Contrastive analyses on annual energy consumption between new residential buildings and old residential buildings in Shanghai, China

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ABSTRACT

The purposes of this research are to contrast the energy consumption characteristics of old residential buildings and new residential buildings in Shanghai, China, and to analyze influence factors of residential energy consumption. 1610 families in Residential District A constructed in the 1980s and 819 families in Residential District B constructed in the 2000s were chosen to trace their monthly energy consumption data in the whole year of 2006. 300 families in each district were further selected from all above investigated families to do questionnaires in the year of 2007, so as to master building characteristics, the possession and utilization of space heating and cooling appliances, energy-saving consciousness and so on. Annual energy consumption of the two kinds of buildings is contrasted and energy consumption quantities of spacing cooling and heating are calculated. Influencing factors of residential energy consumption are further analyzed by the quantification theory. Conclusions are as follows: the average annual energy consumption quantity is 23.27 GJ/household for new buildings and 14.40 GJ/household for old buildings. The ratio of space heating and cooling to total annual energy consumption is just 11.6% and 16% for old buildings and new buildings respectively. Energy consumption and its variance lie on the integrated influence of many factors, while the floor area, materials of window frames, the number of family members, use months of space heaters in winter and air conditioners in summer, and energy saving actions are the main factors.

1. INTRODUCTION

Residential energy consumption has been increasing sharply in China these years. Shanghai is the largest city with the largest population and largest GDP value in the mainland of China. Many factors, such as the hot summer and cold winter climate, the improvement of living standard and so on, result in the rapid growth of residential energy consumption. Related statistics show that the annual electricity consumption for living life increased by a factor of 7.5 in the last 16 years and reached 12.24 G KWh in the year of 2006, and the coal gas consumption for living life is as large as 1.72 Gm^3 in 2006 (Statistics bureau of Shanghai, 2007). Therefore, it is very important to look into the actuality of urban residential energy consumption. In this paper, investigations of residential energy consumption were made in Shanghai and the annual energy consumption actuality of the investigated families was analyzed.

2. INVESTIGATION METHODS

Table 1 shows the general condition of the investigations. The buildings in District A were all built in the 1980s while those in District B were all new buildings built in the 2000s. Monthly energy consumption data of all the investigated families were traced in 2006. 300 residences in each district were selected from all the investigated families to do questionnaires in summer and winter of 2007. The contents of the questionnaire surveys cover the architecture characteristic, household information, usage of space heating and cooling equipment, energy

Table 1: General information of the investigated families

	Residential districts	Investigated families	Construction year	Total floors of the buildings	Construction structure
Tracing the annual data	District A	1610	in the 1980s	5~6 floors	brick-concrete
	District B	819	in the 2000s	6~7 floors	

	Residential districts	Investigated families	Household rate		Energy Sources
			Space heating	Space cooling	
Questi-onnaire survey	District A	300	Air conditioner :79% Electric heater: 38%	Air conditioner: 99.0%	Electricity, city gas(coal)
	District B	300	Air conditioner: 95% Electric heater: 49%	Air conditioner: 99.6%	Electricity, city gas(coal)

saving actions and so on.

3. RESULTS OF THE QUESTIONNAIRES

The questionnaires of 300 families in each district are analyzed in this part. Figure 1 shows the household floor areas. 75.3% of the families in District A have the floor area below 50 m^2/household, while the values of all the families in District B are all above 50 m^2/household. The average floor area is 42.8 m^2/household and 98.6 m^2/household in Districts A and B respectively. As for the materials of window frames, half of the families in District A use the iron for window frames, and aluminum alloy and plastic steel account for 28.9% and 25.8% respective, while aluminum alloy is widely used in District B with the percentage of 78.3%.

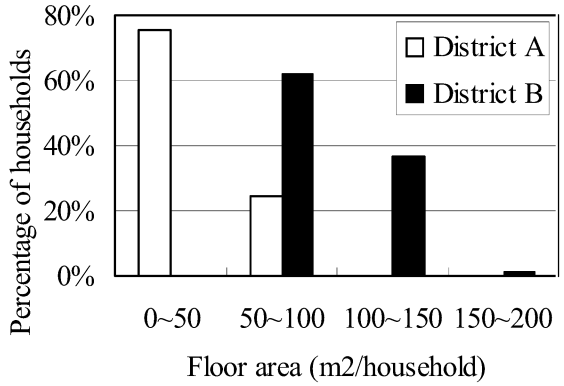


Figure 1. Household floor areas in two districts

As for the number of family members, 77.4% of the families in District A have the members between 2 and 3 persons, while 85% of the families have 3 to 5 members per household. Figure 2 shows the annual income. 68.1% of the families in District A have the annual income below 20000 yuan, while 42% of the families have the annual income above 40000yuan and the households above 60000yuan account for the largest percentage. According to the data in the statistics yearbook, the families in District A are in the low-income level in Shanghai, while the families in District B can stand for the general condition in this city.

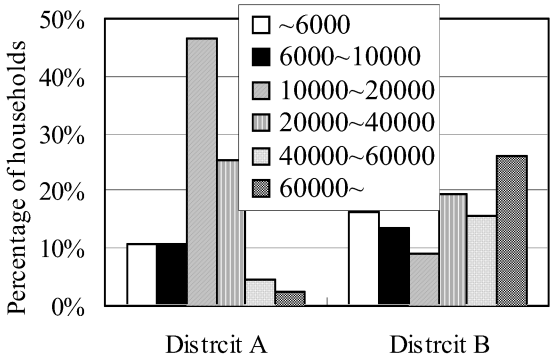


Figure 2. Household annual income in the two districts (unit: RMB yuan)

Air conditioners and local electric heaters are the two main space heating appliances. Figure 3 shows the monthly usage of space heating equipment. The peak time of space heating is from Dec. to Feb. in both districts and the monthly percentages of households with space heating in District B are slightly higher than that in District A. As for the space heating area of the families, 72% of the households in District A have space heating only in bedrooms, while in District B, 26% of the Households have space heating in both living rooms and bedrooms and 30% have space heating in all the rooms except toilets and kitchens. Figure 4 shows the monthly usage of space cooling equipment in the two districts. More than 80% of the families in both districts us air conditioners and electrical fans

from July to Sep. and the household percentage in District B is also slightly higher than that in District A. As for the space cooling area, 70.1% of the families in District A use air conditioners only in bedrooms, while in District B, 51.7 of the families use air conditioners in both living rooms and bedroom and 30% use it in all the rooms expect toilets and kitchens.

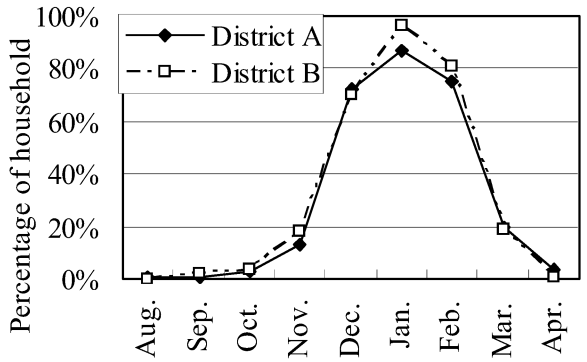


Figure 3. Monthly usage of space heating equipment

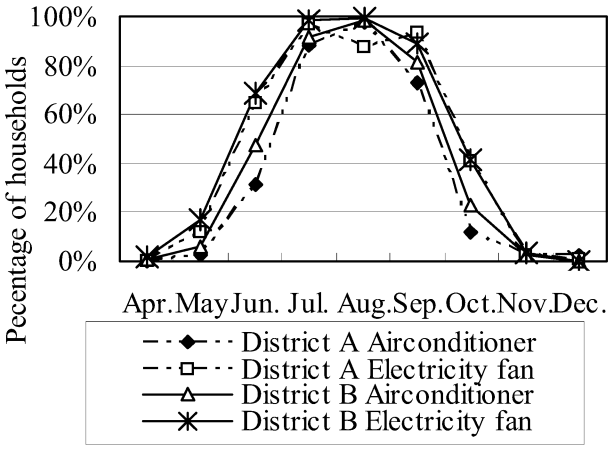


Figure 4. Monthly usage of space cooling equipment

4. ENERGY CONSUMPTION

4.1 Energy consumption of all the families

The energy consumption of 1610 families in District A and 819 families in District B are analyzed in this part. Figure 5 shows that the monthly household gas consumption on average in District A ranges from 557~921 MJ/household, while that in District B is from 644~1603 MJ/household. The maximum value occurs in winter while the minimum value occurs in summer in both districts. Fig.6 shows the monthly electricity energy consumption. In District A, the monthly average electricity amount ranges from 323.8~905.5 MJ/household, while that in District B is from 6351.1~1821.2 MJ/household. The monthly amounts in summer are larger than those in winter and the values in winter are also larger than those in spring and autumn in both districts. Figure 7 shows the annual total consumption. More than 60% of families in District A have the annual energy use amount between 10GJ/household and 20 GJ/household, while 75% of the families in District B have the annual energy use amount in the range of 10 GJ/household ~30 GJ/household. The average annual quantity in District B is 23.27 GJ/household, while the value in District A is only 14.40 GJ/household.

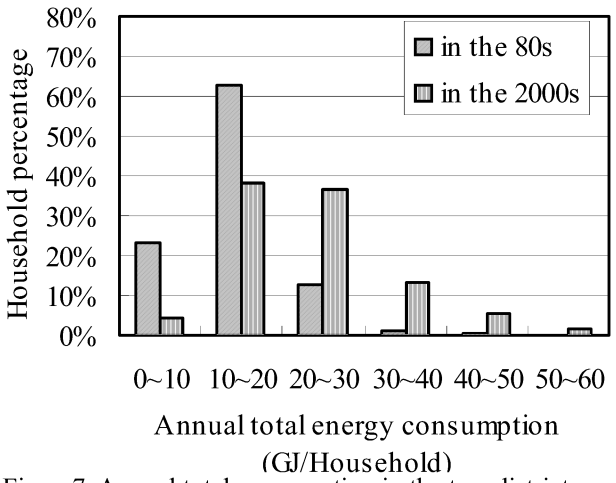


Figure7. Annual total consumption in the two districts

4.2 Energy consumption of 300 families in each district

The energy consumption of 300 families in each district is further analyzed. The detail data of monthly gas and electricity usage are shown in Figure 8. The total amount of each month in District B is larger than that in District A. Figure 9 shows the annual amounts of space heating and cooling. The space cooling amount is larger than space heating amount in both districts: in District A, 94% of the families have space heating amount below 1GJ/household, while 41% and 33% of the families have space cooling amount below1GJ/household and between 1~2 GJ/household, respectively; in District B, 59% of the families have the space heating amount below 1GJ/household and there are 21% of the families with the value between 1~2 GJ/household, while 31% of the families have the space cooling amount between 1~2 GJ/household and there are 39% of families

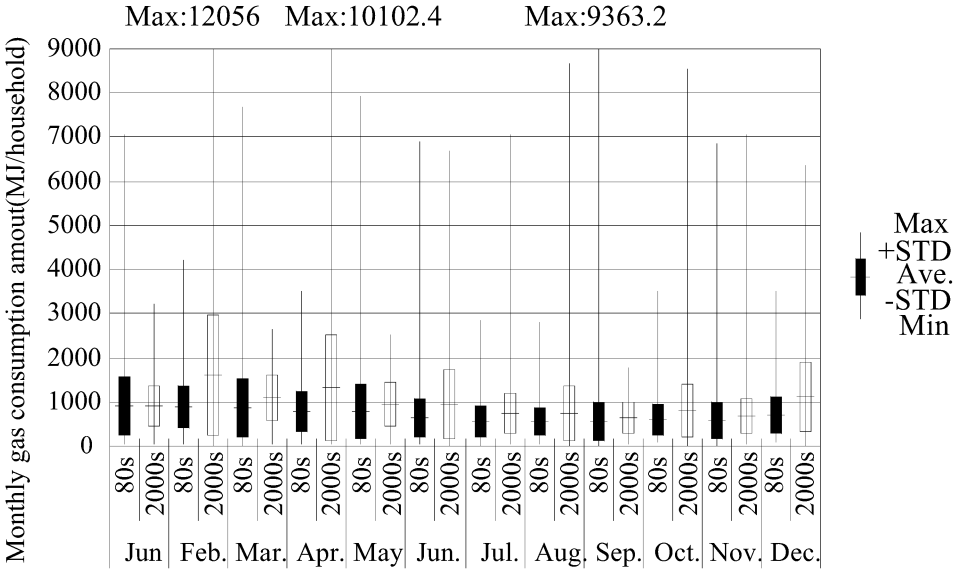


Figure 5. Monthly gas energy consumption of all the families in the two districts

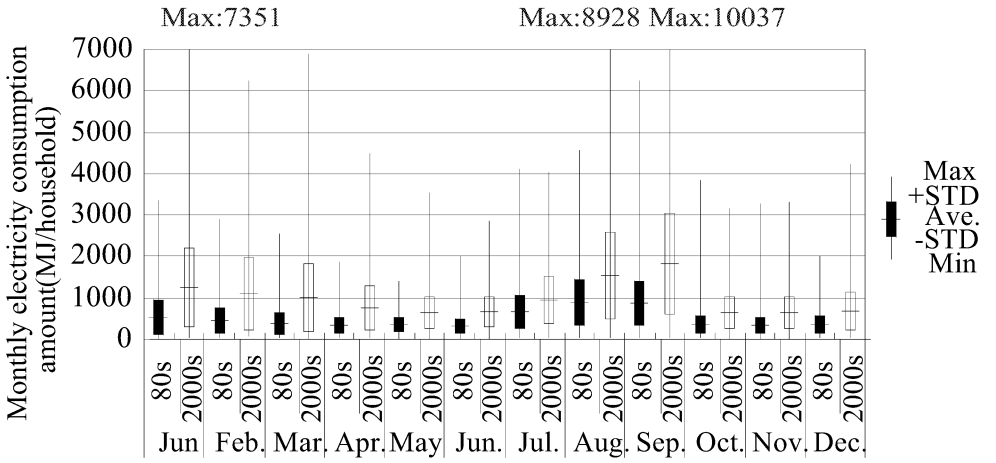


Figure 6. Monthly electricity consumption of all the families in the two districts

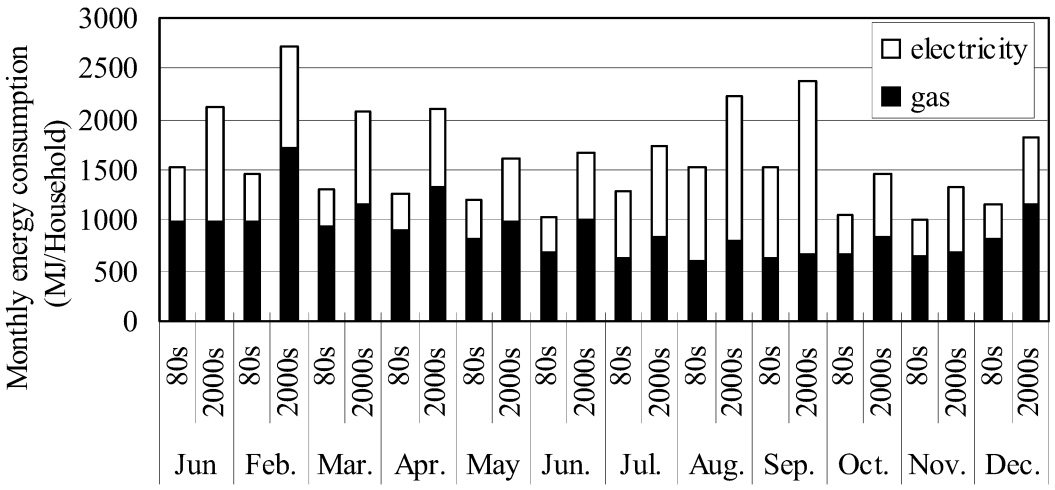


Figure 8. Average monthly electricity and gas consumption of 300 families in each district

with the value between 2~6 GJ/household. Figure 10 further shows the breakdown of end users in the annual average amount. The space heating and cooling amount in District B is 3.71 GJ/household, larger than the value of 1.78 GJ/household in District A. The ratio of space heating and cooling to total annual energy consumption is just 11.6% and 16% in Districts A and B respectively.

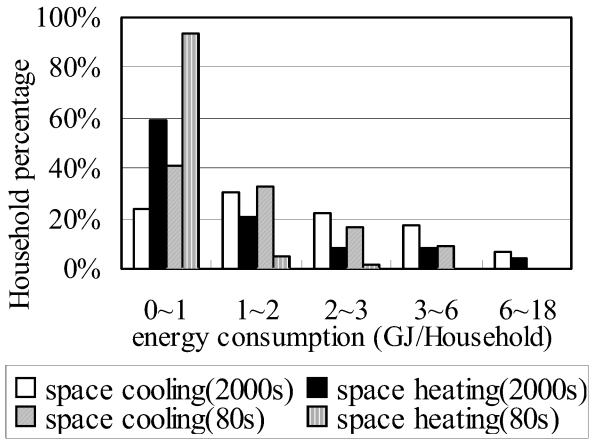


Figure. 9 Annual amounts of space cooling and heating of 300 families in each district

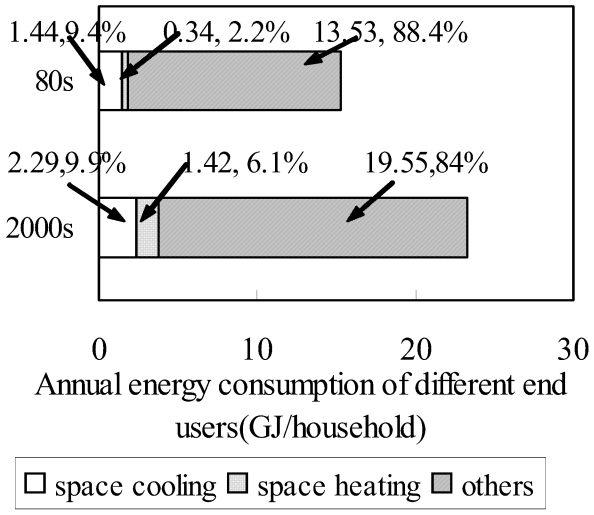


Figure 10 Breakdown of end users in annual energy consumption

5. ANALYSES ON INFLUENCE FACTORS OF ANNUAL ENERGY CONSUMPTION BY THE QUANTIFICATION THEORY

Influence factors of residential energy consumption are analyzed here. Qualitative variables can not be analyzed in traditional statistical theories, while qualitative variables are introduced into this model by the quantification theory. Analyzed variables refer to building properties, household characteristics, energy consuming equipment, and energy saving actions. The partial correlation coefficient is used to weigh contribution extents of independent variables to the dependent variable. The significance test is taken to judge how large the partial correlation coefficient is, the factors will affect residential energy consumption. The bigger the significance probability is, the less the partial correlation coefficient is, and the less the factor′ effects on residential energy consumption is (Liu and Chen, 2004). In this model, it is assumed that if the significance probability is smaller than 0.05, the factor has effect on energy consumption.

Table 2 shows that the influence extent of the factors on energy consumption is established in following order: the floor area＞ the number of family member ＞ usage months of AC in summer ＞ energy saving actions ＞ usage months of space heaters＞materials of window frames. As for the energy saving actions, using energy efficiency appliance is the most effective way to save energy among all the actions, and reducing standby power consumption is also a very effective method; the effects of using space heating/cooling appliances and lights as little as possible rank behind the above two ways, while the energy will consumed much more if no energy saving actions are adopted.

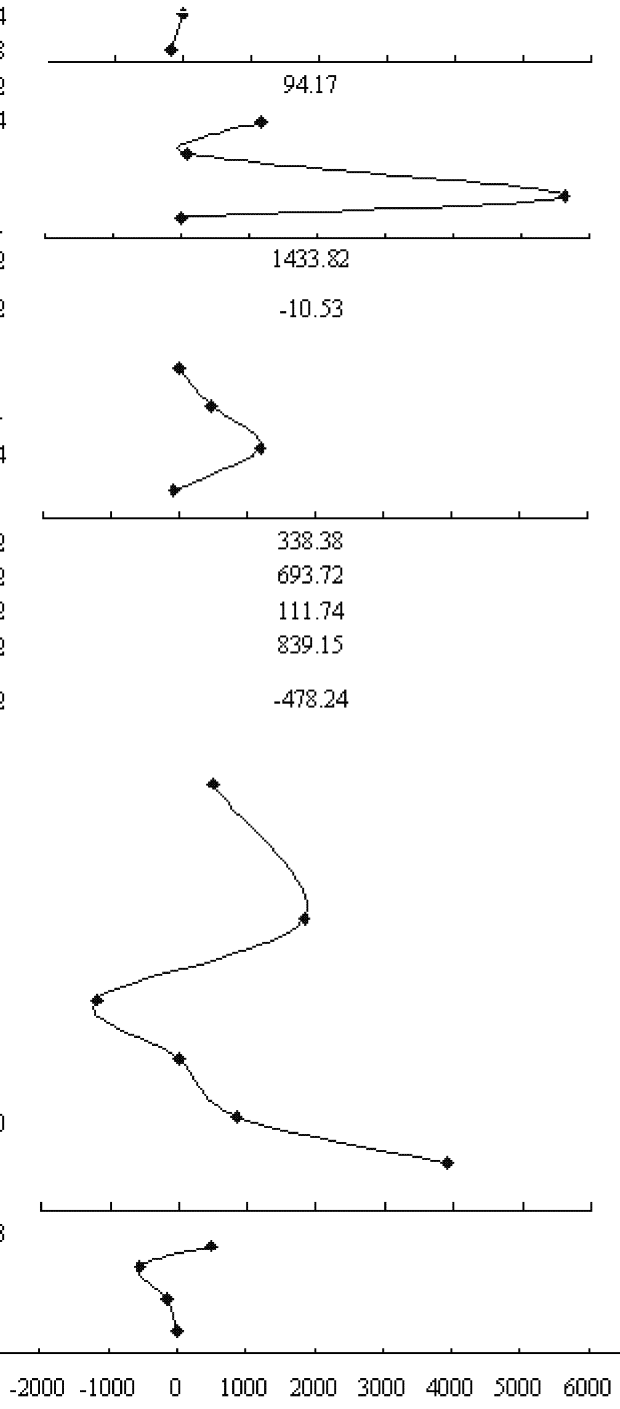
6. CONCLUSIONS

The construction year of the buildings in District A is much older than that in District B. The household rates of space heating and cooling is slightly higher, and space heating and cooling areas are much larger in District B.

The average annual energy consumption quantity is 23.27 GJ/household for new buildings and 14.40 GJ/household for old buildings. The ratio of space heating and cooling to total annual energy consumption is just 11.6% and 16% for old buildings and new buildings respectively. The influence factors of total energy consumption include the floor area, materials of window frames, the number of family members, use months of space heaters in winter and air conditioners in summer, and energy saving actions.

Table 2: The analysis on influence factors of annual energy consumption

Influence factors	Categories	Number of samples	Scores	Partial correlation coefficient	Significance probality
Construction time	1980s	194		0.01	0.88
	2000s	228			
Floor area		422	94.17	0.25	2.25E-07
Material of window frames	Aluminum alloy	224		0.11	2.98E-02
	Plastic steel	93			
	Wood	4			
	Iron	101			
Number of family members		422	1433.82	0.21	1.42E-05
The ratio of energy expenditure to annual income		422	-10.53	-0.01	0.83
Annual income	Below10000	57		0.08	0.10
	Below20000	131			
	Below40000	174			
	Above40000	60			
Number of space heaters		422	338.38	0.05	0.27
Use months of space heaters		422	693.72	0.11	2.60E-02
Daily use hours of space heater		422	111.74	0.06	0.23
Usage months of AC in summer		422	839.15	0.16	1.45E-03
Usage months of electric fans in summer		422	-478.24	-0.07	0.16
Energy saving actions	Use space heating/cooling appliances as little as possible	26		0.15	2.86E-03
	Use illumination appliances as little as possible	32			
	Use energy efficiency appliances	3			
	Reduce standby power consumption	5			
	Adopt more than two actions above	320			
	No energy saving actions	36			
The categories of water heaters	Gas	353		0.05	0.29
	Elec+gas	39			
	Electricity	17			
	Others	13			



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