysia is still very little due to the reluctance of Malaysian customers to buy energy-efficient products due to the high cost [17] . Schipper and Bartlett [18] showed in their research that about 45 to 55% of total energy consumption is inclined by user's activities at homes, personal transportation, and services. In Australia, the maximization of user activities results from the increment of energy and greenhouse gases [19]. Therefore, it is assumed that consumer's behavioral activities and lifestyles have an impact on increased energy consumption and CO_2 emissions.

Various studies have been performed on energy utilization, which was first introduced by Reistad [20] in the USA, and since then, it has been applied in several countries such as Canada [21], Japan, Finland and Sweden [22], Italy [23], Turkey [24,25], the UK [26], Norway [27,28], and Saudi Arabia [29]. Therefore, this study aims to assess the current status of household CO_2 emission from different household activities and potential energy savings.

2. Materials and Methods

The survey area of Greater Kuala Lumpur covers 10 municipalities, each governed by local authorities in the Federal Territory of Malaysia and the state of Selangor. The area extends from Selayang in the north to Sepang in the south, encompassing Kuala Lumpur, Putrajaya, Shah Alam, Petaling Jaya, Klang, Kajang, Subang Jaya, and Ampang [30]. The survey covered residents living in areas of Kuala Lumpur, Rawang, Petaling Jaya, Kajang, Klang, Subang Jaya, and Shah Alam among the 10 municipalities of Greater Kuala Lumpur.

Obtaining accurate information is highly dependent on the survey method. The direct face-to-face interview is the most commonly used approach in contingent valuation studies [31] and it is applied in this study. The data for this study was taken to reflect the objectives of the study. The data was obtained through a questionnaire survey and the purposive random sampling method was followed to collect the data from the secondary and pre-university students of Methodist Girls' School Kuala Lumpur and Taylor's College Subang Jaya, respectively. A total of 197 households were surveyed in which each respondent represented one household. The questionnaire was prepared by considering

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related questions and variables of carbon emission patterns and socio-economic characteristics of individual households.

In general, electricity consumption is the outcome of appliance utilization in hours and the power rating of an appliance [12]. This section explains the method of estimating the appliance's electricity consumption, which is presented below:

The fraction of electrical energy (E_e) used by an appliance can be determined using the following equation:

$$E_e = N_a \times P_r \times D_u \quad (1)$$

Where, N_a is the number of the appliance, P_r is the power rating of the appliance in watts, and D_u is the duration of an appliance usage in hours.

The sum of energy used by all household electrical appliances for a month can be calculated using the following equation:

$$EP^n = \sum_{i=1} E_i^n \quad (2)$$

Where, EP^n represents the energy by all household electrical appliances for the month n; and E_i^n represents the energy used by an appliance i for the month n. CO_2 has a serious negative impact on the environment thus in this study, the emission of household CO_2 from electricity generation has been calculated using the following equation, which was adopted from [32]:

$$CO_{2i} = EP_i\left(PE_i^1 \times Em_p^1 + PE_i^2 \times Em_p^2 + PE_i^3 \times Em_p^3 + \cdots PE_i^n \times Em_p^n\right) \quad (3)$$

Where, CO_{2i} = carbon dioxide reduction in year i (kg Tonne), EP_i = electricity production in year I (GWh), PE_i^n = percentage of electricity generation in year i of fuel type n (%), and Em_p^n = fossil fuel emission for unit electricity generation of fuel type n (kg).

The study also calculated the emission of CO_2 from the transportation sector for unit fuel consumption in (kg/GJ) using the following equation, which was adopted from the consultancy unit of University of Malaya [33]:

$$TM_i = ES_i^n \times FE_p^n \quad (4)$$

Where, TM_i = Total emission in year i, ES_i^n = Energy use in a year i the of fuel type n, and FE_p^n = Emission per unit energy of fuel type n.

3. Results and Discussions

Households were divided into three groups to calculate the average household carbon emission such as low emission group, less than 50 tonnes per month (tonne/month); medium emission group, 50 – 150 tonnes/month and high emission group, more than 150 tonnes/ month

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as described in Figure 3. According to Figure 3, maximum respondents are from the medium level of carbon emission group, which is fifty-four percent while 46% are from the high level (>150 tonnes/month) and low level (<50tonne/month) of carbon emission groups, respectively.

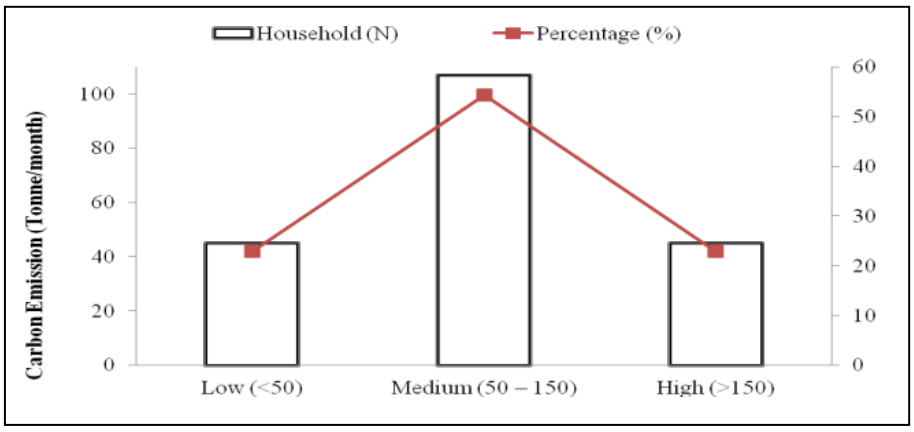

Figure 3. Carbon emission groups by households in Malaysia.

Among these three groups, the highest numbers of respondents are from the medium emitting group and the minimum number is from the low emitting group. The medium emitting group in Kajang (86%), Rawang (83%), Subang Jaya (67%), and Klang (50%) is in the higher position in terms of carbon emission. On the other hand, Kuala Lumpur is in a higher position from the low emitting group with the emission of about 46% (Figure 4).

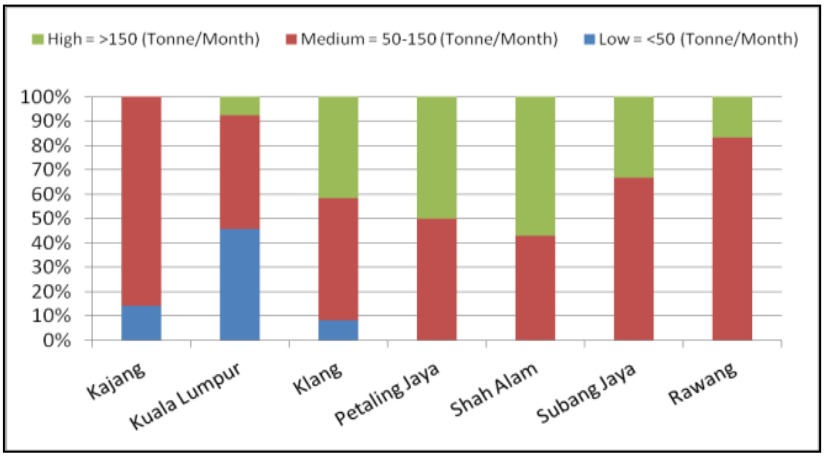

Figure 4. Carbon emission groups by households in different areas in Malaysia.

According to the survey result, about 68% of respondents have more than one refrigerator-freezer and 84% of the respondents have more than 2 air conditioners in their houses located in the area of Kajang, Rawang, Subang Jaya, and Klang. At the same time, the survey displayed that 64% of respondents' average household incomes are RM3000 – RM12000 from the same area and 86% are living in a type of bungalow, semi-detached and terraced link houses. Moreover, 36% of the respondents own mid-sized cars and 35% own full-sized cars from the same group of respondents.

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In terms of the high emitting group, Shah Alam (57%) and Petaling Jaya (50%) are in the highest position. Bungalow and semi-detached houses are more spacious compared to the flat and apartment type houses. Hence, this type of house consumes more electricity for cooling spaces with air conditioners and requires more lights at night. It was also found that 100% of people who are living in a bungalow, terraced link, and semi-detached houses use 5-8 air conditioners per house. Furthermore, 73% of mothers are homemakers and consume more electricity compared to the working mother.

On the other hand, 93% of respondents from Kuala Lumpur are living in a flat and apartment type house. In addition, 69% of respondents' income levels are below RM 3000. Thus, they cannot afford the air conditioner (95%) and less than 40% are using 1 refrigerator per household. Moreover, 44% of respondents avail motorcycles for their daily transportation.

The calculated value of carbon emission for different household activities has been reported in Table 1. According to Table 1, the average total carbon emission is 103.4 tonne per month with a standard deviation of 54.6. The most carbon-emitting activities are space cooling (63.2± 47.0 tonnes/month) and kitchen apparatus (17.9± 6.6 tonnes/month).

Table 1: Carbon emission for different household activities.

No.	Activities	Carbon Emission (Mean)	Standard Deviation
1	Space Cooling	63.2	47.0
2	Kitchen Apparatus	17.9	6.6
3	Living	15.1	4.5
4	Entertainment	6.7	3.0
5	Transportation	0.6	0.2
6	Total Carbon Emission	103.4	54.6

N.B. Carbon emission tonne is the most commonly used unit in every country and from the previous analysis.

According to Figure 5, the household carbon emission comes from the kitchen apparatus, space cooling, and living area, and accounts for approximately 95% of the total monthly energy consumption. The average household's carbon emission detected by monthly basis is found in Petaling Jaya about 153 tonnes (highest carbon emission); in Shah Alam, 150 tonnes (second highest), in Klang areas, 142 tonnes (third highest), in Subang Jaya, 128 tonnes, in Rawang, 114 tonnes, in Kajang, 84 tonnes, and in Kuala Lumpur, it is about 69 tonne.

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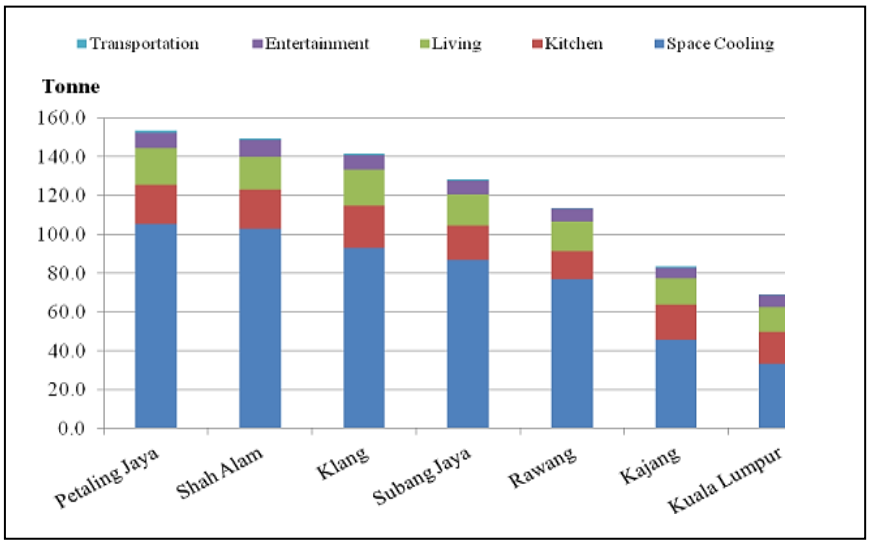

Figure 5. Carbon emission from different activities in households of Malaysia

It is also recorded that respondents from Petaling Jaya, Shah Alam, Klang, and Subang Jaya are living in new types of buildings and bigger houses such as bungalows and semi-detached houses. These types of houses require more electricity compared to the flat and apartment type houses because of the cooling space. Additionally, they use bigger freezers and refrigerators in their houses. The breakdown of the total carbon emission shows that more than 50% of the carbon emission comes from space cooling and 10% is from the kitchen area.

The respondents from Petaling Jaya, Shah Alam, and Klang areas are the highest carbon-emitting group in their everyday life. The average household size of these three areas is five persons and 96% of respondents live in houses such as bungalows, terraced links, and semi-detached houses. Additionally, more than 57% of the household's income level is higher than RM 8000 in this area. Thus, it is assumed that the living standard of these areas is higher as well as the emission of CO_2. On the other hand, 77% of fathers and 57% of mothers from these areas hold a University degree and they are willing to pay for green products (68%). However, to date, the emission in these areas is higher and it is assumed to be due to the higher living standards.

On the contrary, the lowest carbon emission is recorded in Kajang and Kuala Lumpur. 68% of the respondents of these areas live in flats and apartments, and 82% of the respondents' household income is less than RM 8000. Furthermore, 73% of fathers and mothers do not hold a University degree. Moreover, 60% of the respondents are not willing to pay for green products. As a result, it is suspected that the living standard is comparatively lower than in Petaling Jaya, Shah Alam, and Klang, and the emission is lower. Hence, it could be assumed that the living standard is a significant contributor to household CO_2 emission.

In this study, the household appliances were divided into 4 categories according to their usage (Figure 6). Space cooling is the highest contributor (61%) to total household CO_2 emission. In reference to this space cooling option, air conditioners are responsible for 85% of CO_2 whereas fans only contribute 15%. Thus, to reduce the household CO_2 emission, the first target should be the space cooling options. If the usage of the air conditioner could be limited

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to a maximum of 3 units per household, then the CO_2 from air conditioners could be decreased by up to 38% in Table 2. Similarly, another space cooling option could be adopted by increasing the usage of fans by up to 50% and decreasing the usage of the air conditioner by 50%. It has been calculated that this option could reduce CO_2 emission by up to 35% from the current level of space cooling. However, there is not enough information regarding the potential reduction of household CO_2 emission through lifestyle changes. Nevertheless, several studies have focused on household energy efficiency using air conditioners. In the USA, it was reported that by introducing energy-efficient air conditioners, CO_2 emission could be reduced by up to 157 (kt) per year [10]. Similar studies have reported that CO_2 could be reduced by up to 28 (kt) per year and 235 (kt) per year for Australia and Thailand, respectively [34,35]. However, it was reported that 30 (kt) CO_2 per year could be reduced in the case of Malaysia [36].

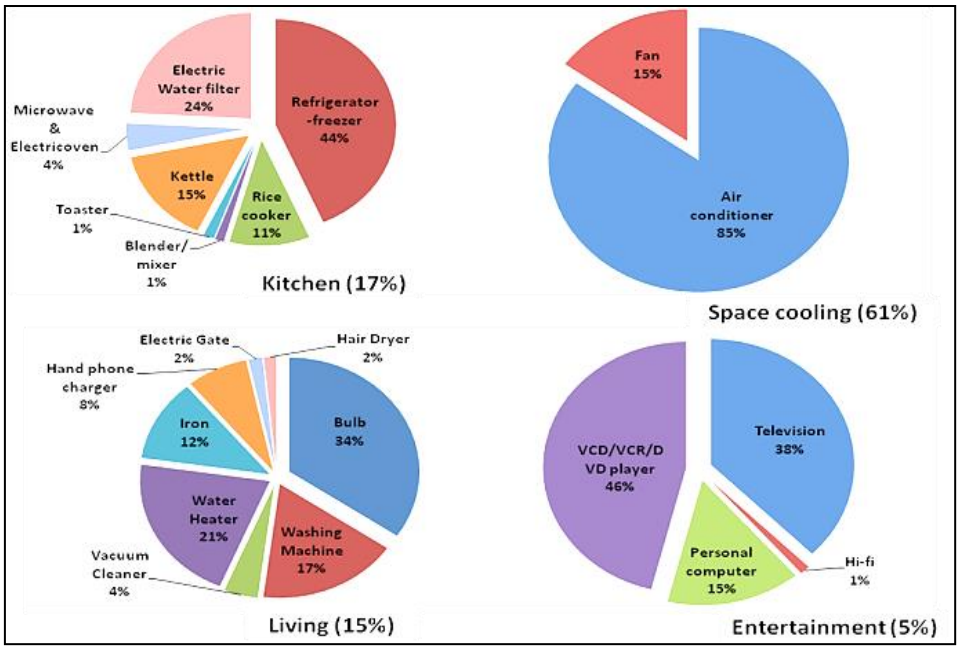

Figure 6. Breakdown of CO_2 emissions from household appliances.

Table 2: Different options of using behavioral changes for potential household carbon emission reduction (Tonne per month)

No.	Options	Current Emission	Estimated Emission	Potential Reduction	%	RM per household per month (*)
1	Reducing the number of air-conditioners (maximum 3 per household)	53.7	32.9	20.8	38	58.4
2	50% decrease in A/C and 50% increase in fans	63.2	41.1	22.1	35	62.1

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3	Reduction of one hour of watching TV in daily life	2.5	2.1	0.4	16	1.1
4	Using 10 lights per household	5.2	4.8	0.4	8	1.1
5	Adopting options 2, 3, and 4	104	81	23	22	64.1

* TNB [37] (Average electricity tariff 0.218 RM/kWh)

The second highest contributor to household CO_2 emission is the kitchen apparatus where the refrigerator accounts for 44% of CO_2. It is well known that the reduction of CO_2 emission from a refrigerator is only possible by using an energy-efficient refrigerator [10,34,35,36,38,39]. There is another option of reducing CO_2 emission from refrigerators i.e., reducing the number of refrigerators per household. However, the survey demonstrated that the average number of refrigerators per household is not more than 2.

The third position is occupied by living in terms of household CO_2 (16%) and the main contributor is the electric bulb (Figure 6). This study calculated that if the number of the bulb could be limited to 10 units per household, then the CO_2 could be reduced by up to 8% from the current level.

Even though entertainment contributes comparatively low CO_2 (5%) emission, adopting some lifestyle patterns could reduce the CO_2 emission further. Figure 4.7 demonstrates that among the entertainment appliances, the DVD player (46%) and Television (38%) contribute the highest CO_2 emission. According to the survey, the daily usage rate of DVD and Television is 3 hours and 6.5 hours, respectively. Therefore, television usage has been selected as an option for the reduction of CO_2 emission. Consequently, this study has calculated that if the usage of television could be reduced by one hour from the current level, the potential CO_2 emission is assumed to reduce by up to 16% from the current level. This study reveals that the adoption of the 2nd, 3rd, and 4th options as shown in Table 2 could reduce CO_2 emission by up to 22% from the total household CO_2 emission in the present scenario.

4. Conclusions and Recommendations

Malaysia has enjoyed remarkable economic growth over the last few decades where industrialization, agriculture, and tourism have contributed a lot to their success stories. However, nowadays, despite a relatively positive environmental record, there are some indications of environmental issues relating to the energy sector. These are currently the most pressing global issues related to the environment, society, and technology. Energy is one of the foundations in the development of a country. The main issue is the ability of a country to provide the people's needs and the ever-increasing energy costs concurrently. However, this energy consumption leads to drastic environmental challenges by increasing the concentration of hazardous greenhouse gases. Therefore, domestic, commercial, and industrial consumers must realize the importance of efficiency in the usage of energy and should play important roles and share responsibility with the government. This study also provided evidence of household CO_2 emission insignificant levels. The lowest emission was recorded in Kajang and Kuala Lumpur. On the other hand, Petaling Jaya and Shah Alam represented the higher emitting areas. The reason could be the types of houses as bigger houses require more energy for cooling

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purposes, thus releasing more CO_2. The electrical appliances have been categorized according to their usage for different purposes and ranked as space cooling > kitchen > living > entertainment. Air conditioners have been identified as the major CO_2 emitting appliance followed by fans, refrigerator-freezers, and electric bulbs. Therefore, the results of this study, which was based on several assumptions, could be extended in future research when more information would be available. First, this research only focused on CO_2 emission from direct sources of consumption. However, a great scale of consumption and emission comes from indirect sources in our daily lifestyle. Nevertheless, the present study could not cover indirect consumption due to the limited availability of data. Thus, there is scope for conducting research on the indirect consumption of households leading to household CO_2 emission. Second, this study could not focus on the transportation sector due to the limitation of data. However, there is no doubt that transportation is an important source of CO_2 emission. Therefore, a further study focusing on the transportation sector would be beneficial.

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