State of residential energy consumption in Southeast Asia: need to promote smart appliances because urban household consumption is higher than some developed countries

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Abstract

Energy use in Southeast Asian countries increases annually, and will continue to rise with improving living standards. However, data collection related to residential energy consumption lags behind, and understanding the state of consumption is challenging.

In 2015, we conducted a field study on residential energy consumption in Malaysia, Thailand, Vietnam and Cambodia to indicate how improved lifestyles result in increased energy consumption compared to the other developed countries in Southeast Asia and Japan. To analyse these relationships, we surveyed energy use and people's lifestyle, including equipment ownership and methods of use. As a result, we found that energy consumption of lighting, plug loads, cooling and cooking in urban areas of Southeast Asia approaches that found in developed countries and in some cases exceeds this. In other words, energy consumption in emerging countries has become a more critical issue than in developed countries.

In this paper, we explain the variance in energy consumption of developing, emerging, and developed countries, due to differences in housing, equipment, income, and lifestyle. Next, we explain the new energy efficiency policy in Thailand, Energy Efficiency Development Plan 2015. EEDP 2015 is the most advanced policy in Southeast Asia that includes an Energy Efficiency Obligation. We also discuss the importance of strengthening of MEPS, energy efficiency labelling and promotion of smart appliances.

Eventually, we aim to collect and analyse energy consumption patterns in households in several Southeast Asian countries, to create a database with the results from the surveys, to develop scenarios in order to mitigate CO_2 emissions, and to develop a platform that can examine the gradual effects at different stages of national development. Moreover, we aim to develop an open platform database, to share our survey results with international experts, researchers, professors and policymakers in the future.

Introduction

It is expected that CO_2 emissions of Southeast Asian countries will continue to increase in the future. A high percentage of CO_2 emissions are from the civilian sector, in particular, the residential sector. As living standards improve, emissions are expected to increase, so effective climate change countermeasures are needed. On the one hand, with the exception of measures addressing large-scale commercial facilities, it is challenging to take regulatory climate change countermeasures for the residential sector. In particular, it is extremely difficult to implement policies that restrict improvements in living standards. In this context, limited resources must be used effectively in order to propose and implement effective residential sector climate policies. To develop such effective climate change countermeasures, in parallel with grasping the actual situation of energy use, it is desirable to identify target fields for climate change countermeasures by analyze the factor such as household members, type of housing, ownership of AC or income level, and to estimate the effects of the measures.

However, data on actual residential sector energy use in Southeast Asian countries are limited to what can be gained from macro level data on energy use by type of energy, made public by international organizations and the governments of various countries. There has been almost no collection and maintenance of data related to energy consumption by end use, nor breakdowns of electricity consumption, which comprises much of residential sector energy use. Further, data regarding living standards, and appliance possession and ways of use are also limited to macro level data for housing and appliance ownership ratios. There are no detailed data regarding what kinds of households live in various kinds of housing, and what kinds of appliances are used, in what ways. Also, other data indispensable to implementing energy efficiency measures have hardly been collected, such as the energy efficiency performance of housing and appliances, both existing stock and those that will be purchased. Accordingly, it is necessary to understand actual conditions of energy use and the factors that influence it: households, housing, equipment, lifestyle, and ways of using appliances. Also, besides estimating how all of these will change with future growth, there is a need to construct a mechanism for monitoring on a continuous basis.

In order to realize this, we conducted a field survey on household energy consumption in Malaysia, Thailand, Vietnam and Cambodia and got started with database creation as well. In addition, to understand how the major home appliances are used in homes, an electrical load measurement for home appliances has been carrying out since 2016. The stage of economic development is different in these countries, Malaysia and Thailand are emerging countries, Cambodia is a developing country and the present stage of economic development in Vietnam is between emerging and developing status. This paper shows the results of field survey on household energy consumption compared to the other developed countries. Moreover, the main factors affecting household energy consumption are explored.

Household energy use survey method

SUBJECT REGIONS AND SAMPLE SIZE

We carried out a survey by questionnaire in order to understand actual conditions of energy use in urban areas in Malaysia and urban areas and outlying farming villages in Thailand, Vietnam, and Cambodia. Vietnam extends a long way from north to south, so in consideration of climate variation, 110 households in each of Hanoi and Ho Chi Minh City were surveyed. The farming villages are Samut Sakorn, about 50 km from Bangkok, Hoa Binh, about 100 km from Hanoi, and Kandal, about 50 km outside Phnom Penh. A total of 1,190 surveys were collected. Number of sample is shown in Table 1.

Regarding to sample selection, all households are divided into Primary Sampling Units (PSU) every hundreds households, and several dozen PSUs are randomly extracted from among these. Furthermore, we set the distribution ratio of number of household members, the type of housing and household monthly income, and we selected the samples that meet these conditions. On the other hand, we pre-recruited by using snowball sampling research method in the case that household statistics are not maintained, the investigators cannot obtain a cooperation from wealthy people because of auto-lock security system or they said they were too busy. And we extracted final targets with eliminate bias from pre-recruited samples. Furthermore, in order to improve the accuracy of the survey, we set upper limit of samples to each researcher.

SURVEY METHOD

All surveys were interviews by investigators. When surveys are carried out in developed countries, generally they are carried out expeditiously and at a large scale via the internet, but in Southeast Asia, even a mail-in survey would have an extremely low rate of return, so face-to-face interview surveys by investigators are commonly used.

SURVEY ITEMS

In all, there were 38 survey items, in seven categories, as illustrated in Table 2. The survey carried out was quite detailed. The investigators asked each question and entered the responses on the survey sheet themselves, so we believe the responses are accurate. But there were some months for which energy consumption data could not be obtained, for reasons such as not having kept the utility bills. There were cases in which these data could be obtained directly from the electric utility website, and this method was used in Vietnam, Thailand, and Malaysia to understand monthly electricity use. The monthly energy consumption data surveyed were from October 2014 to September 2015.

Household energy use survey results

BASIC CHARACTERISTICS

Household and housing characteristics are shown in Figure 1. The average number of people in the household was about the same for the urban Kuala Lumpur, 4.6, Bangkok, 4.6, Ho Chi Minh City, 4.7, and Hanoi, 4.3, but Phnom Penh was larger, with 5.2 people per household. For outlying farming villages, average household size varied from 3.6 to 5.2 people, but was generally somewhat smaller than urban households. Compared to each country's census results for average number of people per household (Malaysia, 4.5 in 2010; Bangkok, 3.6 in 2015; Hanoi, 3.9 in 2012; Ho Chi Minh City, 3.8 in 2012; and Cambodia, 4.6 in 2013), Thailand and Vietnam were slightly larger than the census values. Compared to the Japanese average of 2.5 people per household, these countries have larger households, but in Southeast Asia we think that the large-family system is in place to some extent, as there are cases such as multiple households living together, and relatives living in the neighborhood. In particular, the occurrence of someone being home during the day on weekdays exceeded 70 % for each region, a high ratio compared with 55 % in Japan. In strongly pro-family Southeast Asia it is not uncommon to have dual wage earning families, but not necessarily working at a company. It is not unusual to work at home (there are cases in which people bring their work home) or run a business out of the house while also doing housework and childrearing. The investigators frequently found people with side jobs at home such as sewing. The number of people with jobs per family was slightly larger in urban areas than in farming villages, but except for Cambodia was lower than two. Monthly household income is about twice as high in Thailand

Table 1. Number of sample.

Malaysia	Thailand		Vietnam			Cambodia		Total
Kuala Lumpur	Bangkok	Sumut Sakorn	Hanoi	Ho Chi Minh City	Hoa Binh	Phnom Penh	Kandal	
100	300	150	110	110	110	210	100	1,190

Table 2. Survey items.

Part 1: Identification of Household	number of household members, age, gender, occupation, the days that people usually at home during the daytime on weekdays, annual income of all family members
Part 2: Housing Characteristics	building type, structure type of building, number of floors, gross floor area, established year, ownership, number of rooms
Part 3: Energy Consumption and Energy Bills	monthly energy use by fuel type, monthly energy bills by fuel type
Part 4: Home Appliances and Electronics	space cooling (room air-conditioning, fan, etc.), space heating (room air-conditioning, heaters, etc.), home appliances, lighting
Part 5: Hot Water	type and number of water heating equipment, hours of use, bathing habits
Part 6: Vehicles	Type, number and frequency of use of automobiles and motorbikes/scooters
Part 7: Lifestyle and Behaviour	ways of keeping home cool, satisfaction with the indoor environment, willingness to buy energy-efficient home appliances in the future and problems when buying energy-efficient home appliances, energy saving behaviours

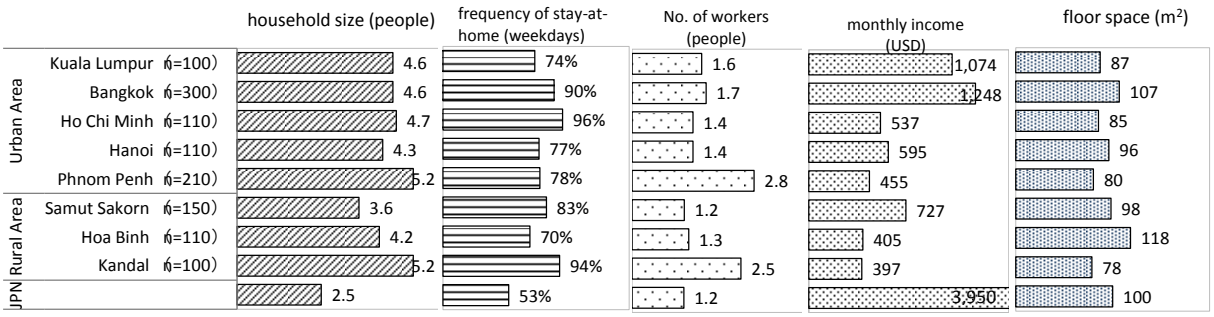

Figure 1. Characteristics of households and housing.

and Kuala Lumpur as in Vietnam and Cambodia, but the gap with developed countries remains large.

Although in Southeast Asia there is a trend of increasing construction of attached housing (such as condominiums), detached houses and townhouses are still the norm. The average floor area per dwelling unit for the countries studied is nearly identical to that for all of Japan (93 m^2), but the per person floor area is only 15 to 28 m^2/person, bottoming out at a level less than half of Japan's average value of 40 m^2/person (34 m^2/person in the Tokyo metropolitan area of Kanto)

PENETRATION RATES OF MAJOR HOUSEHOLD ELECTRICAL APPLIANCES

Saturation rates and penetration rates of major household electrical appliances are shown in Table 3 and 4. Table 3 display air conditioners (heat pump air conditioners), electric fans, flat screen and CRT televisions, while Table 4 show refrigerators, rice cookers, personal computers and cell phones.

The penetration ratio of air conditioners is highest in Hanoi at 91 %, with Kuala Lumpur, Ho Chi Minh City and Bangkok all at around 50 %, but in Phnom Penh only 15 % of households have an air conditioner. In contrast, in outlying farming villages in Thailand and Vietnam both around 30 %, while in Cambodia only about 10 % of households have air conditioners. Due to the tropical climate, air conditioners in most Southeast Asian countries are cooling-only machines. In contrast, Hanoi was the only city in this study with a space heating demand, which is probably the reason it is normal to have an air conditioner including heat pump. In Hanoi there were 1.6 units per household, and except for in Cambodia, many urban households had more than 2 units. In Cambodia, electric power infrastructure is not yet well developed, and it is said that only half the population can access the grid. Thus, electricity prices (Table 5) are double or higher than in the other countries, and this, as well as income differences, are likely to contribute to the low penetration of household electronics.

The spread of flat screen TVs has been rapid, with rates in Malaysia and Vietnam similar to those in Japan, much higher than those in Thailand and Cambodia. In contrast, CRT-type TVs have higher penetration rates in Thailand and Cambodia. Also, the spread of CRT-type TV happened earlier in Thailand than in Vietnam, so there are many CRT-type TVs left in Thailand. There remains a market for used household electrical appliances in Thailand, Vietnam, and Cambodia, so old air conditioners, TVs, refrigerators and others are distributed.

Saturation rates of refrigerators and rice cookers are around 100 % everywhere but Cambodia, as in developed countries.

Table 3. Household saturation ratio (%) and penetration ratio (units/household) of home appliances (1).

		Air Conditioner	Electric Fan	Flat TV	CRT-TV
Malaysia	Kuala Lumpur (n=100)	54/0.9	83/1.9	86/1.0	27/0.3
Thailand	Bangkok (n=300)	40/0.6	100/3.5	68/1.0	62/1.0
	Samut Sakorn (n=150)	29/0.3	100/2.6	57/0.7	59/0.7
Vietnam	Ho Chi Minh City (n=110)	55/0.8	99/3.1	85/1.3	26/0.4
	Hanoi (n=110)	91/1.6	99/2.8	91/1.5	31/0.4
	Hoa Binh (n=110)	38/0.5	100/2.5	83/1.1	25/0.3
Cambodia	Phnom Penh (n=210)	15/0.2	97/2.8	40/0.5	67/0.8
	Kandal (n=100)	11/0.1	99/2.5	22/0.3	84/1.0
Japan (n=11,632)		91/2.2	–/–	88/1.9	19/–

Note: numerator: Household saturation ratio (%)/denominator: Household penetration Ratio (Units/household).

Table 4. Household saturation ratio (%) and penetration ratio (units/household) of home appliances (2).

		Refrigerator	Rice cooker	PC	Cellular phone
Malaysia	Kuala Lumpur (n=100)	100/1.0	97/1.0	58/0.8	100/3.9
Thailand	Bangkok (n=300)	98/1.1	98/1.0	44/0.5	98/4.1
	Samut Sakorn (n=150)	98/1.0	99/1.0	31/0.3	99/2.7
Vietnam	Ho Chi Minh City (n=110)	96/1.0	100/1.0	79/0.9	100/3.6
	Hanoi (n=110)	99/1.1	100/1.0	77/0.9	99/3.3
	Hoa Binh (n=110)	100/1.0	100/1.0	33/0.4	98/3.1
Cambodia	Phnom Penh (n=210)	44/0.4	79/0.8	35/0.5	89/4.0
	Kandal (n=100)	26/0.3	72/0.8	17/0.2	95/3.5
Japan (n=11,632)		99/1.2	89/0.9	84/1.4	95/3.0

Note: numerator: Household saturation ratio (%)/denominator: Household penetration Ratio (Units/household).

Table 5. Electricity price (in USD).

Malaysia	Bangkok, Thailand	Vietnam	Phnom Penh, Cambodia	Japan
8 cent/kWh	13 cent/kWh	8 cent/kWh	21 cent /kWh	27 cent/kWh

Furthermore, no difference is seen between urban and outlying farming areas. Saturation rates of personal computers in Vietnamese cities are similar to Japan, but in other regions are below 50 %. While penetration ratio of cell phone exceeds one person in Japan, Southeast Asian countries are slightly lower this, but it reaches nearly same level.

ENERGY CONSUMPTION PER HOUSEHOLD

The energy consumption and CO_2 emissions reported here are aggregated, excluding cases in which the amount of electricity or LPG used or the amount paid was unknown. Here we show comparison of the countries studied with other developed countries, including Japan.

Annual energy consumption per household is shown in Figure 2. For the countries studied, except Cambodia, the average urban household used around 20 GJ/year while the average farming village household used roughly 10 GJ/year, a difference of a factor of two from urban areas. In Cambodia, households in Phnom Penh used on average 13 GJ/year, much less than urban areas in other countries, and very similar to the 12 GJ/year of the outlying village, Kandal. Compared to the average value per household in Japan in 2015, urban areas in Malaysia, Thailand, and Vietnam remain at about ⅔ the consumption.

Looking at energy use by type of energy, in the urban areas studied electricity use comprises about 80 % of the total. In Southeast Asian cities gas delivery pipelines have not been laid, so there is no consumption of piped gas. Accordingly, nearly all the demand is covered by electricity, with LPG used for cooking. In outlying farming villages electricity use is about half that in urban areas, with LPG and other fuels, such as biomass fuels, used. Biomass fuel is mainly firewood, but coal briquettes are also used for cooking. Generally, urbanization is proceeding in Southeast Asia. While the rural population is flowing into cities, electrification of rural areas is expected to progress.

In comparison with developed countries, electricity consumption per household in urban areas in Malaysia, Thailand, and Vietnam is nearly equal to that in Japan, and exceeds that in Korea, the UK, and Germany. In Southeast Asia, electricity is mainly consumed by space cooling, lighting and plug load, and thermal demands such as water heating, kitchen and space heating are small. If we look at electricity use only, we can see that energy use in Southeast Asian urban areas has reached levels on a par with or higher than in developed countries.

Figure 3 shows energy use by end use. In all regions lighting and plug loads holds the highest percentage, except in Kandal. For all cities except Phnom Penh, this amounts to just under 13 GJ/hh/year, exceeding annual consumption per household in Japan, Korea and the UK, all at 11 GJ, France at 10 GJ, and Germany at 8 GJ. There are various factors thought to contribute to this, such as more people per household, high rates of

daytime occupancy, and penetration of major appliances like TVs and refrigerators to about the same degree as in developed countries, while on the other hand, appliance efficiencies may be lower than those in developed countries.

Energy used for space cooling is also higher than that for developed countries. Contributing factors include longer cooling seasons due to tropical climates, and low efficiencies of air conditioners. The highest space cooling energy use was Ho Chi Minh City, at 3.8 GJ/hh/year, followed by Hanoi, 2.5 GJ, Bangkok, 2.4 GJ, followed by Kuala Lumpur and Phnom Penh, with 1.7 GJ each. Compared with 0.6 GJ per household in Japan, this is much higher consumption. Cooling energy use in outlying villages is smaller, but not at a level where it can be ignored, with Kandal at 1.3 GJ, Samut Sakorn, 0.9 GJ, and Hoa Binh, 0.5 GJ per household. The cooling season in Hanoi is 5 months long, unlike Bangkok and Ho Chi Minh City, where it is year-round, but Hanoi's rank in cooling energy use behind Ho Chi Minh City is likely due to the high penetration ratio of air conditioners.

Annual cooking energy use per household was 4.7 GJ in Kuala Lumpur, 3.4 GJ in Bangkok and 2.6 GJ in Thailand's outlying village area; in Vietnam, 4.1 GJ in Hanoi and 2.9 GJ in Ho Chi Minh City; and in Cambodia, 6.5 GJ in Phnom Penh. These all exceeded the Japanese value of 2.0 GJ. Due to large households, someone being at home in the daytime 70 to 90 % of the time, and also to there being many children, the custom of cooking remains deeply rooted. Further, in Cambodia, there are households where, to get drinking water, water is boiled every morning and set aside for the day.

Very little energy is used for water heating. Taking a cold shower twice a day is typical, and except for in Hanoi during the winter, hot showers are hardly ever used. Also, although there is some energy used for space heating in Hanoi and Hoa Binh, it is less than 1 % of total energy use.

Due to the tropical climate, use of water heating and space heating is not required in Southeast Asia. Accordingly, comparing energy used for lighting and plug loads, space cooling, and cooking only, with that in developed countries, consumption in Southeast Asian urban areas exceeds that in Japan, Korea, the UK, Germany and France. It is not an overstatement to say that levels of energy use have passed those of developed countries and these Southeast Asian countries have already become major consumers of energy.

Compared to census data for each country, the household sizes in these survey results are a bit large. This is a contributing factor to higher energy use. When annual energy use per capita is compared (Figure 4), urban areas range from 4.0 to 4.4 GJ/person, and outlying areas from 2.3 to 2.9 GJ/person. In comparison, developed countries, with Japan at 5.3 GJ/person, except for the USA and Canada, generally use a little more than 5 GJ/person. Thus, in urban areas the difference is on the order of 20 %, and considering that the household size differs by about 40 %, levels of residential energy consumption in Southeast Asian urban areas are high. Swift formulation of sweeping energy efficiency measures is needed.

LIFESTYLE

Daytime and nighttime room cooling methods

Survey results regarding ways to manage the indoor temperature during daytime and nighttime are shown in Figure 5, for the example of Bangkok. During the day, regardless of the presence or absence of an air conditioner, many respondents answer that they cope with the heat of the day by "turning on fans with windows open," or "turning on fans." Even among households with an AC, less than 10 % say that they "turn on AC" or "turn on AC and fans." In other regions, percentages of households with AC responding that they use it during the

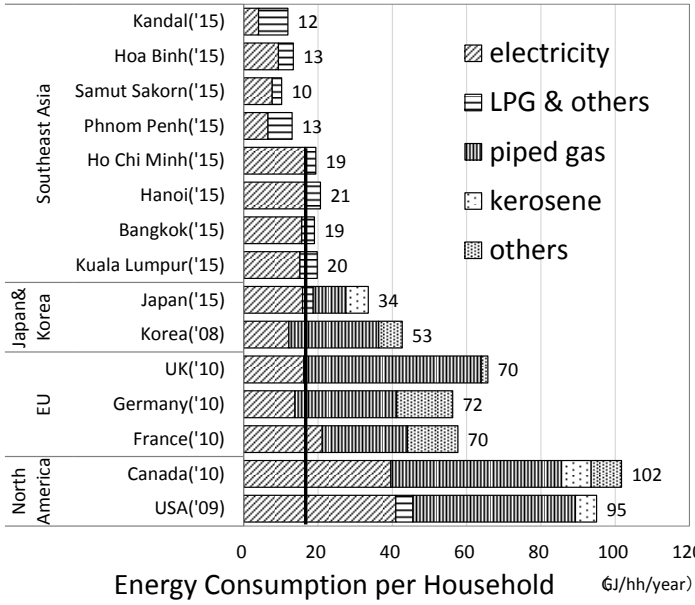

Figure 2. Energy consumption per household by type of energy. Note: Please note that the data of Europe, US and Korea are 2008, 2009 or 2010.

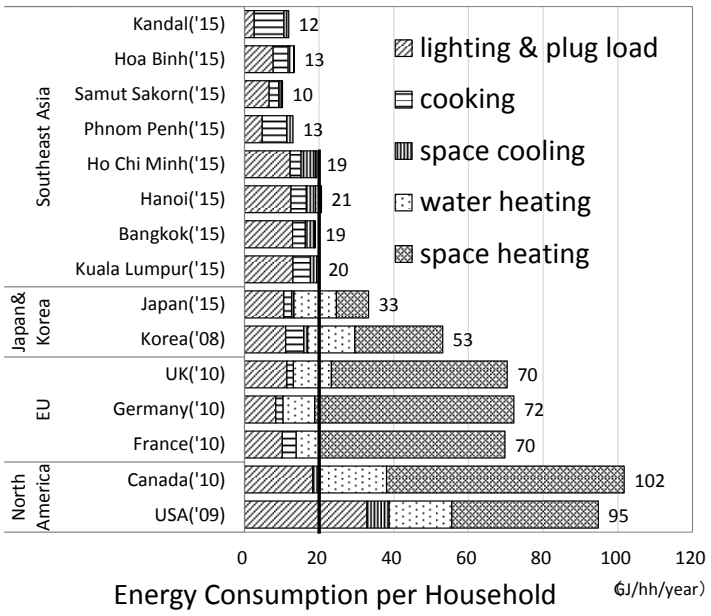

Figure 3. Energy consumption per household by type of use.

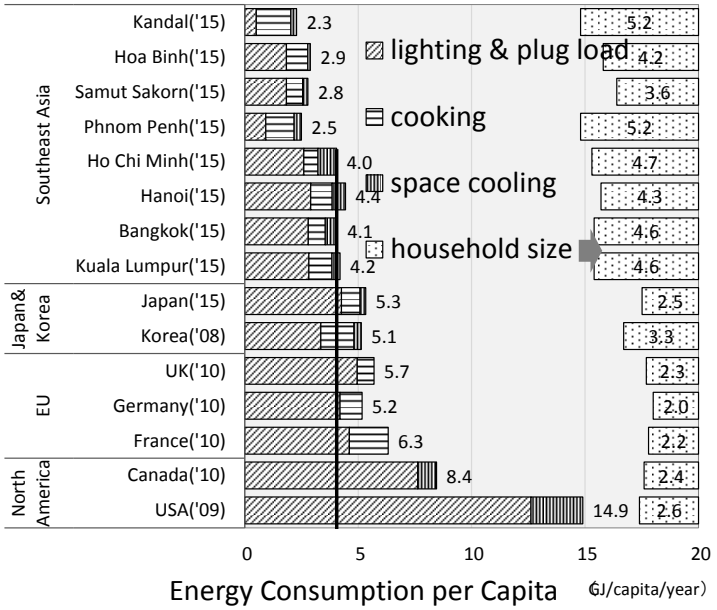

Figure 4. Energy consumption per capita by type of use, and household size.

daytime are higher than in Bangkok, with 24 % in Ho Chi Minh City, 20 % in Phnom Penh, 18 % in Kuala Lumpur, but most households do not use AC during the day. At night, households without AC have fans on with windows open, but 78 % of Bangkok households having AC use it. In other regions, in urban areas 50 to 80 % and in rural villages 20 to 50 % of households with AC use it at night. Weekday length of AC use is 10 h/day in Bangkok, 7 h/day in Kuala Lumpur, 13 h/day in Ho Chi Minh City, 11 h/day in Hanoi, 10 h/day in Phnom Penh, and from 8 to 10 h/day in outlying villages.

It is evident that in Southeast Asia, even households with AC use it mainly at night. As an extreme example, housing was found with low heat barrier performance resulting in top floor indoor surface temperatures of 30 to 40 °C, where even if the AC were used, the room temperature would not decrease. For two-story housing there are many cases where people live on the first floor during the day using fans, and at night on the second floor using AC. Thus, installation of high power AC units, used with very low temperature settings, has become typical. These conditions of use can invite lowered AC efficiency. To realize energy efficiency, together with encouraging the introduction of highly efficient AC, increasing the heat barrier performance of housing, installing AC of appropriate output power, and popularizing higher temperature settings are all needed.

Satisfaction with the indoor environment

Air conditioning is not used very much during daytime, but regardless of the presence or absence of AC, nearly all households do not feel major dissatisfaction with either heat or humidity levels. In Bangkok, a low 5 to 6 % and 11 to 12 % were dissatisfied with the temperature and humidity levels, respectively (Figure 6). As for other regions, in Kuala Lumpur and Hanoi people were even less dissatisfied than in Bangkok. In Ho Chi Minh City they were equally dissatisfied, and in Phnom Penh a little more dissatisfied. We discussed reasons that people do not feel much discomfort with local specialists, but were unable to get a clear answer. Thailand has such a hot climate throughout the year that it can be said that there are three seasons: hot, hotter, and hottest. Probably there is a common awareness that being hot is only natural. On the other hand, contradictory situations coexist, such as the aspect of office buildings and public spaces with air conditioning to the point of being too cold, and also the condition of public hospital waiting rooms generally not being air conditioned at all.

CO_2 EMISSIONS

Table 6 shows CO_2 emissions per household for various end uses, and Table 7 shows each country's electricity emission factor. The highest annual CO_2 emissions per household arising from within the home are from Kuala Lumpur, at 2.7 t-CO_2/year, followed by the urban areas of Bangkok at 2.2 t-CO_2, Hanoi at 1.9 t-CO_2, and Ho Chi Minh City, at 1.8 t-CO_2. Phnom Penh, at 1.1 t-CO_2, has about the same emissions as the outlying villages. Emissions are largely due to lighting and plug loads, cooling, and other electricity use, but in outlying villages of Vietnam and Cambodia, besides electricity, use of LPG and biofuels account for nearly half of CO_2 emissions. Japan emits 3.5 t-CO_2 per household annually, arising from within the home. Southeast Asia has lower emissions, but this is also influenced by major differences in the electricity emission factors. The electricity emission factor varies greatly among Southeast Asian countries, and is high for Malaysia and Thailand, and low for Vietnam and Cambodia. This is due to the structures of their electric power supplies. The former have high proportions of LNG and other fossil fuel generation, while the latter have high proportions of hydroelectric generation. However, according to Vietnam's 7th Power Development Plan, there are future plans to develop coal-fired power plants on a large-scale, so future CO_2 emissions will be greatly influenced by changes in the electric generation structure.

CO_2 emissions from cars and motorcycles are seen to be of the same scale as CO_2 emissions from energy use in the home. In particular, Kuala Lumpur, at 3.8 t-CO_2 per household an-

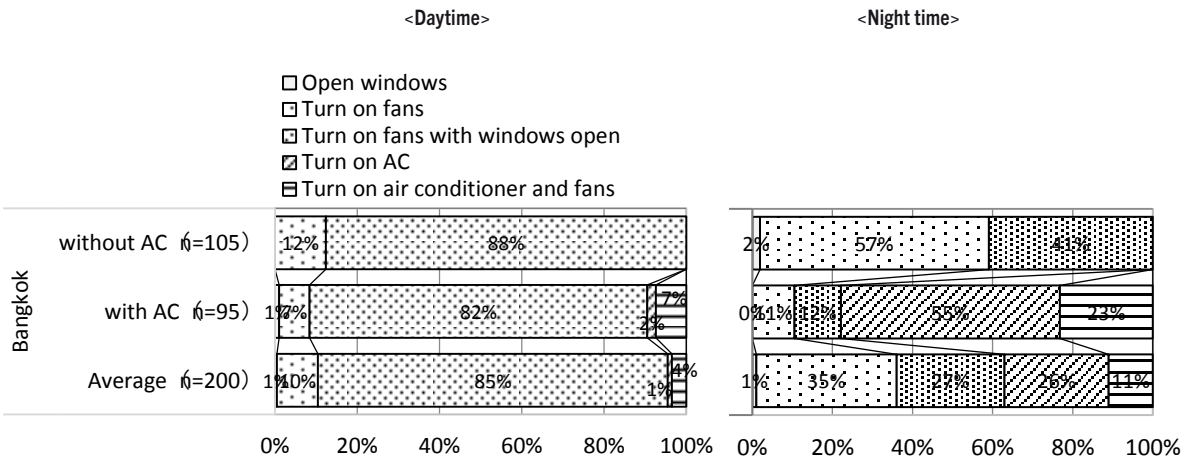

Figure 5. Ways to keep cool (in Bangkok, Thailand).

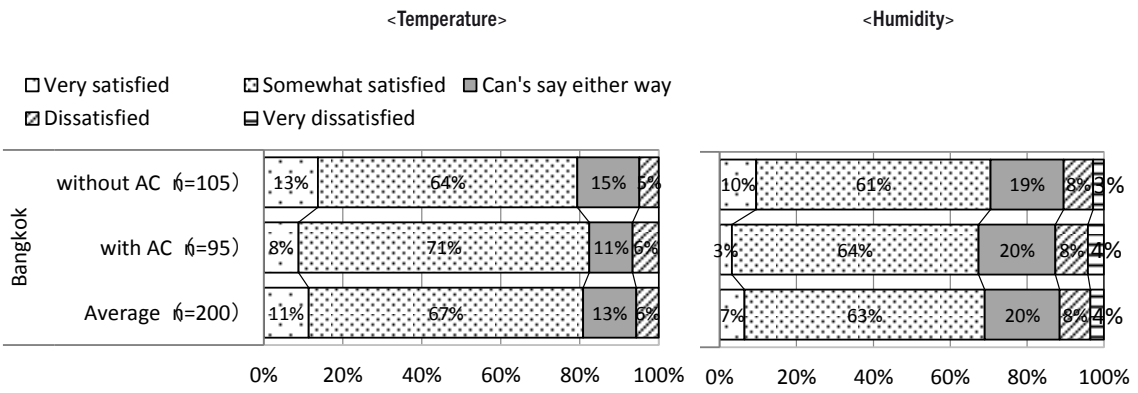

Figure 6. Satisfaction with indoor environment (in Bangkok, Thailand).

nually, exceeds the in-home emissions, and when added to the in-home emissions amounts to 6.4 t-CO_2, which greatly exceeds Japan's value of 4.8 t-CO_2. For cars and motorcycles, CO_2 emissions vary widely. In Malaysia and Thailand the spread of cars has progressed, so their CO_2 emissions are large. In contrast, in Vietnam and Cambodia, a motorcycle is a necessity for daily life, and a great many households have more than one. Compared to a car, a motorcycle is fuel efficient, but in Vietnam and Cambodia CO_2 emissions from motorcycles are larger than from cars. The share of total household CO_2 emissions held by motorcycles is somewhat under 30 % in Hanoi and Ho Chi Minh City, and climbs to somewhat under 40 % in Phnom Penh. With economic growth and urbanization comes increased traffic, and with that comes increased vehicle emissions. At the same time that air pollution issues have become serious, measures to raise vehicle efficiencies and decrease emitted gases have become an urgent issue. With the goal of limiting the number of gasoline motorcycles owned per person, Vietnam recently set a higher registration fee for the second and later gasoline motorcycles, and cases of people buying electric motorcycles for their second or third motorcycle can be noted. This kind of encouragement for the spread of electric motorcycles is important, but it is expected that the shift from motorcycles to cars will accelerate in the future, which could become a very serious problem. Although there is no specific support measure, it should actively support promotion of electric cars.

Development of BELDA Database

We started to build a database on household energy consumption in Southeast Asia, called BELDA, which is short for "Building Energy Structure and Lifestyle Database of Asia". We construct a common web-based platform related to actual conditions of energy use in Southeast Asian countries. Additional objectives are to form a network of international researchers to use this tool, and to produce recommendations to governments of Southeast Asian countries.

Figure 7 shows the composition of the BELDA. BELDA stores raw data of actual survey we investigated, aggregation result of the raw data, macro data, meteorological data, and existing survey results that can be collected in Southeast Asian countries. Registered users can input data in a questionnaire format and compare the results with the data stored in the database. Furthermore, it is possible to upload the collected survey results according to the database format. In addition, by considering the problems of privacy protection, only cooperative researches can access the raw data. However, in order to make effective use of raw data, we are planning to install aggregation software, and general users can to make various simple or cross tabulation based on raw data.

Policy makers, researchers and energy industries whom lead the global warming countermeasure are expected to be the user of BELDA. For this reason, we have discussed with stakeholders in each countries from 2015 and also we are conducting joint researches with Chulalongkon University, King Mongkut's University, Excellent Energy International, Hanoi Architectural University, Vietnam Institute of Energy and Institute of Technology of Cambodia.

Energy efficiency policy issues

Possibilities of implementing energy efficiency measures vary depending on the state of a country's public policy systems and on energy prices. In general, the state of a country's public policy apparatus conforms to the country's stage of economic development, while energy prices are greatly influenced by the presence or absence of energy resources in that country.

As has also been experienced in Japan, the promulgation of energy efficiency laws and the setting of energy efficiency

Table 6. CO_2 emissions (Unit: t-CO_2/household-year).

		In home				Car & motorbike			Total
		Lighting & plug loads	Space cooling	Others	Total	Car	Motorbike	Total	
Malaysia	Kuala Lumpur (n=100)	2.0	0.3	0.4	2.7	3.4	0.3	3.8	6.4
Thailand	Bangkok (n=297)	1.6	0.3	0.2	2.2	1.3	0.2	1.5	3.6
	Sumut Sakorn (n=147)	0.8	0.1	0.2	1.1	0.7	0.1	0.8	1.9
Vietnam	Ho Chi Minh City (n=110)	1.2	0.4	0.2	1.8	0.0	0.7	0.7	2.6
	Hanoi (n=110)	1.3	0.3	0.4	1.9	0.0	0.7	0.7	2.7
	Hoa Binh (n=110)	0.8	0.0	0.4	1.2	0.1	0.3	0.3	1.5
Cambodia	Phnom Penh (n=208)	0.5	0.2	0.4	1.1	0.2	0.7	0.9	2.0
	Kandal (n=99)	0.3	0.1	0.5	0.9	0.1	0.8	0.9	1.8
Japan (n=11,632)					3.5			1.3	4.8

Table 7. Emission factors of electricity (Unit: g-CO_2/kWh).

Malaysia	Thailand	Vietnam	Cambodia	Japan
567	459	363	358	497–816

Note: For Japan, the highest and lowest emission factors of the regional electric utilities are shown. CO_2 emissions are calculated for each region and a national average value is then calculated.

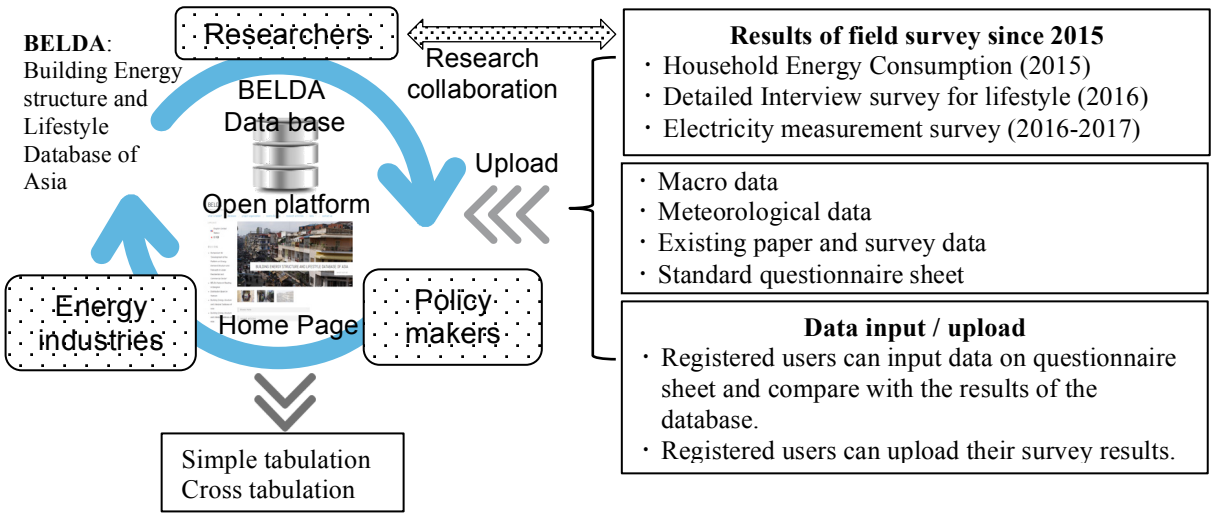

Figure 7. Composition of BELDA.

standards are fundamental to national energy efficiency policy. Among the developing and emerging countries, there are those in which laws and setting of standards are not yet well furnished, and there are those that have regarded energy efficiency measures as important public policies. At the same time, policies first target large-scale industrial and commercial facilities. Setting of standards, regulatory control measures, and incentive programs also begin by targeting large-scale facilities, and then progress to implementation of policies that address small-scale facilities and the residential sector. Measures vary, depending on the relationship to each country's economic and welfare policies and on the tightness of electric power supply and demand conditions, and there are also programs carried out that are recommended and supported by international organizations.

Economic development of the four countries has advanced in the following order: Malaysia, Thailand, Vietnam, and Cambodia. Income for a typical family is at the same level in Malaysia and Thailand, followed by Vietnam and Cambodia, and residential energy use is at the same level in Malaysia, Thailand, and Vietnam. But big differences in the countries' energy efficiency policies can be seen. Thailand's Energy Conservation Promotion Act is the foundation for various standards, financial support programs, and other measures that have been taken regarding energy efficiency policy. In contrast, no definitive energy efficiency policy law exists in Malaysia, where energy efficiency policy is developed in the Malaysia Plan, produced every five years. In Vietnam, the Law on Energy Saving and Efficiency came into operation in 2011, and measures including strengthening of management requirements for factories, housing energy efficiency standards, minimum energy performance standards (MEPS) and labelling for household appliances, have been implemented sequentially. On the other hand, Cambodia does not have an energy efficiency law and in the residential sector, characteristic policies have not been implemented. Although energy efficiency policies and conditions of policy apparatus differ in this way, except for housing energy efficiency standards and household electrical appliance MEPS, all residential sector measures are not mandatory regulations, but are voluntary standards.

The situation is as described above, but the need for energy efficiency is also sinking in at the policy level. For example, in Thailand, Energy Efficiency Development Plan 2015–2036 was announced. Compulsory measures in the plan include, "enforcement of energy efficiency standards in designated factories and buildings," "energy labeling on equipment/appliances," and "enforcement of Energy Efficiency Resource Standard." Voluntary measures include "supporting financial tools to hasten change to high efficiency equipment," and "promoting greater use of LED by price mechanism." Further, complementary measures, including support for "human resource development for energy conservation," and "creation of public awareness and behavioral change" have been announced. In Malaysia, the 11th Malaysia Plan (2016–2020) includes measures such as formulation of a comprehensive demand side management master plan and encouraging its spread.

There is not only progress on the policy front. In 2015, Chulalongkorn University conducted a demand response pilot project targeting 100 households, monitoring whole-house and AC electricity consumption, temperature and humidity, and experimenting with switching the AC on and off remotely during peak periods. The purpose of this project was system development, so no analysis of peak cutting or saved energy was done, but it was concluded that technology was developed with which it is possible to stop all AC units for a fixed amount of time. Also, Chiang Mai University has begun a survey of actual residential energy consumption for a sample size of 5000 households, and a Malaysian electric utility, Tenaga Nasional Berhad (TNB) has begun a demonstration test of a home energy management system (HEMS), albeit on a small scale.

Conclusion and recommendations

In this paper, we have shown results of a survey of actual conditions of residential energy use in urban areas and outlying farming villages in Malaysia, Thailand, Vietnam, and Cambodia. These results show that electricity use by urban households in Southeast Asia is already at the same levels as developed countries, including Japan. Considering that space heating and water heating are hardly required in various Southeast Asian

countries, when we compare only demand for space cooling, lighting and plug loads, and cooking, we see that consumption in urban Southeast Asian countries exceeds consumption in developed countries. We also see that cars in Malaysia and Thailand, and motorcycles in Vietnam and Cambodia emit large quantities of CO_2. This result dispels the conventional idea of Southeast Asian countries that although residential energy use will be continuous increasing, it is important to stem the ratio of future increases. However, because electricity prices in Southeast Asian countries are kept low for people's welfare, countries' energy efficiency policies are mainly implemented to target industry and large commercial buildings, while residential energy efficiency measures lag behind.

Considering future economic growth, and trends such as urbanization, extension of hours of AC use, and switching from motorcycles to cars, energy consumption will surely increase in the future. In order to stem the increase, early adoption of the newest technologies from around the world and thorough, in-depth energy efficiency policies are needed. New technologies that Southeast Asia should become a world leader in introducing include improvement of heat barriers in housing construction and renewable energy. In particular, in order to reduce space cooling, lighting and plug loads, which use lot of electricity, there is need to implement stronger mandatory energy efficiency standard and accelerate the introduction of smart appliances and HEMS. Energy efficiency standards are typically MEPS, but it would be advisable to introduce standards that, like Japan's Top Runner standards, are the strictest in the world.

On the other hand, there has been hardly any collection and maintenance of basic information needed in order to plan these. We have, as one step in this process, as well as collecting and providing energy consumption data, developed a database to provide information to people involved in Southeast Asia. At the same time, we are also building networks of each country's governmental parties with researchers, and working to collect field data. Also, in 2016 fiscal year we are conducting a monitoring study of electricity consumption and an interview study about lifestyle, and in 2017 fiscal year we plan to build an open platform database that can be accessed freely by interested parties, and to recommend policies for each country that are produced jointly by specialists in Japan and Southeast Asia.

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