STUDY ON THE ENERGY USE BEHAVIOR OF THE ELDERLY RESIDENTS IN THE COLD AREA OF CHINA- USING OLD COMMUNITIES IN TIANJIN CITY AS AN EXAMPLE

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0.Overview

By the end of 2017, China had more than 240 million elderly people over the age of 60, accounting for 17.3 percent of the total population, which marks that China has entered an aging society. The energy consumption of residential buildings in China accounts for 10.6% of the total energy consumption[1]. However, the elderly people spend an average of 19-22 hours/day at home, far longer than the 10-12 hours/day for young people. Therefore, the energy use behavior of the elderly occupies an important proportion in the energy saving behavior of residential buildings. Older users' behavior research has certain gaps in China. According to several most widely used in Chinese academic database including CNKI, Wanfang Data, Chinese Journal of Scientific and Technical Periodicals full-text database, etc., only a translation of Japanese paper in the 80s can be found on the topic of the elderly people's energy consumption. The research of this field is still blank in China. Therefore, in this study, the elderly residents in urban and suburban areas of Tianjin were selected as survey objects, whose behaviour data of using heating, refrigeration, refrigerator and television was tracked for a period of one year, in order to summarize the energy use behavior of elderly users in cold regions, and to draw suggestions for energy-saving measures for elderly residents living in such regions.

1.Surveyed Objects and Contents

Tianjin, the third most aging city in the country, lies in the cold zone of China. The lowest temperature in winter can be as low as -8℃, and the highest temperature in summer can be as high as 31℃, and so Tianjin is characterized by cold winters and hot summers. According to relevant research, the urban living floor area of Tianjin accounts for 77% of the living floor area. Therefore, in this study, 50 elderly residents aged between 60 and 90 years old living in different old residential areas(scope of old residential areas) in urban and suburban areas (the elderly live alone or live with his/her partner, the samples exclude cases where elderly residents living with their children) were selected and tracked for 1 year by means of questionnaire records. The data collected in the questionnaires was classified into the following categories: heating (divided into municipal central heating and domestic heating), cooling use (air conditioning and fan), refrigerator and TV use. Among them, heating and cooling are limited to early November to mid-march of the next year (person /month *50 person =250 copies), June to September (person /month *50 person *4 months =200 copies), and refrigerator and TV use are samples tracked throughout the year (person /month *50 persons *12 months =600 copies). Finally, effective data was input into SPSS for relevant analysis to form the energy use behavior database of elderly residents, which can provide support for the further interpretation of energy use behaviors of elderly residents

2.Data Analysis and Results

2.1Basic Information of Surveyed Objects

2.1.1 Regional Distribution of Surveyed Objects (Pie Chart Attached)

The elderly residents in this survey are located in a wide range of districts (as shown in Figure 1), among which the urban area of Tianjin is evenly distributed (including Heping District 6, Hexi District 7, Hedong District 5, Hebei District 5, Hongqiao District 4, Nankai District 10 and Binhai New District 6), and the effective data of Xiqing District 4 and Beichen District 3 are the most significant in the suburbs.

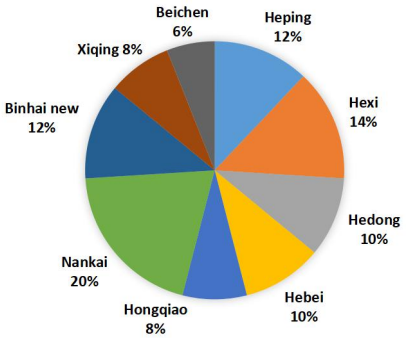

Figure 1 Regional Distribution of Surveyed Objects

2.1.2 Residential Building Overview (Table Attached)

The buildings surveyed are mainly multi-storey houses with 7 floors and below, among which residential buildings with 4 to 7 floors account for 78%. Most of the buildings were built in the 1980s and 1990s. In terms of floor space, the ones smaller than 70 ㎡ take up 46%, followed by 79-90 ㎡ (42%), while only 2% of the surveyed households have an floor space larger than 120 ㎡ (see table 1).

Table 1 Type of building, completion date and floor area

Type of Building	Multi-storey (4-7 storeys)	High-rise Towers (7 storeys and above)	High-rise slab-type apartment building (1-7storeys)	Other Types
	78% (39 households)	18% (9 households)	4% (2 households)	0
Completion Date	Before 1970s	1980s-1990s	1990s-2000s	After 2000s
	8% (4 households)	56% (28 households)	24% (12 households)	12% (6 households)
Floor Area	⩽70 ㎡	70-90 ㎡	90-120 ㎡	> 120 ㎡
	46% (23 households)	42% (21 households)	12% (6 households)	2% (1 household)

2.1.3 Basic Information of Surveyed Households

(1) Family Structure of Surveyed Objects

The objects of this survey are primarily the elderly people living alone or with his/her couple, and the sample does not include the type of cohabitation with children. However, in the follow-up study, it is found that frequent visits by children or relatives will have a greater impact on the energy use behavior of the elderly residents.

(2) Income Status of Surveyed Objects

The annual household income is divided into 5 groups: 24,000 to 36,000 yuan (25); 36-60,000 yuan (9); 6,000-96,000 yuan (7); 96,000 to 120,000 yuan (4); above 120,000 yuan (5) (see Figure 2). With reference to the average income of urban population in Tianjin of 28,400 yuan, the sample used in this study is considered reasonable.

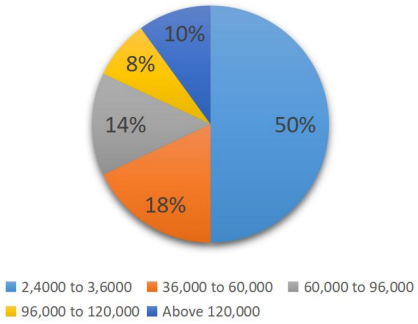

Figure 2 Annual Household Income

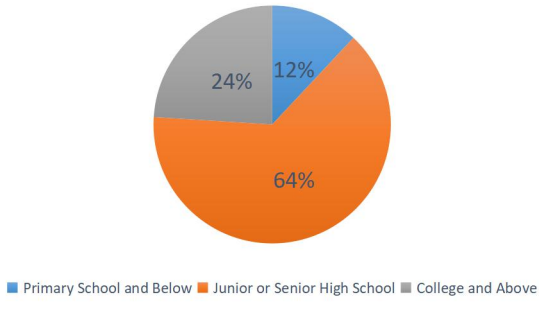

Figure 3 Education Level

(3) Education Level of the Surveyed Objects

The education level of the objects is divided into 3 groups: primary school and below (6), junior or senior high school (or vocational school, etc.) (32), college and above (12) (See Figure 3).

2.1.4 Ownership of Energy-Consumption Facility of Surveyed Objects

(1) Heating Facility and Forms

Tianjin is located in the cold region of China, so the ownership rate of heating facilities in the form of hot water heating is 100%. Heating forms include municipal central heating and self-heating (self-heating includes electric heating[21] and gas heating). In the sampling of the research objects, municipal central heating accounts for 94%, electric heating form accounts for 4%, and gas heating accounts for 2%.

(2) Cooling Facility and Forms

The refrigeration facilities ownership rate in Tianjin is very high. Many families have a variety of refrigeration facilities. 6% of the 50 households surveyed own 3 and 22% own 2. 72% of households have at least one air conditioner (see Figure 4). Among them, rate of living room air conditioning ownership is 99.5%, higher than bedroom air conditioning ownership rate of 67.5%. Type of air conditioning facilities: split type air conditioning is represented in the figure below as A1, central air conditioning A2, fan B, others C(see Figure 5). The fan ownership rate is 74%. The use of cooling facilities is mainly concentrated in July and August, and the mode of use is mainly intermittent.

[1] The residential electricity consumption in Tianjin electric heating communities is divided into two periods on the basis of annual cycle settlement: electric heating period, i.e., November 1 of each year to March 31 of the next year, during which the electricity consumption for heating can be implemented according to the electricity price of 0.51 yuan per kilowatt hour for residential users in the combined table. In non-electric heating period, Tianjin residential electricity price ladder policy applies.

Figure 4 The Total Number of The Refrigeration Plants for Each Household

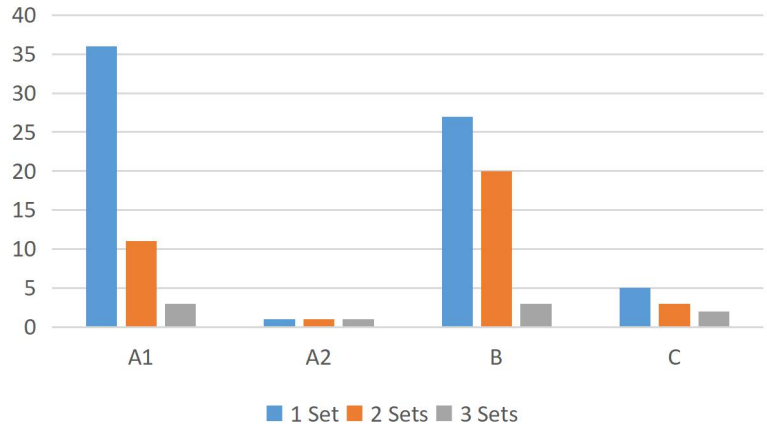

Figure 5 The Types of the Refrigeration plants for Each Household

(3) Refrigerator Ownership Rate

The ownership rate of refrigerators among elderly residents in Tianjin is 100%, and 6% of households (3 households) own more than one refrigerator.

(4) TV Ownership Rate

The TV ownership rate of the sample is 100%. Among them, 26% (13 households) own more than one television.

Results

According to the data of this study, the energy use behaviors of these 50 households are as follows: **(Histogram attached)**

1. According to indoor temperature measurement, indoor heating temperature of 76% of the residents is between 20-25 ℃, 20% of the residents' indoor heating temperature is between 18-20 ℃, 4% of the residents' indoor temperature is below 18 ℃. In the case of central heating, only 10 percent of elderly residents turn down the heat when they leave their homes. In the case of self-gas/electric heating, 100% of the elderly residents (including those living in urban and those in suburban areas) will turn down the heating temperature.
2. When it comes to refrigeration, 85% of elderly households will choose fans first, especially in June. In the hot season, 95% of the elderly residents will choose air conditioning. In temperature setting process, living room temperature and bedroom temperature are slightly different: bedroom temperature setting is slightly higher than living room temperature setting. 84% of the elderly users would set the temperature between 26-30℃; 12% would set the air conditioner temperature between 22 to 25 ℃; only 4% of users would set the air conditioner temperature below 22℃ (Figure 6).

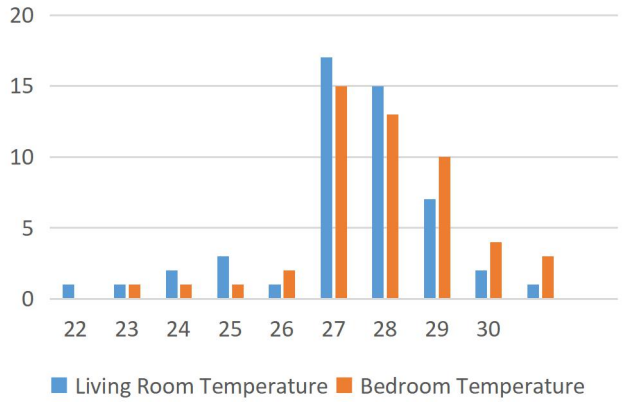

Figure 6 The Temprature Sets for the Living Room and Bed Room

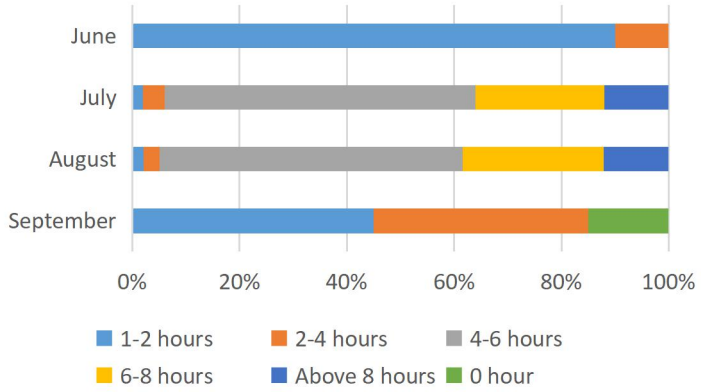

Figure 7 Duration of Using the Air Conditioners

3. The duration of use is as follows: in June, 90% of households use air conditioners for 1-2 hours a day, and 10% use them for more than 2 hours a day. In July-August, 12% of households use more than 8 hours, 24% use 6-8 hours, 58% use 4-6 hours, 4% use 2-4 hours, and 2% use less than 2 hours. In September, 45% of households will use air-conditioning for 2-4 hours, 40% for 1-2 hours and 15% would choose not to use air-conditioners (Figure 7).

In addition, due to the urban heat island effect, the temperature of the cities and suburbs in summer displays more obvious temperature differences, and this number is 0.5 to 1.5 ℃ on average in summer. Temperature difference is most obvious at nightfall, and the maximum temperature difference can reach 1.5 to 2.5 ℃. Therefore, in summer during nightfall to night period, urban and rural residents' behaviors display bigger differences: rural users use 1-1.2 hours less than the urban users.

3.1 The period of use is as follows: in June, the period of use of air conditioning is concentrated at noon from 13:30 to 15:30. In July, the cooling period of air conditioning fluctuates from 11 am to 11 pm, with the first peak from 12.00 am to 16.00 pm and the second peak from 8.30 to 11.00 pm, in which the former concerning living room and bedroom air conditioning use, while the latter is more concerning air conditioning of bedroom. (Figure 8)

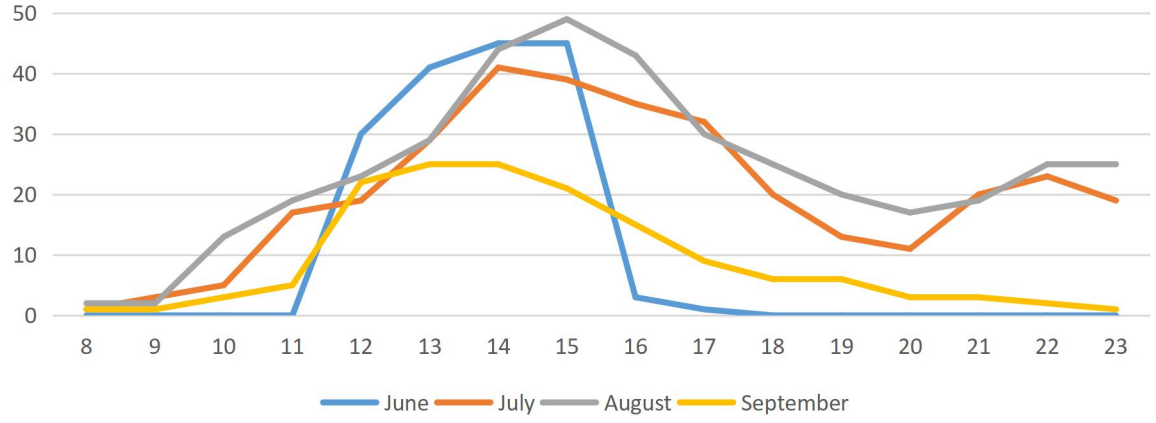

Figure 8 Usage Hours of the Air Conditioners

3.2 On and Off Conditions of Cooling Facilities

（1） Turning on air conditioner: upon arrival, when feeling hot, when visitors come, before sleep. Turning on fan: upon arrival, when feeling hot, when visitors come, before sleep. (Figure 9)

（2） Turning off air conditioner: when feeling cold, set time, before sleep, never. Turning off fan: when feeling cold, set time, before sleep, never (Figure 10).

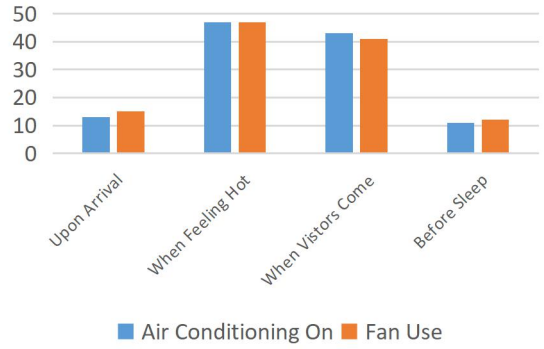

Figure 9 The methods for Turing on the Refrigeration Plants

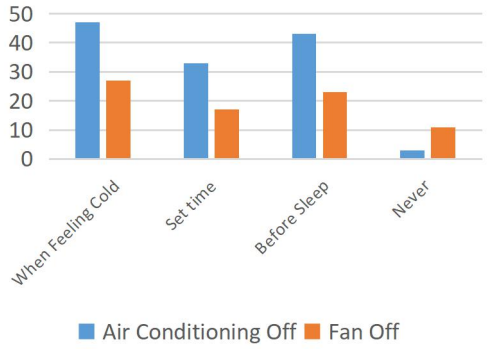

Figure 10 The methods for Turing off the Refrigeration Plants

4.Refrigerator usage is comparatively complicated, as it involves several aspects. For instance, the volume of the fridge, the cooling energy consumption etc. Therefore, the study chooses 2 behaviors to collect the 2 sets of data: whether the resident bought an energy-saving fridge (a fridge with an energy-saving level label) and whether the resident would set the fridge to the energy-saving model. 100% of the residents chose an energy-saving fridge, among which 76% of the residents chose the first-class energy-saving types (best), 18% chose the second-class energy-saving label, and 6% chose the third-class energy-saving label. But 86% of the surveyed residents do not know how to adjust the temperature of the fridge, and 14% of them would adjust the temperature to save energy.

5. Among the surveyed objects, the TV ownership rate was 100% and the usage rate was also 100%. According to the survey data, 60% of the elderly use TV for 4-6 hours, 10% for 2-4 hours, 15% for 1-2 hours, and 15% for more than 8 hours.

Conclusions

1. Background: the choice of energy saving behavior has no significant correlation with education background, gender, income, building construction age, but has clear correlation with building area, visitor density, etc.

2. Heating: In case of central supplied heating, Tianjin municipality charges a flat rate according to the heating area, instead of actual consumption. Compare to the self-heating residents who use the natural gas or electricity (charged by actual usage), it is indicated that the motivation for energy conservation of self-heating residents is much stronger than the ones using central supplied heating. Thus, the study suggests adopting actual energy consumption tariff which can be more effective towards energy consumption.

3. Air conditioning: Tianjin is very hot in summer, so air conditioning is a must for elderly residents. When using air conditioners, most elderly residents choose energy saving mode and set a relatively comfortable temperature, i.e., 26 to 30 ℃. In the comparison with the energy use behavior of elderly suburban residents, it can be found that the urban heat island effect causes the air-conditioning cooling time of elderly urban users to be longer than that of suburban users. Therefore, increasing green plants in old communities and expanding the park area between community clusters can reduce the heat island effect in a direct and convenient way, thus reducing the cooling energy consumption in summer. At the same time, as another effective way of cooling, electric fans are second only to air conditioning refrigeration, and even some users prefer electric fans than air conditioning. In the research it is found that the introduction of new refrigeration facility air conditioning fan, to some extent, helps conserving energy. Its cooling method is to supplement the moisture in the air, reducing the body temperature. Comparing that with an air conditioner set to 26℃, this facility can save … kwh, according to cooling time of ..., it has the potential to save... kwh electricity. Therefore, the popularization of new refrigeration facilities for elderly residents also has a certain significance of energy saving. And the SPSS software correlation analysis shows that the building energy consumption in summer is significantly correlated with the number of household permanent residents, the number of household air conditioners, the total household income and the temperature setting of the air conditioners in the living room, but not significantly correlated with the building area or building age.

4. Refrigerators: in the purchase process of refrigerators, all elderly residents will choose energy-saving refrigerators due to the popularity of energy-saving labels and their linkage with prices and subsidies. However, after the purchase, the lack of awareness of energy-saving methods results in many elderly people not knowing how to adjust and use the energy-saving mode of refrigerator, which puts forward the requirements for relevant professionals, that is, the publicity and popularization of energy-saving awareness should be raised and the corresponding knowledge should be updated.

5. Usage of TV. The study indicates that elderly people tend to use TV more than others, due to their emotion needs. Some of them watch TV all day long. This study suggests that accessible facilities and indoor/outdoor venues for elderly activities be built in communities, to conserve energy, and also to satisfy the emotion need of the elders for them to stay healthy.

6. In addition, public activity sites and good neighborhood relations are also of positive significance to the energy saving behavior of the elderly residents. For example, Kaili Garden (good neighbourhood) has 200m2 more outdoor public activity area than Hongkan Community, and therefore the elderly residents of Kaili Garden have a longer outdoor activity time: on average 0.5 hours longer than the Hongkan Community. (In Fengheyuan Community, which is near the Central Park, and Xuehuli Community, which is near the university campus, the outdoor activity time of the elderly residents is 0.3 hours longer than the average activity time of the elderly residents in other communities.)

Acknowledge

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