Factor Analysis Focusing on Lifestyle Factors of Utility Costs for One-person Student Households in Tohoku Region of Japan before the Great East Japan Earthquake

Kahori Genjo

Graduate School of Engineering, Nagasaki University, 1-14 Bunkyo-machi, Nagasaki, 852-8521, Japan.
Tel: +81-95-819-2598
E-mail: genjo@nagasaki-u.ac.jp

(Received on 15th November, 2019, accepted on 12th February, 2020)

Abstract

A questionnaire survey on both the lifestyle and energy consumption of 626 university students in Tohoku region was conducted in 2007 and 2008 to assess energy conservation behaviors and energy consumption in one-person student households. This study aims to clarify the influence of each lifestyle factor that would affect the energy consumption of one-person student households. Of the 626 respondents, 344 one-person households and 215 family households were analyzed via the method of quantification theory type I, as the explanatory variables were roughly divided into hard and soft factors. In this study, the hard factors are considered to be the age of the building, the space heating and cooling period, the set point temperature of space heating appliances, heat source of hot water supply, and the set point temperature of hot water in winter. The soft factors are considered to be the degree of action of the energy conservation behavior in the house, consciousness of global environmental issues, consideration for energy conservation in daily life, and the degree of energy conservation efforts.

The following conclusions of this study were obtained: 1) It was found that the heat source of hot water supply and set point temperature of hot water supply in winter were important factors that have a great impact on the annual utility costs among the six hard factors used in the analysis in one-person student households and family households, respectively. 2) Space cooling period had clear association with the annual utility costs in one-person households, whereas space heating period had clear association with the annual utility costs in family households. 3) The annual utility cost of one-person student households was greatly influenced by how to use appliances and energy conservation efforts. 4) The tendency of the partial correlation coefficients of soft factors to be higher in family households than those of hard factors was stronger than that of one-person households. 5) Differences in energy conservation efforts and consciousness of global environmental issues among family households were greatly reflected in annual utility costs compared to one-person households. 6) The effect of the degree of action of energy conservation behavior in the house on the annual utility costs was found to be greater or comparable to that of the hard factors including how to use equipment in both one-person households and family households. 7) It was shown that the correlation with the annual utility costs is higher when considering not only hard factors but also soft factors in both one-person households and family households. 8) It is important not only to save energy, but also to confirm that the indoor thermal comfort is secured in one-person households.

Since the number of one-person households is expected to increase in the future in Japan, the findings of this study are expected to be useful to promote energy conservation nationwide by developing energy-conservation techniques for one-person households. At the same time, energy conservation measures should be developed that take into account the importance of lifestyle-related factors depending on the household type.

Keywords: one-person household, lifestyle, utility cost, questionnaire survey, multivariate analysis
1. Introduction

According to the household projections for Japan (National Institute of Population and Social Security Research, 2019) based on census data of 2015, out of the total of about 53 million households in Japan, one-person households account for 34.5%, which is the largest family type, outweighing the percentages of couple-and-child (ren) households. The number of one-person households continues to rise. The percentage of one-person households is projected to reach 39.3% by 2040. On the other hand, it was reported that a decrease in the number of household members leads to an increase in energy consumption per individual, and that the energy consumption per individual of one-person households accounts for about 1.5 times as much as that of four-person households based on a national scale questionnaire by a special committee in AIJ (Hasegawa and Inoue, 2004). The rise of one-person households may cause overall residential energy consumption to increase. Based on the changes in household type mentioned above, it is important to clarify the characteristics of energy consumption for one-person households, to improve energy-efficiency for the reduction of carbon dioxide in residential areas. However, much less research has been conducted on one-person households than on family households (e.g. Sawachi et al., 1994; Ishida, 1997, Murakami, 2006), and it can be said that the lifestyle and energy consumption for such one-person households are not fully clarified.

In a related previous study, Murota and Yuasa (2001) estimated energy consumption by end-use and emission of carbon dioxide using an integration method from appliance size and hours of use, or energy consumption per single use and frequency of use for 38 young one-person households in the Tokyo area. This study showed that the compositions of annual prime energy consumptions by end-use per head greatly differed between the young one-person households and four-person households (couple-and-child (ren) households). In addition, Yuasa et al. (2009) made clear that the energy saving potential of low-impact lifestyles varied by season, by measuring energy consumption for six one-person households composed of students and workers around the Tokyo area for two weeks in the summer, autumn, and winter. In this research, low-impact lifestyles with regards to the use of refrigerator, lighting and air conditioning were effectively practiced in one-person households. The surveyed area was limited to the Tokyo region for both studies mentioned above. The former research did not include clear methods for estimation, whereas the latter research could not be said to have widely applicable conclusions because of the small sample size. On the other hand, there is some previous research conducted by questionnaire worth mentioning. Takaguchi et al. (2008) carried out questionnaires on lifestyle and energy consumption of 858 one-person households in Tokyo and the whole country were surveyed, mostly on the internet, but only 41 responses yielded valid answers on annual energy consumption. Fukuyo (2008, 2009) carried out a questionnaire on the consciousness of lifestyle and energy-consuming actions in one-person households twice. In the first questionnaire, the impact of demographic attributes such as gender, age, residential area, annual income, and residence on the consciousness of life and energy-consuming actions was considered for 1,030 one-person households. However, the applicability of the survey is limited by the fact that half of the respondents reside in the Kanto area, and only one monthly electric bill is surveyed in the questionnaire. The second questionnaire studied 385 one-person households in Kanto, Tokai, and Kinki composed of individuals who were public or company employees. Although it did succeed in establishing an association between personality attributes e.g. values, preference, etc. and energy consciousness, the impact for energy consciousness on energy-saving actions, and energy consumption, it yielded few valid responses, and failed to consider heat sources other than electricity and gas such as kerosene. For these reasons it cannot be said that the energy consumption of one-person households has been made clear. The internet survey has the advantage of easily collecting many samples, but there is concern that the method may introduce bias to the survey. Recently, Konaka et al. (2016) investigated the indoor environment and energy consumption of 14 student households (including 12 one-person households) in Kyoto, but they are focusing on air conditioning usage and electric consumption during the summer and mid-terms. The characteristic and the cause of energy consumption of one-person student households has not been clarified yet.

The authors measured the energy consumptions of one-person worker and one-person university student households in cold climatic areas, that is, the Tohoku area of Japan (Genjo et al., 2008a, Genjo et al., 2008b), and surveyed the lifestyle energy consumption in student households by questionnaires in the same area four times, in the summer of 2007 (Genjo et al., 2008b, Genjo et al., 2008c), the winter of 2007 (Genjo et al., 2008d), the summer of 2008 (Genjo et al., 2009a, Genjo et al., 2009b), and the winter of 2008 (Genjo et al., 2010). In the previous report (Genjo et al., 2012), lifestyle and energy consumption of one-person student households were analyzed, focusing on the difference with family households, and clarified that the factors related to lifestyle affect the annual energy consumption of one-person student households. It was concluded that any energy-efficiency measures provided must be suitable for each family type. However, it was
not possible to grasp the influence of each lifestyle factor that would affect the energy consumption of one-person student households. Therefore, this study aims to clarify them using multivariate analysis. In addition, in this study, it is considered that the lifestyle of one-person student households who spent less time at home would not change significantly before and after the Great East Japan Earthquake.

2. Outline of survey

2.1. Target and method of survey

A questionnaire was created based on lifestyle, energy conservation behavior, residential energy consumption in addition to possession of housing equipment, and appliances. The questionnaire was intended for university students of three universities located in the northern part of Honshu, Japan (i.e., Tohoku region) such as Miyagi Prefecture, Akita Prefecture and Aomori Prefecture. The survey was conducted a total of four times, in the summer and the winter of 2007 and of 2008. As shown in Table 1, the investigated areas in the Tohoku region were different among the four questionnaires, which were conducted four times in Miyagi Prefecture, three times in Akita Prefecture, and once in Aomori Prefecture. Table 2 shows the normal value from 1981 to 2010 of outdoor air temperatures for the months of August and January, snowfall depth, and duration of sunshine in winter (from December to February) at the capital of each prefecture (National Astronomical Observatory of Japan, 2018 and Japan Meteorological Agency, 2019). The summer climate of the three prefectures is relatively cool, but the winter climate is very different between Miyagi Prefecture on the Pacific side and Akita Prefecture and Aomori Prefecture on the Japan Sea side. Akita and Aomori Prefectures have shorter duration of sunshine in winter and more snow than Miyagi Prefecture. Questionnaire sheets were distributed for not only students who live alone (i.e., one-person households) but also students who live with their family (i.e., family households) and the students who live in dormitories (i.e., dormitory households), and they were collected one or two weeks later in a collection box. A liquid crystal thermometer with a questionnaire sheet was distributed to each student in order to measure the indoor temperature of their residence. Statistical analysis was conducted with BellCurve for Excel.

| Survey period | Investigated area | Household type | Total (Response rate) |
|---------------|------------------|----------------|----------------------|
| Summer, 2007  | ○ ○ ○           | Family (17, 16) | 33 | 63 | 8 | 104(72%) |
| Winter, 2007  | ○ ○ ○           | One-person (38, 25) | 65 | 120 | 16 | 201(73%) |
| Summer, 2008  | ○ ○ ○ ○        | Dormitory (53, 67) | 67 | 106 | 18 | 191(86%) |
| Winter, 2008  | ○ ○ ○ ○        |                | 56 | 61 | 13 | 130(96%) |
| Total         | 221              |              | 350 | 55 | 626(80%) |

Table 2 The normal value from 1981 to 2010 of outdoor air temperatures for the months of August and January, snowfall depth, and duration of sunshine in winter (from December to February) at the capital of each investigated prefecture.

| City name (Prefecture name) | Longitude/Latitude | Outdoor air temperature of August [℃] | Outdoor air temperature of January [℃] | Snowfall depth in winter [cm] | Duration of sunshine in winter [h] |
|-----------------------------|--------------------|----------------------------------------|----------------------------------------|--------------------------------|----------------------------------|
| Sendai City (Miyagi)        | E140°52’/N 38°16’  | 24.2                                   | 1.6                                    | 53                            | 438.5                            |
| Akita City (Akita)          | E140°06’/N 39°43’  | 24.9                                   | 0.1                                    | 320                           | 147.5                            |
| Aomori City (Aomori)        | E140°45’/N 40°49’  | 23.3                                   | −1.2                                   | 554                           | 173.9                            |
2.2. Survey contents

The investigated items are shown in Table 3. Possession and usage of each building system, possession and usage of appliances, consciousness of environmental problems, resource conservation behavior (Takatsuki, 1998), energy conservation behaviors, indoor temperature, and energy consumption were investigated in all of the four questionnaires. Energy consumption which dates back to one year from the survey execution period is answered for each respondent. The surveys were conducted four times. The students were then requested to set the thermometer in their living rooms and measure the temperature three times a day for one week. Monthly energy consumption was also investigated using utility bills, such as electricity, gas, kerosene and water bills, and annual energy.

| Categories                     | Items in the questionnaire                                                                 | Survey period             |
|--------------------------------|-------------------------------------------------------------------------------------------|----------------------------|
| Respondent's characteristic    | House type, Structure, Number of stairs or stories, Age of buildings, Total floor area,  | Summer, 2007              |
|                                | Number of residents                                                                      | Winter, 2007              |
| Usage of space cooling systems | Possession and usage of cooling systems, Duration of space cooling system use, Timing of | Summer, 2008              |
|                                | daily space cooling system use, Temperature setting of space cooling systems              | Winter, 2008              |
| Usage of space heating systems | Possession and usage of heating systems, Duration of space heating system use, Timing of | Summer, 2008              |
|                                | daily space heating system use, Temperature setting of space heating systems              | Winter, 2008              |
| Heat source and usage of       | Heat source, Setting point temperature of domestic hot water (for summer and winter use),  | Summer, 2007              |
| domestic hot water system      | Weekly frequency of baths and showers (for summer, spring and fall, winter use)           | Winter, 2007              |
| Heat source and frequency of   | Heat source, Average daily number of cooking (on weekdays, on weekends)                   | Summer, 2007              |
| cooking system use             |                                                                                          | Winter, 2008              |
| Usage of electric appliances   | Possession and frequency of electric appliances' use                                       | Summer, 2007              |
|                                |                                                                                          | Winter, 2008              |
| Clothes                        | Clothes in the living room during the evening family time                                  | Winter, 2007              |
|                                |                                                                                          | Summer, 2008              |
|                                |                                                                                          | Winter, 2008              |
| Consciousness of global        | Consciousness of global environmental issues, Consideration for energy conservation in     | Summer, 2007              |
| environmental issues           | daily life, Behaviors on resource conservation and reuse                                   | Winter, 2007              |
|                                |                                                                                          | Summer, 2008              |
| Energy conservation            | Degrees of actions on behaviors on resource conservation and residential energy conservation | Winter, 2008              |
| Indoor temperature             | The temperature 1.1 m above the floor level in the living room measured by a liquid       | Summer, 2007              |
|                                | crystal thermometer (measurable from 8 to 34 degrees Celsius at 1 degrees Celsius)       | Winter, 2007              |
| Energy consumption             | Heat source, Annual utilities, Annual expenses for electricity and gas, Annual purchase   | Summer, 2007              |
|                                | rate and amount of kerosene, Monthly rate or amount of electricity, gas, kerosene*       | Winter, 2007              |

* Summer, 2007: from August 2006 to July 2007, Winter, 2007: from January 2007 to December 2007,
Summer, 2008: from July 2007 to June 2008, Winter, 2008: from February 2008 to January 2009
consumption was investigated using questions selected from some of the choices on the questionnaire. Whether the houses are rental or not was not investigated and remains unclear. It is possible that this would have an impact on lifestyles, such as possession of electric appliances.

3. Results

3.1. Response rate

The response rates of the surveys are summarized in Table 1. Except for the households of which tenancy periods are under one year and those of which energy sources are changed, there were 626 valid respondents, for a valid response rate of 80%.

3.2. Characteristics of respondents

In the four questionnaire surveys conducted in 2007 and 2008, 350 one-person households, 221 family households and 55 dormitory households of the total 626 respondents were investigated. The mean number of residents per household was 2.1 persons. The predominant house type was apartment house for 98% of one-person households. The mean floor area was 22.5 m² for one-person households. The common structure of houses was reinforced concrete construction (55% of total apartment houses) in apartment houses. With regard to the age of buildings, 55% of the one-person households were built within less than ten years.

3.3. Possession of space cooling and heating system

Concerning space cooling systems, 77% of one-person households used air-conditioners in summer. “Air-conditioners for cooling and heating” was predominant with regard to the type of cooling appliances.

Concerning space heating systems, the common appliances used as space heating appliances were “Air-conditioner (38%)” and “Kotatsu (29%)” in one-person households.

3.4. Energy consumption

The energy consumption characteristics are analyzed using the results of 188 households (64 family households and 124 one-person households) that are clear in total annual energy consumption estimated from utility bills. Dormitory households were excluded from analysis because fixed amounts were paid for their utility costs. Calorie conversion was performed for each energy source, that is, 3.6 MJ/kWh for electricity (secondary conversion value), 37.3 MJ/L for kerosene, 45.9 MJ/Nm³ for city gas and 100.5 MJ/Nm³ for LPG. The factors which influence the dispersion are considered in the next chapter.

As reported in the previous report (Genjo, 2012), the annual energy consumption of one-person households was found to be 11.4 GJ/year, and it was confirmed to be less than the average annual energy consumption of one-person households according to other surveys (Inoue, 2006; Jyukankyo Research Institute, 2009) (15.68 GJ/year) as a calculation of the one-sample t-test (\( p < 0.05 \)). The annual energy consumption of one-person households in this research was low in spite of the prediction that the respondents would require lots of energy for space heating because they live in northern area of Japan. Thus, the energy consumption of one-person student households in the Tohoku region has been low since before the Great East Japan Earthquake.

3.5. Indoor temperature

The results of indoor temperature investigated in the summer of 2007, the winter of 2007, and the summer and the winter of 2008 are displayed in Table 4, Table 5, and Table 6, respectively. The timing of indoor temperature measurement differed from year to year, and season to season in 2007.

From Table 4 and Table 5, the indoor temperature in the summer was not much different by household type, but the indoor temperature in the winter was different by household type, particularly in Akita Prefecture. The indoor temperatures when getting up, when coming home, and in the bedtime in the summer were rather low at around 21-23°C. The indoor temperatures in the morning, in the daytime, and in the night in the winter were found to be low at 10-18°C for both household types, and the indoor temperature in family household was found to be 2-5°C higher than one-person households. It was not clear whether the indoor temperatures measured in the winter, 2007 and in the summer, 2007 were during heating or cooling.

From Table 6, the indoor mean temperatures during occupancy in the summer were found to be 26-28°C and were not much different by household type. On the other hand, the indoor mean temperatures during occupancy in the winter were found to be 16°C for one-person households and 20°C for family households. The mean indoor temperature and the lowest indoor temperature of one-person households during occupancy were found to be 4-7°C lower than those of family households.

The room occupancy temperatures were investigated in the 2008 survey and were likely to be using heating and cooling. The 2008 winter survey was conducted only in Miyagi Prefecture, but found that the indoor mean temperature in winter was as low as 16°C for one-person households. Throughout the two-year survey, there was no remarkable difference in the temperature during occupancy between prefectures.
4. Multivariate analysis on annual utility costs of student one-person households

As mentioned above, the annual energy consumption of one-person student households in the Tohoku region is generally small. It is thought that this is influenced by the fact that a student would spend less time at home. In this chapter, a multivariate analysis was conducted with more responses of the annual utility cost than those of the annual total energy consumption as the objective variable, and the factors affecting the annual utility cost of one-person student households and their degree of influence were clarified using the results of the summer and the winter questionnaires both in 2007 and 2008. Of the 626 respondents, 344 one-person households and 215 family households, which were described in the next chapter, were analyzed by the method of quantification theory type I, as the explanatory variables were roughly divided into hard and soft factors. In this study, the hard factors are considered to be the age of the building, the space heating and cooling period, the set point temperature of space heating appliances, heat source of hot water supply, and the set point temperature of hot water in winter. The soft factors are considered to be the degree of action of the energy conservation behavior in the house, consciousness of global environmental issues (i.e. global warming, destruction of forests, depletion of the ozone layer), consideration for energy conservation in daily life, and the degree of energy conservation efforts. As shown in the previous report (Genjo, 2012), the total floor area of one-person student households varied within a narrow range, and it was shown that the

---

**Table 4** The results (Mean ± S.D.) of indoor temperature investigated in the summer of 2007 for student one-person households and family households

| Household type | Prefecture (n) | Temperature when getting up (°C) | Temperature when coming home (°C) | Temperature in the bedtime (°C) |
|----------------|----------------|-----------------------------------|-----------------------------------|--------------------------------|
| One-person     | Miyagi (38)    | 21.2 ± 3.9                        | 21.5 ± 5.3                        | 21.2 ± 3.8                      |
|                | Akita (24)     | 22.3 ± 4.8                        | 22.6 ± 4.8                        | 22.1 ± 4.7                      |
| Family         | Miyagi (30)    | 21.1 ± 2.3                        | 22.0 ± 2.3                        | 21.3 ± 2.2                      |
|                | Akita (1)      | 24.0                              | 24.0                              | 22.4                            |

**Table 5** The results (Mean ± S.D.) of indoor temperature investigated in the winter of 2007 for student one-person households and family households

| Household type | Prefecture (n) | Temperature in the morning (°C) | Temperature in the daytime (°C) | Temperature in the night (°C) |
|----------------|----------------|---------------------------------|--------------------------------|-------------------------------|
| One-person     | Miyagi (46)    | 9.9 ± 3.0                       | 11.1 ± 3.0                     | 13.3 ± 4.1                    |
|                | Akita (44)     | 10.2 ± 2.7                      | 11.5 ± 3.1                     | 13.2 ± 3.3                    |
| Family         | Miyagi (60)    | 10.3 ± 4.3                      | 13.0 ± 2.9                     | 15.2 ± 3.5                    |
|                | Akita (4)      | 14.1 ± 1.8                      | 15.8 ± 2.3                     | 18.2 ± 1.8                    |

**Table 6** The results (Mean ± S.D.) of indoor temperature during occupancy investigated in the summer and the winter of 2008 for student one-person households and family households

| Household type | Season (n) | Prefecture (n) | Mean temperature (°C) | Lowest temperature (°C) | Highest temperature (°C) |
|----------------|------------|----------------|------------------------|-------------------------|--------------------------|
| One-person     | Summer     | Miyagi (56)    | 26.8 ± 1.4             | 25.3 ± 1.5              | 28.7 ± 1.8               |
|                |            | Akita (31)     | 27.0 ± 1.9             | 25.8 ± 2.5              | 28.5 ± 1.6               |
|                |            | Aomori (16)    | 26.3 ± 1.9             | 25.1 ± 2.3              | 27.6 ± 2.1               |
| Winter         | Miyagi (61)| 16.2 ± 3.9     | 14.0 ± 4.6             | 18.6 ± 4.0              |                          |
| Family         | Summer     | Miyagi (47)    | 27.0 ± 1.2             | 25.6 ± 1.3              | 28.6 ± 1.5               |
|                |            | Akita (1)      | 28.0                   | 28.0                    | 28.0                     |
|                |            | Aomori (14)    | 26.4 ± 1.1             | 24.7 ± 1.5              | 28.2 ± 1.4               |
| Winter         | Miyagi (52)| 19.7 ± 3.5     | 18.0 ± 4.1             | 21.1 ± 3.4              |                          |
correlation between the total floor area and annual energy consumption is low, this is why the total floor area is not adopted as explanatory variables. The multicollinearity of each factor is considered in multivariate analysis.

4.1. Effects of hard factors on annual utility costs

Figure 1 shows the result of multivariate analysis by selecting six hard factors as explanatory variables (n = 195). The multiple correlation coefficient of 0.48 and the ratio of contribution of 0.23 were found. The value of the partial correlation coefficient of each factor was considered generally small. “Heat source of hot water supply” was higher than any other factors with the partial correlation coefficient, and “Night-time power” was found to be the most effective in reducing annual utility costs in the one-person households probably due to night-oriented lifestyle. “Set point temperature of space heating” was the factor that had large partial correlation coefficients next to “Heat source of hot water supply”. Except for some categories, the higher the set point temperature of space heating, the higher the annual utility costs. “Space cooling period” was the factor that had the large partial correlation coefficient next to “Set point temperature of space heating”. It can be seen that the annual utility cost is lower as the space cooling period is shorter, and is higher as the space cooling period is longer. “Space heating period” had the large partial correlation coefficient next to “Space cooling period”. For one-person households, “Space cooling period” had a clear relationship with the annual utility costs compared to “Space heating period”. Regarding “Age of building” and “Set point temperature of hot water supply in winter”, no clear relationship was found between categories or between category scores.

4.2. Effects of soft factors on annual utility costs

4.2.1. Effects of consciousness of global environmental issues and the degree of energy conservation efforts on annual utility costs

Figure 2 shows the result of multivariate analysis by selecting five soft factors as explanatory variables (n = 192). The multiple correlation coefficient of 0.40 and the ratio of contribution of 0.16 were found. The value of the partial correlation coefficient of each factor was lower than the hard factors. Table 1 shows the factor that had the large partial correlation coefficient next to “Set point temperature of space heating”. It can be seen that the annual utility cost is lower as the space cooling period is shorter, and is higher as the space cooling period is longer. “Space heating period” had the large partial correlation coefficient next to “Space cooling period”. For one-person households, “Space cooling period” had a clear relationship with the annual utility costs compared to “Space heating period”. Regarding “Age of building” and “Set point temperature of hot water supply in winter”, no clear relationship was found between categories or between category scores.

| Factor (partial correlation coefficient) | Category | n | Category score (× ¥1,000) |
|----------------------------------------|----------|---|--------------------------|
| Age of building (0.132) | Within 5 years | 61 | -30 |
| | Within 6~10 years | 66 | -20 |
| | Within 11~15 years | 27 | -10 |
| | Within 16~20 years | 22 | 0 |
| | Within 21~25 years | 14 | 10 |
| | Over 26 years | 5 | 20 |
| Space cooling period (0.221) | Less than 1 month | 22 | 30 |
| | 1 month or more and less than 2 months | 94 | 40 |
| | 2 months or more and less than 3 months | 60 | 50 |
| | 3 months or more | 19 | 60 |
| Space heating period (0.180) | 1 months or more and less than 2 months | 4 | 70 |
| | 2 months or more and less than 3 months | 17 | 80 |
| | 3 months or more and less than 4 months | 45 | 90 |
| | 4 months or more and less than 5 months | 66 | 100 |
| | 5 months or more and less than 6 months | 51 | 110 |
| | 6 months or more | 12 | 120 |
| Set point temperature of space heating (0.252) | Less than 18℃ | 10 | 130 |
| | 18 ℃ or more and less than 20 ℃ | 23 | 140 |
| | 20 ℃ or more and less than 22 ℃ | 35 | 150 |
| | 22 ℃ or more and less than 24 ℃ | 32 | 160 |
| | 24 ℃ or more and less than 26 ℃ | 31 | 170 |
| | 26 ℃ or more and less than 28 ℃ | 41 | 180 |
| | 28℃ or higher | 4 | 190 |
| | Cannot set | 19 | 200 |
| Heat source of hot water supply (0.333) | Gas | 169 | 220 |
| | Electric power | 10 | 230 |
| | Night-time power | 16 | 240 |
| Set point temperature of hot water supply in winter (0.153) | 37 ℃ or more and less than 39 ℃ | 7 | 250 |
| | 39 ℃ or more and less than 41 ℃ | 31 | 260 |
| | 41 ℃ or more and less than 43 ℃ | 61 | 270 |
| | 43 ℃ or more and less than 45 ℃ | 27 | 280 |
| | 45℃ or higher | 4 | 290 |
| | Cannot set | 65 | 300 |

Figure 1. Result of multivariate analysis on annual utility costs for one-person households by selecting the six hard factors as explanatory variables (n = 195, multiple correlation coefficient: 0.48, Mean: ¥69,296, S.D.: ¥28,207).
### Table 1: Multivariate Analysis on Annual Utility Costs for One-Person Households

| Factor (partial correlation coefficient) | Category                      | n   | Category score (× ¥1,000) |
|-----------------------------------------|-------------------------------|-----|----------------------------|
| Consciousness of global environmental issues (0.181) | Concerned                    | 166 | -30 -20 -10 0 10 20 30   |
|                                         | Not concerned                 | 8   |                           |
|                                         | Cannot say which              | 18  |                           |
| Consideration for energy conservation in daily life (0.117) | Consider | 86  |                           |
|                                         | Do not consider               | 47  |                           |
|                                         | Cannot say which              | 59  |                           |
| Regulate heat and cold by amount of clothing (0.268) | Not acting at all             | 7   |                           |
|                                         | Occasionally acting           | 19  |                           |
|                                         | Sometimes acting              | 31  |                           |
|                                         | Generally acting              | 34  |                           |
|                                         | Always act                    | 101 |                           |
| Utilize leftover hot water for washing clothes (0.098) | Not acting at all             | 136 |                           |
|                                         | Occasionally acting           | 15  |                           |
|                                         | Sometimes acting              | 21  |                           |
|                                         | Generally acting              | 3   |                           |
|                                         | Always act                    | 17  |                           |
| Early to bed and early to rise (0.135) | Not acting at all             | 66  |                           |
|                                         | Occasionally acting           | 58  |                           |
|                                         | Sometimes acting              | 27  |                           |
|                                         | Generally acting              | 10  |                           |
|                                         | Always act                    | 25  |                           |

Figure 2. Result of multivariate analysis on annual utility costs for one-person households by selecting the five soft factors as explanatory variables (n = 192, multiple correlation coefficient: 0.40, Mean: ¥69,560, S.D.: ¥29,344).

### Table 2: Multivariate Analysis for One-Person Households

| Factor (partial correlation coefficient) | Category                      | n   | Category score (× ¥1,000) |
|-----------------------------------------|-------------------------------|-----|----------------------------|
| Reduce usage time of space heating and cooling appliances (0.393) | Not acting at all             | 6   |                           |
|                                         | Occasionally acting           | 8   |                           |
|                                         | Sometimes acting              | 17  |                           |
|                                         | Generally acting              | 20  |                           |
|                                         | Always act                    | 69  |                           |
| Clean air filters for space heating and cooling appliances (0.244) | Not acting at all             | 61  |                           |
|                                         | Occasionally acting           | 24  |                           |
|                                         | Sometimes acting              | 27  |                           |
|                                         | Generally acting              | 5   |                           |
|                                         | Always act                    | 3   |                           |
| Regulate heat balance with curtains or blinds (0.401) | Not acting at all             | 21  |                           |
|                                         | Occasionally acting           | 15  |                           |
|                                         | Sometimes acting              | 19  |                           |
|                                         | Generally acting              | 22  |                           |
|                                         | Always act                    | 43  |                           |
| Do not overload the refrigerator (0.209) | Not acting at all             | 13  |                           |
|                                         | Occasionally acting           | 20  |                           |
|                                         | Sometimes acting              | 20  |                           |
|                                         | Generally acting              | 16  |                           |
|                                         | Always act                    | 51  |                           |
| Reduce insulation time of rice cooker (0.317) | Not acting at all             | 11  |                           |
|                                         | Occasionally acting           | 8   |                           |
|                                         | Sometimes acting              | 14  |                           |
|                                         | Generally acting              | 13  |                           |
|                                         | Always act                    | 74  |                           |
| Adjust the set point temperature of the heated toilet seat according to the season (0.293) | Not acting at all             | 37  |                           |
|                                         | Occasionally acting           | 5   |                           |
|                                         | Sometimes acting              | 8   |                           |
|                                         | Generally acting              | 4   |                           |
|                                         | Always act                    | 66  |                           |

Figure 3. Result of multivariate analysis for one-person households by selecting the six soft factors as explanatory variables (n = 120, multiple correlation coefficient: 0.60, Mean: ¥71,374, S.D.: ¥29,921).
4.2.2. Effects of the degree of action of energy conservation behavior in the house on annual utility costs

Figure 3 shows the result of multivariate analysis by selecting six soft factors as explanatory variables ($n = 120$). The multiple correlation coefficient of 0.60 and the ratio of contribution of 0.36 were found. The partial correlation coefficient of "Regulate heat balance with curtains or blinds" was 0.401 and the largest among the six variables, and "Not acting at all" showed the largest category score, except that "Generally acting" was inexplicably showing the next highest category score after "Not acting at all". "Sometimes acting" showed the lowest category score in the factor of "Regulate heat balance with curtains or blinds". "Reduce usage time of space heating and cooling appliances" had a large partial correlation coefficient next to "Regulate heat balance with curtains or blinds", and "Always act" showed the lowest category score, although "Occasionally acting" inexplicably showed a higher category score than "Not acting at all". Following the above two factors, the partial correlation coefficient increased in the order of "Reduce insulation time of rice cooker", "Adjust the set point temperature of the heated toilet seat according to the season", "Clean air filters for space heating and cooling appliances", and "Do not overload the refrigerator". It was inconsistent that "Not acting at all" showed the lowest category score and "Occasionally acting" showed the highest category score in the factor of "Reduce insulation time of rice cooker". Similarly, it was also inconsistent that "Sometimes acting" showed the highest category score in the factor of "Adjust the set point temperature of the heated toilet seat according to the season", although it is consistent that "Generally acting" and "Always act" showed negative category scores in this factor. "Generally acting" in the factor of "Clean air filters for space heating and cooling appliances" showed the lowest category score of all the categories in the quantification analysis, although "Always act" somehow showed a positive category score. "Occasionally acting" showed the lowest category score of the five categories in the factor of "Do not overload the refrigerator", although it was inconsistent that "Generally acting" and "Always act" showed the positive category scores. As described above, since there were some inconsistent items, it seems to be difficult to predict annual utility costs from only the factor on the degree of action of energy conservation behavior. However, it is noteworthy that the way of living, such as "Regulate heat balance with curtains or blinds", showed a partial correlation coefficient comparable to the way of using the equipment itself, such as "Reduce usage time of space heating and cooling appliances".

4.3. Effects of factors combining hard and soft factors on annual utility costs

Multivariate analysis was performed by adding six soft factors shown in Figure 3 to six hard factors shown in Figure 1. Figure 4 shows the result of multivariate analysis by selecting the six hard factors and six soft factors as explanatory variables ($n = 88$). The multiple correlation coefficient of 0.81 and the ratio of contribution of 0.66 were found. Since this model has the highest multiple correlation coefficient of all the multivariate analysis results by the method of quantification theory type I, it was confirmed that the correlation with the annual utility costs is higher when considering not only hard factors but also soft factors such as the degree of action of energy conservation behavior in the house. Among the twelve factors combining hard and soft factors, "Reduce usage time of space heating and cooling appliances"
“cooling appliances” had the largest partial correlation coefficient, and “Do not overload the refrigerator” was the factor showing the second largest partial correlation coefficient after “Reduce usage time of space heating and cooling appliances”.”Regulate heat balance with curtains or blinds” showed the third largest partial correlation coefficient after “Do not overload the refrigerator”. Following the above three factors, the partial

| Factor (partial correlation coefficient) | Category                     | n   | Category score (× ¥1,000) |
|-----------------------------------------|------------------------------|-----|---------------------------|
| Age of building                         | Within 5 years               | 31  | 30                         |
|                                         | Within 6–10 years            | 31  | 30                         |
|                                         | Within 11–15 years           | 12  | 30                         |
|                                         | Within 16–20 years           | 5   | 30                         |
|                                         | Within 21–25 years           | 5   | 30                         |
|                                         | Over 26 years                | 4   | 30                         |
| Space cooling period                    | Less than 1 month            | 11  | 30                         |
|                                         | 1 month or more and less than 2 months | 46  | 30                         |
|                                         | 2 months or more and less than 3 months | 23  | 30                         |
|                                         | 3 months or more             | 8   | 30                         |
| Space heating period                    | 1 months or more and less than 2 months | 4   | 30                         |
|                                         | 2 months or more and less than 3 months | 7   | 30                         |
|                                         | 3 months or more and less than 4 months | 22  | 30                         |
|                                         | 4 months or more and less than 5 months | 29  | 30                         |
|                                         | 5 months or more and less than 6 months | 20  | 30                         |
|                                         | 6 months or more             | 6   | 30                         |
| Set point temperature of space heating  | Less than 18°C               | 4   | 30                         |
|                                         | 18 °C or more and less than 20 °C | 8   | 30                         |
|                                         | 20 °C or more and less than 22 °C | 18  | 30                         |
|                                         | 22 °C or more and less than 24 °C | 14  | 30                         |
|                                         | 24 °C or more and less than 26 °C | 15  | 30                         |
|                                         | 26 °C or more and less than 28 °C | 18  | 30                         |
|                                         | Cannot set                  | 11  | 30                         |
| Heat source of hot water supply         | Gas                          | 71  | 30                         |
|                                         | Electric power               | 8   | 30                         |
|                                         | Night-time power             | 9   | 30                         |
| Set point temperature of hot water supply in winter | 37 °C or more and less than 39 °C | 1   | 30                         |
|                                         | 39 °C or more and less than 41 °C | 16  | 30                         |
|                                         | 41 °C or more and less than 43 °C | 25  | 30                         |
|                                         | 43 °C or more and less than 45 °C | 11  | 30                         |
|                                         | Cannot set                  | 35  | 30                         |
| Reduce usage time of space heating and  | Not acting at all            | 3   | 30                         |
| cooling appliances                       | Occasionally acting          | 6   | 30                         |
|                                         | Sometimes acting             | 14  | 30                         |
|                                         | Generally acting             | 18  | 30                         |
|                                         | Always act                   | 47  | 30                         |
| Clean air filters for space heating and  | Not acting at all            | 45  | 30                         |
| cooling appliances                       | Occasionally acting          | 21  | 30                         |
|                                         | Sometimes acting             | 17  | 30                         |
|                                         | Generally acting             | 3   | 30                         |
|                                         | Always act                   | 2   | 30                         |
| Regulate heat balance with curtains or   | Not acting at all            | 12  | 30                         |
| blinds                                  | Occasionally acting          | 10  | 30                         |
|                                         | Sometimes acting             | 17  | 30                         |
|                                         | Generally acting             | 17  | 30                         |
|                                         | Always act                   | 17  | 30                         |
| Do not overload the refrigerator         | Not acting at all            | 8   | 30                         |
|                                         | Occasionally acting          | 18  | 30                         |
|                                         | Sometimes acting             | 16  | 30                         |
|                                         | Generally acting             | 8   | 30                         |
|                                         | Always act                   | 38  | 30                         |
| Reduce insulation time of rice cooker   | Not acting at all            | 9   | 30                         |
|                                         | Occasionally acting          | 5   | 30                         |
|                                         | Sometimes acting             | 11  | 30                         |
|                                         | Generally acting             | 6   | 30                         |
|                                         | Always act                   | 57  | 30                         |
| Adjust the set point temperature of the  | Not acting at all            | 27  | 30                         |
| heated toilet seat according to the season | Occasionally acting          | 5   | 30                         |
|                                         | Sometimes acting             | 8   | 30                         |
|                                         | Generally acting             | 2   | 30                         |
|                                         | Always act                   | 46  | 30                         |

Figure 4. Result of multivariate analysis for one-person households by selecting the six hard factors and six soft factors as explanatory variables (n = 88, multiple correlation coefficient: 0.81, Mean: ¥71,991, S.D.: ¥32,388).
correlation coefficient increased in the order of “Set point temperature of space heating”, “Heat source of hot water supply”, “Age of building”, “Space heating period”, “Space cooling period”, “Clean air filters for space heating and cooling appliances”, “Reduce insulation time of rice cooker”, “Adjust the set point temperature of the heated toilet seat according to the season”, and “Set point temperature of hot water supply in winter”. Of the above partial correlation coefficients, those of “Set point temperature of space heating” and “Heat source of hot water supply” were the same. Thus, in terms of the partial correlation coefficients, the top three of the 12 factors were occupied by soft factors, exceeding hard factors. In this analysis, the hard factors also include factors related to how to use the equipment, such as “Set point temperature of space heating”, “Space heating period”, “Space cooling period”, and “Set point temperature of hot water supply in winter”. In this way, the effect of the degree of action of energy conservation behavior in the house on the annual utility costs was found to be greater or comparable to that of the hard factors including how to use equipment, for example, space heating period, space cooling period, and set point temperature.

Next, as for the results of category score, the following factors showed a clear correspondence between each category score and the annual utility cost: “Space cooling period”, “Set point temperature of hot water supply in winter”, and “Reduce usage time of space heating and cooling appliances”. As for the factor of “Space cooling period”, the longer the space cooling period, the higher the annual utility cost. As for the factor of “Set point temperature of hot water supply in winter”, the lower the set point temperature of hot water supply in winter, the lower the annual utility cost. As for the factor of “Reduce usage time of space heating and cooling appliances”, the lower the degree of action of energy conservation behavior, the higher the annual utility cost, for example, “Not acting at all” and “Occasionally acting” showed the highest category score and the second highest category scores of all the 61 categories, respectively, and “Always act” showed a negative category score. Thus, it can be seen that the annual utility cost is decreasing as the degree of action of energy conservation behavior increases. From the result of the category score of “Age of building”, it can be seen that the older the building is, the lower the annual utility cost is, although this fact is required to consider carefully. The result of the category scores of “Heat source of hot water supply” showed that “Night-time power” has the lowest annual utility cost, followed by “Electric power” and “Gas”. One reason for this is that one-person households are likely to take on a night-oriented lifestyle. On the other hand, there is no correspondence between each category score and each annual utility cost as for the following factors: “Do not overload the refrigerator”, “Reduce insulation time of rice cooker”, and “Adjust the set point temperature of the heated toilet seat according to the season”.

As shown above, the annual utility cost of one-person student households, that is, the annual energy consumption, was small, but it was greatly influenced by how to use appliances and the degree of action of energy conservation behavior such as the usage time of space heating and cooling appliances, the cleaning of air filters for space heating and cooling appliances, and the regulation of heat balance with curtains or blinds. On the other hand, degree of consciousness of global environmental issues and consideration for energy conservation efforts in daily life showed a small impact on the annual utility costs of one-person student households. This analysis shows that the impact of not only the hard factors but also the soft factors are significant; therefore, energy conservation measures should be developed that take into account the importance of lifestyle-related factors depending on the household.

4.4. Limitation and supplement

Two years of questionnaire surveys were analyzed in this study. Because the question items and options in each questionnaire survey were not necessarily the same, and the annual utility costs in the questionnaire survey in 2007 were estimated from the median of the options, there were limitations to improve the accuracy of quantification analysis.

When the analysis was performed including the prefecture as a factor of the quantification theory type I shown from Figure 1 to Figure 4, the multiple correlation coefficients were found to be 0.52, 0.43, 0.60, and 0.82, respectively. The figures are omitted because the sample size of Aomori Prefecture is extremely small and the number of samples in Miyagi Prefecture was more than twice that of Akita Prefecture, so it is difficult to read the trends by prefecture. With the exception of the result when using six soft factors shown in Figure 3, the multiple correlation coefficients were slightly larger compared to the case without considering the prefecture. As a result, excepting use of five soft factors shown in Figure 2, annual utility costs were higher in Miyagi Prefecture and lower in Akita and Aomori Prefectures. The result when using five soft factors showed that the annual utility costs were highest in Aomori Prefecture, followed by Miyagi Prefecture, and Akita Prefecture in descending order. Adding the prefecture to the factors did not change the order of the partial correlation coefficients for each factor, compared with not adding the prefecture to the factors.
5. Multivariate analysis on annual utility costs of family households

Using the same factors as those used in the quantification analysis for one-person households, with the annual utility cost of 215 family households as the objective variable, a multivariate analysis was performed by quantification theory type I. Floor area was not included in the factors in order to compare the results of the quantification analysis with one-person households. The results of multivariate analysis by selecting the six hard factors, the five soft factors, the six soft factors, and the six hard factors and six soft factors as explanatory variables are shown in Figure 5, Figure 6, Figure 7, and Figure 8, respectively.

The multiple correlation coefficients were found to be 0.44 in Figure 5, 0.65 in Figure 6, 0.45 in Figure 7, and 0.84 in Figure 8. The highest multiple correlation coefficient among the multivariate analyses of family households was found when six hard factors and six soft factors were selected as explanatory variables, and this result was similar to one-person households. Compared with one-person households, the multiple correlation coefficient when five soft factors were used as explanatory variables was higher than that of one-person households by 0.25, as shown in Figure 6, and the multiple correlation coefficient when six soft factors were used as explanatory variables was lower than that of one-person households by 0.15, as shown in Figure 7. The multiple correlation coefficients when six hard factors, and six hard factors and six soft factors were used as explanatory variables were similar to those of one-person households. “Consciousness of global environmental issues”, “Consideration for energy conservation in daily life”, and energy conservation efforts (e.g. “Regulate heat and cold by amount of clothing”, “Utilize leftover hot water for washing clothes”, and “Early to bed and early to rise”) were adopted as explanatory variables in Figure 6. Differences in energy conservation efforts (particularly in “Regulate heat and cold by amount of clothing”) and “Consciousness of global environmental issues” among family households were greatly reflected in annual utility costs compared to one-person households. The reason for this is that family households require more energy for space heating than one-person households, and differences in “Consciousness of global environmental issues” can easily lead to differences in energy conservation behaviors compared to one-person households.

| Factor (partial correlation coefficient) | Category | n | Category score (× ¥1,000) |
|------------------------------------------|----------|---|--------------------------|
| Age of building (0.076)                   | Within 5 years | 12 | 30 |
|                                         | Within 6–10 years | 28 |
|                                         | Within 11–15 years | 20 |
|                                         | Within 16–20 years | 23 |
|                                         | Within 21–25 years | 10 |
|                                         | Over 26 years | 16 |
| Space cooling period (0.196)              | Less than 1 month | 15 | 30 |
|                                         | 1 month or more and less than 2 months | 54 |
|                                         | 2 months or more and less than 3 months | 27 |
|                                         | 3 months or more | 13 |
| Space heating period (0.192)              | 1 months or more and less than 2 months | 6 |
|                                         | 2 months or more and less than 3 months | 2 |
|                                         | 3 months or more and less than 4 months | 19 |
|                                         | 4 months or more and less than 5 months | 47 |
|                                         | 5 months or more and less than 6 months | 22 |
|                                         | 6 months or more | 13 |
| Set point temperature of space heating (0.288) | Less than 18℃ | 6 | 30 |
|                                         | 18℃ or more and less than 20℃ | 29 |
|                                         | 20℃ or more and less than 22℃ | 33 |
|                                         | 22℃ or more and less than 24℃ | 16 |
|                                         | 24℃ or more and less than 26℃ | 13 |
|                                         | 26℃ or more and less than 28℃ | 8 |
|                                         | Cannot set | 4 |
| Heat source of hot water supply (0.185)   | Gas | 62 |
|                                         | Electric power | 24 |
|                                         | Night-time power | 3 |
|                                         | Kerosene | 15 |
|                                         | Others | 5 |
| Set point temperature of hot water supply in winter (0.293) | 39℃ or more and less than 41℃ | 35 |
|                                         | 41℃ or more and less than 43℃ | 59 |
|                                         | 43℃ or more and less than 45℃ | 5 |

Figure 5. Result of multivariate analysis on annual utility costs for family households by selecting the six hard factors as explanatory variables (n = 109, multiple correlation coefficient: 0.44, Mean: ¥193,775, S.D.: ¥113,207).
Factor Analysis Focusing on Lifestyle Factors of Utility Costs for One-person Student Households in Tohoku Region of Japan before the Great East Japan Earthquake

On the other hand, the multiple coefficient was small in Figure 7 and there was a correspondence between each category score and each annual utility cost only in the factors of “Regulate heat balance with curtains or blinds” (0.181), “Do not overload the refrigerator” (0.254), “Reduce insulation time of rice cooker” (0.181), and “Adjust the set point temperature of the heated toilet seat according to the season” (0.213).

---

### Table 1: Lifestyle Factors and Utility Costs for One-person Student Households

| Factor (partial correlation coefficient) | Category | \( n \) | Category score (\( \times ¥1,000 \)) |
|------------------------------------------|----------|--------|-------------------------------|
| **Consciousness of global environmental issues (0.369)** | Concerned | 108 | -87.5  |
| | Not concerned | 1 | 96.4  |
| | Cannot say which | 17 | 0  |
| **Consideration for energy conservation in daily life (0.048)** | Consider | 57 | 96.4  |
| | Do not consider | 17 | 0  |
| | Cannot say which | 52 | 0  |
| **Regulate heat and cold by amount of clothing (0.531)** | Not acting at all | 3 | 221.9  |
| | Occasionally acting | 9 | 0  |
| | Sometimes acting | 37 | 0  |
| | Generally acting | 27 | 0  |
| | Always act | 50 | 0  |
| **Utilize leftover hot water for washing clothes (0.158)** | Not acting at all | 31 | 0  |
| | Occasionally acting | 8 | 0  |
| | Sometimes acting | 15 | 0  |
| | Generally acting | 3 | 0  |
| | Always act | 69 | 0  |
| **Early to bed and early to rise (0.288)** | Not acting at all | 29 | 0  |
| | Occasionally acting | 41 | 0  |
| | Sometimes acting | 24 | 0  |
| | Generally acting | 8 | 0  |
| | Always act | 24 | 0  |
| **Reduce usage time of space heating and cooling appliances (0.170)** | Not acting at all | 7 | 0  |
| | Occasionally acting | 13 | 0  |
| | Sometimes acting | 12 | 0  |
| | Generally acting | 18 | 0  |
| | Always act | 43 | 0  |
| **Clean air filters for space heating and cooling appliances (0.307)** | Not acting at all | 19 | 0  |
| | Occasionally acting | 23 | 0  |
| | Sometimes acting | 26 | 0  |
| | Generally acting | 8 | 0  |
| | Always act | 17 | 0  |
| **Regulate heat balance with curtains or blinds (0.181)** | Not acting at all | 12 | 0  |
| | Occasionally acting | 8 | 0  |
| | Sometimes acting | 20 | 0  |
| | Generally acting | 19 | 0  |
| | Always act | 34 | 0  |
| **Do not overload the refrigerator (0.254)** | Not acting at all | 13 | 0  |
| | Occasionally acting | 24 | 0  |
| | Sometimes acting | 26 | 0  |
| | Generally acting | 13 | 0  |
| | Always act | 17 | 0  |
| **Reduce insulation time of rice cooker (0.181)** | Not acting at all | 21 | 0  |
| | Occasionally acting | 11 | 0  |
| | Sometimes acting | 14 | 0  |
| | Generally acting | 11 | 0  |
| | Always act | 36 | 0  |
| **Adjust the set point temperature of the heated toilet seat according to the season (0.213)** | Not acting at all | 21 | 0  |
| | Occasionally acting | 10 | 0  |
| | Sometimes acting | 15 | 0  |
| | Generally acting | 12 | 0  |
| | Always act | 35 | 0  |

---

**Figure 6.** Result of multivariate analysis on annual utility costs for family households by selecting the five soft factors as explanatory variables (\( n = 126 \), multiple correlation coefficient: 0.65, Mean: ¥197,137, S.D.: ¥114,198).

**Figure 7.** Result of multivariate analysis for family households by selecting the six soft factors as explanatory variables (\( n = 93 \), multiple correlation coefficient: 0.45, Mean: ¥221,604, S.D.: ¥122,647).
curtains or blinds” and “Do not overload the refrigerator”. For other factors, there was no correspondence between each category score and each annual utility cost.

Next, as seen in Figure 5, the influence of “Age of building” seems to be smaller than that of one-person household. In “Space heating period” and “Space cooling period”, the influence of “Age of building” is larger than that of one-person household. In “Set point temperature of space heating in winter”, the influence of “Heat source of hot water supply” is larger than that of one-person household.

| Factor (partial correlation coefficient) | Category                          | n  | Category score (×1,000) |
|----------------------------------------|-----------------------------------|----|------------------------|
| Age of building (0.531)                | Within 5 years                    | 8  |                        |
|                                        | Within 6-10 years                 | 20 |                        |
|                                        | Within 11-15 years                | 11 |                        |
|                                        | Within 16-20 years                | 11 |                        |
|                                        | Within 21-25 years                | 5  |                        |
|                                        | Over 26 years                     | 10 |                        |
| Space cooling period (0.397)           | Less than 1 month                 | 7  |                        |
|                                        | 1 month or more and less than 2 months | 33 |            |
|                                        | 2 months or more and less than 3 months | 18 |            |
|                                        | 3 months or more                   | 7  |                        |
| Space heating period (0.386)           | 1 months or more and less than 2 months | 2  |            |
|                                        | 2 months or more and less than 3 months | 4  |            |
|                                        | 3 months or more and less than 4 months | 12 |            |
|                                        | 4 months or more and less than 5 months | 27 |            |
|                                        | 5 months or more and less than 6 months | 14 |            |
|                                        | 6 months or more                   | 6  |                        |
| Set point temperature of space heating (0.687) | Less than 18°C                    | 1  |                        |
|                                        | 18°C or more and less than 20°C    | 16 |                        |
|                                        | 20°C or more and less than 22°C    | 18 |                        |
|                                        | 22°C or more and less than 24°C    | 11 |                        |
|                                        | 24°C or more and less than 26°C    | 11 |                        |
|                                        | 26°C or more and less than 28°C    | 5  |                        |
|                                        | 28°C or more and less than 30°C    | 6  |                        |
|                                        | Over 30°C                         | 50 |                        |
|                                        | Cannot set                        | 3  |                        |
| Heat source of hot water supply (0.632) | Gas                               | 35 |                        |
|                                        | Electric power                    | 20 |                        |
|                                        | Night-time power                  | 2  |                        |
|                                        | Kerosene                          | 5  |                        |
|                                        | Others                            | 3  |                        |
| Set point temperature of hot water supply in winter (0.443) | 39°C or more and less than 41°C | 21 | 191.9                  |
|                                        | 41°C or more and less than 43°C    | 37 | 191.5                  |
|                                        | 43°C or more and less than 45°C    | 2  |                        |
|                                        | Cannot set                        | 5  |                        |
| Reduce usage time of space heating and cooling appliances (0.559) | Not acting at all                | 5  |                        |
|                                        | Occasionally acting               | 7  |                        |
|                                        | Sometimes acting                  | 9  |                        |
|                                        | Generally acting                  | 13 |                        |
|                                        | Always act                        | 31 |                        |
| Clean air filters for space heating and cooling appliances (0.723) | Not acting at all                | 11 | 191.9                  |
|                                        | Occasionally acting               | 16 |                        |
|                                        | Sometimes acting                  | 22 |                        |
|                                        | Generally acting                  | 3  |                        |
|                                        | Always act                        | 13 |                        |
| Regulate heat balance with curtains or blinds (0.757) | Not acting at all                | 7  |                        |
|                                        | Occasionally acting               | 7  |                        |
|                                        | Sometimes acting                  | 13 |                        |
|                                        | Generally acting                  | 10 |                        |
|                                        | Always act                        | 28 |                        |
| Do not overload the refrigerator (0.520) | Not acting at all                | 11 |                        |
|                                        | Occasionally acting               | 15 |                        |
|                                        | Sometimes acting                  | 17 |                        |
|                                        | Generally acting                  | 11 |                        |
|                                        | Always act                        | 11 |                        |
| Reduce insulation time of rice cooker (0.292) | Not acting at all                | 15 |                        |
|                                        | Occasionally acting               | 8  |                        |
|                                        | Sometimes acting                  | 7  |                        |
|                                        | Generally acting                  | 8  |                        |
|                                        | Always act                        | 27 |                        |
| Adjust the set point temperature of the heated toilet seat according to the season (0.648) | Not acting at all                | 12 | 178.7                  |
|                                        | Occasionally acting               | 8  |                        |
|                                        | Sometimes acting                  | 11 |                        |
|                                        | Generally acting                  | 11 |                        |
|                                        | Always act                        | 23 |                        |

Figure 8. Result of multivariate analysis for family households by selecting the six hard factors and six soft factors as explanatory variables (n = 65, multiple correlation coefficient: 0.84, Mean: ¥229,319, S.D.: ¥127,061).
cooling period”, there was a correspondence between each category score and each annual utility cost. For family households, “Space heating period” had a clear relationship with the annual utility costs compared to “Space cooling period”. “Heat source of hot water supply” showed a tendency to be slightly different from that of one-person households. The households using “Kerosene” in addition to the households using “Night-time power” also had lower annual utility costs. The result of “Set point temperature of hot water supply in winter” was also different from that of one-person households, and the annual utility costs in “Cannot set” was found to be the lowest.

Finally, as seen in Figure 8, in family households, the tendency of the partial correlation coefficients of soft factors to be higher than those of hard factors was stronger than that of one-person households. Also, among the hard factors, the partial correlation coefficients of “Set point temperature of space heating” and “Heat source of hot water supply” were large. On the other hand, among the soft factors, the partial correlation coefficients of “Clean air filters for space heating and cooling appliances” and “Regulate heat balance with curtains or blinds” were as large as 0.723 and 0.757, respectively, and have a strong influence on annual utility costs. In “Space heating period”, “Regulate heat balance with curtains or blinds”, “Do not overload the refrigerator”, and “Adjust the set point temperature of the heated toilet seat according to the season” there was a correspondence between each category score and each annual utility cost. From Figure 8, the most influential categories reducing annual utility costs were “Less than 18℃” in “Set point temperature of space heating” and “Night-time power” in “Heat source of hot water supply”. On the other hand, the most influential categories increasing annual utility costs were “Not acting at all” in “Regulate heat balance with curtains or blinds”, “Cannot set” in “Set point temperature of space heating”, and “43℃ or more and less than 45℃” in “Set point temperature of hot water supply in winter”. However, “Always act” in “Clean air filters for space heating and cooling appliances” and “Occasionally acting” in “Adjust the set point temperature of the heated toilet seat according to the season” inexplicably had large positive category scores.

6. Conclusions

Surveys on lifestyle and energy consumption intended for one-person student households in Japan were conducted in 2007 and 2008. In order to clarify the influence of each lifestyle factor that would affect the energy consumption of one-person student households, 344 one-person households and 215 family households who answered in 2007 and 2008 were analyzed via the method of quantification theory type I, as explanatory variables were roughly divided into hard and soft factors. The results are summarized below.

1) It was found that the heat source of hot water supply and set point temperature of hot water supply in winter were important factors that have a great impact on the annual utility costs among the six hard factors used in the analysis in one-person student households and family households, respectively. Night-time power was found to be the most effective in reducing annual utility costs in one-person households probably due to night-oriented lifestyle.

2) Among the six hard factors, space cooling period had a clear association with the annual utility costs in one-person households, whereas space heating period had a clear relationship with the annual utility costs in family households.

3) The annual utility cost of one-person student households was greatly influenced by how to use appliances and energy conservation efforts, such as whether the usage time of space heating and cooling appliances is shortened in one-person student households and the regulation of heat balance with curtains or blinds in family households, respectively. Despite the fact that there were some inconsistent items, it is noteworthy that the way of living showed a partial correlation coefficient comparable to the way of using the equipment itself.

4) The factors such as set point temperature of space heating and set point temperature of hot water supply in winter had a greater effect on annual utility costs in family households than in one-person student households. Moreover, the tendency of the partial correlation coefficients of soft factors to be higher in family households than those of hard factors was stronger compared to one-person households.

5) Differences in energy conservation efforts and consciousness of global environmental issues among family households were greatly reflected in annual utility costs compared to one-person households.

6) The effect of the degree of action of energy conservation behavior in the house on the annual utility costs was found to be greater or comparable to that of the hard factors including how to use equipment in both one-person households and family households.

7) It was shown that the correlation with the annual utility costs is higher when considering not only hard factors but also soft factors in both one-person households and family households. Therefore, it was shown that not only hard factors but also soft factors need to be considered for residential energy conservation.

8) The mean indoor temperature and the lowest indoor temperature of one-person households during occupancy were found to be 4-7℃ lower than those of
family households. Therefore, it is important not only to save energy, but also to confirm that the indoor thermal comfort is secured in one-person households with a saved life.

Since the number of one-person households is expected to increase in the future in Japan, the findings of this study are expected to be useful to promote energy conservation nationwide by developing energy-conservation techniques for one-person households. At the same time, energy conservation measures should be developed that take into account the importance of lifestyle-related factors depending on the household type.

Acknowledgement
This study was supported by TOSTEM Foundation for Construction Materials Industry Promotion, Japan and Grant-in-Aid for Young Scientists(B) (No.20760931) provided by the Ministry of Education, Culture, Sports, Science and Technology, Japan. The author would like to extend my sincere gratitude to all the respondents and collaborators in this study. The author would also like to express my gratitude to Prof. Genjo, K., Matsumoto, S., Hasegawa, K., Sugawara, M. (2008) Case study on characteristics for residential energy conservation behavior of student single households, in: Summaries of Technical Papers of Annual Meeting, Architectural Institute of Japan, D-2, pp.129-130 (in Japanese).

Genjo, K., Sugawara, M., Matsumoto, S., Hasegawa, K. (2008) Questionnaire survey on residential energy consumption of student single household, in: Summaries of Technical Papers of Annual Meeting, Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, Vol.I, pp.513-516 (in Japanese).

Genjo, K., Matsumoto, S., Hasegawa, K., Sugawara, M. (2009) Questionnaire survey on characteristics for residential energy consumptions of student single households, in: Summaries of Technical Papers of Annual Meeting, Architectural Institute of Japan, D-2, pp.129-130 (in Japanese).

Genjo, K., Matsumoto, S., Hasegawa, K., Sugawara, M. (2009) Questionnaire survey on characteristics for residential energy conservation behavior of university students in Japan, in: Proceedings of Healthy Buildings 2009, Paper 805.

Genjo, K., Sugawara, M., Matsumoto, S., Hasegawa, K. (2010) Lifestyle and Energy Consumption for One-person Households -Results of Questionnaire Survey of University Students in Miyagi Prefecture-, in: Proceedings of AIJ Tokai Chapter Architectural Research Meeting, No.48, pp.277-280 (in Japanese).

Hasegawa, Y., Inoue, T. (2004) Energy consumption in housing on the basis of national scale questionnaire, Study on influence of residential characteristic and dispersion of energy consumption Part 1. Journal of Environmental Engineering (Transactions of AIJ) 671: 11-18 (in Japanese).

Inoue, T., Mizurani, S., Tanaka, T. (2006) Energy consumption in housing on the basis of national scale questionnaire, Analysis of influence of various factors on annual energy consumption Part 2, Journal of Environmental Engineering (Transaction of AIJ) 606: 75-80 (in Japanese).

Ishida, K. (1997) Energy consumption of detached houses, Journal of Architecture, Planning and Environmental Engineering (Transactions of AIJ) 583: 23-28 (in Japanese).

Japan Meteorological Agency, https://www.jma.go.jp/jma/indexe.html, 2019.

References
Fukuyo, K. (2008) Consciousness of life and energy-consuming actions in single households, Part 1 Effects of demographic attributes on consciousness and actions regarding energy consumption, Journal of Society of Heating, Air-Conditioning and Sanitary Engineers of Japan 139: 1-10 (in Japanese).

Fukuyo, K. (2009) Consciousness of life and energy-consuming actions in single households, Part 2 Association between personality attributes, energy consciousness, energy-saving actions, etc., Journal of Society of Heating, Air-Conditioning and Sanitary Engineers of Japan 149: 11-21 (in Japanese).

Genjo, K., Matsumoto, S., Hasegawa, K. (2008) Case study on characteristics for residential energy consumption of single households, Effects on energy conservation lifestyle on annual energy consumption, in: Summaries of Technical Papers of Annual Meeting, Architectural Institute of Japan, D-2, pp.169-170 (in Japanese).

Genjo, K., Matsumoto, S., Hasegawa, K., Sugawara, M. (2008) Energy conservation behavior and energy saving potential of single households in Japan, in: Proceedings of SB08 (The World Sustainable Building Conference in Melbourne), Vol.II, pp.2079-2086.

Genjo, K., Sugawara, M., Matsumoto, S., Hasegawa, K., Onodera, Y. (2008) Survey on Characteristics for Residential Energy Consumption of Single Household, Part 2: Annual Energy Consumption and Energy Saving Behavior of Student Single Household, in: Proceedings of AIJ Tohoku Chapter Architectural Research Meeting, No.71, pp.25-30 (in Japanese).
Factor Analysis Focusing on Lifestyle Factors of Utility Costs for One-person Student Households in Tohoku Region of Japan before the Great East Japan Earthquake

Konaka, M., Matsubara, N., Shibata, Y. (2016) Study on the Indoor Environment of Houses for Single People, Part 2-Results of the survey for the energy consumption and the way of living of the students in Kyoto city-, Summaries of Technical Papers of Annual Meeting, Architectural Institute of Japan, D-1: 137-138 (in Japanese).

Murakami, S., Bogaki, K., Tanaka, T., Hayama, H., Yoshino, H., Akabayashi, S., Inoue, T., Iio, A., Hokoi, S., Ozaki, A., Ishiyama, Y. (2006) Detail survey of long-term energy consumption for 80 houses in principal cities of Japan, Journal of Environmental Engineering (Transactions of AIJ) 603: 93-100 (in Japanese).

National Astronomical Observatory of Japan (2018), Chronological Scientific Tables, Maruzen, Japan.

Yuasa, K., Yoo, J., Yoshino, H., Hasegawa, K. (2009) Energy saving potential of low-impact life style in residential buildings, Journal of Environmental Engineering (Transactions of AIJ) 642: 1019-1024 (in Japanese).