Significance of Household Composition on Electricity Consumption and Carbon Emissions

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The Asian Conference on Sustainability, Energy & the Environment 2017
Official Conference Proceedings

Abstract
In one country, there are various patterns of household composition consisting of the number of member and the age of each member in the household. Additionally, the consumption patterns of member in each age range are different. Consequently, the estimation of household electricity consumption and its carbon emissions without considering on the household composition is not enough and will lead to inaccurate results. Therefore, this paper emphasizes on investigating the change of electricity consumption and carbon emissions of household when the household composition change. The Age-Oriented Linear Expenditure System and the household socio-economic survey of the national statistical office of Thailand were utilized to econometrically estimate the household consumption model. The results of this paper expressed that household composition or the living style of people significantly caused different electricity consumption and carbon emissions. Living together with other family members or friends in the same household was the alternative way to reduce the aggregate electricity consumption and mitigate the aggregate carbon emission of the whole country. The government may apply the results on the energy and environmental policy relating to the population demographic change.

Keywords: household composition, electricity, consumption, carbon emissions

1. Introduction

The National Statistical Office (NSO) has begun to do reports on household energy consumption since the year 1995. The household in the urban area consumed the energy commodities higher than that the household in the rural area. The average household expenditure on energy was about 10% of total household expenditure. About 60% of energy consumption was for gasoline and liquid petroleum gas (LPG) commodities, while about 30% of energy consumption was for the electricity. The trend of household consumption on electricity and cooking gas has increased every year, while the trend of household consumption on charcoal and fire wood has decreased continuously. Most of consumption on charcoal and fire wood are that of the household in rural area. Thai household has tended to use the alternative energy or the renewable energy more and more in the future.

Regarding to the Input-Output table of Thailand in the year 2010, it showed that the direct consumption or the final demand on electricity of the household sector was about 103,381.4 Million Baht or about 14.45% of the aggregate electricity consumption of the whole country. Energy Research Institute (2000) analyzed the demand for energy of Thailand during the year 1995 - 2000 and forecasted the demand for energy of Thailand in the future during the year 2002 - 2025. The study found that the demand for energy of Thailand will increase around 2 times from 48.74 Mtoe in the year 1995 to 158.87 Mtoe in the year 2025. While demand for energy of the household sector will increase around 1 time from 10.3 Mtoe in the year 1995 to 19.75 Mtoe in the year 2025. The household consumption on electricity and cooking gas will increase around 0.63 time and 1.22 time respectively in the year 2025 comparing with that of in the year 1995. It reflected that Thailand tended to face the problem of energy shortage in the coming future.

Gamtessa (2003) studied the demand and consumption pattern in the urban area of Ethiopia. He found that 92.83% of household used the electricity as the primary household energy and 70.99% of household used the kerosene as the household energy. The interesting found was that there was up to 67.95% and 57.48% of Ethiopia household used the charcoal and fire wood respectively, while there was only 1.86% of household used cooking gas. He also found that the household expenditure share on electricity decreased when the household income increased. The low income household had the household expenditure share on electricity at 17.6%, while the high income household had the household expenditure share on electricity at 9.3%.

Stone (1954) proposed the famous household consumption model named Linear Expenditure System (LES) which explain the relationship of household consumption behavior to commodity prices and household budget. He assumed that all household consumers want to maximize their happiness by utilizing their limited budget. However there were many economists tried to fulfill the weakness of the LES model by adding other significance factors in the model.

Howe (1977) added some sociodemographic variable into the subsistence quantity variable term of the original LES model. He classified the member age into 3 age groups i.e. 0-7 years old, 8-17 years old, and over 17 years old. Nevertheless, he emphasized on the member who are younger than 17 years old, while the member

who are older than 17 years old was categorized into only one group. Pollak and Wales (1981) utilized the generalized Constant Elasticity of Substitution (CES) demand system to analyze the household behavior with demographic variables. Unfortunately, they still focused only on the number of children in household but not interested in the member age. Derrick and Wolken (1982) investigated the difference of estimated results of the household demand system between the pooled household data and the unpooled household data. They applied some dummy variables into subsistence quantity variable term of the original LES model. The disadvantage of their model was that their model cannot differentiate the impacts of number of member in each age because their dummy variables are not the quantitative variable.

Chomtohsuwan (2010) tried to investigate the difference in consumption pattern of each member age group by separating the household data into four member age group and applying the original LES model to each member age group. He found that the committed consumption level and marginal expenditure of each member age group were significantly different. It showed that the data separation was the one of method which can solve some weakness of the original LES model. The consumption patterns of member in each age range are different. Nevertheless, the data separation method was still not enough to represent the complex behavior of the household which there were various member age living together in the same house. Chomtohsuwan (2012) developed the household consumption model named the Age-Oriented Linear Expenditure System (ALES) by modified the committed consumption level and marginal expenditure coefficients of the original LES model with the household composition coefficients and variables. The ALES model was able to well explain the difference and significance of the change of household composition, which are the number of member and the age of each member, on the household consumption.

Because of the various patterns of household composition and the various member ages. Although each households has the same number of member but the different member age, the pattern of consumption of each household is also different. Consequently the estimation of household consumption and carbon emissions need to consider the household composition factor. Therefore, this paper aim to investigate the effect of change in household composition on the household electricity consumption and carbon emission by utilizing the ALES model. The results of this paper can be applied to estimate the more accurate electricity supply for supporting the household sector in the future especially in coming aged society. It also can be the tool for population policy planer to develop the population and household policies which help to solve the problem of energy shortage and climate change.

2. Methodology

The study investigated the household characteristic and consumption behavior by utilizing the two main secondary data of the year 2010 i.e. the household socio-economics survey data collected by the National Statistical Office and the retail price of commodities survey collected by Ministry of Commerce. To simplify the model, the study classified the member age into 4 age groups i.e. Young age group which covered the member who was between 0 and 19 years old, Adult age group which covered the member who was between 20 and 39 years old, Middle age group which covered the member who was between 40 and 59 years old, and Old age group which covered the member who was older than 60 years old. The commodities were

categorized into 4 commodity groups i.e. Food commodity group, Electricity commodity group, Cooking gas commodity group, and Other nonfood commodity group.

The study applied the Age-Oriented Linear Expenditure System (ALES) model developed by Chomtohsuwan (2012) to represent the household consumption behavior, as shown in Equation 1 to Equation 3.

$$E_i = P_i\left[\bar{\gamma}_i + \sum_{a=1}^{m}\tilde{\gamma}_i^a N^a\right] + \left(\bar{\beta}_i + \sum_{a=1}^{m}\tilde{\beta}_i^a N^a\right)\left[E - \sum_{j=1}^{n} P_j\left(\bar{\gamma}_j + \sum_{a=1}^{m}\tilde{\gamma}_j^a N^a\right)\right] \quad \text{... (1)}$$

$$E_i = P_i Q_i \quad \text{... (2)}$$

$$E = \sum_{i=1}^{n} E_i \quad \text{... (3)}$$

Where E is the expenditure on a commodity, i and j is the subscript of each commodity group, P is the commodity price, Q is the consumption level on a commodity, $\bar{\gamma}$ is the common committed consumption level which $\bar{\gamma} \geq 0$, $\tilde{\gamma}$ is the additional committed consumption level of each member which $\tilde{\gamma} \geq 0$, a is the superscript of each member age group, N is the number of household members which $N = \sum N^a$ and $0 < \bar{\gamma} + \sum \tilde{\gamma}^a N^a < Q$, $\bar{\beta}$ is the common marginal expenditure which $\bar{\beta}_i \geq 0$ and $\sum \bar{\beta}_i = 1$, $\tilde{\beta}$ is the additional marginal expenditure of each member representing the effect of the member age on the change of the household marginal expenditure which $\sum \tilde{\beta}_i = 0$.

The relative price index was applied to estimate the representative price of each commodity group in each region for solving the obstacles about the differences in the commodity unit of each commodity in the same commodity group, as shown in Equation 4. This study separated household location into 4 regions i.e. Bangkok, East, North, Northeast, and South. Bangkok was defined to be the reference region.

$$\overleftrightarrow{P}_{ir} = \sum_{k=1}^{n}\left(\frac{P_{kr}}{P_{kx}}\right)\omega_{kr} \quad \text{... (4)}$$

Where $\overleftrightarrow{P}$ is the relative price index, P is the commodity price, i is the subscript of each commodity group, r is the subscription of each region, k is the subscription of each commodity in the commodity group i. x is the subscription of the reference region, ω is the expenditure share of a commodity.

The study developed the regression model to estimate the total household expenditure which varies on number of household member in each member age group to be representative total household expenditure of each household composition scenario, as shown in Equation 4.

$$\ddot{E} = \delta + \sum_{a=1}^{m} \left[\alpha^a N^a \right] \quad \text{... (5)}$$

Where $\ddot{E}$ is the total household expenditure, δ is the common household expenditure level, α is the additional household expenditure level of each member, a is the superscript of each member age group, N is the number of the household members which $N = \sum N^a$.

Carbon emission of Greenhouse gas (GHG) was estimated by applying the formula and parameters from Thailand Greenhouse Gas Management Organization (TGO) as shown in Equation 6. Where ε is the greenhouse gas emission of a commodity in CO2e unit, Q is the consumption level of a commodity, λ is the greenhouse gas emission factor of a commodity, μ is the global warming potential of greenhouse gas.

$$\varepsilon_i = Q_i \sum_{g=1}^{h} \left[\lambda_i^g \mu_i^g \right] \quad \text{... (6)}$$

The study evaluated the impact of change in household composition on electricity consumption and carbon emissions by estimating the electricity expenditure of each household composition scenario and comparing the results with the base scenario. There were four scenarios in this study. Scenario I was the Representative household scenario or Base scenario which was used to estimate the aggregate household consumption by managing the household composition of every household to be the average household composition. Scenario II was the Single household scenario which was used to estimate the aggregate household consumption by managing the household composition of every household to be the one member household. Scenario III was the None alone household scenario which was used to estimate the aggregate household consumption by managing the household composition of the single household to be the two member household. These new households of Scenario II were the households of the two members who have the same age group. Scenario IV was the Four generation household scenario which was used to estimate the aggregate household consumption by managing the household composition of every household to have eight members from every age group. The population constraint of these scenarios was every household compositions of four scenarios were managed based on the same population demographic of the whole country. In other words, the aggregate populations of each age group are same in every scenario.

3. Results

The study analyzed 44,273 samples of the household socio-economics survey and over 500 commodities of the retail price of commodities survey. The results were as follows.

3.1 Household characteristics

In the year 2010, there were around 19.74 million households in Thailand. The average household size was 3.23 members per household. Most household sizes were 2 members, 3 members, and 4 members at 24.99%, 23.15%, and 18.98% of total household respectively. There was 15.27% of total household which had only 1 member. The average household expenditure was 15,407.71 Baht per month. The household expenditure tended to be higher when the household size was bigger. It should be noted that the household consumption behavior of the household which was bigger than 12 members was high volatility, as shown in the Figure 1.

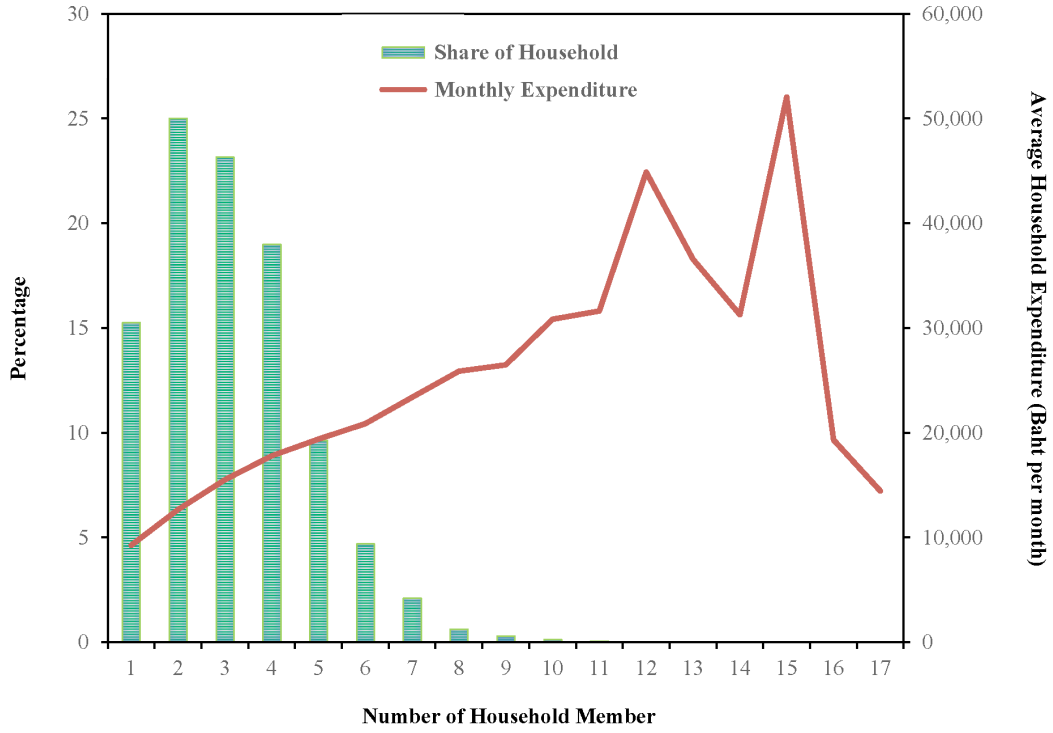

Figure 1: Distribution of household size and its monthly expenditure

The small household had the high proportion of Adult age member, Middle age member, and Old age member. The most members of the single household were Middle age member, while the Young age members rarely lived alone. The big household had the high proportion of the Young age member and the low proportion of Old age member. The representative household had Young age member, Adult age member, Middle age member, and Old age member about 27.58%, 25.65%, 31.01%, and 15.76% respectively, as shown in the Figure 2.

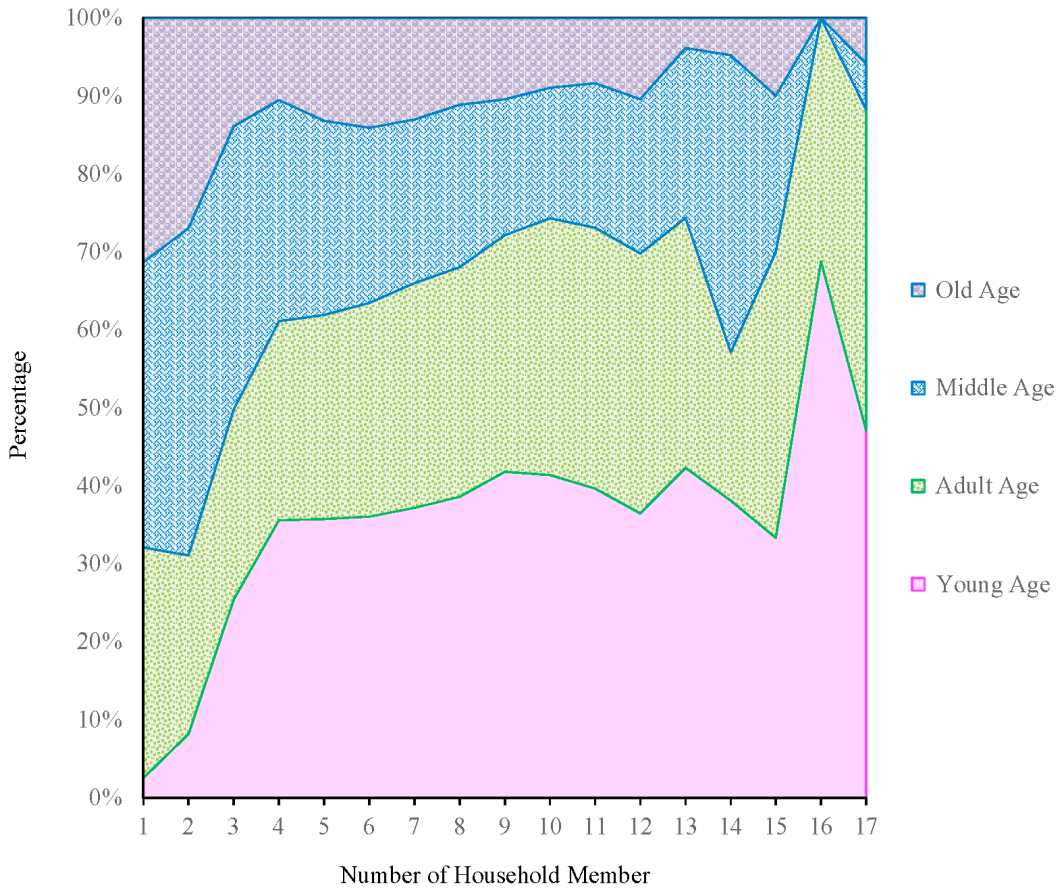

Figure 2: Percentage share of member age in each household size

The average household expenditure on the Food commodity group was 5,528.49 Baht per month or 35.88% of total household expenditure. The average household expenditure on the Electricity commodity group was 535.05 Baht per month or 3.47% of total household expenditure. The average household expenditure on the Cooking gas commodity group was 67.05 Baht per month or 0.44% of total household expenditure. The average household expenditure on the Other nonfood commodity group was 9,277.12 Baht per month or 60.21% of total household expenditure. The household expenditure on every commodity group tended to be higher when the total household expenditure was higher, as shown in the Figure 3.

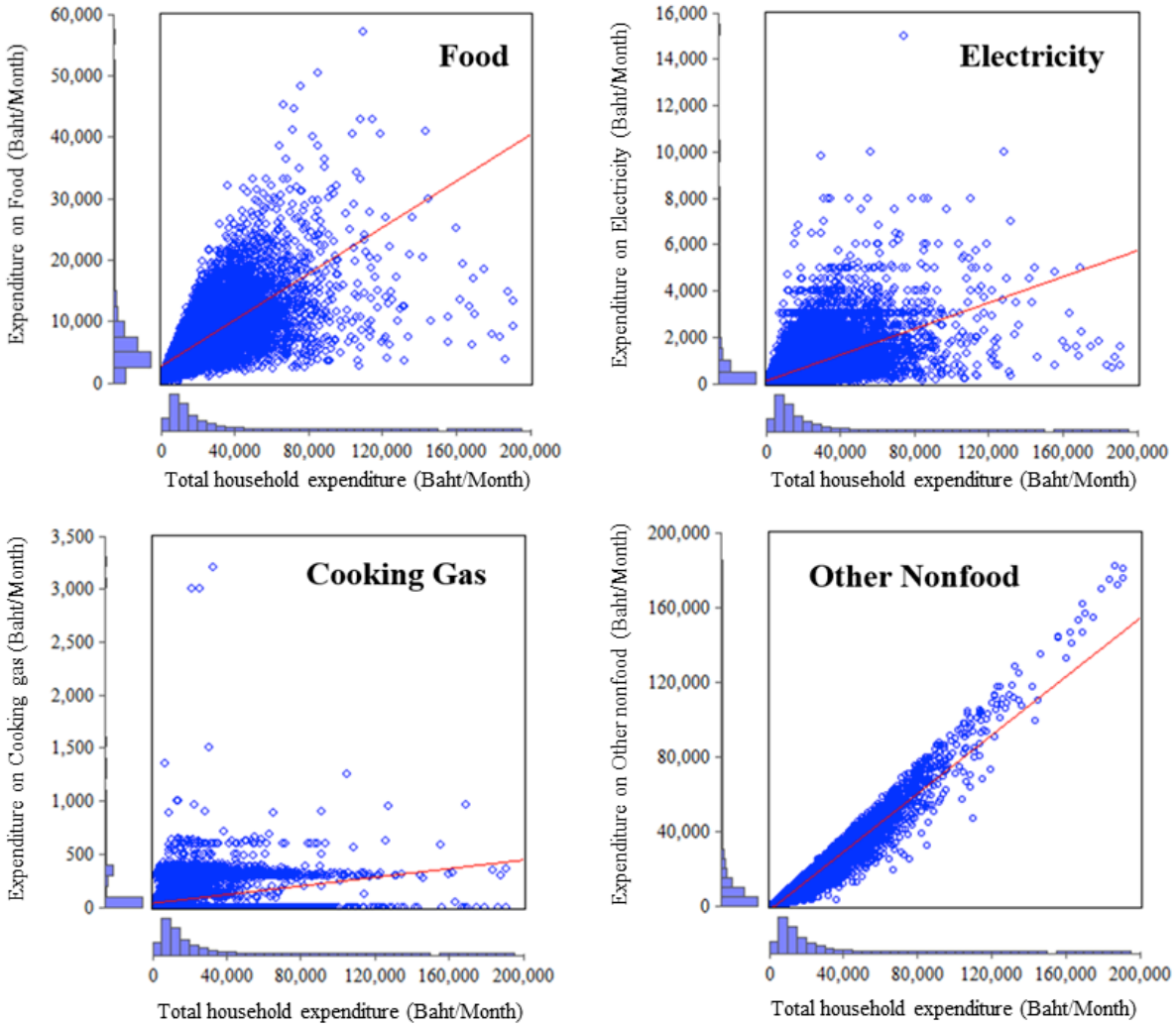

Figure 3: Relationship between commodity consumption and total household expenditure

Nevertheless the determiners of household consumption were not only the commodity prices and the household income but also the member age and the number of member in the household which were quite hard to explain. Therefore this study utilized the mathematical model to learn about the household consumption behavior which varied on the change of the household composition, as described in the next section.

3.2 Household consumption patterns

The relative price index results showed that the prices of electricity in every region were same. The price of Food commodity group in South region was higher than that in other regions. The price of Cooking gas commodity group in Bangkok was lower than that in other regions but the price of Other nonfood commodity group was higher than that in other regions, as in the Figure 4.

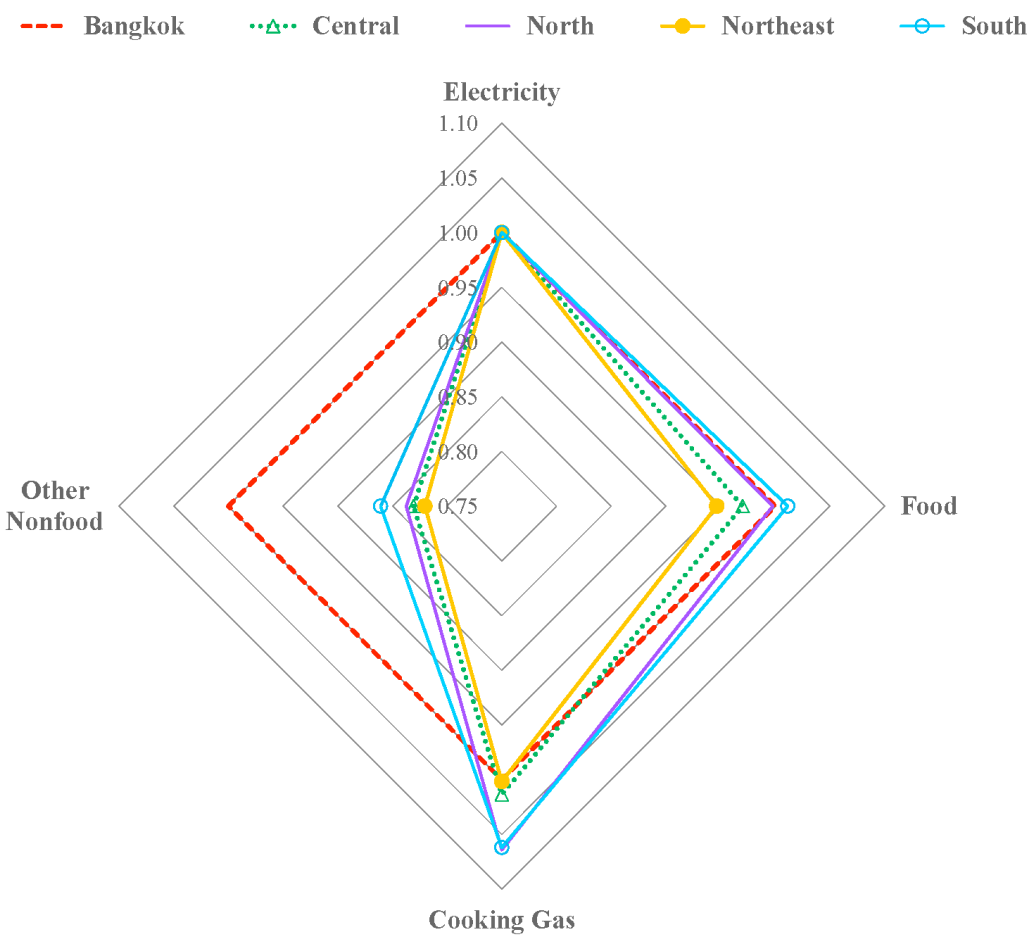

Figure 4: Relative price index of each commodity group

In the Table 1, the estimated coefficients of the ALES model implied that the committed consumption of the member in Young age group was lowest and continually increased when the member age increased. The committed consumption was highest when the member age was in Middle age group and then slightly decreased when the member age was in the Old age group.

When the household income increased, the Young age member increased consumption on Other nonfood commodity at the highest proportion, followed with Food commodity, Electricity commodity, and Cooking gas commodity respectively. Adult age member and Middle age member increased consumption on Other nonfood commodity at the highest proportion, followed with Electricity commodity, Cooking gas commodity, and Food commodity respectively. Old age member increase consumption on Electricity at the highest proportion, followed with Other nonfood commodity, Cooking gas commodity, and Food commodity respectively.

Coefficient		Commodity Group			
		Food	Electricity	Cooking Gas	Other Nonfood
Committed consumption level (γ)	Common	523.5520	60.0033	9.0147	341.6267
	Young age	352.5318	9.1695	3.3167	70.8489
	Adult age	1186.1540	53.2654	14.5482	168.1790
	Middle age	1302.4740	88.9511	21.5743	180.2750
	Old age	856.7273	61.9250	14.3089	145.5643
Marginal expenditure (β)	Common	0.192426	0.019513	0.000463	0.787598
	Young age	0.015480	0.001538	0.000519	-0.017537
	Adult age	-0.006458	0.001402	-0.000041	0.005097
	Middle age	-0.021204	0.001835	0.000204	0.019165
	Old age	-0.009868	0.005462	0.000662	0.003744

Table 1: Estimated coefficients of the ALES model

The interesting found was the member in Old age group had the highest marginal expenditure on Electricity and Cooking gas. While Young age member had the highest marginal expenditure on Food commodity and Middle age member had the highest marginal expenditure on Other nonfood commodity. Most estimated coefficients in the model had the significance level of 0.01. R-square value of the Food equation, Electricity equation, and Other nonfood equation were 0.5747, 0.3869, and 0.9517 respectively.

δ	α			
	Young age	Adult age	Middle age	Old age
6476.507	745.052	4112.103	4179.085	1521.364

Table 2: Estimated coefficient of the total household expenditure model

In the Table 2, the estimated coefficients of the total household expenditure model implied that the Young age member had the lowest impact on household expenditure. The Middle age member had the highest impact on household expenditure, followed with the Adult age member and Old age member respectively. All estimated coefficients in the model had the significance level of 0.01. The R-square value of the model was 0.1225.

3.3 Significance of household composition

The Table 3 revealed the impacts of change in household composition. In the Scenario I or Representative household scenario which was the Business as usual (BAU) case, the annual aggregate household consumption on electricity commodity was 10,419.08 million baht per year. When the every people changed their living style to living alone as Scenario II or Single household scenario, the annual aggregate household consumption on electricity commodity increased to be 17,300.57 million

baht per year. It reflected that when the trend of living alone increased the problems of world energy shortage and carbon emissions were more intense.

Unit: Million baht per year

Commodity Group	Scenario I Representative Household	Scenario II Single Household	Scenario III None Alone Household	Scenario IV Four Generation Household
Food	106,917.72	177,528.38	101,999.28	85,355.90
Electricity	10,419.08	17,300.57	10,037.02	9,562.00
Cooking Gas	1,387.87	1,821.18	1,350.28	1,402.30
Other Nonfood	187,375.10	394,546.77	176,897.15	133,551.25
Total	306,099.76	591,196.90	290,283.73	229,871.44

Table 3: Estimated annual aggregate expenditure of the all households

On the other hand, when we were able to motivate the people who were living alone to change their living style to live together with another one person who was also living alone and was in the same age group. Consequently the single household in the Scenario I became the couple household as Scenario III or None alone household scenario. It reduced the aggregate household consumption on electricity commodity to be 10,037.02 million baht per year. Moreover when we were able to motivate every people to change their living style to live with their family or warm family household which children, mother, father, grandfather, and grandmother lived together in the same household as Scenario IV or Four generation household scenario. It was able to reduce the aggregate household consumption on electricity commodity to be 9,562.00 million baht per year.

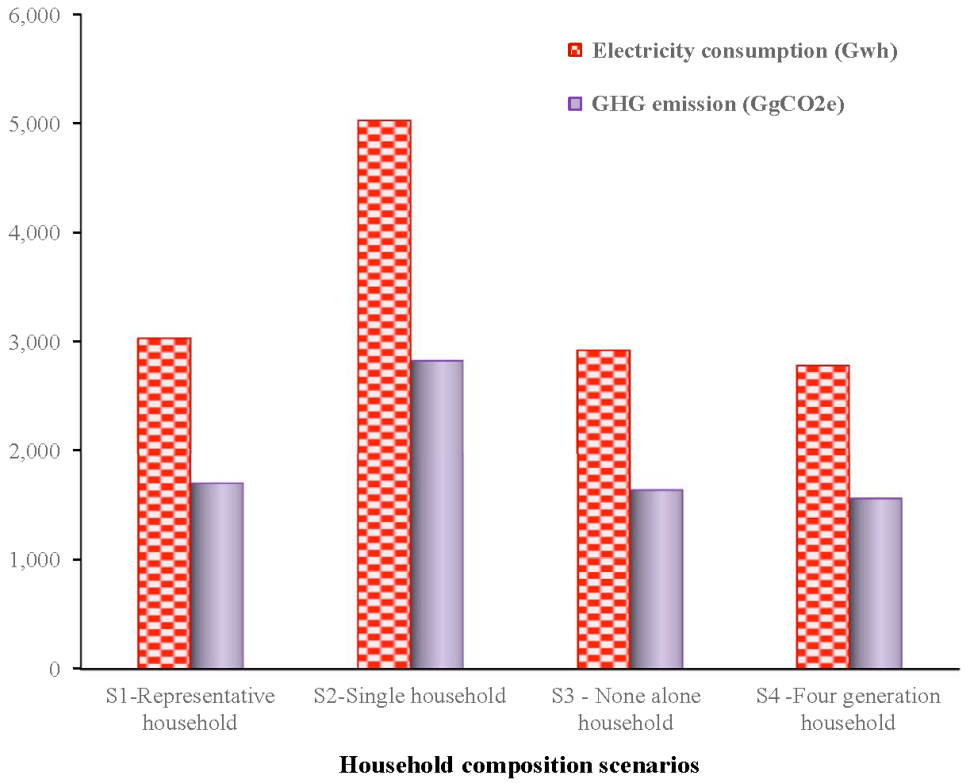

Figure 5: Electricity consumption and Carbon emission by scenario

The effects of household composition change as the results in Figure 5 expressed that the Scenario I or Representative household scenario (BAU scenario) consumed the electricity about 3,028.73 Gwh and emitted the Greenhouse Gas (GHG) about 1,699.12 GgCO2e. The Scenario II or Single household scenario was the worst case of this study that consumed the electricity about 5,029.12 Gwh and emitted the GHG about 2,821.33 GgCO2e which increased by 66.05% comparing with the BAU scenario. The Scenario III or None alone household scenario consumed the electricity about 2,917.67 Gwh and emitted the GHG about 1,636.81 GgCO2e which decreased by 3.67% comparing with the BAU scenario. While the Scenario IV or Four generation household scenario was the best case of this study that consumed the electricity about 2,779.59 Gwh and emitted the GHG about 1,559.35 GgCO2e which was able to decrease up to 8.23% comparing with the BAU scenario.

4. Concluding remark

This study points the qualitative and quantitative significances of household composition consisting of the member age and the number of member. The living style of people cause different electricity consumption and different carbon emissions. Living together with other family members or friends in the same house will help to reduce the aggregate electricity consumption and mitigate the aggregate carbon emissions of the whole country.

Therefore, the way to solve the problem of energy shortage and climate change in the future is not only investigating the new energy resources, supporting the green energies, promoting the green technologies but also encouraging the world population

to reverse their living style from living alone to become living together especially the family members live in the same house.

Author hopes that this research would spark the government sector and the non-governmental organization (NGO) to do research and development not only on the digital and mechanical technology but also the human and social technology. It is because sometimes the human and social technology may be able to solve the hard problems of this planet better than the digital and mechanical technology.

Acknowledgements

Author would like to thank National Statistical Office for supporting the survey data and Rangsit University for supporting the research fund.

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