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FACTORS AFFECTING ENERGY CONSUMPTION FOR TRAVELING OF HOUSEHOLDS IN BANGKOK METROPOLITAN AREA

ปัจจัยที่ส่งผลกระทบต่อการใช้พลังงานสำหรับการเดินทางของครัวเรือนในเขตกรุงเทพมหานคร

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

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

พัฒนา ศิริโชติบัณฑิต[1*] จำลอง โพธิ์บุญ[1] ดุจเดือน พันธุมนาวิน[1] และวิสาขา ภู่จินดา[1]

[1] คณะพัฒนาสังคมและสิ่งแวดล้อม สถาบันบัณฑิตพัฒนบริหารศาสตร์ กรุงเทพมหานคร 10240 ประเทศไทย

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Abstract

This study aimed to examine factors affecting energy consumption for traveling of households in Bangkok metropolitan area. Data were collected by surveying 1,150 households in 15 districts of Bangkok Metropolitan Administration. The hypotheses were tested by multi regression analysis. Results of the analysis revealed that there were two factors significantly having positive effects on the quantity of energy use for traveling which were physical and structure factors and social and cultural factors. Suggestions for reducing energy use for traveling including promoting working close to living place, improving public transportation service, restricting private vehicle use in the inner zone, and keeping on subsidizing alternative fuel.

Keywords: Households' Energy Consumption, Traveling, Factors, Bangkok

บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อตรวจสอบปัจจัยที่ส่งผลกระทบต่อการใช้พลังงานสำหรับการเดินทางของครัวเรือนในเขตกรุงเทพมหานคร เก็บรวบรวมข้อมูลโดยการสำรวจครัวเรือนจำนวน 1,150 ครัวเรือนใน 15 เขตของกรุงเทพมหานคร การทดสอบสมมติฐานใช้สถิติสมการถดถอยพหุคูณ ผลการวิจัยพบว่าปัจจัยทางด้านกายภาพและโครงสร้างและปัจจัยทางด้านสังคมและวัฒนธรรมส่งผลกระทบเชิงบวกต่อปริมาณการใช้พลังงานสำหรับการเดินทางของครัวเรือนในเขตกรุงเทพมหานครอย่างมีนัยสำคัญทางสถิติ ข้อเสนอแนะในการลดการใช้พลังงานสำหรับการเดินทางประกอบด้วยการส่งเสริมให้ทำงานใกล้กับที่พักอาศัย การปรับปรุงระบบขนส่งสาธารณะ การเข้มงวดกับการใช้รถยนต์ส่วนตัวในเขตชั้นใน และการอุดหนุนราคาของพลังงานทดแทนต่อไป

คำสำคัญ: การใช้พลังงานของครัวเรือน, การเดินทาง, ปัจจัย, กรุงเทพมหานคร

* corresponding author
E-mail : pattanas@rocketmail.com
Phone : + 66-2160-1516

Introduction

Global warming is mainly the result of human beings and activities. The earth's environment and climate have significantly affected all countries around the world. Burning of fossil fuel is the major source of carbon dioxide (CO_2) emitted into the earth's atmosphere. Carbon dioxide is the major cause of greenhouse effects and global warming. 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 records, 11 occurred between 1995 and 2006. In recent years, recorded CO_2 reached 32 million metric tons[1]. This has led scientists, private and public organizations to seriously find ways to reduce CO_2 emission into the earth's atmosphere.

In 2008, the world 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. Combustion of gas fuels accounted 18.5% from fossil fuels and reflected a gradually increasing global use of natural gas in 2006[2]. The 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 including China and India. Emissions from the developing countries are expected to grow above the world average at 2.2% annually between 2006 and 2030[3].

Thailand CO_2 emission was 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%, transportations 29.79%, manufacturing 22.15%, commercial and households 2.73%, and others including agriculture, construction and mining 5.90% [4].

Bangkok, the capital and biggest city of Thailand, has registered population of around 5.7 million or 8.93% of the whole kingdom. Population density of Thailand is 124 persons/km^2 where that of Bangkok is 3,634 /km^2. However, the real number of people in Bangkok is higher than this. In 2010, total number of vehicles which registered in Thailand was 28,484,829 units, of which 11,328,108 were cars and 17,156,721 were motorcycles. Bangkok had 6.44 million units or 22.62% of that of Thailand and consumed petroleum products 2,836 baht per month or more than 42% of the whole kingdom [5]. Hence, energy consumption for traveling in Bangkok metropolitan area is enormous and it is one of the major sources of CO_2 emissions. Therefore, objectives of the study are 1) to investigate energy consumption for traveling of households in Bangkok metropolitan area, 2) to examine significant

factors affecting energy consumption and energy saving in traveling of households in Bangkok metropolitan area and 3) to suggest policies for reduction of energy consumption for traveling of households in Bangkok metropolitan area. Scope of the study are 1) study factors affecting energy consumption and energy saving in traveling of households in Bangkok metropolitan area. 2) units of analysis are household units in Bangkok metropolitan area.

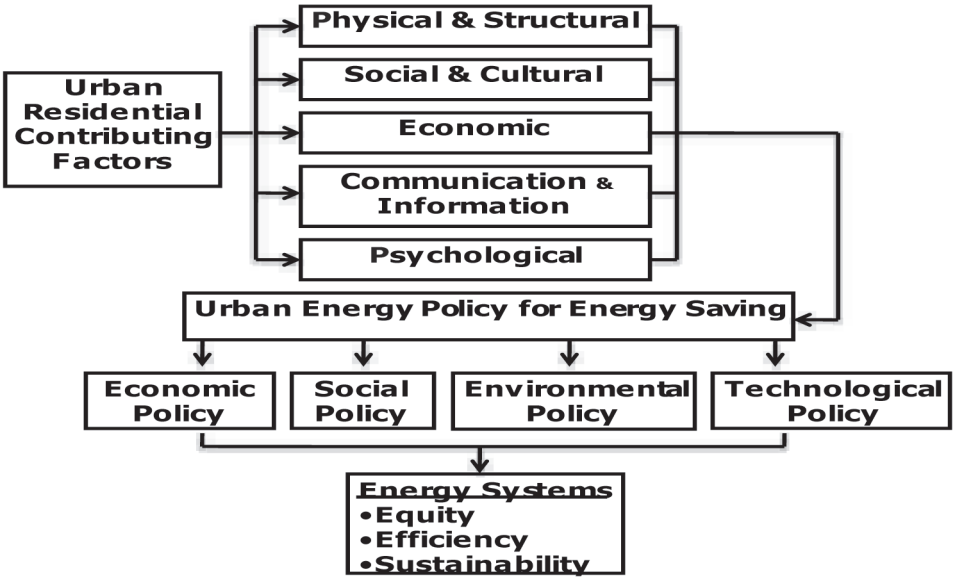

Figure 1 Theoretical Concept of Urban Residential Energy Management

Materials and Methods

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 for the traveling of households in Bangkok which were as following.

1) Physical and structural factors: house type, location, number of household's member, mode of travel, and distance between house and workplace.

2) Social and cultural factors: years of education, income/household, and number of holiday time.

3) Economic factors: household expenditure and number of household's vehicle.

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.

Ten hypotheses were proposed:

H_1 and H_2: physical and structural factors have positive effect on the quantity of energy use in traveling (B1) and energy saving practices in traveling (B2);

H_3 and H_4: social and cultural factors have positive effect on B1 and B2:

H_5 and H_6: economic factors have positive effect on B1 and B2;

H_7 and H_8: communication and information factors have positive effect on B1 and B2; and

H_9 and H_{10}: psychological factors have positive effect on B1 and B2.

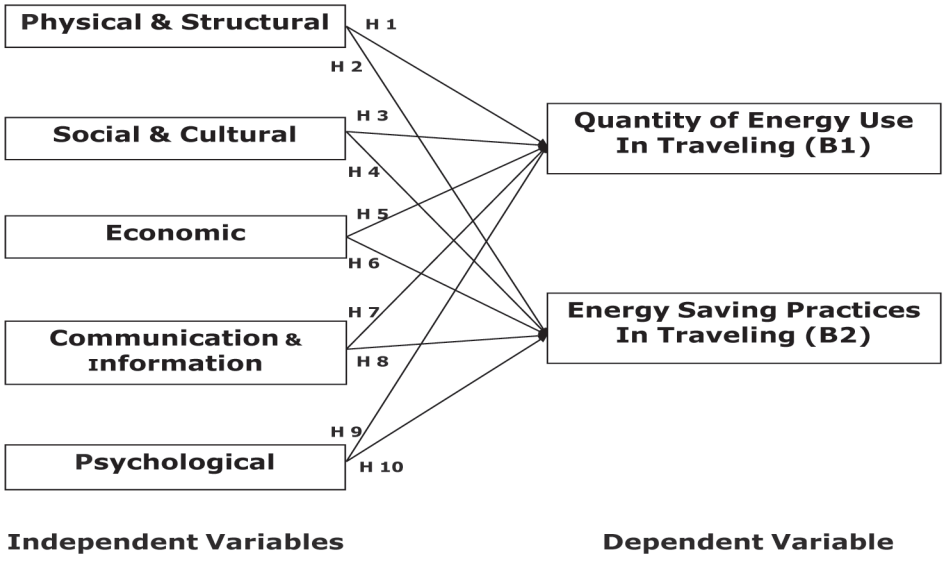

Figure 2 Conceptual Framework of the Study

Population and Sampling

Household population were 2,400,540 and from 50 administrative districts. Sample size was 1,150 households which was equivalent to sampling ratio of 0.048%. The multi-stage sampling and proportional allocation method were employed for selecting the samples[6, 7]. This method consisted as following.

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

Stage 2: randomly selected of 4-6 districts from each zone.

Stage 3: randomly selected 3 streets from each district.

Stage 4: randomly selected of 20-30 households from each street.

Instrument

Face-to-face interview using 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 of the household members i.e. household member, gender, age, education, occupation, income/person, mode of transport, distance between home and workplace.

Part 2 energy consumption in transportation and traveling i.e. types of vehicle, quantities of fuel consumption, expenses on their transportation, other expenses on public transport, changing transport modes for daily transport in the future, and the numbers of the household's holiday or traveling days in each year.

Part 3 energy conservation and saving factors i.e. practices of fuel use reduction. The others were knowledge, opinion, belief, attitude, motivation and communication, and information factors in their behavioral characteristics.

Part 4 suggestions on how-to reduce fuel use at present and in the future.

Reliability of the questions:

Draft questions were designed based on operational definitions of the variables and were tested with 105 households in Bangkok. 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.

Data Collection

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

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

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

3) Outer area from 299 households in 4 out of 11 districts

Secondary data were compiled from several sources such as reports of relevant organization, internet, and etc.

Data Analysis

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

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 $Y_i = a + b_1 (X_{i1}) + b_2 (X_{i2})...+ b_N (X_{iN})$, where a = value of Y before other factors' effect were considered, b_1, b_2 and b_N are an estimate of each effect of X_{i1}, X_{i2}, ...$X_{iN,}$ when X is any independent variable.

Results

The average expenditure of households for energy consumption was 2,361.74 baht/ month which were 835.54 baht for energy consumption at home and 1,526.20 baht for vehicle transportation. Households used 4 fuel types of vehicles and those helped to save fuel energy were compressed natural gas (CNG) or natural gas for vehicle (NGV) and other cars, gasohol 91 or 95 for motorcycle and passenger car. Meanwhile they used 15 energy saving practices for traveling by using public transport, around 63% using bicycling and walking, and shopping near home in a half of all. Other 12 saving practices helped save energy less than 10%.

Table 1 General Information of the Households

Household Information	Mean	SD.	n
Population Density (People/km^2)	7,783.59	5,872.045	280
Members of the Household	3.23	1.639	280
Age of all Household Member (y)	34.54	n/a	3,364
Study of all Household Members (y)	33.64	17.437	693
Space of the Household (m^2)	82.38	56.643	280
Income of Household/Month (baht)	34,533.32	32,994.597	693
Expenditure of Household/Month (baht)	14,568.63	7,075.962	1,126

SD. – Standard deviation

n – No. of samples

Table 2 Relevant Information on Traveling of Households

Traveling Information	Mean	SD.	n
Number of Vehicle (unit)	0.90	0.879	1,126
Distance to Workplace (km.)	21.97	19.823	280
Distance to Workplace (min)	66.44	59.812	280
Expense for Their Own Vehicle/Month (baht)	2,467.59	2,118.797	280
Expense for Public Transport/Month (baht)	660.57	538.432	280
Expense for Provincial Trip/Year (baht)	4,423.57	3,702.365	280
Expense for All Traveling (baht)	4,615.95	4,534.177	1,107

SD. – Standard deviation

n – No. of household samples

From the study, households can save energy in two ways.

1) 4 types of fuel used for vehicles are gasohol, biodiesel, CNG or NGV, and liquefied petroleum gas (LPG) (Table 3). For examples, gasohol 91 or 95 can reduce the use of conventional fuel (gasoline) at 10-20% of gasoline. Bio-diesel 5% (B5) can reduce 5-100% while B100 and CNG or NGV can reduce 100% and 40 % respectively.[8] and 20% of LPG (compare to diesel) and 40% (gasoline)[9]. In each fuel type, it has been used for traveling 0.51-31.00%, it saved petroleum fuel energy 0.05-1.00/L or kg which depended on type of fuel use, and it can help to reduce CO_2 emission from all fuel types in this study around 133.20-2,663.91 g L^{-1} or g kg^{-1}.

Table 3 Fuel and Vehicle affected on Types affected on Traveling Reduction of Conventional Fuel Use and CO_2 Emissions

Fuel and Vehicle Types	% Reduction in Household Use [1/]	% Reduction in Conventional Fuel Use (L, kg) [2/]	CO_2 Emission of Conventional Fuel Reduction (g L^{-1}, kg)
Fuel Types for Passenger Car			
Gasohol 91 or 95	15.16	0.10-0.20	232.15-464.31
LPG for vehicle	3.68	0.20/0.40 [3/]	821.54/1163.91
NGV or CNG	5.30	0/0.40 [4/]	580.39/665.98
Fuel Types for Pickup Car			
Gasohol 91 or 95	2.20	0.10-0.20	232.15-464.31
Biodiesel	1.07	0.05/1.00	133.20/2663.91
LPG for vehicle	0.51	0.20/0.40 [3/]	821.54/1163.91
Fuel Types for Motorcycle			
Gasohol 91 or 95	17.23	0.10-0.20	232.15-464.31
Fuel Types for Others			
NGV or CNG	31.00	0/0.40 [4/]	580.39/665.98

Notes: 1/ from this study (%in Households × % of Reduction in Conventional Fuel Use)

2/ L = Gasohol, diesel, and biodiesel /kg = LPG and CNG

3/ based on saving 40% of gasoline and 20% of diesel [9]

4/ based on saving 40% of normal uses in gasoline [8]

Table 4 Reduction of Conventional Fuel Use and CO_2 Emissions due to Energy Saving Practices in Traveling

Saving Practices on Fuel Energy Use	% Reduction in Household Use	% Reduction in Fuel Use (L, kg)	CO_2 Emission of Conventional Fuel Reduction (g L^{-1}, kg)
Maintained vehicle properly	2.11	0.01-0.40	5.33-1065.56
Changed to small vehicle	1.19	0.25-0.50	580.39-1160.77
Changed to hybrid vehicle	0.50	0.35-0.60	812.54-1392.93
Changed to CNG or NGV vehicle	1.64	0/0.40	580.39/665.98
Changed to LPG vehicle	1.14	0.20/0.40	821.54/1163.91
Changed to gasohol vehicle	1.42	0.10-0.20	232.15-464.31
Changed to biodiesel vehicle	0.85	0.05/1.00	133.20/2663.91
Used public transport	16.31	1.00	1500-2663.91
Used car pool	7.60	1.00	1500-2663.91
Used bicycle or walking	13.64	1.00	1500-2663.91
Worked from home	5.26	1.00	1500-2663.91
Shopping near home	12.48	1.00	1500-2663.91
Schooling near home	6.20	1.00	1500-2663.91
Reduced travel and trip	2.71	0.33-0.50	145.15-1769.03
Others	0.12	0.50	750-1331.95

2) 15 saving practices of fuel energy use for traveling of households are in Table 4. Fuel energy saving practices can help to reduce the use of conventional fuel 0.12-16.31%. Each saving practice saved petroleum fuel 0.05-1.00 L or kg and reduced CO_2 emission 5.33-2,663.91 g L^{-1} or kg. All figures are depended on this study.

The hypothesis models were tested and resulted in.

1) Two models supported were model 1: physical and structural factors (R^2 .896 or 89.6% and $p < .01$); model 3, economic factors have positive effect on the quantity of energy use in traveling (B1) as the adjusted R^2 higher than .30 and statistically significant $p \leq .05$. for model 3, R^2 is .400 or 40.0% and $p < .01$.

2) Eight models rejected were models 2, 4, and 5-9. They had no positive effect neither on the quantity of energy use in traveling (B1) nor energy saving practices

in traveling (B2) as the adjusted R^2 less than .30 and statistically significant p ≥.05. Models 2, 4, and 5-9 had R^2 and p equal to .111 and <.01; .064 and <.01;.280 and <.01; .247 and <.01; .012 and <.012;.033 and <.01; .036 and <.01; .083 and 0.01<. respectively.

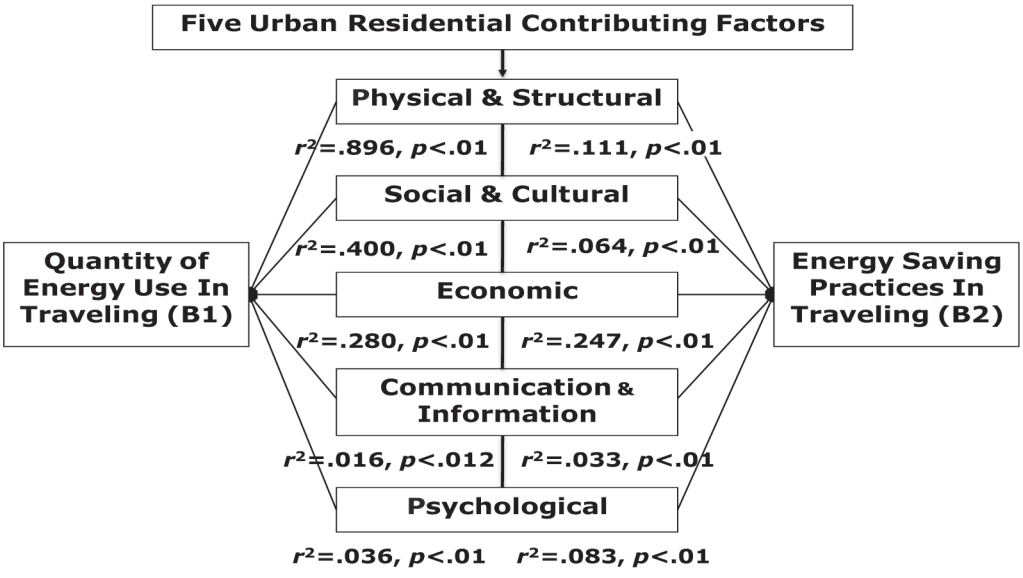

Figure 3 Results from the test on hypothesis models

Summary of all hypothesis model tests from Figure 3 can be ranked from the large effect to the smaller shown in Table 5.

Table 5 Summary of all hypothesis model tests effect of energy use in traveling and energy saving practices in traveling

Factor	Effect of Energy in Traveling	
	Quantity of Use (%)	Saving Practices (%)
Physical and structural	89.6	11.1
Social and cultural	40.0	6.4
Economic	28.0	24.7
Psychological	3.6	8.3
Communication and information	1.6	3.3

Conclusions and Discussions

It can be concluded that two factors (physical and structural factors and social and cultural factors of the households) have affect on the quantity of energy use for traveling significantly.

Physical and structural factors considered are household size, location, number of household member, mode of travel, and distance between home and workplace. These variables can affect on amount of energy use by the households for traveling especially in mode of travel variable. In reducing energy consumption by the households for traveling in Bangkok metropolitan area, smaller household size, compacted housing space, high density area, easy transport between home and work place, reduced household's vehicle and increased mass transportation are required. On the contrary for the aforementioned, more energy uses and more CO_2 emissions in urban area like Bangkok city can be expected.

For social and cultural factors, study years of all household members, total household income and number of holidays are significant. These variables affect on the amount of energy use for traveling especially household income and number of holiday. Therefore, increases on household income, education year of household, and number of households' vehicle, number of holiday time, need to comfort their living, and values of urban households on consumerism push to produce more energy uses and to emit more CO_2 emissions in Bangkok metropolitan area, although energy conservation equipment is limited in the market.

Two factors of this study are based on the economic criteria, social, physical, and other constrains as well as from six types of barriers to energy saving solutions[10, 11]. These two factors are barriers for energy saving solutions but other three factors of economic, communication and information, and psychological are not. At the same time, these three factors can be barriers for energy saving too. Because, these three factors also have the coefficient of determination or the size of effect at a medium degree (1.0% to 10.0%), this implied by Kinnear P.R. and Gray C.D.[12]. That means all factors are the barriers to energy saving solutions in the study of energy consumptions for traveling of households as well as the main three factors: economic, social, and energy function which have been used by Poboon C.[13] for his empirical model study in households' energy consumption.

In comparison to a previous survey in 2010[14], total expenditure for all types of fuel in the whole kingdom was 1,818 baht/

month with household size of 3.20 persons whereas Bangkok and vicinities was 2,836 baht/month with household size of 2.93 persons. Today, Bangkok households consume all types of fuel more than other regions except gasoline, diesel, and bio-diesel. This is due to Bangkok households have higher education, more income, and need to comfort their lives. That means they want to buy a car first and then the house. These will significantly boost the higher energy consumptions and CO_2 emissions in urban area more than rural area. Therefore, urban residential energy management is needed to carry out as economic, social, environmental, and technological policies into energy systems such as energy equity, energy efficiency, and energy sustainability. Recommendations of future research and managerial implication are as follows.

1) Four urban energy policies are required

(1) Economic policy using home appliance standards; using-no.5-label and energy efficiency products; and promoting alternative and renewable energies.

(2) Social policies are energy user and energy producer linkage produced by community, community integration based approach, and private vehicles banned in inner zone.

(3) Environmental policies are city and mass transportation systems, reinventing and rejuvenating the city, and improve cycling and walking.

(4) Technological policies are using distributed generation or small-scale generation; building partnerships with global cities on the application of information, communication and technology (ICT); and using measures related to emission control technology.

2) Ways to reduce energy consumptions in Bangkok area is needed using urban energy management by studying of energy systems and urban energy policy including which and why urban energy policy cannot be implemented at the present situation.

3) A survey research is recommended to conduct every five years on trends of urban energy consumptions for traveling of households, limitation of field survey and data collection. Little is known on factors affecting energy consumptions by the households for traveling.

4) Future study 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 may lack the capital funds to undertake these urban energy policies and projects in a timely manner.

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