International Comparison of Household Energy Consumption and Its Indicator

Hidetoshi Nakagami, Chiharu Murakoshi, and Yumiko Iwafune,
Jyukankyo Research Institute

ABSTRACT

The structure of household energy consumption around the world varies greatly, according to the climate, living standards and lifestyles. It is important to understand the structure of energy consumption and lifestyle circumstances for each country, including developing country, for which energy use is expected to increase, from the past to the present day, in order to investigate the following questions. How much further will the world's household energy use increase? How much energy will be needed to deliver sufficient energy services? Also, where is there room for energy efficiency?

We surveyed residential energy consumption and its indicators in 18 countries, both developed and developing countries such as USA, Canada, Australia, England, France, Germany, Italy, Sweden, Denmark, South Korea, China, Taiwan, India, Malaysia, Thailand, Vietnam and Japan. We surveyed household energy use and the structural factors that influence it, including housing and household types, lifestyles, and types of equipment use. For the various survey categories and survey years, each country's data is scattered, but we attempted, to the extent possible, to assemble continuous time series data. For developing countries of Asia there are big differences within the countries, so we assemble separate data for rural and urban areas.

In the western countries, household energy consumption shows a trend toward saturation, but in the Asian countries it is likely that household energy consumption will continue to rise. In the developing countries of Asia, we do expect future changes in the structure of energy consumption to occur. The process by which such changes happen can be broken down into four parts. These are shown in Figure 8, for the Asian countries we studied here.

Introduction

We surveyed residential energy consumption and its indicators in 18 countries such as USA, Canada, Australia, England, France, Germany, Italy, Sweden, Denmark, South Korea, China, Taiwan, India, Indonesia, Malaysia, Thailand, Vietnam, and Japan. The study period is from July, 2004 to June, 2006.

We surveyed residential energy use and the structural factors that influence it, including housing and household types, lifestyles, and types of equipment used. For the various survey categories and survey years, each country's data is scattered, but we attempted, to the extent possible, to assemble continuous time series data. For developing countries of Asia there are big differences within the countries, so we assemble separate data for rural and urban areas. The main survey categories are shown in Table 1.

Initially, we assembled statistical data and actual survey results for each country from the literature and from websites. In addition, we visited research organizations and energy-related

companies in the countries to conduct interviews, in order to obtain more detailed data. In addition, the data are all by final energy use in this paper.

Table 1. Main Survey Categories

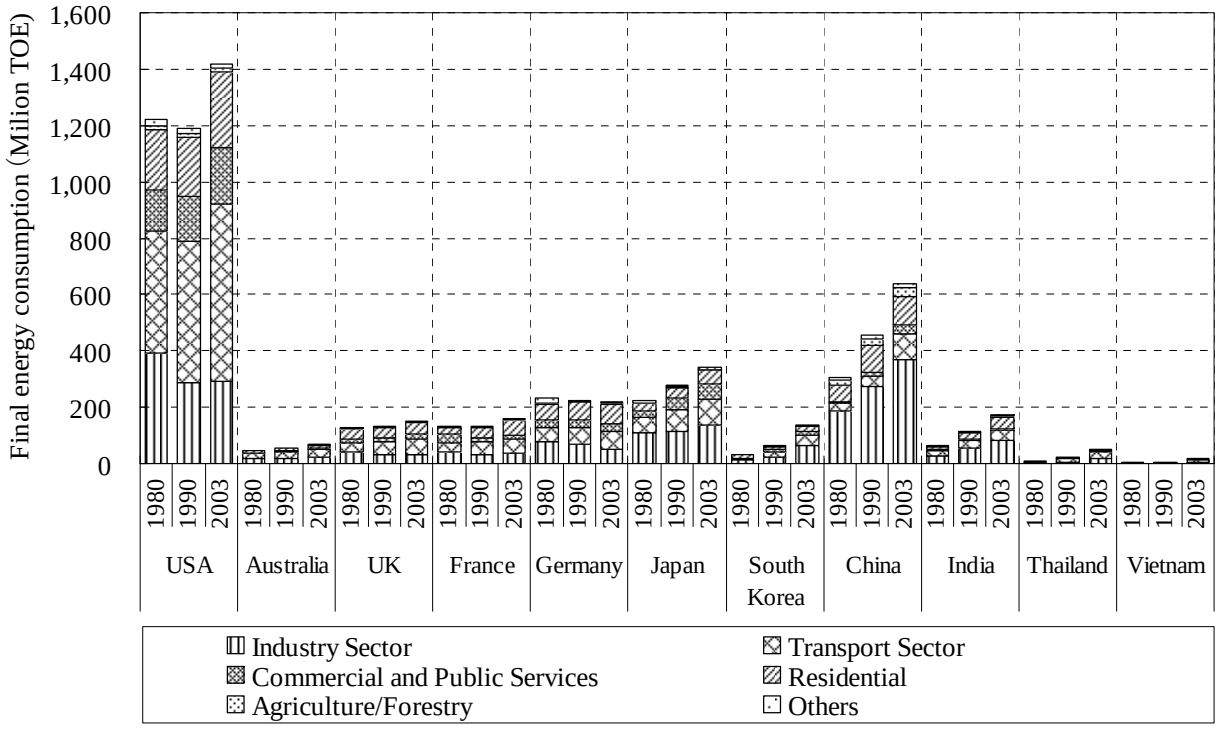
Basic data	
Population、number of households、climate conditions(monthly average population-weighted temperature、heating and cooling degree days)、GDP、per household expenditures	
Housing data	
Number of residences	Stock and flow numbers、breakdowns for owners vs. renters、building type、household members、building year
Floor area	Average or frequency distribution
Equipment	Heating and cooling equipment(by fuel type), water heater(by fuel type), breakdown of central heating energy type
Energy data	
Macro data	Whole country final energy use by fuel type and end use
Per household energy consumption	by fuel type, end use, fuel type x end use (including vehicles)
Per household energy cost	by fuel type and end use (including vehicles)
Equipment data	＜kitchen appliances＞ oven, range, grill, refrigerator (breakdown by capacity and model year), freezer, dishwasher, microwave oven, and others ＜electrical appliances＞ air conditioner, television, broadcast satellite tuner, video and DVD player, stereo, personal computer, washer, dryer, electric water heater, and others ＜other＞ diffusion of vehicles, internet users, cell phones, and others
Energy use per equipment type	Refrigerator, freezer, dishwasher, washer, dryer, range (flow and stock)
Energy price	By fuel, for residential customers
Other kinds of indicators	
Indicators and activities related to energy use	Insulation, heating/cooling thermostat settings, frequencies of dishwasher, washer, and dryer use, water temperature setting for clothes washer, cooking frequency, lighting types, time of occupation, time of TV watching, frequencies of showers and baths, amount of water usage, etc.

Final Energy Consumption

When one examines the final energy consumption of each country (Fig. 1), the USA is overwhelmingly large; with 2003 consumption about four times that of Japan. China has a high rate of growth, in 2003 just under twice that of Japan. South Korea and Thailand have high rates of increase in final energy consumption, using over twice as much in 2003 as in 1990. Both the USA and Japan consumed about 20% more in 2002 than in 1990.

Except for India, all these countries have a large increasing trend for the transport sector. Japan, South Korea, China, and India all have industrial sectors with large shares of final energy consumption. The European countries have residential sectors with relatively large shares.

Figure 1. Final Energy Consumption of Each Country

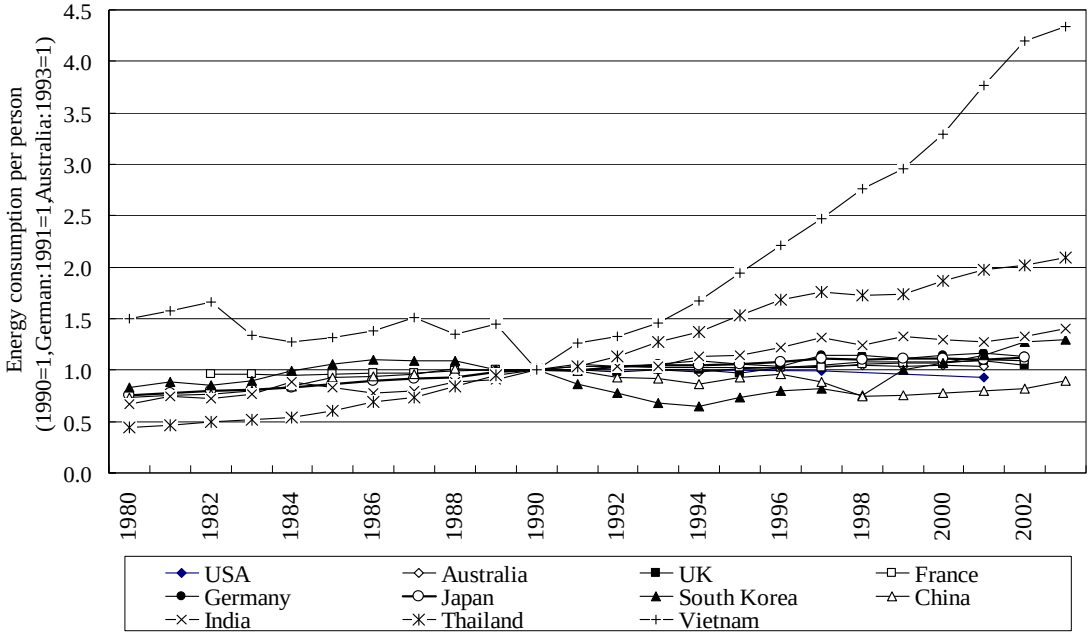


Source: IEA"Energy Balances OECD Countries", IEA " Energy Balances Non-OECD Countries"
(excluding Combustible Renewable Energy Sources and Waste)

Changes in Household Energy Consumption

Household energy use per person is shown in Figure 2. Vietnam, Thailand, India, and the other Asian countries have high rates of increase. Japan and the European countries have small rates of increase, and the USA has a small decreasing trend. For South Korea, levels of consumption were lower than that of 1990 until the second half of that decade, but have increased greatly from then on. This is attributable to improved energy consumption efficiency due to fuel switching from coal to natural gas and LPG in that country in the 1990s. In the same way, because switching from coal to other fuels progressed in China, energy use per person was less in 2003 than in 1990. The actual demand increased in China, for which these decreasing values of energy consumption take advantage of the increase in conversion efficiency. Between 1990 and 2003, effective energy consumption per person increased by factors of 1.4 in urban areas and 1.2 in rural areas (Yadong Ning 2006).

Figure 2. Change in Energy Consumption per Person for Each Country



Source: Western countries and Japan: Estimated by Jyukankyo Research Institute .Others: IEA. Energy Balances Non-OECD Countries (excluding Combustible Renewable and Waste)

Energy Consumption per Household

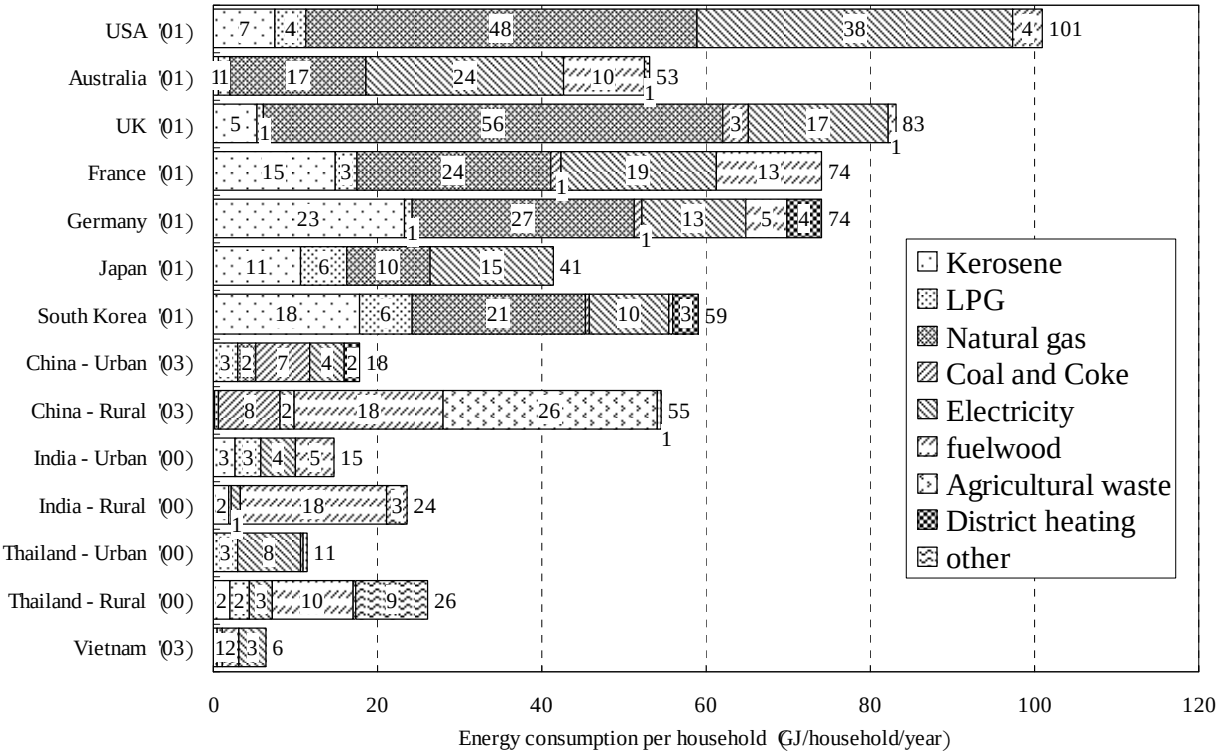
The country with the largest energy consumption per household is the USA, with the European countries also having relatively high consumption. Compared to other developed countries, Japan consumes a small amount. Figure 3 shows the breakdown by fuel type. Natural gas consumption is high in the USA and England, while electricity consumption is high in the USA and Australia. Germany has relatively high kerosene consumption. France has high consumption of wood. South Korea consumes more city gas and kerosene than Japan, and less electricity. Energy consumption per household in rural China is high. Because 80% of this is wood or agricultural waste, with a low efficiency of conversion, a rural Chinese household uses more energy than does an urban one. For households in rural India, "other" is livestock dung, while for those in rural Thailand it is charcoal. Just as with China, the low efficiency of conversion means that a rural household in these countries uses more energy than does an urban one. In India, Thailand, Vietnam, and other tropical countries, there is no heating demand. In these countries the main demand is from heating water and showers, or sometimes a lifestyle that does not even use hot water predominates, so this does not amount to that much energy use. Therefore, in these countries, I think that the main energy expenditure is for cooking exclude electricity.

Figure 4 shows energy consumption per household by end use. Compared to the western countries, Japanese households use very little energy for space heating. French and German households use little energy for water heating. The temperature in the Seoul metropolitan area, where a majority of South Koreans live, is comparable to that of the Tohoku region of Japan, but the heating demand for South Korean households is larger than that of Tohoku households. We speculate that South Korea has higher levels of space heating than Japan. For rural Chinese

households, energy used for space heating, water heating, and cooking is nearly all agricultural waste and firewood, with the actual demand being not large. For households in rural India, Thailand, and Vietnam, the majority of energy is used for cooking, and this is also mainly firewood and agricultural waste.

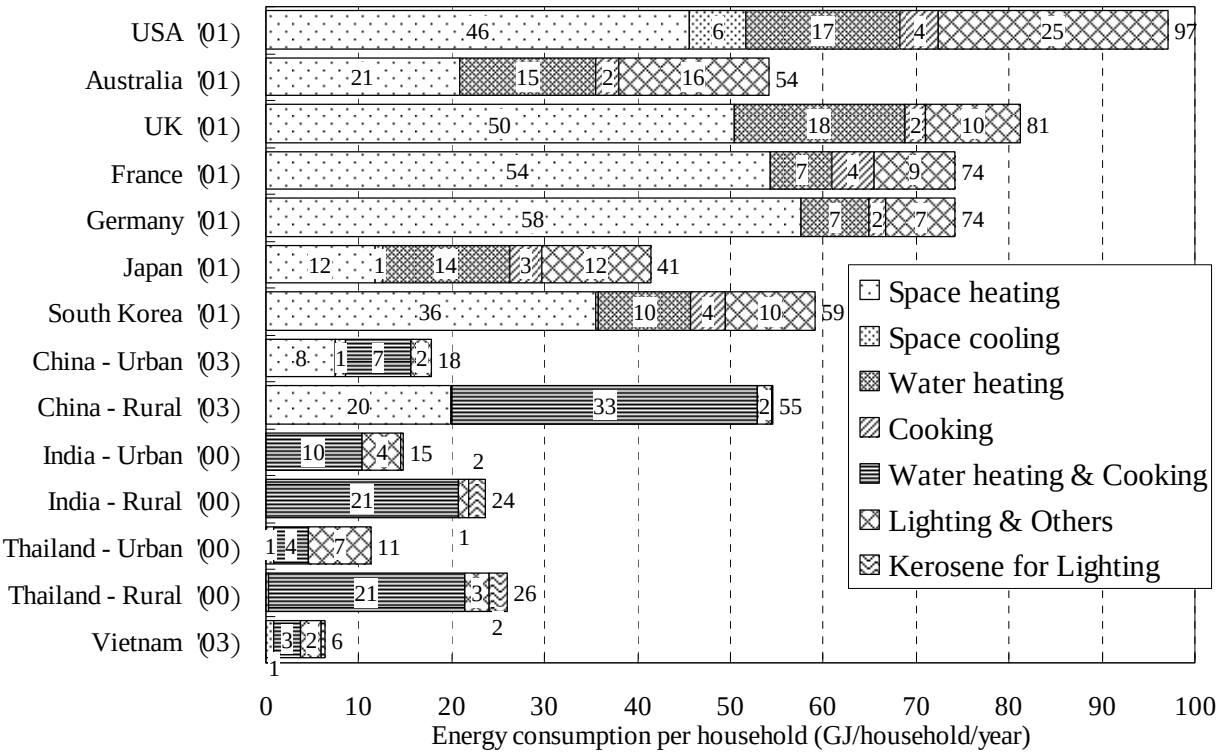
When energy from automobiles and motorcycles is included, energy use of households in many countries doubles. Currently, the diffusion of cars and motorbikes is still low in China and India, so consumption is still low, but in the same way as with the other Asian countries, as this diffusion expands, it is likely that energy use will greatly increase.

Figure 3. Energy Consumption per Household by Fuel Type



Note: Figures for Vietnam's fuel wood, agricultural waste, etc. are unknown and therefore not included

Figure 4. Energy Consumption per Household by Final Energy Use



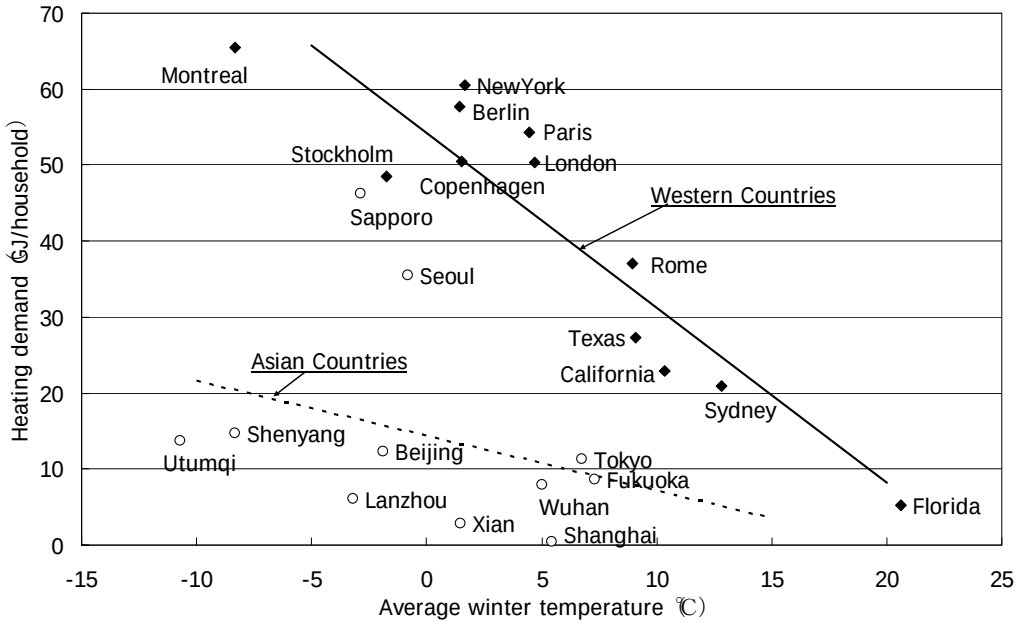
Note: With regard to Vietnam, the figure for cooking includes only LPG and natural gas. (Figures for fuel wood, agricultural waste, etc. are unknown and therefore not included)

Correlations of Household Energy Consumption with Other Indicators

Figure 5 shows the relation between winter average temperature and space heating energy use per urban household. For the western countries, there is a negative linear correlation. We can see that, compared to the western countries, there is less energy consumption by households in Japan, South Korea, and China. However, South Korean households have relatively small floor areas, because multifamily housing is major. When one considers space heating energy consumption per unit area, Korean consumption is at a level comparable to that of western households.

Figure 6 shows the relation between per capita GDP and electricity consumption, excluding that used for cooling and water heating. On the whole, as per capita GDP rises, so does electricity consumption. Although its per capita GDP is about the same as Japan, electricity consumption is highest in the USA, at more than twice that of Japan. When the breakdown of electricity end use is considered, much electricity is used for cooking in Canada, Sweden, and England. In countries such as Canada, Australia, and the USA, in addition to refrigerators, many households have freezers, with high electricity consumption. Although, Europeans have higher ownership of freezers than North Americans, the electricity consumption is less than North Americans. Among Asian countries, there are many electric cooking appliances, such as the electric hot water pot, and these consume much electricity.

Figure 5. Correlation between Average Winter Temperature and per Household Heating Demand for Western Countries and Urban South Korea and China



Note: Chinese heating demand is for urban household. Source: Heating demand for all locations with the exception of China estimated by Jyukankyo Research Institute. Heating demand for China is from Yadong Ning, 2006. Prospects for policy effects and analysis of current conditions related to energy and environmental issues of the Chinese residential sector: dissertation.

Major electricity use in Japan is by home appliances and it had been increased. But in recent years, it had saturated, because high efficient appliances spread by Top-Runner regulation. Although per capita GDP of South Korea is only about one fourth that of Japan, per household electricity consumption is at about the same level. Major electricity use in South Korea is home appliances and the owner ship of major appliances such as refrigerator; TV, VTR, and PC are almost same level with Japan. Per capita GDP of Taiwan is a little higher than that of South Korea, but per capita household electricity consumption exceeds those of both South Korea and Japan, because of high electricity use by air conditioner, hot water supply and home appliances. For the other Asian countries, it is likely that the saturation of household electrical appliances will increase. As the number of air conditioners in use grows, it is possible that electricity consumption will grow to exceed the levels of Japanese households. In particular, the latent cooling demand in tropical regions is larger than that of Taiwan, and it is likely that increases in standards of living will have a major influence on electricity consumption.

Figure 6. Correlation between per Capita GDP and Electricity Consumption (Excluding Cooling and Water Heating)

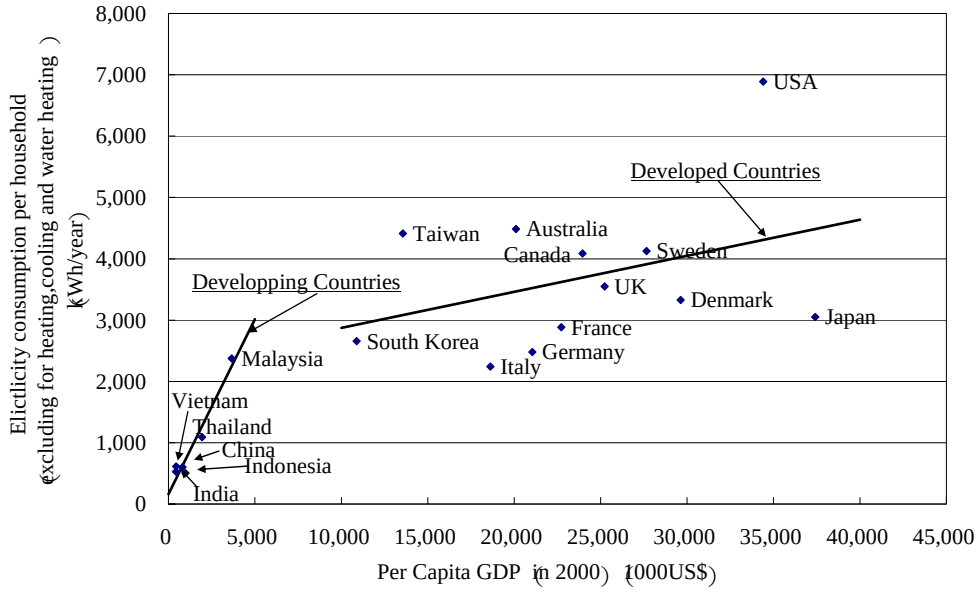
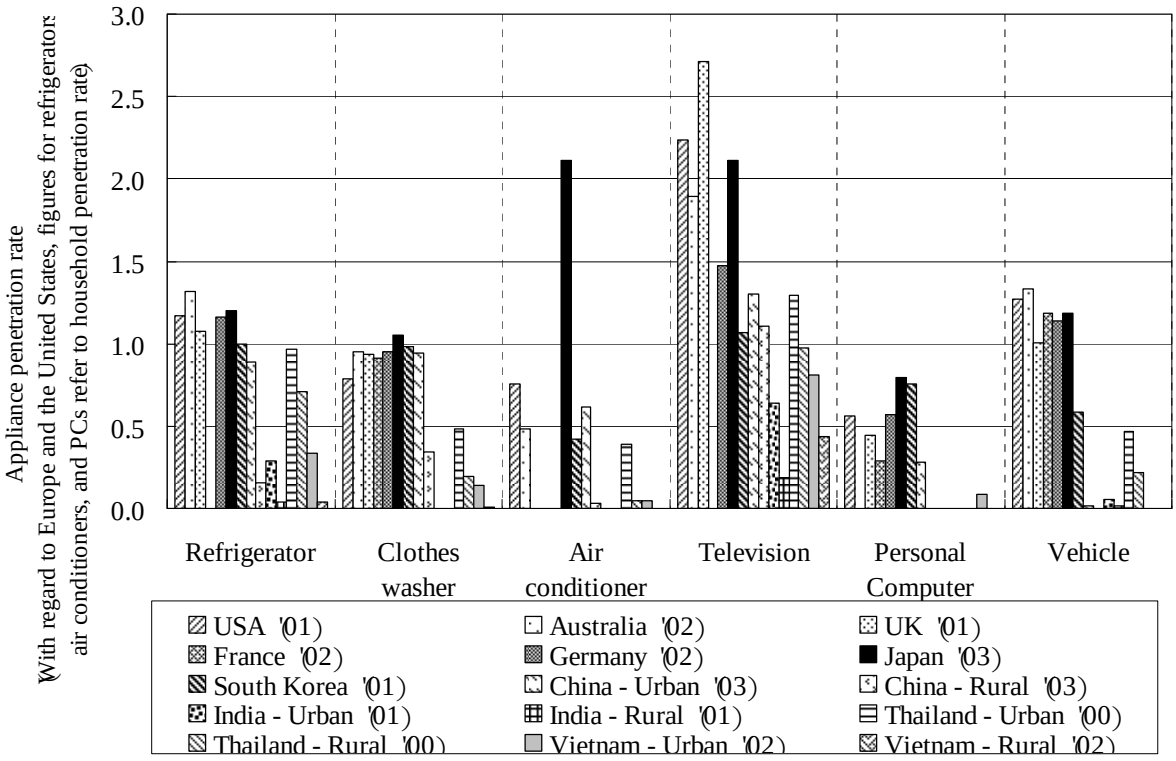


Figure 7 shows diffusions of various equipment and appliances in each country. In North America, Japan, and South Korea, refrigerators, televisions, and washers have saturated all households, and, except for South Korea, the number of vehicles exceeds one per household. Japan has many air conditioners, with more than two per household. The relatively low rate of 0.76 units per household in the USA is probably due to the penetration of central air conditioning in that country. In Europe, there has hardly been any penetration of air conditioners, but recently the number of households installing them is apparently on the rise. Japan has a high rate of personal computer penetration.

In urban areas of China and Thailand, there is relatively high penetration, with nearly all households having refrigerators and televisions. In Thailand, the rate of car ownership is also high. In India and rural parts of Asia, as a rule, penetration is low.

Figure 7. Penetration of Major Equipment and Appliances in Each Country



Changes in the Structure of Household Energy Consumption

In the western countries, household energy consumption is already at levels of saturation, so we do not expect big changes. In the developing countries of Asia, we do expect future changes in the structure of energy consumption to occur. The process by which such changes happen can be broken down into four parts, described below. These are shown in Figure 8, for the Asian countries we studied here. These steps do not necessarily take place in stages, but can occur simultaneously.

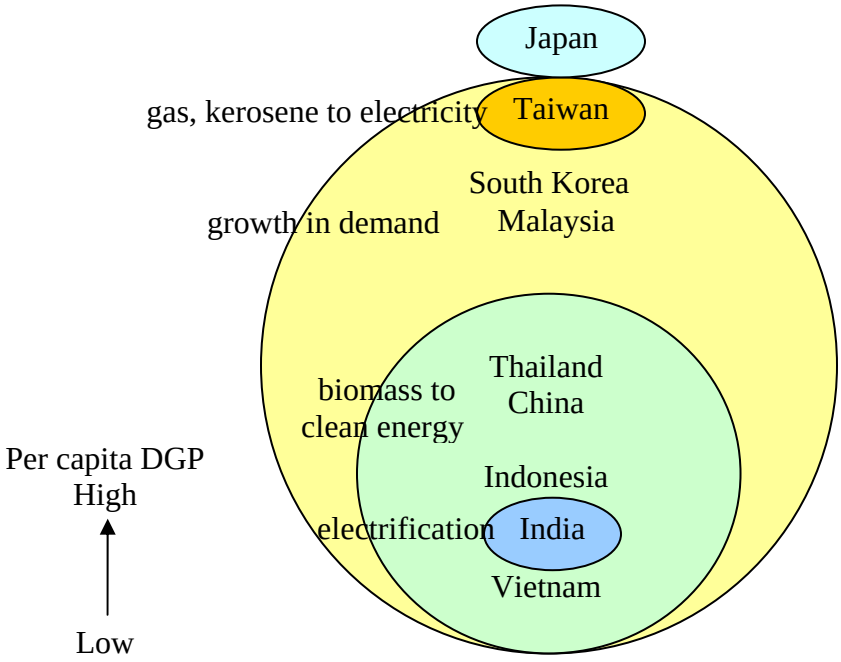
(1) electrification (expansion of electricity supply)
(2) switching from biomass to cleaner energy sources for cooking and heating use; due to switching from inefficient fuels like firewood and agricultural waste to LPG, natural gas, and electricity, the efficiency of conversion increases, leading to decreased primary energy consumption. However, fossil fuel use increases.
(3) growth in actual demand, mainly in electricity demand, which accompanies increases in floor areas and improving living standards.
(4) Switching from direct combustion type fuels, such as gas and kerosene, to electricity.

Among the Asian countries studied here, the places which most lag in (1) are rural India, with an electrification rate of 44% in 2001, and also rural Vietnam, Thailand, and Indonesia, which all have more than 10% of households without electrification. The places where (2) is

under way are rural China, India, Indonesia, Thailand, and Vietnam, as well as urban India and Indonesia. Urban China, with its heavy use of coal for heating, is still in the process of switching to cleaner sources. Urban Thailand and Vietnam are in the process of (3), while urban China is undergoing (2) and (3) in parallel. Electricity consumption in Vietnam and China has grown by more than 10% annually, over the past five years. In Malaysia, compared with South Korea and Taiwan, there is room for future growth in penetration of refrigerators, washers, and air conditioners, with an increasing trend for electricity consumption. In South Korea and Taiwan, basic home appliances are already finished diffusing, and as a part of overall energy consumption, they have reached a fixed level, with the rate of increase becoming small. However, electricity consumption is clearly increasing. Particularly in Taiwan, in recent years, LPG consumption has been decreasing, and it seems that, together with increasing demand for electrical appliances, electrification of energy for water heating and kitchen use (process (4)) is proceeding. Also in Japan, levels of energy conservation are generally high, but the switch to electricity for water heating and cooking is proceeding, so we can see that process (4) is under way.

In contrast, since 1990, energy consumption in the western countries has not increased that much, being at sufficient levels. Due to the circumstances of each country, there are differences in the degree to which they depend upon electricity, but, except for a small increase in USA electricity consumption, there has been essentially no change since 1990, with no trend toward fuel switching. We think this may be due to the way heating equipment is treated in these countries. In most cases, heating equipment is built into houses, which have long lifetimes, and when the heating equipment is replaced, it can be difficult to switch to a different fuel.

Figure 8. Circumstances of Household Energy Consumption in the Asian Countries



In these Asian countries, future large increases in energy consumption appear unavoidable, due to increasing populations and improved living standards. Numbers of automobiles and home appliances will probably increase greatly. Especially in tropical regions, the potential demand for cooling is extremely large. Also, due to switching to cleaner fuels for cooking, fossil fuel consumption will probably increase.

Conclusion

In this study, we surveyed household energy consumption and related indicators in various western and Asian countries. In the western countries, household energy consumption shows a trend toward saturation, but in the Asian countries it is likely that household energy consumption will continue to rise. In rural areas of Asia, especially because the energy infrastructure has not yet been completed, there may also be, on the positive side, opportunities to encourage acquisition of innovative energy systems. For example, these countries have skipped over mass use of the fixed telephone, and jumped straight to the cellular phone. There are currently investigations proceeding about shifting directly to the clean use of biomass, away from the use of low-efficiency combustion of firewood and agricultural waste, without passing through the intermediate step of commercial fuels, such as LPG.

It is necessary to understand conditions in each country precisely, in order to implement more effective energy policies. But, especially for the rural regions of Asia, there is still insufficient information about such things as conditions of biomass energy usage, conditions of home electrical appliance use, and water heating needs. We think it is important to produce a data base of energy efficiency indicators for each country in the Asian region, similar to the European Union program, ODDYSSEE, thereby sharing information and goals.

Acknowledgement

We appreciate Barbara Litt's help in translating this paper from Japanese.

References

[IEA] International Energy Agency, Energy Balances OECD Countries.

[IEA] International Energy Agency, Energy Balances Non-OECD Countries.

Hidetoshi Nakagami. 2007. Research on residential energy consumption in Japan: dissertation.

Jyukankyo Research Institute. 2006. Annual statistics of house hold energy consumption.

Yadong Ning. 2006. Prospects for policy effects and analysis of current conditions related to energy and environmental issues of the Chinese residential sector : dissertation (Chuugoku no kateibumon enerugii kankyou mondai ni kansuru genkyou bunseki to taisaku kouka no yosoku.; in Japanese:).