STUDY OF CHINESE URBAN HOUSING ENERGY USE: BEIJING CASE STUDY 1991-1997

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SUMMARY

To understand how energy is actually consumed by urban housing in different areas with different climatic and economic situation, we have been conducting a number of social surveys. Limited by the limited resource, we selected three cities for the current study phase. These cities are located in three typical Chinese climatic zones respectively : Beijing in the northern China cold zone, Yichang, Hubei in the central China summer hot/winter cold zone, and Shenzhen, Guangdong in the southern China hot and humid zone. The three cities have significantly different economic level. Three types of survey have been conducted: typical pilot projects, utility suppliers' interview, and tenants questionnaire surveys. Via survey, we have achieved a lot of essential data that shows us how energy is consumed in urban housing and how it is varying. The data is thereafter being analyzed to generate descriptive statistics of urban housing energy conservation. This paper will briefly introduce the surveys, some results achieved, and study plans for the future.

INTRODUCTION

Although China is richly endowed with conventional energy resources (6), limited energy production has developed adverse impacts on sustainable development of the country, so how to more efficiently utilize the limited energy and invest in the national energy system is a very important issue for the China central government. Therefore, the government needs to set up a suitable energy policy and a number of energy saving regulations. To do this properly, it needs to understand how energy is actually consumed by different users in different places, and how it is affected by the varying factors. Building is one of the biggest energy consumption sectors. The percentage of building energy consumption of the total consumption is currently about 30% (3), and is still increasing. Over the last 10 years, improving energy efficiency of buildings is a popular issue in China. The governmental authorities have developed a number of regulations and guidelines for energy efficient development(4)(5). Many new building technologies have been introduced to China, coming from different countries whose climatic and economic situation is significantly different from China (3). Unfortunately, it is impossible to accurately assess the actual impact of these approaches on building energy efficiency improvement because essential information presenting the reality of building energy consumption is insufficient. So it is invaluable to study and find out this information.

Presently public housing is being developed rapidly creating a huge energy demand. Also, improvements in living standards eventually result in more energy consuming domestic appliances being used. While energy use of residential buildings can be improved by applying energy efficient technology, there are a lot of uncertainties regarding understanding of actual energy consumption in residential buildings. Our study is focused on residential buildings. The target is to resolve these uncertainties.

ISSUES ADDRESSED

Energy consumption in urban housing is mainly caused by:

1. Space thermal environment control devices, including heating systems and air-conditioners;
2. Cooking devices and hot water supply;

3. Domestic electronic appliances;
4. Lighting.

Local weather, economic level, living styles, and energy policy all have a significant effect on these four aspects, so the study must be focused on some particular locations.

Regarding the climatic situation, China is usually classified into 7 typical climatic zones. We started our study with focus on three zones, and in each zone, chose a typical city for developing and implementing the study methodology. For each particular climatic zone, different study issues are addressed as listed below:

1. In *The Northern China Cold Zone*, the study is conducted with focus on the following heating system issues:
   - Energy sources and pricing structures;
   - Impact of tenants' behavior on heating energy efficiency and indoor thermal environment;
   - Energy pricing and its impacts on tenants behavior;
   - Control of terminal devices;
   - Terminal energy metering and it's impacts on structures of terminal distribution systems;
   - Application and impacts of Energy efficient building materials and devices;
   - Application of technology and systems for preliminary water network;
   - Indoor air quality issues during winter.

2. In *The Central China Summer Hot/Winter Cold Zone*, the study is conducted with focus on the following issues about domestic unitary air-conditioners:
   - Utilization of domestic air-conditioning;
   - Annual air-conditioning energy analysis for typical residential buildings;
   - Application of heat pumps;
   - Application of variable frequency air - conditioning systems;
   - Natural ventilation during transition seasons.

3. In *The Southern Hot and Humid Zone, the* following issues are addressed :
   - All issues in 2. Above with exception the of heat pump application;
   - Tenants' behavior and impacts on energy efficiency;
   - Dehumidification problems;
   - Space heating during winter;
   - Indoor air quality during summer.

4. In all three areas, the following issues about domestic appliances and cooking devices are addressed :
   - Using frequency, energy sources;
   - Application of high efficiency lighting devices;
   - Water, electricity, and fuel gas supply system.

METHODOLOGY

In terms of land and population, China is a very variable country. Climatic conditions, living styles, and economic development levels are significantly different throughout China. Even divided into 7 typical climatic zones, each zone is still too big to be studied in detail. In the current phase, the study is only conducted in three zones, and in each zone, only one typical city is selected to be the location where the study is done in depth. Beijing is selected in *the Northern China Cold Area*, Yichang, Hubei in *the Central China Summer Hot and Winter Cold Area,* Shenzhen, Guangdong in *the Southern China Hot and Humid Area.*

Essential information is collected via three types of social surveys, which include:

1. Site study of some typical housing projects;
2. Utility suppliers and management offices interviews;
3. Tenants survey by questionnaire.

A number of questionnaires have been developed according to the particular situation of each location.

Once the essential information has been collected, *SPSS* is used to do statistical analysis. In this way, we can produce descriptive statistics of housing energy consumption in the last ten years. Based on this information, we can develop or verify energy models predicting future energy demand by residential buildings in these locations.

Thermal simulation technology is also applied to perform annual energy analysis and to study to local energy regulations. The software packages are BLAST, E20-II, TRNSYS, and BTP. To run the software, a supporting system has been developed to provide information about residential buildings and local climatic information.

Figure 1 demonstrates the study methodology.

CASE STUDY (Beijing)

In Beijing, three public housing centers are selected for the study. The buildings are all low-rise brick wall construction, very typical in Beijing. In terms of construction, energy use, and estate management, the three centers are very representative. The surveys we conducted include interviewing utility management offices, deep investigation the estate centers, and tenants questionnaire surveys. A lot of essential information has been collected via these surveys. They are in turn analyzed by SPSS and the analyzing software, generating descriptive results, which are attached in Figure 2,3,and 4.

For 1991, the seasonal difference is only 10-20%. Quarter 3 has the highest electricity consumption, but only 20% higher than quarter 1. In 1997, the average seasonal difference is much more. Electricity consumption in quarter 3 is 40%-50% higher than the other quarters. Obviously this is the result of increasing utilization of domestic air-conditioners. Overall, annually averaged seasonal electricity consumption in 1997 is 70% higher than 1991.

We define percentile in the following manner:

x-tile is the level of electricity use that x% of housing units exceed in a season

Figure 2-A, 2-B, 2-C, and 2-D show how seasonal electricity consumption varies from 1991 to 1997. Figure 2-A shows that seasonal electricity consumption in quarter 1 has not increased too much from 1991 to 1997. The an annual increase is at a rate of 5%. This slow increment is mainly caused by increased utilization of domestic appliances. Similar characteristics can be found in quarter 2 (figure 2-B), and quarter 4 (figure 2-D). But figure 2-C indicates that the electricity consumption of 30% families has increased significantly, at an annual increasing rate of 10-13%. We believe that this is the result of increased utilization of domestic air-conditioners.

We define the peak seasonal electricity difference (Epd) as

$$\text{Epd (Res, Flat, Yr)} = \text{Max(Res, Flat, Yr, Qtr)} - \text{Min (Res, Flat, Yr, Qtr)}$$

where

Res : residence number;
Flat : flat number;
Yr : year;
Qtr : quarter;
Max:maximum seasonal electricity consumption(kWh);
Min : minimum seasonal electricity consumption (kWh).

We assume that we can detect if a flat often run their air-conditioner if the Epd is greater than 80 kWh and Min is not less than 300 kWh. Based upon this assumption, we can generate figure 3-C, which shows how the percentage of units that often run air-conditioners varies from 1991 to 1997. Figure 3-C says that in 1997 about 30.7% families in Beijing often run their air-conditioners, 20.4% higher than 1991. Meanwhile, statistical results achieved by other organizations say that the percentage of families owning an air-conditioner is 34% in 1997, and 12% in 1991. This value is slightly higher than the value we present in figure 2-C. The difference can be explained as some families owning air-conditioners might not often run the air-conditioners.

Via questionnaire survey, we can achieve basic information about the tenants' family background, family income, utility expense, and energy consuming appliances. The families are classified as three groups: high income, medium income and low income. Annual family income, annual utility expense and percentage of utility expense over family income are presented in figure 4. In this figure,

FAI :Family Annual Income (10k RMB Yuan)
UAE: Utility Annual Expense(k RMB Yuan)
UP : Utility Percentage over Income

$$UP = UAE / FAI$$

Figure 4 says that FAI and UAE of high income families increased quickly during the last 4 years. Although UP is going down because of the faster increasing speed of FAI, the increment of UAE is still much higher than the other two groups. FAI and UAE of medium income families increased significantly during the last 3 years. Very slow absolute increments of UAE and FAI are found in low income families.

We have performed an annual energy consumption evaluation for the buildings surveyed by means of the software mentioned above. As it is impossible to find out how climatic conditions and tenants' behavior affect energy consumption, we have performed simulation for different climatic data and tenants' behavior. The simulation results show that the two factors significantly influence energy consumption.

CONCLUSION

Increasingly the huge energy demand of China urban housing will adversely influence sustainable development of the country. Energy consumption also causes environmental pollution, a global problem, so it is invaluable and urgent to study how to improve energy efficiency, suitably set up energy policies, accurately predict future energy demand. Our study is conducted for this purpose.

The descriptive statistic of data achieved via social survey and simulation shows

1. From 1991 to 1997, average electricity consumption of a residential unit in Beijing has increased by 70%.

2. In Beijing, annual family income has increased by 50%- 90%, while the number of energy consuming domestic devices has increased by 45%, especially air-conditioners. The percentage of households owning an air-conditioner increased from 8% in 1991 to 34% in 1997.

3. Climate is the most important factor that affects residential building energy consumption. Big differences exist between northern and southern China.

4. Tenants' behavior puts significant impacts on energy efficiency.

5. Energy (especially electricity) demand of China urban housing is increasing rapidly. Residential energy requirement will increase to 0.35 tce per capita. The value in 1988 is 0.14 tce per capita.

NEXT STEP

The study is currently being conducted in the three cities, to be finished in August 1998. Then we plan to

1. Create a number of databases to describe residential buildings energy of these cities;

2. Based on the databases, develop pertinent models to predict residential building energy demand in the next 5 - 10 years.

3. Systematically finalize a series of China Housing Energy Social Survey Questionnaires, and make them publicly accessible over the internet so that partners can easily perform this study in their places. Only in this way, we can actually achieve wider understanding of residential building energy consumption throughout China.

4. Conduct study in other climatic zones, including the extremely cold zone, and the western China cold and dry zone.

The study will continue for at least another three years.

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5 China Energy Saving Law. 1997

6 Jonathan E. Sinton and Jiang Zhenping . *China Energy Databook, 1995.*

Figure 1 Illustration of study methodology

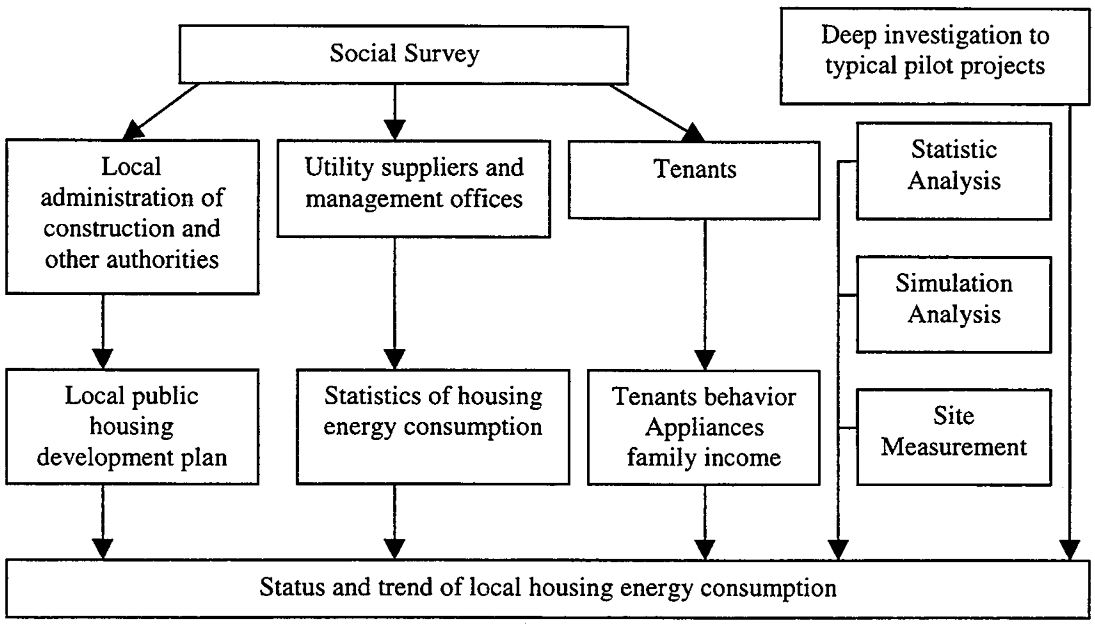

Figure 2-A : Quarter 1 (1, 2, 3) Housing Electricity Consumption in Beijing

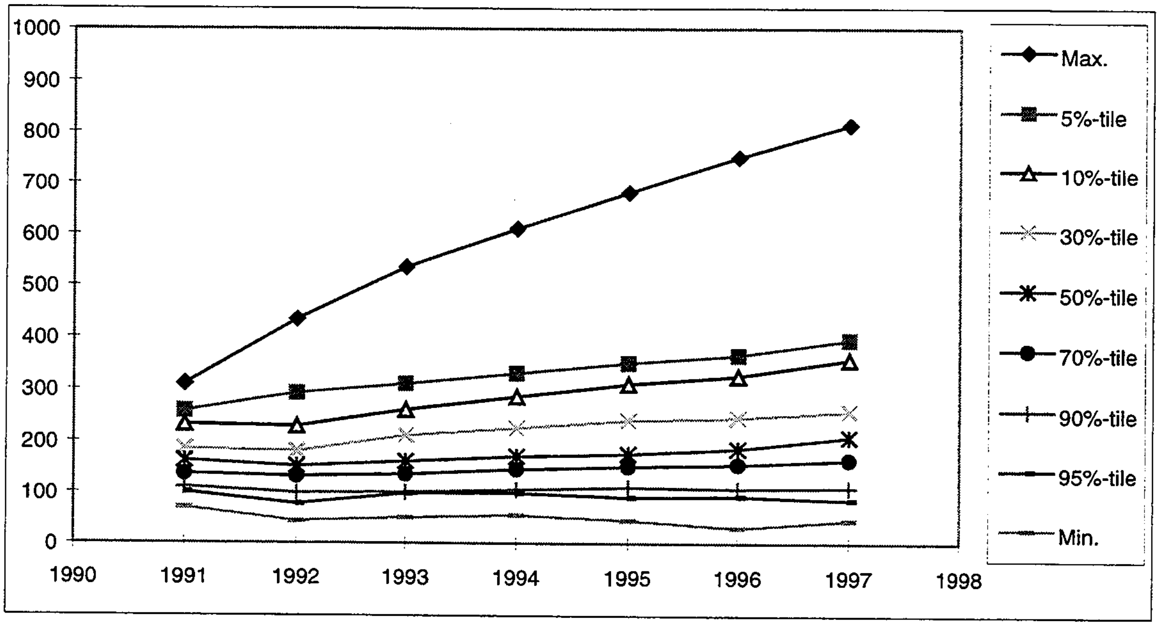

Figure 2- B : Quarter 2 (4, 5, 6) Housing Electricity Consumption in Beijing

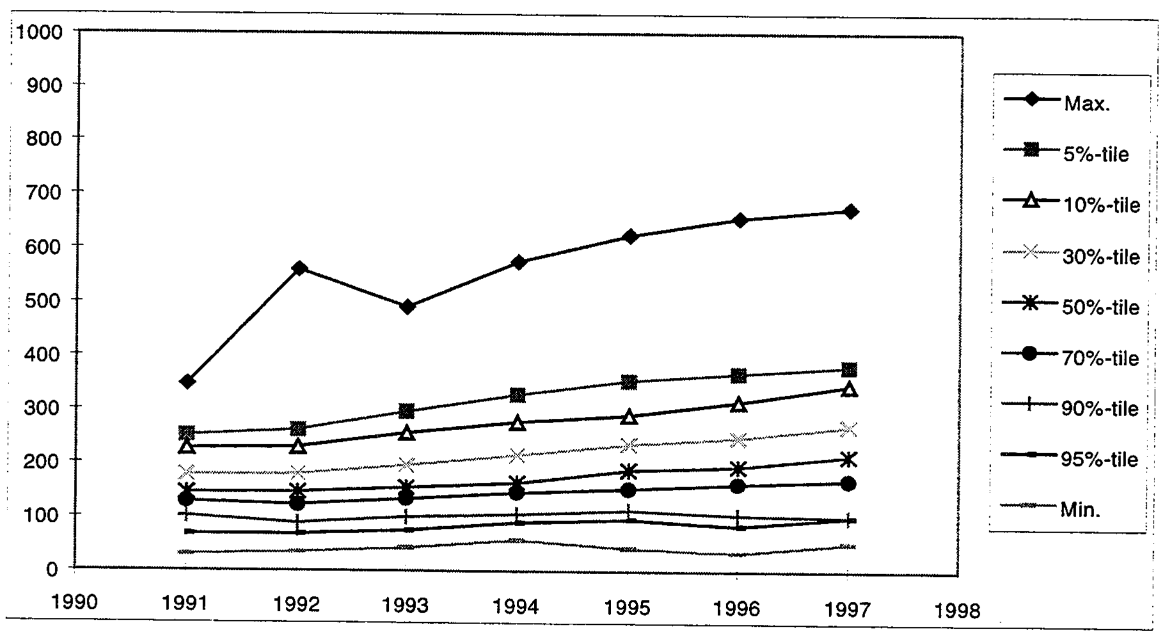

Figure 2-C : Quarter 3 (7, 8, 9) Housing Electricity Consumption in Beijing

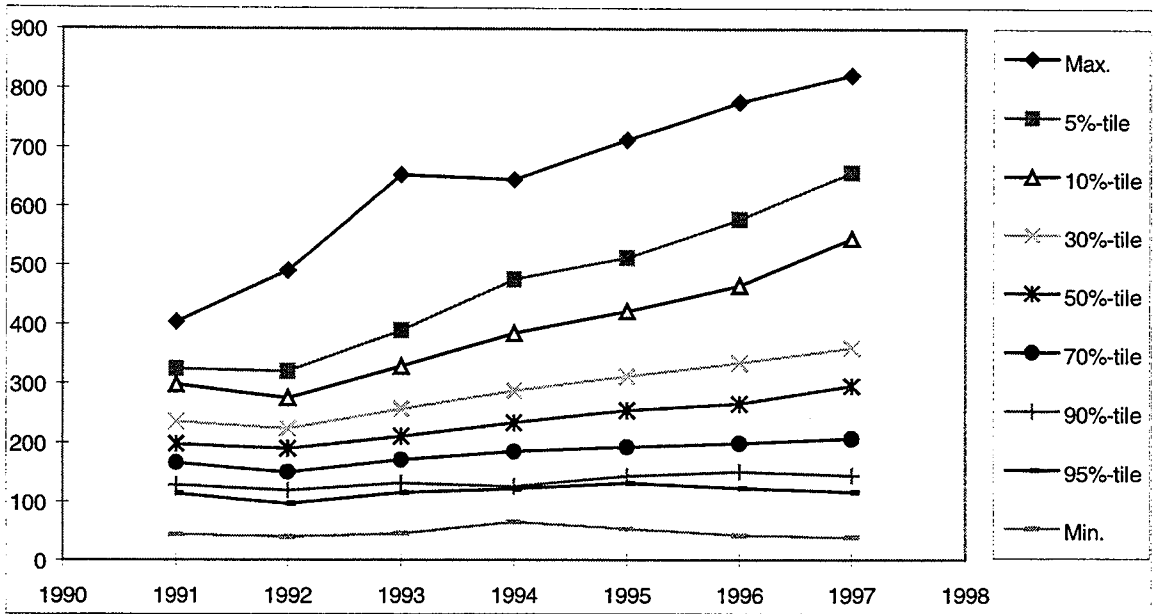

Figure 2-D : Quarter 4 (10, 11, 12) Housing Electricity Consumption in Beijing

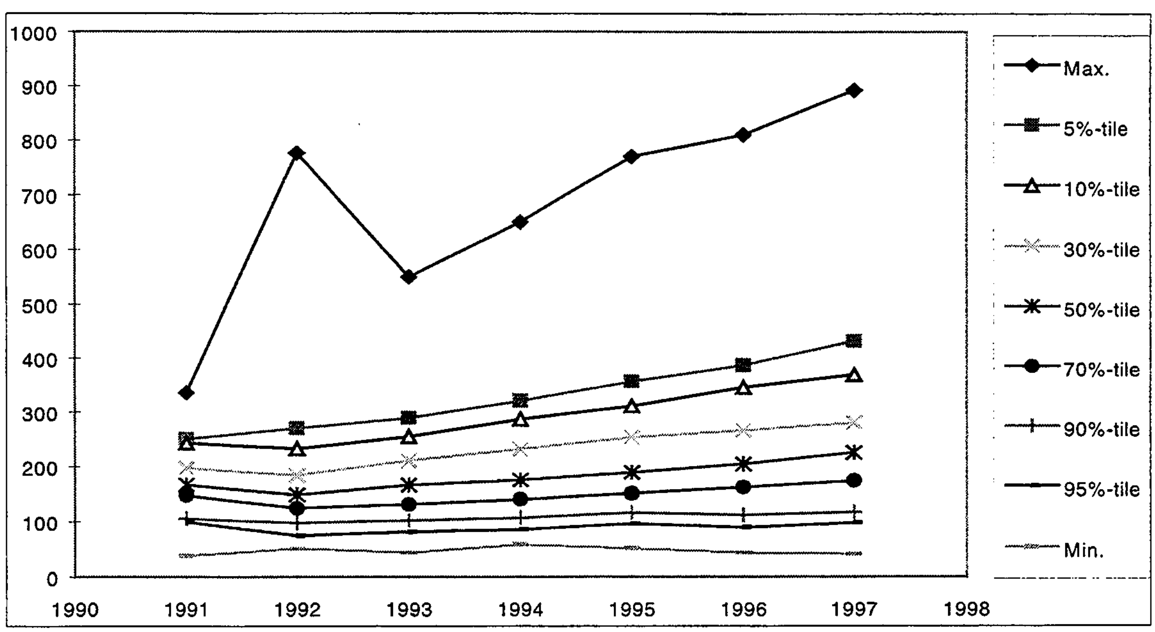

Figure 3-A : Annually Average Seasonal Electricity Consumption in Beijing

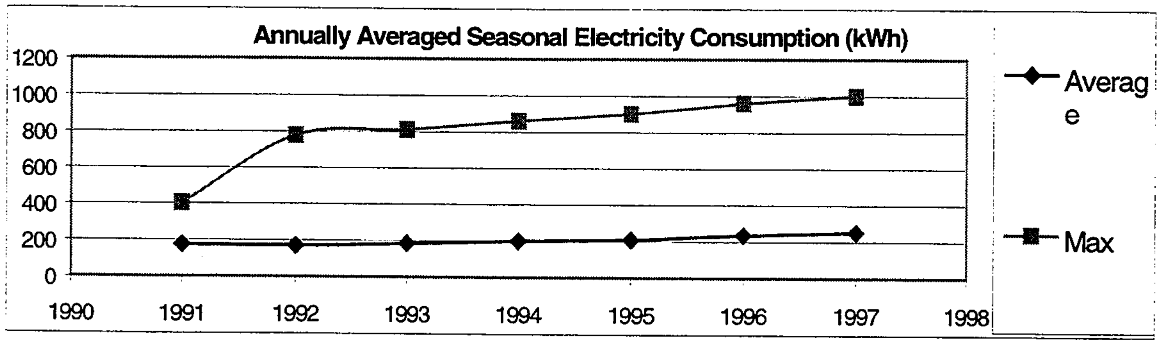

Figure 3-B : Annual Averaged Seasonal Electricity 30%-tile in Beijing

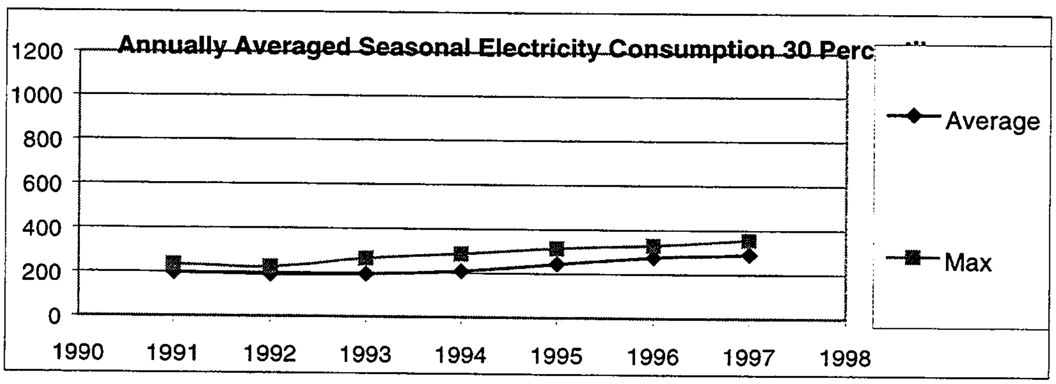

Figure 3-C : Percentage of Units Often Running Air-Conditioner in Beijing

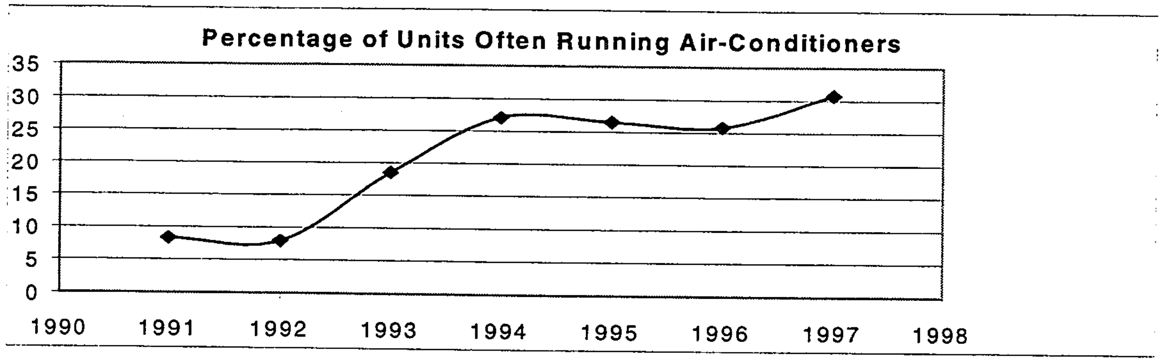

Figure 4-A : High Income Family

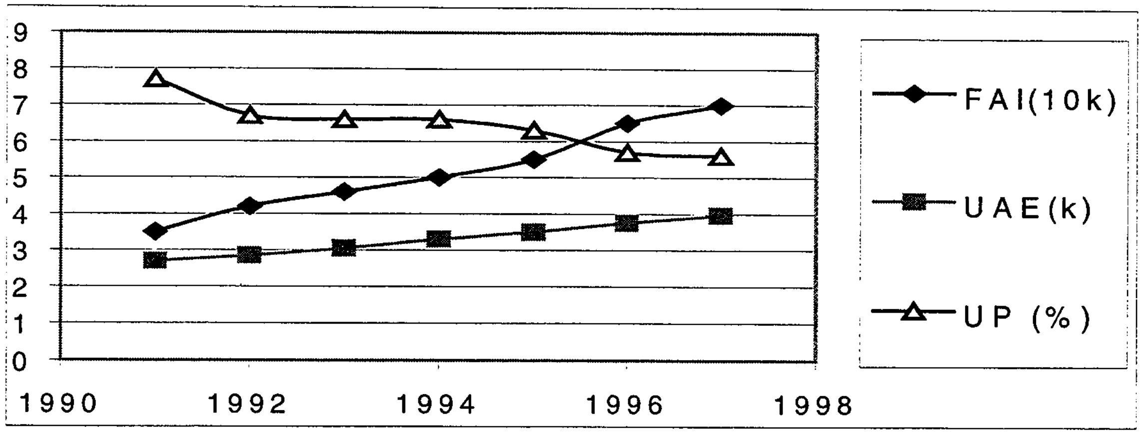

Figure 4-B : Medium Income Family

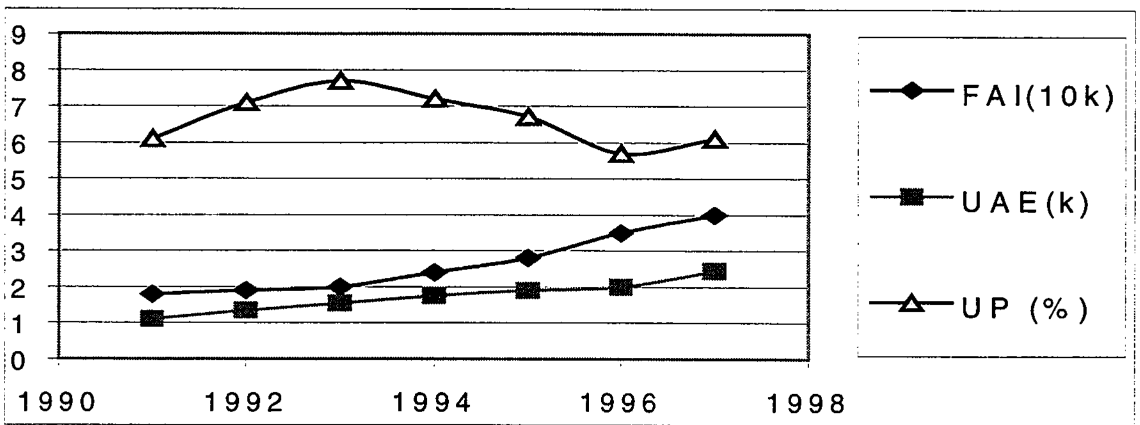

Figure 4-C : Low Income Family