Factors Affecting Energy Consumption of Households in Bangkok Metropolitan Area

Pattana Sirichotpundit[1]*, Chamlong Poboon[2], Dujduen Bhanthumnavin[2], and Wisakha Phoochinda[2]

[1]Faculty of Management Science, Rajabhat Suan Sunandha University (SSRU), Bangkok, 10300, Thailand

[2]School of Social and Environmental Development, National Institute of Development Administration (NIDA), Bangkok, 10240, Thailand

Abstract

This study aimed to examine factors affecting energy consumption for home energy of households in Bangkok metropolitan area. Data was collected by surveying 1,150 households in 15 districts of the Bangkok metropolitan administration. The hypotheses were analyzed by multiple regression analysis. Results of the analysis revealed that there were three factors significantly having positive effects on the quantity of home energy use. These are: physical and structural, social and cultural, and economic factors. Suggestions for reducing home energy use include compact household size, home locations are in densely populated areas, home appliances used should be energy saving types, and renewable energy use in the city must be encouraged.

Key words: Households' energy consumption/ Home energy/ Factors/ Bangkok

1. Introduction

Global warming is mainly caused by human beings and their associated activities. The Earth's environment and climate have been significantly affected by many countries around the world. Burning of fossil fuels is a major source of carbon dioxide (CO_2) emitted into the Earth's atmosphere. Carbon dioxide is a major cause of the greenhouse effect and thus global warming. The atmospheric level of CO_2 is now 379 part per million (ppm) higher than at any time in the past 650,000 years. Of the 12 warmest years on record, 11 occurred between 1995 and 2006. In recent years, recorded CO_2 reached 32 million metric tons (Klugert, 2007). This has led scientists, private, and public organizations to seriously try to find ways to reduce CO_2 emission in the Earth's atmosphere.

In 2008, the world's top-10-countries emitted 80.56% of the total greenhouse gases. Thailand emitted 0.95% of the total and ranked 22nd. Globally, liquid and solid fuels accounted for 76.6% of CO_2 emissions from fossil fuel burning. Fossil fuels accounted for 18.5% of combustion gases and reflect a gradually increasing global use of natural gas in 2006 (Boden and Andres, 2009). World CO_2 emissions are expected to increase 1.4% annually between 2006 and 2030. Much of the increase in these emissions is expected to occur in the developing world, which includes China and India. Emissions from developing countries are expected to grow above the world average at 2.2% annually between 2006 and 2030 (EIA, 2009).

Thailand's CO_2 emissions were 285 million metric tons in 2008 and the growth rate from 2007 was 4.85%. These CO_2 emissions can be classified into power generation 39.42%, transportation 29.79%, manufacturing 22.15%, commercial and households 2.73%, and others including agriculture, construction and mining 5.90% (Ministry of Energy, 2009).

*Corresponding author:
E-mail: pattana98@hotmail.com

Bangkok which is the capital and biggest city in Thailand, has a registered population of around 5.7 million or 8.93% of the whole kingdom. The population density of Thailand is 124 persons/km^2 whereas in Bangkok it is 3,634 persons/km^2. However, the real number of people in Bangkok is higher than this. In 2010, there were 16 million electricity consumers in Thailand. Bangkok had 2,958,586 electricity consumers or 18.50% of the total. Household consumers had 2,439,689 or 82.46% of electricity consumption share in the total (Metropolitan Electricity Authority (MEA), 2010). Categories of electricity energy sales in Bangkok were residential 82.46%, small business 16.37%, and medium business 0.65%. Total electricity consumption of Thailand was 134,937 GWh. and Bangkok consumed around 25% or one-fourth of the whole kingdom. Hence, energy consumption in homes, in the Bangkok metropolitan area is enormous and it is one of the major sources of CO_2 emissions for the country. Therefore, home energy consumption in Bangkok city is greater than all the other provinces in Thailand and it is therefore the focus of this research study.

1.1 Objectives of the Study

1) To investigate energy consumption for home energy of households in Bangkok metropolitan area.

2) To examine significant factors affecting energy consumption and home energy savings in the Bangkok metropolitan area.

1.2 Scope of the Study

1) Study factors affecting home energy consumption and energy saving of households in Bangkok metropolitan area.

2) Unit of analysis is the household units which are located in Bangkok metropolitan area.

3) Study period was 2 months, from January to February 2011.

2. Literature review

In the city, environmental problems are based on three propositions which Kingsley (1994) suggested: the per capita amount of energy and materials used, the discharge of pollutants, and infrastructure systems available to help control these urban problems are at present inadequate for the task of urban energy management. Urban areas are the main source of CO_2 emissions due to their heavy use of energy. To address global environmental threats of greenhouse gas emissions, Leitmann (2006) suggested two important elements which are policies and investments. The following reviews are used in this study.

1) The practical application of energy saving in residential sectors requires the disaggregation, analysis and measurements of energy saving. It is based on economic, social, and physical criteria as well as other constraints peculiar to the country concerned which were applied by Siddayao (1991). In the USA, Pimentel et al. (2006) commented that the key sectors of energy use in residential areas are energy use for personal transportation, transportation of goods and materials, and energy use in the food system. The energy performance of UK households was improved by consumers' adoption and use of low-and zero-carbon technologies as documented by Caird and Herring (2008).

2) The six types of barriers to energy saving solutions were proved by Throne-Holst et al. (2008), and ranked from macro to micro perspectives: physical and structural, political, cultural-

normative, economic, information, and individual-psychological barriers.

From the reviews, this study proposes a theoretical framework on urban residential energy management. There are 5 factors potentially affecting energy consumption and energy saving in the urban residential areas. The five factors consist of physical and structural, social and cultural, economic, communication and information, and psychological factors. In addition, this framework suggests 4 areas of urban energy policies for urban energy management consisting of social, economic, environmental, and technological policies. These policies are accepted to lead urban households' energy consumption as equity, efficiency, and sustainability (Figure 1).

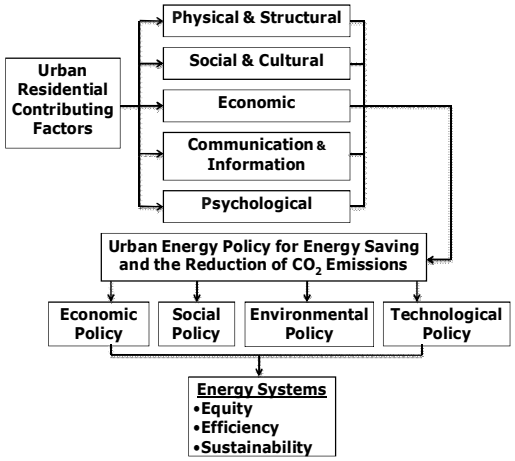

Figure 1 Theoretical Concept of Urban Residential Energy Management

3. Methodology

3.1 Conceptual Framework

The work was based on the concept as shown in Figure 2. Five factors were examined and assumed to have influences on energy consumption and energy saving of households in Bangkok which were as follows;

1) Physical and structural factors: house type (single house, building, town house, condo/apartment, rental house, and others, calculated by space in square meters), location, number of household members, and household appliances.

2) Social and cultural factors: level of education and income/household.

3) Economic factors: household expenditure.

4) Communication and information factors: industry source, government source, professional, interpersonal, law and regularity, government support, and public information.

5) Psychological factors: attitudes, knowledge, beliefs, and motives. Two dependent variables were the quantity of energy use and energy saving practices in household.

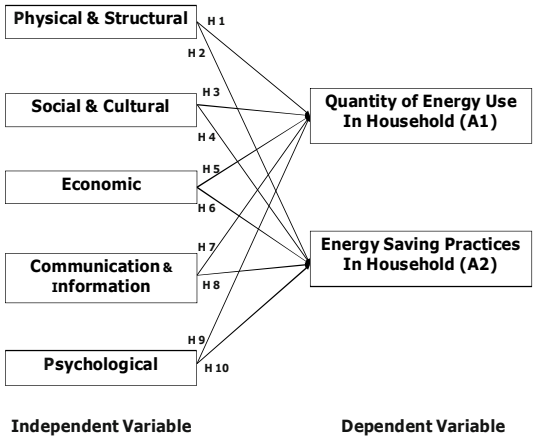

Figure 2 Conceptual Framework of the Study

Ten hypotheses are proposed: H_1 and H_2: physical and structural factors have a positive effect on the quantity of energy use in households (A1) and energy saving practices in household (A2); H_3 and H_4: social and cultural factors have positive effect on A1 and A2: H_5 and H_6: economic factors have positive effect on A1 and A2; H_7 and H_8: communication and information factors have positive effect on A1 and A2; and H_9 and H_{10}: psychological factors have positive effect on A1 and A2.

3.2 Population and Sampling

The household population of Bangkok was 2,400,540 taken from 50 administrative districts. The sample size was 1,150 households which is equivalent to a sampling ratio of 0.048%. The multi-stage sampling technique and proportional allocation method were employed for selecting the samples (Pantipa, 1986; Neuman, 2006). This multi-stage sampling technique and method consisted of the following.

Stage 1: The Bangkok area was classified into three zones: the inner area (21 districts), the middle area (18 districts), and the outer area (11 districts).

Stage 2: Random selection of 4-6 districts from each zone.

Stage 3: Random selection of 3 streets from each district.

Stage 4: Random selection of 20-30 households from each street.

3.3 Instrument

1) Face-to-face interviews using a questionnaire:

The representative of each household was the head of the household or a household member who was over 18 years old. The survey questionnaire contained closed-end questions of a Likert and semantic differential scales and opened-end questions. They were as following.

Part 1 Basic and general information about the household members comprised of: household members, gender, age, education level, occupation, income/person, mode of transport, distance between home and workplace.

Part 2 Energy consumption in the home, which included the use of: electrical appliances, monthly electrical bills, monthly payment of home energy, alternative energy uses, and their home energy saving equipment.

Part 3 Energy conservation, saving factors, and their behavioral characteristics which practices or actions for reducing electricity consumption in their homes is used. The other was knowledge, opinion, belief, attitudes, motivation and communication, and energy conservation information.

Part 4 Suggestions on how-to reduce household energy consumption at present and in the future.

2) Reliability of the questions:

Draft questions were designed based on operational definitions of the variables and were tested with 105 households in the Bangkok area. The reliability of the questions from the test of the Cronbach's alpha coefficiency of internal consistency score was 0.84. Some questions were revised and adjusted or changed according to the result of the test.

3.4 Data Collection

1) Primary data was collected by 20 trained researcher assistants from January to February 2011, about 71-91 households per district. Total households were 1,150 and from 15 of 50 districts, 3 zones of Bangkok area.

1.1) Inner area from 473 households in 6 out of 21 districts

1.2) Middle area from 378 households in 5 out of 18 districts

1.3) Outer area from 299 households in 4 pit of 11 districts

2) Secondary data was compiled from several sources such as reports of relevant organization, the internet, etc.

3.5 Data Analysis

1) Descriptive statistics comprises of frequency distribution, measures of central tendency and dispersion, e.g. percentage, maximum, minimum, mean, and standard deviation.

2) Hypotheses were tested by inferential statistics and quantitative

method. Ten hypothetical models were tested by multiple regression analysis (MRA) at statistically significance of confident level $p \leq .05$ and $R^2 \geq .30$. Formula of test was $Y_i = a + b_1 (X_{i1}) + b_2 (X_{i2}) \ldots + b_N (X_{iN})$, where a = value of Y before other factors' effect are considered, b_1, b_2 and b_N are an estimate of each effect of X_{i1}, X_{i2}, $\ldots X_{iN}$, when X is any independent variable.

4. Results

Households' general information, as shown in Table 1 comprises of the population density of all 15 districts, members of the household, age of the household, education of the household, space of the household, income/month and expenditure of the household.

Table 1 General Information of the Households

General Information of Households	Mean	S.D.	n
1.Population Density (People/km^2)	8,722.34	7,002.48	1,150
2.Number of the Household's Members	2.93	1.614	1,150
3.Age of Household Members	34.54	n/a	3,364
4.Education Year of Household Members	31.58	16.888	1,150
5.Space of the Household (m^2)	75.05	53.192	1,150
6.Income of Household/Month	30,658.43	28,142.41	1,150
7.Expenditure of Household/Month	14,863.72	7,618.12	1,150

The average expenditure of households for energy consumption was 2,361.74 baht/month which was 835.54 baht for energy consumption at home and 1,526.20 baht for vehicle transportation. The households can save energy from home energy use and consumptions in three ways.

1) Households used technological and alternative products for home energy saving are electrical saving label products or no.5-saving-label products and Compact Fluorescent Lamp (CFL) bulbs equal to nearly a half of all types. Other products are Liquid Crystal Display and Light Emitting Diode (LCD&LED) and Energy Efficiency Ratio (EER) products. These electric energy savings come from electrical saving label products, CFL bulbs, auto power off equipment, LED light bulbs, and LCD&LED televisions at an average rate of saving in reduction of household use between 2.66-5.29 percent (Table 2).

Table 2 Technological and Alternative Products Used for Home Energy Saving

Types of Technological and Alternative products	% Rate of Saving[1]	Electrical Unit Saving (Watts-hour)[2]	CO_2 Emission Unit (Gram)[3]
1.Compact fluorescent light bulbs (CFL)	4.23	2.00-4.00	1.22-2.44
2.Electrical saving label products	5.29	10.00-20.00	6.10-12.20
3.LED light Bulbs	3.77	27	16.47
4.Auto power off equipment	3.95	19.00-28.00	11.59-17.08
5.LCD & LED television	2.66	18.12-31.75	11.06-19.37
6.EER refrigerator	2.13	16.27-67.50	9.93-41.17
7.LCD & LED personal computer	2.52	5.00-61.25	3.05-37.36
8.EER air conditioner	0.43	16.27-67.50	9.93-41.17
9.Power saving unit	1.14	19.00-28.00	11.59-17.08
10.Solar energy products	0.63	201.6	1,047.98
11.Wind energy products	0.19	n/a	14.00-33.00

Notes: [1] based on this research study (% Use in Households × % of Saving)
[2] watts per hour saving unit in home electrical use
[3] calculation come from [2]
n/a = not available

2) Energy saving practices which have been used in home energy saving are: turning electricity off, growing trees around the home, making terraces longer, using fluorescent light bulbs, and insulating the ceiling and have resulted in an average rate of saving per household use of between 1.78-24.82 percent (Table 3).

3) Producing less consumer waste is also an energy saving practice in households. Households used them by reducing consumer food waste while others practices are reusing products, refuse separation, selling, or recycling paper, plastic, and metal from consumer waste. Food and vegetable components can also be used for fertilizer. These practices have an average rate of saving in energy reduction of household use at around 0.25-14.40 percent (Table 4).

Table 3 Saving Practices in Home Electricity Energy

Home Electricity Energy Saving Practices	% Rate of Saving[1]	Electrical Unit Saving (Watts-hour)[2]	CO_2 Emission Unit (Gram)[3]
1.Making thicker wall	1.17	1.19-4.17	0.73-2.54
2.Insulating above ceiling	1.78	1.19-4.17	0.73-2.54
3.Growing tree around home	3.36	0.28-22.22	0.17-13.56
4.Coloring outside the house	1.38	0.28-22.22	0.17-13.56
5.Making terrace longer	3.07	0.28-22.22	0.17-13.56
6.Turning electrical equipment off	24.82	0.11-8.89	0.07-5.42
7.Adjusting air conditioner	1.04	10-144.00	6.1-69.54
8.Filling gaps around floor and others	1.41	1.19-4.17	0.73-2.54
9.Upgrading old equipments	1.14	0.33-27.67	0.20-16.27
10.Using fluorescent light bulbs	2.92	0.33-27.67	0.20-16.27
11.Using effective saving bathroom & etc	0.38	0.08-6.44	0.05-3.93
12.Others	0.08	0.11-8.89	0.07-5.42

Notes: [1] based on this research study (% Use in Households × % of Saving)
[2] watts per hour saving unit in home electrical use except no. 5, 6, and 10 are watts per day saving unit
[3] calculation come from [2]

Table 4 Home Energy Saving in Consumer Waste

Consumer Waste Saving Practices	% Rate of Saving[1]	Electrical Unit Saving (Watts-hour)[2]	CO_2 Emission Unit (Gram)[3]
1.Reducing consumer food waste	10.21	0.25-0.40	230-360
2.Use food and vegetable components for fertilizer	3.79	0.27	240
3.Recycle paper, plastic, and metal from consumer waste	11.62	0.30-0.90	0.41-1.23
4.Reuse, separate, and sell consumer waste	14.4	0.25-0.90	0.34-1.23
5.Use biogas from recycle consumer waste food	2	0.85	1.57
6.Bring food and vegetable components to produce bio-extract water and fertilizer	1.5	0.12-0.74	0.17-1.02
7.Others	0.25	0.27-0.85	0.37-1.16

Notes: [1] based on this research study (% Use in Households × % of Saving)
[2] watts per hour saving unit in home electrical use
[3] calculation come from [2]

Households can save electrical energy at about 0.19-5.29% by using technological and alternative products approximately 0.08-24.82% of energy saving practices, and approximately 0.25-14.40% by using consumer waste saving practices. All of these can help to save electrical energy or around 2.00-201.60, 0.11-144.00, and 0.12-0.90 watts-hour and they can reduce CO_2 emissions from electrical energy use and consumption by about 1.22-1,047.98, 0.07-69.54, and 0.17-360.00 grams, respectively. Figures in Table 1-4 are dependent on this study.

The hypothesis models (H1-H10) were tested and the results were as follows:

1) Three models supported were model 1, physical and structural factors (R^2 .715 or 71.5% and $p<$ .01); model 3, social and cultural factors (R^2 .502 or 50.2% and $p<$ .01); and model 5, economic factors (R^2 .552 or 55.2% and $p<$ .01) have positive effect on the quantity of energy use in households (A1) as the adjusted R^2 is higher than .30 and statistically significant at $p \leq .05$.

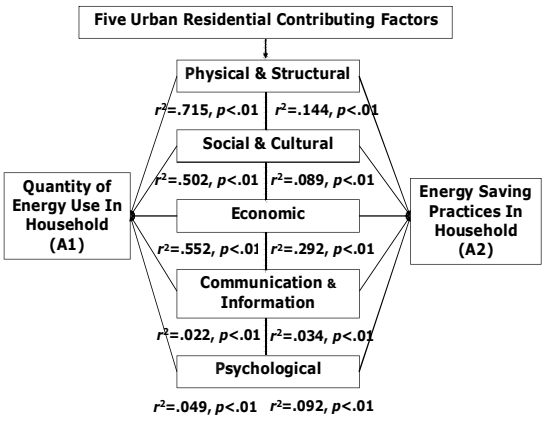

Figure 3 Results from the Test on Hypothesis Models

2) Seven models rejected were model 2, 4, and 6-10. They had no positive effect neither on the quantity of energy use in household (A1) nor energy saving practices in household (A2) as the adjusted R^2 less than .30 and statistically significant $p \geq .05$. Models 2, 4, and 6-10 had R^2 and p equal to .144 and < .01; .089 and < .01; .292 and < .01; .022 and < .01; .034 and < .01; .049 and < .01; .092 and < .01, respectively.

Table 5 Summary of All Hypothesis Model Test Effects of Energy Use and Energy Saving Practices in Home Energy

Factors	Effect of Home Energy	
	Quantity of Use (%)	Saving Practices (%)
Physical and structural	71.5	14.4
Social and cultural	50.2	8.9
Economic	55.2	29.2
Psychological	4.9	9.2
Communication and Information	2.2	3.4

The summary of all hypothesis model tests from Figure 3 are ranked from the largest effect to the smallest as shown in Table 5.

5. Conclusions

It can be concluded that three factors (physical and structural, social and cultural, and economic factors) can significantly affect the quantity of household energy use and consumption.

Physical and structural factors that were investigated and are house type, location, number of household members, and household appliances. These variables can affect the amount of energy use and consumption in the households, especially with household appliances which are considered to be a major

variable. In order to reduce energy consumption of the households' home energy within Bangkok metropolitan area, the household size must be smaller; house space needs to be more compact, when located in a high density area. The number of household appliances needs to be reduced and the number of energy saving and efficient appliances needs to be increased. On the contrary, in the future for the aforementioned area, it would seem that we can expect more energy use and more CO_2 emissions in urban areas.

For social and cultural factors, education levels of all household members and total household income are significant. These two variables can affect the amount of energy use and consumption in the households, especially critical is education levels of households with higher incomes. Therefore, the increase of household incomes and education levels of household, causes a need for more comfortable living, also the values of urban households and consumerism push the demand to produce more energy and more CO_2 emissions in the Bangkok metropolitan area, because energy conservation equipment is limited in the market.

Finally, the economic factor investigated and examined is just one variable that is significant factor in household expenditure. This variable can affect the amount of energy use in a positive way i.e. consumption in households which come from higher incomes usually results in higher expenditure. Therefore, higher household incomes, results in higher use of home energy, this is due the purchase of more electrical appliances. This then requires more energy production and causes more CO_2 emissions as well.

6. Discussions

Three factors of this study are based on the economic, social, and physical criteria, and other constraints, as well as from six types of barriers to energy saving solutions (Siddayao, 1991; Throne-Holst et al., 2008). These three factors are barriers for energy saving solutions but the other two factors of communication and information, and psychological are not. Because, these two factors also have a coefficient of determination or the size of effect in a medium degree (1.0% to 10.0%), this is implied by Kinnear and Gray (2009: 441). That means all factors are barriers to energy saving solutions in the study of energy consumptions for home energy of households as well as the main three factors: economic, social, and energy function which have been used by Poboon (1981) for his empirical model study of households' energy consumption.

Energy consumption of the households in comparison to a previous survey from 2010, electricity consumption in the Bangkok metropolitan area was 1,010 baht/month with a household size of 2.93 persons, whereas the average for the rest of the kingdom electricity consumption was 491 baht with 3.20 persons per household (National Statistical Office of Thailand, 2010). Today, Bangkok households consume all types of home energy more than other regions, except charcoal and LPG for cooking. In summary, Bangkok households have higher education levels, more income, and need more comfort. This means they want to buy more electrical appliances for their houses. These will significantly boost energy consumption and CO_2 emissions in urban areas more than in rural areas. Therefore, urban residential energy management is needed to carry out the economic, social, environmental, and technological policies

into energy systems such as energy equity, energy efficiency, and energy sustainability.

Recommendations for future research and managerial implications are as follows.

1) Four urban energy policies are required:

(1) An economic policy using home appliance standards, using the 5 star energy saving label and energy efficient products. Promoting alternative and renewable energy supplies.

(2) A social policy using energy consumer and energy producer linkage produced by communities and community integration based approach.

(3) An environmental policy using city and mass transportation systems, reinventing and rejuvenating the city, smaller houses with compact home areas, and improved cycling and walking spaces.

(4) A technological policy using distributed generation or small-scale power generation, building partnerships with global cities on the application of information, using communication and technology (ICT), and using measures related to emission control technology.

2) Ways to reduce energy consumption in the Bangkok area are needed using urban energy management by studying energy systems and urban energy policies including which urban energy policies cannot be implemented at present and why not.

3) A research survey is recommended to be conducted every five years focusing on trends of urban household energy consumption. Because of the limitation of field surveys and data collection, little is known about factors affecting energy consumption by urban households.

4) Future studies must be addressed on how to fund these urban energy policies, projects, and balance potential projects with other projects around the city area. Finally, the Bangkok Metropolitan Administration (BMA) may lack the capital funds to undertake these urban energy policies and projects in a timely manner.

7. Acknowledgement

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