Influences of Indirect Lifestyle Aspects and Climate on Household Energy Consumption

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Abstract
This study investigated the interrelationships among household energy consumption and indirect lifestyle aspects (including life schedule and family pattern), with particular emphasis placed on energy consumption pattern changes according to climatic characteristics. Instead of the conventional questionnaire survey and on-site measurement methods, this study focused on estimating the lifestyle related household energy consumption using life schedule data, which, in contrast, is low cost and time efficient. This study found that household energy consumption increases according to family size, however the per person energy consumption rate is less in larger size families. Retirees and housewives generally consume more household energy than working and student groups. Among working groups, household energy consumption increases according to age. Employee groups tend to consume less household energy than businessmen/women groups, while female working groups consume more household energy than male working groups. Also, people engaged in the agriculture/forestry sector and the self-employed consume more household energy, while labor and management/technical sectors consume the least. This study also revealed that households in colder regions generally consume more household energy due to higher energy needs for heating and lighting.

Keywords: household energy consumption; indirect lifestyle aspects; climate; family pattern; life schedule

1. Introduction
It has become clear that the continued rise of greenhouse gas (GHG) concentrations in the atmosphere has brought about severe adverse impacts on ecological systems and socio-economic sectors. Although GHG occurs naturally in the atmosphere, it mainly resulted from human activities and is closely related to energy consumption. International efforts are being made to combat climate changes caused by various human activities.

The International Energy Outlook 2006 projects strong growth for worldwide energy demand over the period of 2003 to 2030 (US DOE, 2006). The total world consumption of marketed energy is projected to expand from 421 quadrillion British thermal units (Btu) in 2003 to 722 quadrillion Btu in 2030, a 71% increase over the period of 2003 to 2030. As shown in Fig.1., for the residential sector, the consumption of delivered energy is expected to grow from 50 quadrillion Btu in 2003 to 79 quadrillion Btu in 2030, a 57% increase over the period of 2003 to 2030 (US DOE, 2006).

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out a further study to investigate household energy consumptions under different lifestyles and climates in Japan (Fong et al., 2007b). The findings showed that climate and lifestyle factors in terms of life schedules and family patterns have significant influences on the household energy consumption proclivity. The current study is a continuous work from the previous investigations.

In Japan, there is numerous existing research on household energy consumption and lifestyle. However, the focus has mainly been on direct lifestyle aspects, particularly the usage of energy consuming equipment. Little has been done in understanding the impacts of indirect lifestyle aspects such as family patterns, employment, gender, age and city size, these factors are indeed crucial as they are the main constituents of society. In view of these shortfalls, the purpose of this study is to investigate the impacts of the indirect lifestyle factors (in terms of family patterns, employment, gender, age and city size) and climatic factors (under different climate zones of Japan) upon household energy consumption based on the life schedules of each family member.

The emphasis of this study was on understanding the effects of various indirect lifestyle factors on household energy consumption, under different climatic characteristics. It also aimed to reveal the significance of indirect lifestyle and climate factors in household energy consumption, and to share the information with other countries with similar geographical and socioeconomic characteristics such as aging population and decreasing family size.

2. Methods

The climate of Japan is predominantly temperate, but due to the large north-south extension of the country, it varies greatly in different regions. Generally, northern Japan experiences a cool-temperate climate, central Japan is temperate, while southern Japan has a subtropical climate. Fig.2. shows the average temperatures of Sapporo, Saitama and Kagoshima.

![Fig.2. Average Temperatures of Sapporo, Saitama and Kagoshima, 2006 (Japan Meteorological Agency, 2007)](image)

In order to understand the differences in energy consumption patterns under different climatic characteristics, the case study was considered in three locations according to the above-mentioned climate zones i.e. Sapporo for cool-temperate zone, Saitama for temperate zone, while Kagoshima is in the transition zone from temperate to sub-tropical climate (cf. Fig.3.).

Most of the previous studies found in the literature review essentially used the methods of questionnaire survey and long-term on-site energy consumption measurement/monitoring methods to study the relationships between lifestyle and household energy consumption. Among noteworthy recent studies in Japan include the investigation of indoor environment and energy consumption on 300 well-insulated and airtight houses in the Tohoku region of Japan, by Hasegawa et al. (2002). A study on energy consumption for residential buildings in Japan carried out by the Architectural Institute of Japan (AIJ, 2006), which included an internet questionnaire survey of 4,000 households and detailed on-site investigations of 80 houses throughout Japan. And the two years detailed monitoring of energy consumption and indoor temperature of 13 housing units in the northern region of Honshu Island, Japan, by Yoshino et al. (2006).

Although these types of questionnaire surveys and long-term on-site measurements provide accurate data, they are very costly and time consuming. For that reason, the authors adopted another approach in this study to estimate household energy consumption via the life schedules of people of different employment status, employment sectors, age and gender. With the availability of the Life Schedule Survey Report based on the questionnaire survey on 12,600 respondents throughout Japan (NHK, 2006), using this study methodology would reduce time and cost and yet be able to produce reliable results.

The literature review found a number of previous studies regarding the influence of lifestyle on household energy consumption. However, there are very few of these studies took into consideration aspects such as family pattern, age and life schedule. These very few studies are summarized in Table 1. From these studies, it was found that there were still some shortfalls in the lifestyle aspects. In this study, the authors combined the aspects covered in the previous studies as listed in Table 1., and added some new aspects i.e. employment...
status, employment sector, gender and city size. The comprehensive coverage of family pattern, employment status, employment sector, age, gender, life schedule, city size, geographical locations and climate, are referred to as 'indirect lifestyle aspects' in this study.

Table 1. Previous Studies on Lifestyles and Household Energy Consumption

| Previous studies     | Indirect lifestyle aspects | Case study  |
|----------------------|---------------------------|-------------|
| Kagajo and Nakamura (1997) | Family pattern, aging society, life schedule | Kinki region |
| Nomura and Ohya (2000) | Age, family income, expenditures on electricity | Japan |
| Nakaguchi (2003) | Family size, age, duration staying at home, climate | Iwate Prefecture and Kagoshima Prefecture |
| Tanaka et al. (2006) | Family size, family size, age, income | Various regions of Japan |
| Nishio (2006) | Family size, family pattern, age, life schedule, climate, geographical location | Various regions of Japan |

Fig.4 outlines the study methodology of the current investigation. Firstly, based on the findings of the previous studies (AJ, 2006, Yoshino, 2006, Takuma et al., 2006, Tsurusaki, 2000), it was assumed that space heating, cooling, lighting and usage of electronic entertainment/media equipment are the major sources of household energy consumption that closely related to lifestyle and climate factors (herein after referred to as 'lifestyle related household energy consumption'). Although energy consumption for hot water supply is also one of the main sources of household energy consumption, it was omitted in this study due to unavailability of life schedule data.

Typical life schedules for people under different employment status, employment sectors, gender, age and city size were extracted from the above-mentioned Life Schedule Survey Report (NHK, 2006). In this study, the extracted data included the average duration of time spent at home, sleeping and non-sleeping times, and the usage of electronic media/entertainment equipment (television, radio, CD/MD/cassette player and video).

In order to investigate the differences in energy consumption trends of different climate zones, climatic related data i.e. heating days, cooling days, and lighting needs according to sunrise and sunset times, were obtained from the Japan Meteorological Agency and the National Astronomical Observatory of Japan.

By comparing the life schedules of different population groups and climatic related data (heating days, cooling days, sunrise/sunset times), the durations of each individual's daily needs for space heating, space cooling, lighting, and usage of electronic entertainment/media equipment were calculated. These durations were then multiplied with the average energy consumption rates for each case study area as published by AJ, which was based on the detailed on-site survey of residential energy consumptions on 80 houses in different regions of Japan (AJ, 2006). The calculated results were divided into households of different family patterns, employment status, employment sector, gender, age and city size.

For family pattern, based on the projection by the Japan National Institute of Population and Social Security Research (2006), cf. Fig.5., it was predicted that by the year 2025, about 79.5% of families in Japan would be in the categories of single-person family, husband-wife family (i.e. 2-person family) and husband-wife-child family (i.e. 3-person family). As such, this study focused on these three family groups.

In relation to the three climate zones of Japan mentioned above, the analyses of lifestyle related household energy consumption were carried out for five indirect lifestyles, i.e. family pattern, employment status, employment sector, age and city size (cf. Table 2.).

![Fig.4. Study Methodology](image-url)
3. Results and Discussion

3.1 Energy Consumption by Family Pattern

According to the above-mentioned methodology (cf. Fig.4.), annual household energy consumptions (GJ) for heating, cooling, lighting and media/entertainment were calculated for various types of household patterns. Validation of results has been made by comparing with the other previous studies as shown in Table 3. Although the present calculation results for media/entertainment were slightly higher compared to the AIJ's results, on the whole, the calculation results agreed with other study findings.

Fig.6. illustrates the calculation results of the lifestyle related household energy consumption (per household) for different family patterns in Sapporo, Saitama and Kagoshima, Japan. The figures revealed four energy consumption trends worth mentioning, (1) household energy consumption is closely related to family pattern, (2) households with retirees or housewives generally consume more energy due to longer hours spent at home, (3) the bigger the family, the higher the energy consumption is expected but the per person energy consumption rate is obviously less (cf. Fig.7.), due to shared usage of equipment, and (4) northern Japanese households generally consume more energy due to higher space heating and lighting needs.

3.2 Energy Consumption by Employment Status

The calculated results given in Fig.6. showed that retirees and housewives generally consume more household energy compared to the working groups due to longer hours spent at home. In order to validate that result, further analysis was carried out to investigate the energy consumption patterns of different employment status.

Table 2. Analysis Cases

| Analysis Aspects | Sapporo | Saitama | Kagoshima | Japan |
|------------------|---------|---------|-----------|-------|
| Family pattern   | ○       | ○       | ○         | ○     |
| Employment status| ○       | ○       | ○         | ○     |
| Employment sector| ○       | ○       | ○         | ○     |
| Age              | ○       |         | ○         | ○     |
| City size        |         | ○       | ○         | ○     |

Table 3. Comparison of Calculation Results with Other Studies

| Region | Annual Energy Consumption per Household (GJ) | Data Source |
|--------|---------------------------------------------|-------------|
|        | Space Heating | Space Cooling | Lighting | Media/Entertainment |            |
| Sapporo| 13.0-28.6     | -             | 0.9-8.1  | 1.2-15.5             | Present results |
| Saitama| 3.2-7.1       | 1.3-2.8       | 0.9-7.2  | 1.2-10.7             | Present results |
| Kagoshima| 1.3-2.9      | 3.0-6.3       | 0.9-7.2  | 1.2-15.5             | Present results |
| Japan  | 12.35          | 1.07          | <10      | <10                   | ECCJ (2005)   |
| Hokkaido| 20-60<sup>‡</sup> | <10<sup>‡</sup> | <10      | <10                   | AIJ (2006)    |
| Kanto<sup>†</sup> | <10<sup>‡</sup> | <10<sup>‡</sup> | <10      | <10                   | AIJ (2006)    |
| Kyushu<sup>‡</sup> | <10<sup>‡</sup> | <10<sup>‡</sup> | <10      | <10                   | AIJ (2006)    |
| Tohoku average| 29.38       | 0.24          | 17.70<sup>‡</sup> |          | Yokokyo (2002) |
| Tohoku  | 27.20          | 0.44          | 5.70     | 1.96                  | Yoshino et. al (2006) |

<sup>†</sup> Approximate values; <sup>‡</sup> Including lighting, media/entertainment, kitchen, healthcare, and other electrical appliances; <sup>‡</sup> Including space heating and space cooling.
Fig. 8. presents the analysis results of the energy consumption by employment status, based on the case of single-person family. The employment status was divided into groups of businessmen/businesswomen, male/female employees, retirees and housewives. The results were in line with the earlier finding that colder region’s families consume more household energy than those in the warmer region. These results also reconfirmed the findings of Fig. 6. that retirees and housewives generally consume more household energy than the working groups. The differences were as high as about 12GJ/year for the case of Sapporo. This point is very important for long-term energy planning in Japan due to the rapid aging of the Japanese population. As shown in Fig. 9., it is expected that from the present (2005) proportion of 20.5%, by 2025 about 28.7% of the total population in Japan will be in the age category of 65 and above. Moreover, the situation will be worse with the increasing number of single-person families consisting of retirees. As mentioned above (cf. Fig. 7.), per-person energy consumption of single-person families is higher compared to other family types. Fig. 10. shows that by 2025, about 13.7% of the total families in Japan will be 65 and above.

Among the working groups, cf. Fig. 8., two important points have been identified, (1) businessmen and businesswomen consume more household energy compared to the employee groups. This is due to the fact that businessmen/businesswomen tend to have shorter working hours compared to the employee groups, which was also indicated in the life schedule survey (NHK, 2006); (2) female working groups tend to consume more energy than the male working groups, due to shorter working hours.

From the above analysis results (cf. Figs. 6. and 8.), it is clear that household pattern and employment status are significant in dictating the household energy consumption. The next step of the analysis is to combine these two factors by investigating the energy consumptions of different family patterns under various combinations of family member’s employment status.

Fig. 11. shows the results for husband-wife families and Fig. 12. depicts the results for husband-wife-child families, under various combinations of employment status. The results were in line with the above-mentioned findings, whereby families that consist of housewives or retirees generally consume more energy than the rest. It was also found that (1) Families with both parents and both husband and wife in the employee groups consume least energy. (2) In the case of husband-wife-child families, while there is no obvious trend for the families with a school age child, families with a child below school age generally consume less energy compared to the working child. This can be attributed to factors such as additional energy consumption due to separate bedroom, lighting and separate usage of electronic media and entertainment equipment. (3) Families in northern Japan (Sapporo) consume far more energy than the central and southern regions due to longer hours of space heating during winter, more heating days and shorter daylight that entailed more lighting needs (Fong et al., 2007c).

3.3 Energy Consumption by Employment Sectors

Having seen the energy consumption trends under various types of employment status, the subsequent analysis was to investigate the effects of the employment sector on household energy consumption.

Fig. 10. Growing of Elderly Single-Person Families in Japan, 2000-2025 (Source: National Institute of Population and Social Security Research, 2006)
In line with the Life Schedule Report 2005 (NHK, 2006), the employment sectors were divided into agriculture/forestry, self-employed, sales and services, laborers, management, and technical & professional. Analysis was undertaken for the case of the single-person family, and the results are presented in Fig.13.

The analysis results showed that household energy consumption of families in the colder regions were significantly more than the warmer regions in central and southern Japan. Among the different employment sectors, agriculture/forestry and self-employed sectors have the highest energy consumption rates, while laborer and management/technical sectors have the lowest energy consumption rates. The energy consumption rates were in line with the working hours of each employment sector. People engaged in the agriculture/forestry sector and the self-employed generally have shorter working hours compared to those working as laborers or in the management/technical sector. Shorter working hours under agriculture/forestry sector and the self-employed entailed spending longer hours at home, thus consuming more energy for space heating, cooling, lighting and media/entertainment.

3.4 Energy Consumptions by Age

Fig.14. shows the analysis results on age factor upon household energy consumption. The analysis was based on the case of single-person families, and focused on the employee groups.

This figure shows that the male employee groups generally consume less household energy compared to the female employee groups. This is because men tend to work longer hours and have more social activities compared to women, as also indicated in the Life Schedule Report 2005 (NHK, 2006). This entailed shorter hours spent at home, thus consuming less household energy.

The results obtained in this study also indicate that the household energy consumption increases according to age. This is due to the fact that older people tend to spend longer hours at home.

These findings are deemed important in long-term energy planning in view of the rapid aging of Japanese society (cf. Fig.9.) and the increasing proportion of females (cf. Fig.15.).

3.5 Energy Consumption by City Size

This section presents the results of investigations on relationships among city size, lifestyle and household energy consumption. Fig.16. depicts the lifestyle...
related household energy consumption rates of typical single-member families by city size (regardless of family pattern, employment, age and gender).

The results indicated very slight variations among different city sizes, the per household consumption rates range from about 9.79 GJ/year to 9.94 GJ/year. However, it must be noted that in this calculation, ownership of electrical appliances and size of houses were generalized due to the unavailability of data. It is believed that if the details of electrical appliance ownership and housing size for each category of city size were taken into account in the calculation, more distinctive results would be shown. This can be seen from the energy consumption trends shown in the graph (cf. Fig.16.). Tokyo and Osaka, having populations above 8 million consume less energy per household than other cities of smaller population as well as the rural areas. This could be attributed to reasons such as longer working hours, commuting times, social activities, etc. that result in shorter periods spent at home.

This aspect of the investigation shall be improved in the further study, to take into consideration the differences in terms of electrical appliance ownership and housing size for each category of city size when such data is available.

4. Conclusions

In most previous studies on lifestyle and household energy consumption, questionnaire survey and long-term on-site monitoring/measurement methods were commonly used. Despite better accuracy of data, they are not time and cost effective. Thus, this study stressed the estimation of lifestyle related household energy consumption based on the existing life schedule data, which is low cost and time saving. As shown in Table 3., the results generally agreed with the other findings. Hence, this method is deemed suitable for investigation of general trends of lifestyle related household energy consumption, especially in the case of wider study coverage where questionnaire survey and on-site monitoring are too costly and time consuming.

Besides using a cost-effective approach to estimate household energy consumption, this study also provided a comprehensive coverage of the indirect lifestyle aspects. This study has pointed out that lifestyles in terms of family pattern, employment status, employment sector, gender and age do have a significant impact on household energy consumption. The main findings are as follows:

(1) Household energy consumption is closely related to family size, the bigger the family, the higher the energy consumption is expected but the per person energy consumption rate is less, due to shared usage of equipment. This aspect is very significant regarding long-term energy planning in Japan in view of decreasing family size.

(2) Households with retirees and housewives generally consume more energy due to longer hours spent at home. Higher household energy consumption rate by retirees is an important point regarding long-term energy planning in Japan due to the rapid aging of Japanese society.

(3) Besides retirees, in terms of age among the working groups, it was found that household energy consumption increases according to age, the older the inhabitants are, the more household energy is consumed. This is due to the fact that older people tend to spend more time at home.

(4) Employee groups tend to consume less household energy compared to the businessmen/women groups, due to longer working hours. As such, single-person families, families with both parents and both husband and wife in the employee groups generally consume less household energy.

(5) Female working groups tend to consume more household energy than the male working groups, due to shorter working hours. This finding is deemed vital in view of the increasing proportion of females compared to males in the population.

(6) In terms of employment sectors, people engaged in the agriculture/forestry sector and the self-employed generally consume more household energy, while the laborer and management/technical sectors have the lowest household energy...
Another aspect of lifestyle that has a significant impact on household energy consumption is the climatic lifestyle. This study has pointed out that households in the northern regions (colder region) of Japan generally consume more household energy in comparison with the southern regions (warmer region). The main reasons are higher energy requirements for heating and lighting (Fong et al., 2007c). Thus, as part of the efforts to reduce energy consumption in the colder regions, it is necessary to reduce heating requirement by measures such as airtight buildings and other passive building technologies. Also, it is important to reduce energy consumption through measures such as introducing energy efficient lights.

Although this study has effectively pointed out the importance of some aspects of lifestyle in household energy consumption, it must also be noted that there are some limitations in this study. Firstly, household energy consumption was calculated based on the typical life schedules and energy consumption of household appliances and climatic data. Thus, it may not represent the actual energy consumption of each household. Secondly, as mention above, in the calculations of energy consumption for cities of different sizes, ownership of electrical appliances and house size were generalized due to data being unavailable. This resulted in identical results among different city sizes. However, in this study, the main purpose is to understand the energy consumption trend rather than to calculate the exact energy consumption rates. Hence, the results are deemed sufficient to illustrate the relationships among household energy consumption, climate and lifestyles in terms of family pattern, employment status, employment sector, gender, age and city size. Nevertheless, these limitations will be taken into consideration in future studies.

This study, based on the case of Japan is deemed important as Japan is often used as a model for development in other Asian countries, hence the findings will have implications beyond Japan. Japan is now experiencing social changes such as an aging society and shrinking family size. This study found that these social changes will indirectly result in increased household energy consumption. It is believed that the existing developing countries will also experience similar social changes in the future, which will eventually affect household energy consumption trends. Hence, it is vital to take these aspects into consideration regarding long-term energy planning, not only in Japan, but also in other developing countries.

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