

# STUDY ON DOMESTIC OCCUPANT ENERGY CONSUMPTION BEHAVIOR AND INCOME LEVEL IN BEIJING, CHINA

MUZHOU WANG, NIANXIONG LIU

AUTHOR AFFILIATION  
TSINGHUA UNIVERSITY

## 1. INTRODUCTION

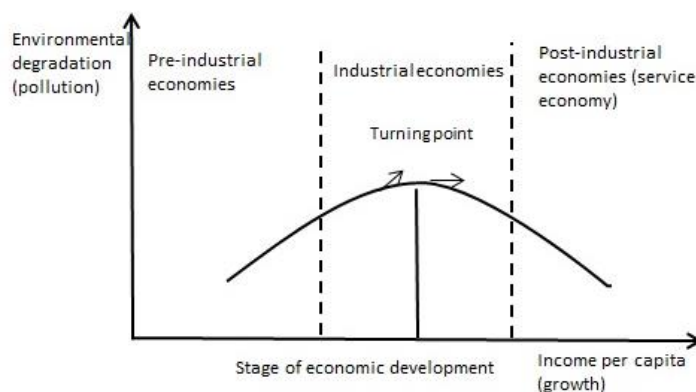


Figure.1 Environmental Kuznet curve

(Source: Panayotou, T. 1993. Working Paper WP238, International Labor Office.)

Environmental Kuznet curve (also known as EKC, shown in Fig.1) illustrates the dynamic relationship between pollution and economic development. Afterwards, the connotation of EKC was expanded to represent the correlation between energy consumption and income level of habitants. But according to actual worldwide research on this topic, such as Azlina in Malaysia<sup>[1]</sup>, Cayla in France<sup>[2]</sup>, Druckman in the UK<sup>[3]</sup>, Ekholm in India<sup>[4]</sup>, Rosas in Mexico<sup>[5]</sup>, Zheng Xinye in China<sup>[6]</sup> and so on, EKC was not always well validated. This research aims to demonstrate how energy consumption behavior is influenced by different household's income and whether the EKC is validated by convincing data or not.

The concept of energy consumption behavior was first proposed by western socialists. The basic theoretical framework of research on human behavior in residential buildings had been developed in 1992 by Lutzenhiser L<sup>[1]</sup> and Hitchcock G<sup>[2]</sup>. Since then many researchers and institutions have been carrying out detailed research in this particular area. For example, AIJ (Architecture Institution of Japan) investigated 80 families comprehensively, using questionnaires and field tests in Japan 2002-2006. As a result, large amount of reliable data was accumulated.<sup>[3]</sup> In terms of China, in 2012 Li Zhe from Tsinghua University systematically studied how behavior influenced energy consumption in the regions with warm summer and cold winter in his master's thesis *Investigation and analysis of the relationship between residential energy use behavior and energy consumption in China*. The data obtained from the field investigation and computer simulation which he had carried out in this thesis concluded that the energy consumption have a strong correlation to the household income level in certain regions<sup>[4]</sup>. More specifically, Huo Yan, in his essay *Low Carbon Lifestyle and Its Determinants: An Empirical Analysis Based on Survey of / Household Energy Consumption and Community Environment in Beijing*, had carried out deep study, exploring different factors which could influent

the household's energy consumption. And the household income level can be seen as one of the factors which has an important effect on daily energy consumption, shown in Fig.2.<sup>[5]</sup>

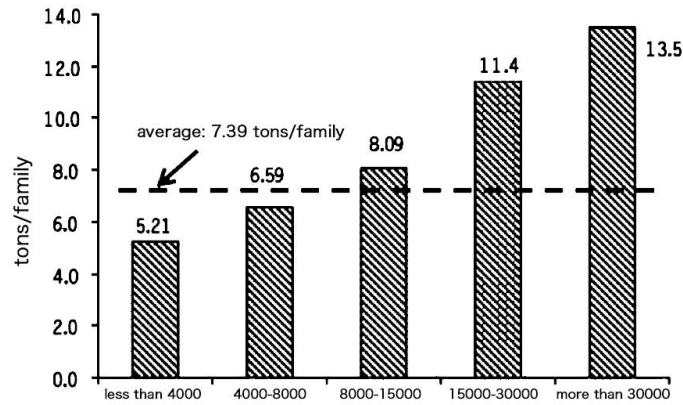


Figure 2 Correlation between carbon emission and income level  
(Source: Li Zhe's master's thesis)

Recently, with the rapid development of urbanization process and increase of income level of inhabitants, new characteristics and challenges arise. Also, the previous research focused more on quantized index like energy consumption, indoor thermal environment, carbon emission and so on. Income level is mentioned, if mentioned, as one of the contributing factors. But there is little research on the actual behavior with strong flexibility, which influences energy consumption directly and is influenced by income level remarkably.

According to the problems stated above, we conduct this investigation in order to elucidate the correlation between energy consumption behavior and income level of urban habitants in Beijing. The results and conclusions of this research provide significant database and theoretical foundation to ecological design strategy of residential buildings and promotion of energy saving projects.

## 2. OUTLINE OF INVESTIGATION AND BASIC INFORMATION

### 2.1 Outline of the Field Investigation and Analysis

Field investigation is conducted as main method in this study. Carefully designed questionnaires which contained more than 60 questions were used to collect essential data regarding people daily routine and living habits which are closely correlated to energy consumption. The questionnaires divided into six categories, focusing at different aspects such as heating in winter, cooling in summer, washing and shower, transportation behavior, energy saving renovation and energy consumption. 119 sample families were selected to participate in this research. The results obtained from the questionnaires had been analyzed and filtered, the number of effective questionnaires was narrowed down to 84.

On each aspect of the six topics mentioned above, quantized energy consumption behavior was conducted corresponding with income level. At last, energy consumption including electricity, gas and water have been analyzed as supporting evidence to review the characteristics of correlation between energy consumption behavior and income level.

### 2.2 Basic Information of Samples

## CONFERENCE: HOUSING – A CRITICAL PERSPECTIVE

Architecture\_MPS; Liverpool University; Liverpool John Moores University  
 Liverpool: 08—09 April, 2015

119 families have been selected and contacted within the urban area in Beijing furthermore to ensure data obtained from the questionnaires are reliable and less biased, the survey have been carried out across different residential districts within Beijing. And through analyzing these questionnaires, the results show that 84 families out of 119 are effective and taken into consideration in further analysis and study. Fig.3-6 shows some basic information of the 84 selected samples of families including occupation, income level, family sizes and education level.

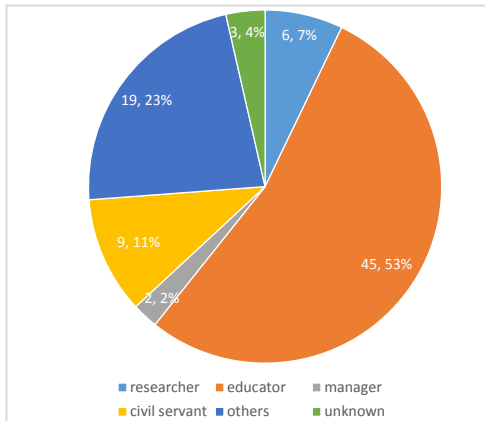


Figure 3. Occupation proportion

(Source: drawn by author)

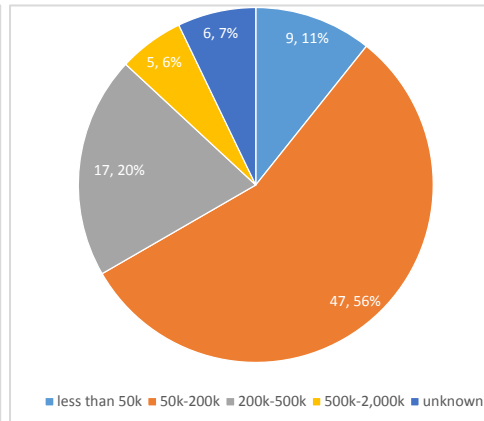


Figure 4. Income level proportion

(Source: drawn by author)

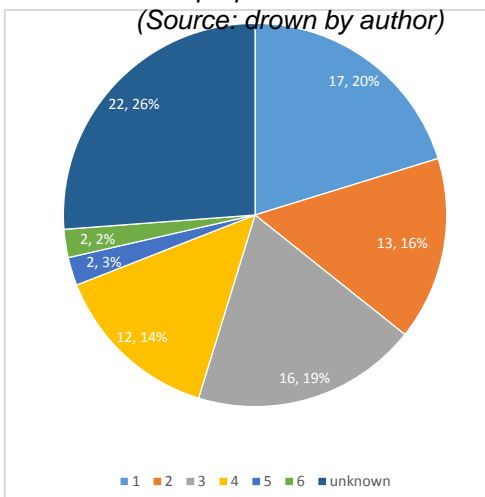


Figure 5. Family size proportion

(Source: drawn by author)

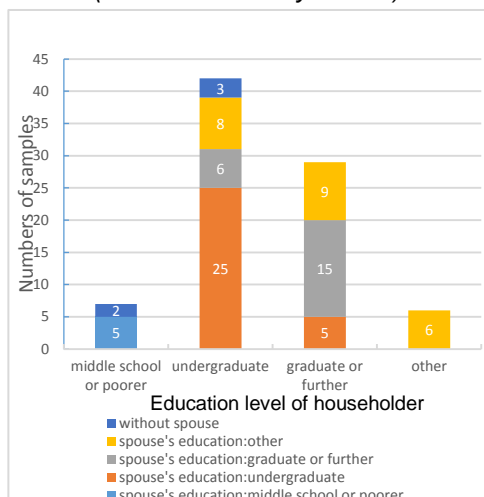


Figure 6. Education level

(Source: drawn by author)

In terms of occupation (see Fig.3), 53% selected samples work in education industry and others are researchers, managers, civil servants and so on. Income level of samples (see Fig.4) is following the normal distribution that groups with income at middle class make up a high proportion of 56%. According to the results (see Fig.5), proportion of families with one to four members is relatively in a balance and each takes up 14% to 20%. Families with five or more members are rare. And the other 26% families skip the question for privacy reasons. Education level of householders and their spouses (see Fig.6) is also following normal distribution. Numbers of householders with undergraduate degrees is 42, taking up more than 50%. Among the undergraduate householders, those whose spouses also accepted undergraduate education take the largest proportion.

3. ANALYSIS AND RESULTS

Among all 69 questions in the questionnaires, 20 questions which directly influence the daily energy consumption are classified into seven main categories and analyzed. Results are as follows.

3.1 Heating in Winter

Central heating system is utilized as main heating source in winter time by 72.6% (61 out of 84) selected families. As shown in Fig.7, in the group of “less than 50k” only, more families use individual heating system. Also, the heating expenditure of this group is slightly higher than the group with yearly income of 50k-200k, except for which, the higher the income of families is, the more money they spend on heating (Fig.8). On the contrary, Fig.9 indicates that there is a negative correlation between additional heating days and income level. Families with yearly income less than 50k need additional heating for 134 days, which is 4.74 times the families 500k to 2000k. The reason is that dwellings of families with higher income always perform better in thermal insulation and heating system and are able to keep the indoor thermal environment comfortable without additional heating.

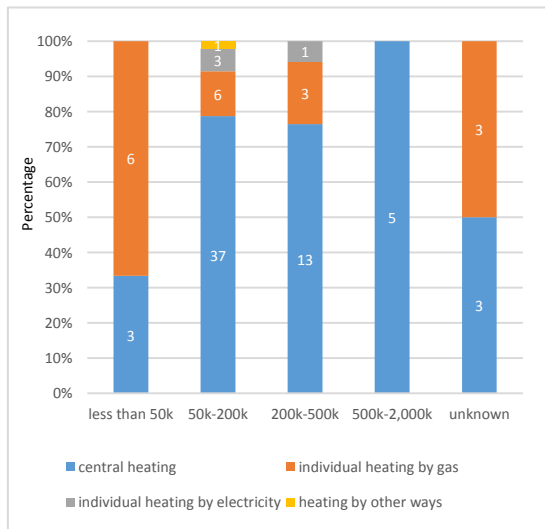


Figure 7. heating pattern in winter  
 (Source: drawn by author)

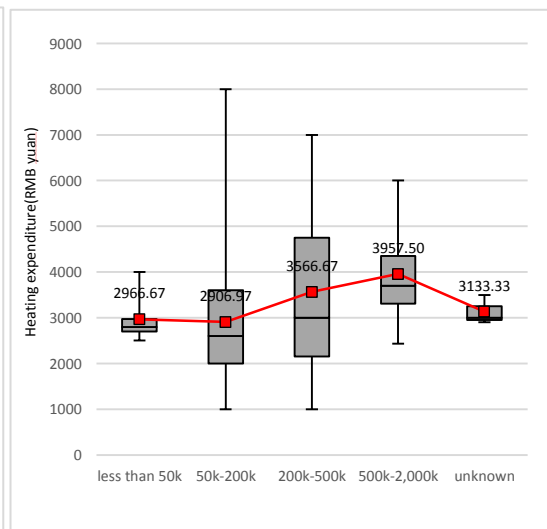


Figure 8. heating expenditure in winter  
 (Source: drawn by author)

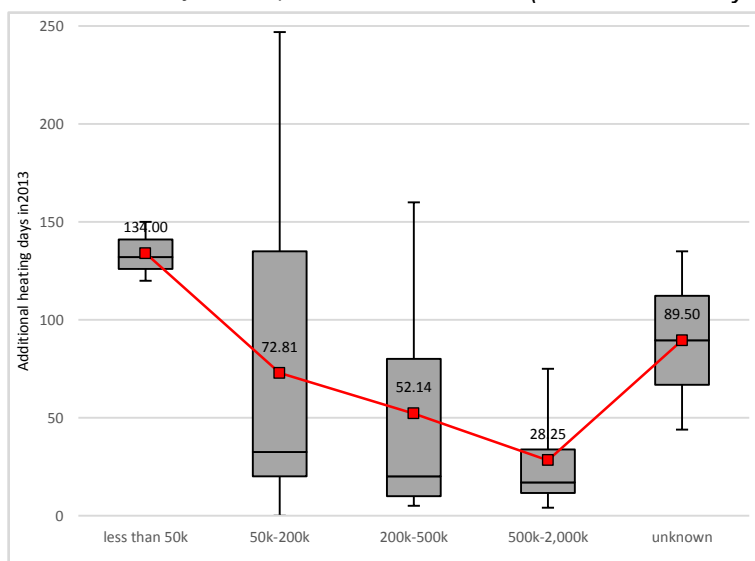


Figure 9. Additional heating days (Source: drawn by author)

### 3.2 Cooling in Summer

Fig.10 and 11 show the habits of using air-conditioner and specific operating hours per week. Based on the four presupposed using pattern - 24 hours on, on in daytime and off at night, off after cool enough and others, the answers given by the samples does not reveal any assured relation between how they like to use air-conditioner and their income level. Case is the same on operating hours. This phenomenon indicates that the using of air-conditioner is not directly influenced by the income level, but probably their concept of health and other elements.

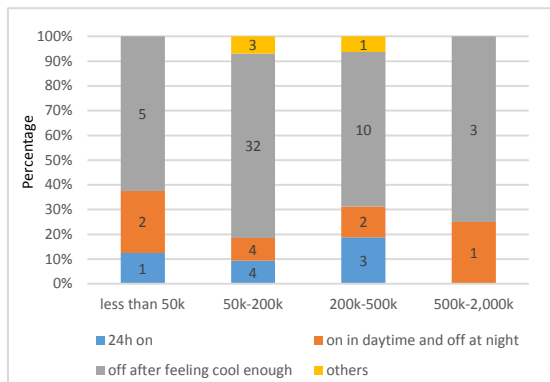


Fig. 10 using of air-conditioner  
 (Source: drawn by author)

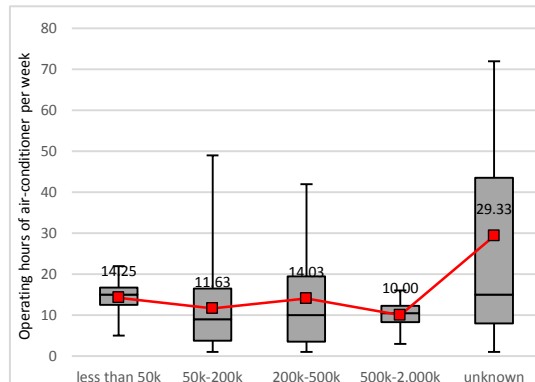


Fig. 11 operating hours of air-conditioner  
 (Source: drawn by author)

### 3.3 Washing and shower

Fig.12 and 13 shows the frequency of washing clothes and time spent on taking showers per week, which are the main consumption of water in daily life. Frequency of washing clothes has limited relevance with the families' income level according to Fig.12. Families with the income of "less than 50k" and "200k to 500k" wash clothes at a higher frequency of about 3.5 times per week than "50k to 200k" and "500k to 2000k" at about 3 times per week. Clear correlation between minutes of taking showers and income level, however, can be illustrated in Fig.13. Along with the income getting higher, the time of taking showers presents a "U"-like curve. The group of "less than 50k" spends 160 minutes on shower on average per week, 21.21 minutes more than the "50k-200k" group. The "500k-2000k" group spends the longest time of 337 minutes per week among all the groups. The time of "200k-500k" group falls between the "50k-200k" group and "500k-2000k" group. It can be concluded that families with higher income spend more time and energy on self-cleaning.

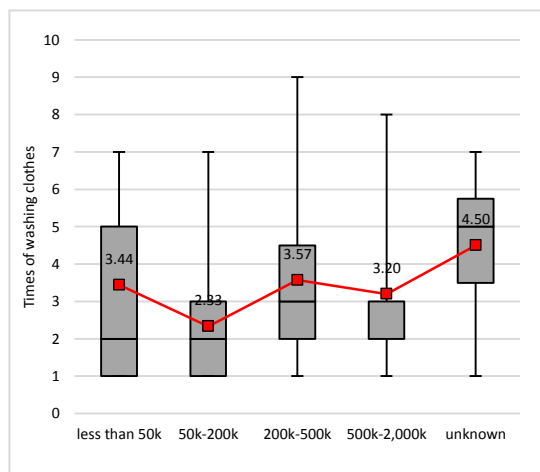


Figure 12. frequency of washing clothes

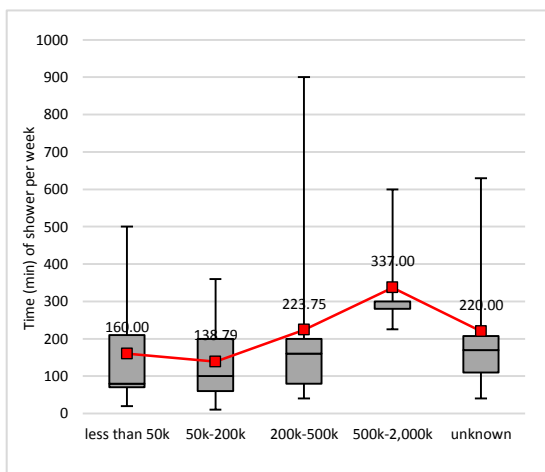


Figure 13. time of shower  
 (Source: drawn by author)

### 3.4 Transportation Behavior

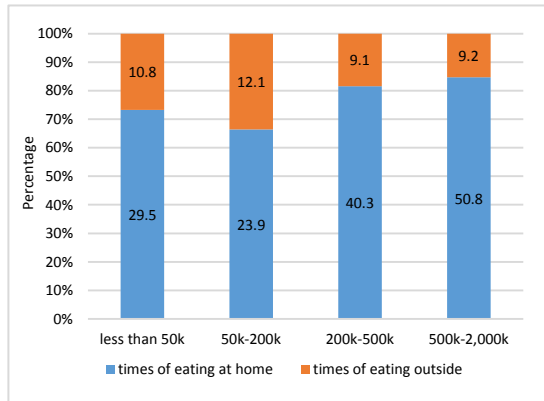


Figure 14 weekly percentage of dining out (Source: drawn by author)

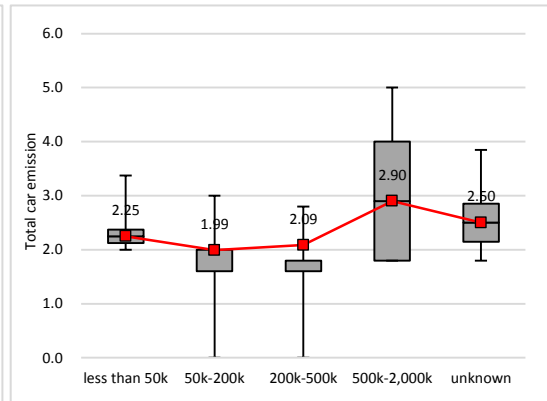


Fig. 15 total car emission (Source: drawn by author)

Fig.14 shows the relationship between average percentage of frequency of cooking at home or having dinner outside and income level, which follows a “U”-like trend. Groups of “50-200k” eat outside at a highest frequency of more than 12 times per week. The percentage of cooking at home of “200k-500k” group and “500k-2000k” group are both over 80%. Car emission, although it’s not taken account in energy consumption at home, composes a large part of the total energy consumption and carbon emission of a family. Fig.15 shows how total car emission changes with different income level. The “U”-like curve is once again presented clearly. Except for “less than 50k” group’s exceeding “50k-200k” group, car emission goes up with the income level increasing. For the high income group of “500k-2000k”, the total car emission is roughly 50% more than other groups, which means an obvious higher gas consumption and carbon emission.

## CONFERENCE: HOUSING – A CRITICAL PERSPECTIVE

Architecture\_MPS; Liverpool University; Liverpool John Moores University  
 Liverpool: 08—09 April, 2015

### 3.5 Energy saving renovation

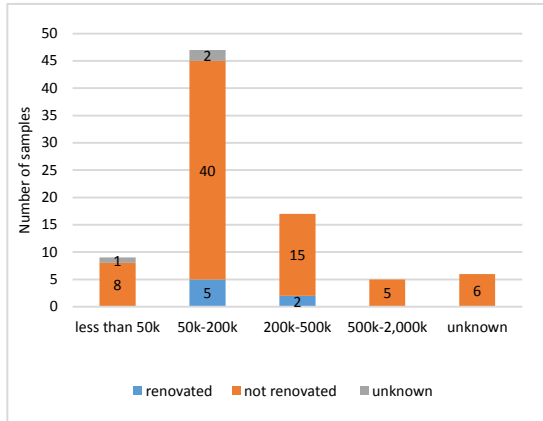


Fig. 16 renovation of building envelop  
 (Source: drawn by author)

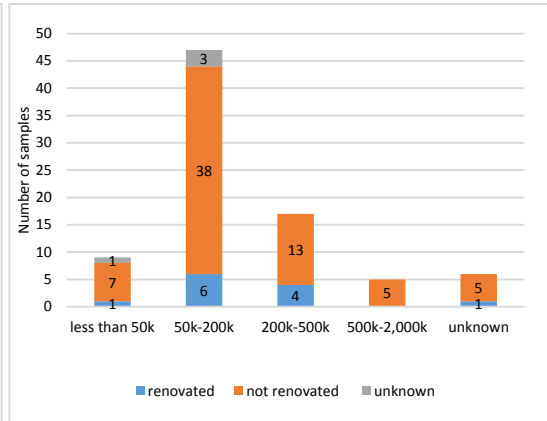


Fig. 17 renovation of pipeline  
 (Source: drawn by author)

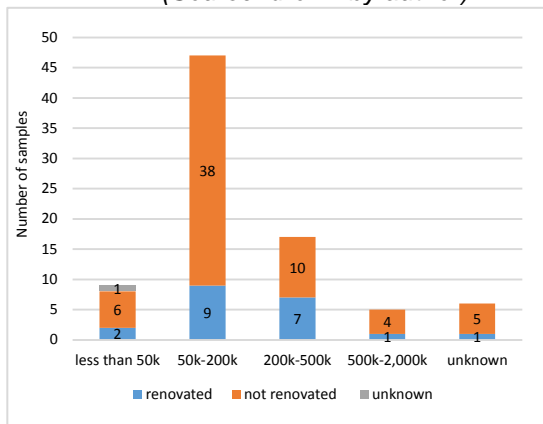


Fig. 18 renovation of doors and windows  
 (Source: drawn by author)

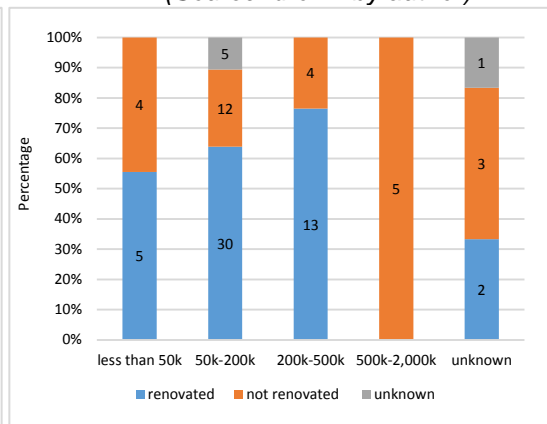


Fig. 19 renovation of balcony  
 (Source: drawn by author)

In terms of energy saving renovation, including building envelop, pipelines, windows and doors, and balcony, the results are shown in Fig.16-19. Only a few families renovated the building envelop, pipeline, windows and doors to promote the thermal performance of their dwellings and the correlation between renovation and income level turns out to be inconspicuous. On the contrary, 59.52% families choose to renovate their balcony and the higher their income is, the more percentage of families conduct the renovation (group with the yearly income between 500k and 2000k could be ignored because of the little number of samples).

**3.6 Energy consumption**

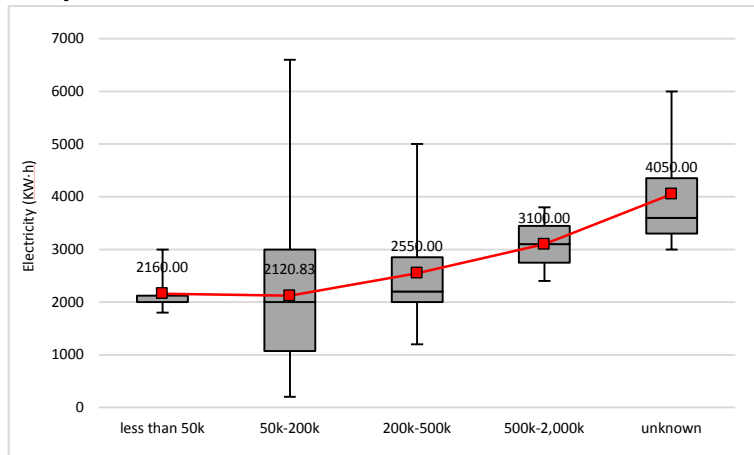


Figure 20. electricity consumption (Source: drawn by author)

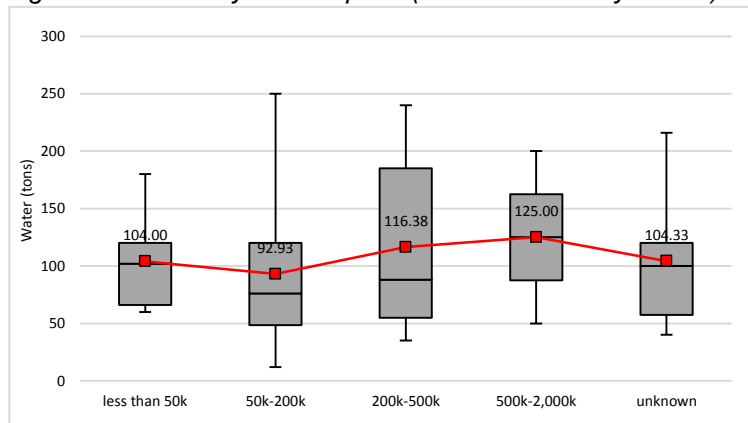


Figure 21. water consumption (Source: drawn by author)

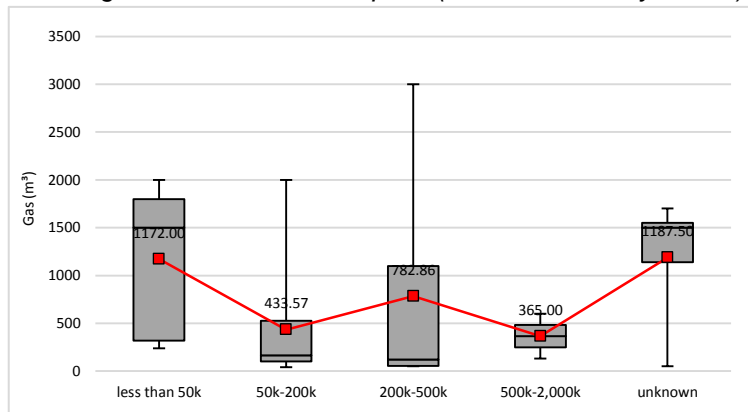


Figure 22. gas consumption (Source: drawn by author)

Fig. 20-22 shows the energy consumption of the selected samples of families. It should be declared that all the consumption results are based on the questionnaire filled out by the inhabitants but not measured data. Strict positive correlation between electricity consumption and income level is shown in Fig.20. Families with higher income level consume more electricity than lower income families. And the difference between the highest electricity consumption and the lowest one is about 1000 KW·h. On the aspect of water consumption, there shows another “U”-like trend that “50-200k” group consumes the least water among all groups. In terms of gas consumption, no dramatic correlation is shown with the income level. The group of “less than 50k” leads all the groups with 1172m³ gas



## CONFERENCE: HOUSING – A CRITICAL PERSPECTIVE

Architecture\_MPS; Liverpool University; Liverpool John Moores University  
Liverpool: 08—09 April, 2015

---

consumption in a year. In all, daily consumption of electricity and water is closely related to income level, but gas doesn't follow the pattern.

### 4. CONCLUSIONS

After analyzing the results of the 84 effective responded questionnaires, we come to the conclusions as follows.

(1) According to the results of this research, we can conclude that income level of urban residents have direct influences on some aspects of the energy consumption behavior, even though not all of them show clear correlation. Behaviors including heating cost and using of additional heating in winter, habits of window opening, renovation of balcony, time needed on shower, frequency of cooking at home and total car emission, are all directly correlated with income level. Some other behaviors, however, show little relevance with income level like using of air-conditioner and frequency of washing clothes.

(2) Energy consumption behaviors which are influenced by income level are mostly following an "anti-Kuznets curve" pattern, meaning a "U"-like curve. Urban residents with income at middle class perform the best on saving energy through daily behavior. Considering that the group of middle income occupies more than half the whole society, researches with more specific investigation should be undertaken to reveal the interior rules of energy consumption. On the contrary, groups with both low and high income hold the greatest potential of energy saving in daily life. Once fundamental living condition like quality of their apartments and basic human needs on comfort are taken into consideration, the more energy consumption behavior of low income groups makes sense. So improving the dwelling condition of low income inhabitants can help to energy saving.

(3) In terms of actual energy consumption, electricity and water consumption is correlated to income level while gas is not. Specifically, electricity consumption is positively correlated with income level and correlation between water consumption and income level follows the "U"-like curve.

(4) As is shown in the study, higher income level does not directly lead to more energy consumption. On the contrary, people with higher income level always have better background of education and are more aware of the importance of energy saving. So more policies on energy saving should be proposed and have wider effect on citizens.

### ACKNOWLEDGEMENTS

This study utilized the data of the research project 51178238 supported by National Natural Science Foundation of China.

—

### ENDNOTES

---

<sup>[1]</sup> A. A. Azlina S.H. Law, and Nik Mustapha NH. "Dynamic Linkages among Transport Energy Consumption, Income and CO2 Emission in Malaysia," *Energy Policy* 73, no. 0 (2014):598-606.

<sup>[2]</sup> J.M. Cayla, N. Maizi, C. Marchand, "The Role of Income in Energy Consumption Behavior: Evidence from French Households Data," *Energy Policy* 39, no. 12 (2011):7874-83.

<sup>[3]</sup> A. Druckman and T. Jackson, "Household Energy Consumption in the UK: A Highly Geographically and Socio-economically Disaggregated Model," *Energy Policy* 36, no. 8 (2008):3177-92.

<sup>[4]</sup> T. Ekholm, V. Krey, S. Pachauri, and K. Riahi, "Determinants of Household Energy Consumption in India," *Energy Policy* 38, no. 10 (2010):5696-707.

<sup>[5]</sup> J. Rosas, C. Sheinbaum, and D. Morillon, "The Structure of Household Energy Consumption and Related CO2 Emissions by Income Group in Mexico," *Energy for Sustainable Development* 14, no. 2 (2010):127-33.

<sup>[6]</sup> X. Zheng, C. Wei, P. Qin, J. Guo, Y. Yu, F. Song, et al, "Characteristics of Residential Energy Consumption in China: Findings from a Household Survey," *Energy Policy* 75 no. 0 (2014):126-35.

<sup>[1]</sup> L. Lutzenhiser, "A Culture Model of Household Energy Consumption," *Energy* 17, no. 1 (1992):47-60.

## CONFERENCE: HOUSING – A CRITICAL PERSPECTIVE

Architecture\_MPS; Liverpool University; Liverpool John Moores University  
Liverpool: 08—09 April, 2015

---

<sup>[2]</sup> G. Hitchcock, "An Integrated Framework for Energy Use and Behavior in the Domestic Sector"

<sup>[3]</sup> Data source: Source: <http://tkkankyo.eng.niigata-u.ac.jp/HP/HP/index.htm>.

<sup>[4]</sup> Li Zhe, "Investigation and Analysis of the Relationship between Residential Energy Use Behavior and Energy Consumption in China," (Master's thesis: Tsinghua University, 2012).

<sup>[5]</sup> Yi Huo, Sigi Zheng, and Zan Yang, "Low Carbon Lifestyle and Its Determinants: An Empirical Analysis Based on Survey of / Household Energy Consumption and Community Environment in Beijing," no. 02 (2010):55-72.

—

### BIBLIOGRAPHY

Chun-sheng, Z., N. Shu-wen, and Z. Xin. "Effects of Household Energy Consumption on Environment and its Influence Factors in Rural and Urban Areas." *Energy Procedia* 14, no. 0 (2012):805-11.

Golley, J. and X. Meng. "Income Inequality and Carbon Dioxide Emissions: The Case of Chinese Urban Households." *Energy Economics* 34, no.6 (2012):1864-72.

Howells, M.I., T. Alfstad, D.G. Victor, G. Goldstein, and U. Remme. "A Model of Household Energy Services in a Low-income Rural African Village." *Energy Policy* 33, no. 14 (2005):1833-51.

Joyeux. R., and R.D. Ripple RD. "Household Energy Consumption Versus Income and Relative Standard of Living: A panel Approach." *Energy Policy* 35, no. 1 (2007):50-60.

Niu S., X. Zhang, C. Zhao, and Y. Niu. "Variations in Energy Consumption and Survival Status between Rural and Urban Households: A Case Study of the Western Loess Plateau, China." *Energy Policy* 49, no. 0 (2012):515-27.

Sun, C., X. Ouyang, H. Cai, Z. Luo, and A. Li. "Household Pathway Selection of Energy Consumption During Urbanization Process in China." *Energy Conversion and Management* 84, no. 0 (2014):295-304.

Vassileva, I., and J. Campillo. "Increasing Energy Efficiency in Low-income Households through Targeting Awareness and Behavioral Change." *Renewable Energy* 67, no. 0 (2014):59-63.

Yan, C. and Z. Yanli. "Analysis on the Environmental Effect of Renewable Energy Consumption by Rural Residents in Daily Life in China- From the Perspectives of Carbon Emissions." *Energy Procedia* 5, no. 0 (2011):1642-6.