Effects of Improved Consumer Behavior on Energy Conservation in the Urban Residential Sector of Hangzhou, China

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Abstract

Consumer behavior is one of the most important issues with respect to household energy consumption. This paper will evaluate the energy-saving potential of improving consumer behavior on the basis of a field study. In the original survey plan, the monthly electricity use of households in three typical residential buildings in the city of Hangzhou, China, were monitored from April 2007 to July 2008. A total of 124 households in those buildings were selected as the subject households. Half of them were informed of 34 energy-saving measures before July 2008 to teach them how to improve their behavior and control electric appliances in their daily lives. Finally, a questionnaire survey was administered in the beginning of August 2008 to identify the changes in the occupants' behavior. Based on the comparison analyses among the differences in the electricity uses of the 71 remaining valid samples, the conclusions can be drawn that: (1) residential electricity use will increase continually in the near future in China due to improved standards of living and a greater dependency on electric appliances, and (2) more than 10% of household electricity use can be conserved by informing occupants of energy-saving measures to improve their behavior.

Keywords: consumer behavior; electricity use; questionnaire survey; improve; electric appliance

1. Background and Introduction

In recent years, rapid economic growth in the coastal cities of China, such as Hangzhou, has generated higher household income and standards of living. It has also provided incentives to purchase more electric appliances and consume more electricity. Fig.1 clearly shows the increases in the number of the primary electric appliances, annual disposable income, and annual electricity use in the residential sector of the city in recent years (Hangzhou Statistical Yearbook, 2007). The increase in the consumption of residential electricity stems from the use of more electric appliances. This reflects the higher economic status of the householders and their lifestyles (K. Genjo et al., 2005). It is certain that electricity consumption will grow rapidly as consumers buy more appliances and keep the appliances plugged in for more hours each day (A. Meier et al., 2004). The experience of Japan from the 1950s to the 1990s (H. Nakagami, 1996) foreshadows the steadily increasing importance of electricity in modern domestic life in the pursuit of a more comfortable life in China, and that the link between lifestyle and electricity will grow stronger. L. Lopes et al. (2005) considered that energy consumption is closely related to the resident's lifestyle. With rising real income, consumption becomes an act of pleasure beyond satisfying basic needs. Therefore, our changing lifestyles have a dramatic impact on world energy demand (P. Anker-Nilssen, 2003).

Many serious problems are attendant with the increased use of electricity, however, including global warming, the creation of urban heat islands, and environmental pollution and degradation. The most striking of these problems for the local government and the general public of Hangzhou is the electricity blackouts that frequently occur during extremely cold winters or hot summers. These consequently have an adverse impact on economic development and caused inconvenience to the general public in their lives at home. Although the local government has implemented many executive policies and measures for saving energy to guarantee a stable energy supply since 2000, the general public is less aware that the electricity consumed in their daily activities in the home is so closely related to the well-known problems. Therefore,
they do very little to save energy, at least in their own households. Hence, reducing energy demand is an important problem, not only worldwide, but also on a true individual level.

Reduced energy consumption in the residential sector is particularly important because energy demand in this sector is significantly rising, unlike demand in the industrial sector (T. Ueno et al., 2006a). While industry in the industrialized world responded to energy price rises by changing their production processes and becoming more energy efficient, households moved in the opposite direction. Despite many campaigns to reduce energy use over the last 25 years, national energy consumption in all the world's industrialized countries continued to rise instead of fall (H. Herring, 2006). Energy conservation studies were conducted and national energy plans were launched in many countries. Yet, only a small share of theoretically calculated energy conservation potentials was put into practice because the impact of consumer behavior was neglected. Consumer behavior might significantly influence the level of energy demand through the choice of different lifestyles and activities in the home. Simply put, consumer behavior is one of the most important issues with respect to energy consumption in households (R. Haas et al., 1998).

Likewise, there are many ways to reduce energy demand in residential buildings, such as better insulation and the use of more efficient appliances. Another possibility is to reduce energy consumption by providing household members with detailed information on domestic energy consumption (T. Ueno et al., 2006a and 2006b).

In essence, there are three general approaches for reducing energy consumption (and thereby CO₂ emissions) in the residential sector:

1. Replace the existing housing stock with low-energy buildings designed primarily to minimize heating and cooling loads;
2. Develop and achieve widespread replication for low energy domestic equipment (e.g. appliances, lighting and IT); and
3. Promote and achieve "energy-conscious" behavior among end users (G. Wood et al., 2003).
Compared to the first two approaches, which are technical measures and require both time and money, a change of behavioral patterns can improve energy efficiency with little additional investment in infrastructure, and the energy saving effect can become manifest quickly (A. Meier et al., 2004; Editorial, 2006; J. Ouyang et al., 2007).

Most of the relative studies and efforts for saving energy in residential buildings in China focus only on the technical approaches, however. Few researchers realize the energy-saving potential to be derived by improving household lifestyles. A. Meier et al. (2004) believed that the standby energy use is responsible for about 10% of the total electricity use in the urban Chinese homes. This suggests it is possible to avoid unwanted waste and save some electricity if the city residents improve their behavior in their daily lives at home. The results of the authors' other research (J. Ouyang et al., 2007) found that energy-saving consciousness can be improved by corresponding education, and energy consumption can be reduced by offering occupants detailed information on energy-saving measures for their lives at home. Nevertheless, the accurate energy-saving potential to be derived by improving consumer behavior at home has rarely been discussed, due primarily to the lack of sufficient survey data.

Therefore, the purpose of this study is to evaluate accurately the energy-saving potential of improving consumer behavior in domestic life. Section 2 will describe the questionnaire survey. Section 3 will analyze and discuss the results of the survey and evaluate the energy-saving potential to be derived by improving consumer behavior. Finally, Section 4 will summarize the results.

2. Outline of the Questionnaire Survey
2.1 Complexity of household lifestyle

Household characteristics (so-called lifestyle) include household income, the number of members, electric appliances, floor area, rooms, and the occupants’ awareness of and behavior when using electric appliances. In general, different people have distinct histories, attitudes, and socio-cultural demographics (age, sex, education and wealth/income). They also show differences in their physical/mental health, relationships with family/friends, and their amount of free time. All these factors affect their energy-using behavior (G. Wood et al., 2003), so every household has its own characteristics. Therefore, differences in household characteristics will lead to differences in electricity use (K. Genjo et al., 2005). In other words, in addition to consumer behavior, many other variables in the household lifestyle affect household electricity use too.

J. Lam (1998) found that both seasonal and yearly electricity use in the residential sector can be estimated from a statistical perspective based on the household income, household size, electricity price, and cooling degree-days by analyzing the economic and energy data for the 23-year period from 1971 to 1993 in Hong Kong. But it is very difficult to predict the electricity use of some individual households with the same method due to the complexity of the multiple effects of all variables on household electricity use. Therefore, when designing the survey plan, the aforementioned variables should be taken into consideration, and their negative impact on the study results should be minimized if possible. Fortunately, energy-saving education enables the improvement of the occupants’ awareness alone, which means it is possible that behavior can be improved. Other variables cannot be improved, however, so the paper’s objective can be accomplished by comparing the difference in electricity use before and after energy-saving education in theory.

2.2 Research subject

There were more than 12 million households in Hangzhou as of the end of 2007. Certainly, the differences in household characteristics lead to significant differences in electricity use. In many similar studies the subject households were selected randomly from a large area (one country, one district, or one city). Considering that the households selected on a smaller scale have less divergence in such factors as income and social level, as well as the limited types of household floor areas, it is advisable for the subject households of this study to be selected from three typical residential buildings in Hangzhou. Their distribution and comparative information regarding the households are shown in Table 1.

In the original survey plan, half of the 124 households were selected and informed of energy-saving tips in June 2008. It was recommended that they try to control their electric appliance use to conform to the tips for domestic life in July 2008. Then the subject households were classified into 16 groups (see Table 2.) by building, floor area and whether or not they were informed of energy-saving tips before July 2008. The households belonging to Groups A1Y, A2Y, A3Y, B1Y, B2Y, C1Y, C2Y, and C3Y were provided with the questionnaire before July 2008. In contrast, the households belonging to Group A1N, A2N, A3N,
The above efforts should minimize to some extent the negative influence of household income, social level, floor area and outdoor weather.

2.3 Questionnaire

The monthly electricity use of the subject households was first monitored from March 2007 to February 2008. Fig. 2 shows that the electricity use in July 2007 was the highest during the period of the hottest mean air temperature in the 12 months of the year. J. Ouyang et al. (2008) analyzed the trends for changes in monthly electricity use during the 12 months of the year for residential buildings with Hangzhou's local weather. Therefore, the most significant step might be trying to reduce electricity use in July 2008 by improving consumer behavior. The monthly electricity use of the subject households continued to be recorded until July 2008.

To effectively promote energy-conscious behavior, it is very important for energy users to have accurate information on how to act. The energy-saving measures for how to control the main electric appliances in their domestic life are listed in detail in the survey questionnaire, as well as such basic information as household size and the primary electric appliances. In the survey, the residents were required to evaluate their own behavior for implementing the energy-saving measures in their daily lives at home in July 2007 and in July 2008, and the importance of the measures for reducing electricity use, according to two 5-grade scales (1-did thoroughly; 2-did; 3-neutral; 4-did not; 5-did not do at all; and 1-very important; 2-important; 3-neutral; 4-unimportant; 5-very unimportant). If some households did not have a particular type of electric appliance, the corresponding behavior grade(s) of the measure(s) for that type were recorded as zero. The behavior grades for all measures of the households belonging to Groups A1Y, A2Y, A3Y, B1Y, B2Y, C1Y, C2Y, and C3Y, respectively in July 2007 and in July 2008 required two answers. We confirmed that the behavior grades for the households belonging to Groups A1N, A2N, A3N, B1N, B2N, C1N, C2N, and C3N in July 2007 were considered the same as those in July 2008.

2.3.1 Air-conditioning

(1) Set temperature as high as possible (Preference temperature: above 26°C)
(2) Reduce usage time
(3) More members stay together in fewer rooms and turn on fewer air-conditioning units if possible
(4) Clean filter frequently
(5) Hang curtains or window blinds to prevent cold air from leaking out and sunshine from entering room

| Building | Group | Floor area (m²) | Households |
|----------|-------|----------------|------------|
| A        | A1Y   | 51.11          | 5          |
|          | A1N   | 5             |            |
|          | A2Y   | 42.94          | 5          |
|          | A2N   | 5             |            |
|          | A3Y   | 63.94          | 7          |
|          | A3N   | 7             |            |
|          | B1Y   | 102.13         | 7          |
|          | B1N   | 7             |            |
|          | B2Y   | 74.45          | 7          |
|          | B2N   | 7             |            |
|          | C1Y   | 114.04         | 11         |
|          | C1N   | 11            |            |
|          | C2Y   | 92.95          | 11         |
|          | C2N   | 11            |            |
|          | C3Y   | 89.41          | 11         |
|          | C3N   | 11            |            |
| Total    |       | 124           |            |

B1N, B2N, C1N, C2N, and C3N were not. Because the outdoor weather would not be identical in the two months in different years, the electricity use in July 2007 and in July 2008 will be compared among the groups, enabling the evaluation of the energy-saving effect from improving consumer behavior.

Fig.2. Mean Monthly Electricity Use in Subject Households and Mean Air Temperature of Hangzhou during 12 Months of One Year
(6) Reduce the amount of time and frequency doors and windows are opened
(7) Turn off a few minutes before going out

2.3.2 Refrigerator
(8) Adjust the temperature setting each season
(9) Store food after it has completely cooled naturally.
(10) Reduce time door is open
(11) Reduce the frequency of opening the door
(12) Do not store too much food or other items
(13) Do not place its cooling unit too close to wall or other objects

2.3.3 TV
(14) Reduce usage time
(15) Turn off completely using the main switch, not by remote control
(16) Reduce the sound level
(17) Reduce the brightness level

2.3.4 Computer
(18) Reduce usage time
(19) Use the electricity-saving mode if possible
(20) Turn off the computer’s main unit and screen and avoid using the stand-by function mode if it will not be in use for a long time

2.3.5 Electric rice cooker
(21) Do not use the warming mode, or use it less frequently in a rational manner.

2.3.6 Lighting
(22) Eliminate needless lighting
(23) Reduce time lights are on.
(24) More members should gather in fewer rooms and turn on fewer lights if possible

2.3.7 Water heater
(25) Turn off if hot water will not be needed for a long time
(26) Reduce usage time for hot water if possible, such as in showers
(27) Reduce hot water temperature if possible
(28) Do not use hot water if not necessary

2.3.8 Washing machine
(29) Wash more clothes in one load if possible
(30) Choose fast-washing mode if clothes are not too dirty

2.3.9 Microwave oven
(31) Thaw frozen foods naturally if possible

2.3.10 Fans
(32) Adjust the fan speed in a rational manner.
(33) Use the timer in a rational manner.

2.3.11 All appliances
(34) Unplug when not in use

3. Results and Analysis
We encountered several difficulties when conducting the survey. Some households worried that private information would be divulged and were reluctant to cooperate with us due to safety considerations. Also, the long-term records of electricity use revealed that a few households were only transient tenants who did not live in one of the three subject buildings throughout the entire survey period. Finally, there were only 71 households that qualified as remaining valid samples: 18 in Building A, 20 in Building B, and 33 in Building C. The survey results regarding electricity use and consumer behavior are shown in Tables 3, 4, and 5.

There was a great variance in electricity use among the households, even those with the same floor area. These large differences reveal that household characteristics might be the factor that most determines household electricity use. On the whole, the households with more members, income, floor area, and electric appliances should consume more electricity in the same time period. Considering the main purpose of the paper, the relationship between changes in consumer behavior and electricity use is the key issue in the following discussion.

Table 3. Results of Electricity Use and Consumer Behavior in Building A

| Group No. | Group | Household No. | Electricity use kWh/household/month July 2007 | July 2008 | Consumer behavior |
|-----------|-------|---------------|-----------------------------------------------|----------|-------------------|
| A1Y  | 1  | 237.1         | 198.5                                         | 30  | 16                |
| A1N  | 4  | 117.5         | 110.6                                         | 60 | 8                 |
| A2N  | 10 | 44.4          | 59.3                                          | 35 | 3                 |
| B1N  | 8  | 386.9         | 558.7                                         | 94 | 6                 |
| B2Y  | 12 | 529.8         | 429.9                                         | 106 | 8                 |

Table 4. Results of Electricity Use and Consumer Behavior in Building B

| Group No. | Group | Household No. | Electricity use kWh/household/month July 2007 | July 2008 | Consumer behavior |
|-----------|-------|---------------|-----------------------------------------------|----------|-------------------|
| A3Y  | 13  | 1085.7        | 941.3                                         | 102 | 87                |
| A3N  | 16  | 227.3         | 314.0                                         | 76 | 6                 |
| B1N  | 8  | 386.9         | 558.7                                         | 94 | 6                 |
| B2Y  | 12  | 529.8         | 429.9                                         | 106 | 8                 |

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The grades for all consumer behavior in every household were recorded by adding the scores of the above-mentioned 34 energy-saving measures. Because of the multiple effects of many variables on electricity use, such as income, household size, and the number of appliances, the relationship between electricity use and consumer behavior cannot be determined using a large-scale comparison. But the following smaller-scale comparisons will reveal the links between them.

The first comparison of the electricity use of the households belonging to Groups A2N, A3N, B1N, B2N, C1N, C2N, and C3N between July 2007 and July 2008 suggests that residential electricity use will continually rise over the next few years because growing numbers of households will use their rising disposable income to gradually purchase more electric appliances and improve their standard of living. The three households (No. 4-6) of the A1N group had a different result, but the heads of the three households confessed they had copied the energy-saving measures from their neighbors in July 2008. This comparison will provide a good reference to estimate the impact of improving consumer behavior on reducing electricity use.

The second comparison of the grades of consumer behavior for the households belonging to Groups A1Y, A2Y, A3Y, B1Y, B2Y, C1Y, C2Y, and C3Y between July 2007 and July 2008 indicates that providing the 34 energy-saving measures can indeed improve consumer behavior.

The third comparison of electricity use in the households belonging to Groups A1Y, A2Y, A3Y, B1Y, B2Y, C1Y, C2Y, and C3Y between July 2007 and July 2008 shows that electricity use can be reduced by informing the households of energy-saving measures to improve their behavior.

One important conclusion that can be drawn from the analysis of the three comparisons is that on average, more than 10% of household electricity use had been reduced in July 2008 in those households (belonging to Groups A1Y, A2Y, A3Y, B1Y, B2Y, C1Y, C2Y, and C3Y) by informing them of energy-saving measures to improve their domestic behavior.

In addition, the grades for the importance of the energy-saving measures indicate that the power and the time of use of the electric appliances are the most important factors for their evaluation. Measures 1, 3, and 25 are the most important and feasible measures. Of course, if a household wants to maximize its energy-saving potential by improving its behavior, no feasible measure should be neglected.

A comparison with the performance of the technical measures (J. Ouyang et al., 2008) shows that the effect on reducing electricity use by improving consumer behavior is quite pronounced, as well as economical and timesaving.

4. Conclusion

The results of the paper highlight the impact of improving consumer behavior in daily domestic life for reducing electricity use in July 2008.

Based on a comparison analysis for the differences in electricity use and the grades of consumer behavior for the remaining 71 households, two important conclusions can be drawn:

(1) Residential electricity use will continually increase in the near future in China due to the improvement in the people's standard of living and a greater dependency on electric appliances. The link between electricity use and lifestyle in Hangzhou will grow stronger.

(2) Improving consumer behavior at home by informing consumers of energy-saving measures can save more than 10% household electricity use on the average.

These findings suggest that the domestic activities of occupants deserve further attention and optimization, and focus should be shifted in part from high-technology measures to the seemingly low-technology measures for ordinary domestic life.

Table 5. Results of Electricity Use and Consumer Behavior in Building C

| Group No. | Household No. | Electricity use kWh/month | Consumer behavior |
|-----------|---------------|---------------------------|-------------------|
|           |               | July 2007 | July 2008 | July 2007 | July 2008 |
| A1Y       | 1             | 526.0     | 463.0     | 97        | 74        |
| A2Y       | 2             | 304.0     | 267.0     | 82        | 73        |
|           | 3             | 1145.0    | 960.0     | 102       | 80        |
| A3Y       | 4             | 364.0     | 294.0     | 77        | 63        |
| B1Y       | 5             | 589.0     | 500.0     | 97        | 73        |
| B2Y       | 6             | 486.0     | 390.0     | 98        | 75        |
|           | 7             | 393.0     | 350.0     | 94        | 72        |
| C1Y       | 8             | 474.0     | 381.0     | 74        | 56        |
| C2Y       | 9             | 568.0     | 458.0     | 94        | 76        |
|           | 10            | 416.0     | 341.0     | 93        | 67        |
| C3Y       | 11            | 674.0     | 869.0     | 92        |           |
|           | 12            | 438.0     | 690.0     | 100       |           |
|           | 13            | 647.0     | 724.0     | 92        |           |
|           | 14            | 370.0     | 349.0     | 78        | 64        |
|           | 15            | 725.0     | 656.0     | 99        | 87        |
|           | 16            | 247.0     | 215.0     | 78        | 61        |
|           | 17            | 344.0     | 287.0     | 85        | 70        |
|           | 18            | 657.0     | 552.0     | 98        | 83        |
|           | 19            | 602.0     | 520.0     | 94        | 80        |
|           | 20            | 392.0     | 329.0     | 86        | 73        |
|           | 21            | 1023.0    | 874.0     | 101       | 82        |
|           | 22            | 436.0     | 436.0     | 96        |           |
|           | 23            | 305.0     | 365.0     | 81        |           |
|           | 24            | 631.0     | 657.0     | 97        |           |
|           | 25            | 773.0     | 691.0     | 100       | 82        |
|           | 26            | 421.0     | 366.0     | 76        | 60        |
|           | 27            | 296.0     | 246.0     | 79        | 65        |
|           | 28            | 559.0     | 470.0     | 81        | 64        |
|           | 29            | 356.0     | 295.0     | 79        | 59        |
|           | 30            | 254.0     | 219.0     | 80        | 68        |
|           | 31            | 771.0     | 689.0     | 86        | 65        |
|           | 32            | 539.0     | 594.0     | 105       |           |
|           | 33            | 524.0     | 576.0     | 95        |           |
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