Effects of Energy Saving Measures for Existing Urban Residential Buildings Based on Thermal Simulation and Site Investigation of Energy Consumption

Jinlong Ouyang\textsuperscript{1}, Jian Ge*\textsuperscript{2}, Jiang Lu\textsuperscript{3}, Kazunori Hokao\textsuperscript{4} and Tingting Shen\textsuperscript{5}

\textsuperscript{1}Doctor Student, Department of Civil Engineering, Saga University, Japan
\textsuperscript{2}Associate Professor, Department of Architecture, Zhejiang University, China
\textsuperscript{3}Associate Professor, Department of Civil Engineering, Zhejiang University of Science and Technology, China
\textsuperscript{4}Professor, Department of Civil Engineering, Saga University, Japan
\textsuperscript{5}Master Student, Department of Architecture, Zhejiang University, China

Abstract
This is one of two papers that predict the effects of energy saving renovation measures for existing urban residential buildings. The previous paper predicted such effects based on thermal simulation, but the simulative outputs are not sufficiently convincing. So in this paper, the measures’ effects will be further analyzed based on the factual electricity consumption from site investigation. Firstly, the monthly electricity consumption of the subject building was investigated in 2007/2008. Then, the factual heating and cooling loads were distinguished through climate analysis. Finally, assuming that the relative energy saving effects of the measures are the same in thermal simulation and in fact, the simulative energy saving effects were revised by applying the factual heating and cooling loads, followed by CO\textsubscript{2} emission and cost for a 40-year residual life span. The results show that the simulative outputs were too exaggerated, and must be revised based on factual electricity consumption. From the viewpoint of reducing energy use and CO\textsubscript{2} emission, it is worth renovating existing residential buildings with energy saving measures, however, the economic benefits following revision are negative because of the too cheap electricity price in China. Therefore the government should provide subsidies for the energy saving renovations of buildings.

Keywords: renovation measure; factual electricity consumption; site investigation; relative energy saving effect; revise

1. Background and Introduction
This is one of two papers that predict the effects of energy saving renovation measures for existing urban residential buildings in Hangzhou city, China. The previous paper (J. Ouyang \textit{et al.}, 2008) firstly advanced six energy saving measures for renovating one existing residential building after analyzing their feasibility in thermal simulation and in practice; then predicted the energy saving effects of the measures by using the feedback coefficient method, the reduction of CO\textsubscript{2} emissions by a simple LCC\textsubscript{2} method and the costs by a simple LCC method, all for a 40-year residual life span. Finally, based upon the results a suitable plan was developed.

In line with the conclusions of relative studies (O. Arslan \textit{et al.}, 2006, H. Tommerup \textit{et al.}, 2006, A. Papadopoulos \textit{et al.}, 2002, T. Siller, 2007 and M. Jakob, 2006), the previous paper had proven that improving the energy performance of existing residential buildings will constitute an important instrument in the efforts to alleviate the pressures of energy shortages and CO\textsubscript{2} emissions. However, outputs through thermal simulation alone are not sufficient. If the assumptions concerning lifestyles in thermal simulation are not the same as those in actual domestic life, the simulative results may be uncertain or false. With this in mind, the actual monthly electricity consumption of the subject building was investigated over a twelve-month period.

Some researchers were aware of the importance of the actual electricity consumption in studying energy conservation of residential buildings. J. Lam (1998) applied the monthly electricity consumption in the residential sector of Hong Kong from 1971 to 1993 to analyze the climatic and economic influence on residential energy consumption. P. Hu \textit{et al.} (2004) investigated the electricity consumption and cooling load of urban and rural buildings in Hubei province from 1998 to 1999. They found that the values were respectively 9.0–36.9 and 1.0–9.8 kWh/(m\textsuperscript{2}·yr). T. Zhong \textit{et al.} (2003) investigated the cooling load of

*Contact Author: Ge Jian, Associate Professor, Department of Architecture, Zhejiang University Zijingang Campus, Hangzhou, 310058 China Tel: +86-571-88206267 Fax: +86-571-88206264 E-mail: ow761202@yahoo.com
(Received April 8, 2008; accepted July 30, 2008)
residential buildings in Shanghai city by a survey undertaken in July 2002, and found the value to be 7.94 kWh/(m²·yr) in summer. J. Ren et al. (2003) investigated the cooling load of urban residential buildings in the summer in Guangzhou city from 1997 to 1999, and found the value to be 7.9 kWh/(m²·yr). Q. Wu (2005) investigated the electricity consumption of residential buildings in Hangzhou city from 2001 to 2004 and calculated that the total heating and cooling loads were 11.10 kWh/(m²·yr), about one third of all electricity consumption of residential buildings.

Most of the prior researchers simply wanted to make clear the status quo concerning energy consumption and heating and cooling loads of residential buildings through investigation. This paper is the first attempt to challenge and evaluate the effects of energy saving measures by applying actual heating and cooling loads from an authentic site investigation.

From the research of Q. Wu (2005), it is known that the total heating and cooling loads of residential buildings in Hangzhou city, in fact, were far less than those calculated by thermal simulation in the previous paper. Accordingly, it could be reasoned that the actual effects of energy saving measures may be exaggerated and unbenevolent from the LCA viewpoint. Therefore it is important to revise the research to account for possible errors.

The purpose of this paper is to make clear the actual energy consumption of the subject building and to further revise the simulative results for accuracy.

The Hangzhou Statistical Yearbook (2007) shows that more than 25 million square meters of residential buildings in the city should be renovated in the near future. It is very meaningful to ascertain the rational behind this claim, as well as to determine the energy saving renovations carried out on buildings up until now and to predict accurately their effects in the future.

2. Methodology

2.1 Description of the subject building

This paper uses a seven-story building built in 1995 in the Zijin neighborhood of Hangzhou city as a typical building in the case study. The standard plan from the first to seventh floor is shown in Fig. 1. The area of the households on every floor is about 355 square meters.

2.2 Description of the renovation measures and simulative results

After the analysis of the variables and the subject building’s thermal attributes, six rational renovation plans (or measures) were suggested as shown in Table 1. The energy saving effects (see Table 4.) of the measures were predicted based on thermal simulation by using the feedback coefficient method, the reduction of CO₂ emissions (see Table 5.) by a simple LCCO₂ method and the costs (see Table 6.) by a simple LCC method, all for a 40-year residual life span. Finally, a suitable plan (Plan 7 in Table 1.) was developed based upon the results. The suitable plan was a blend of the aforementioned six measures.

2.3 Outline of the research

In this paper, the actual monthly electricity consumption of the subject building was firstly investigated over a twelve-month period. Then, the actual heating and cooling loads were determined from...
the results of the site investigation, in conjunction with an annual climate analysis of Hangzhou city. Finally, assuming that the relative energy saving effects of the measures are the same in thermal simulation and in actuality, the simulative energy saving effects were revised according to the factual heating and cooling loads, followed by CO₂ emission and cost for a 40-year residual life span. The detailed process of this paper is shown as a flowchart (see Fig. 2).

3. Site Investigation of Energy Consumption

3.1 Site investigation and results

At present, electricity is indispensable for modern domestic life in Chinese cities. Other than gas for cooking and gasoline for cars, the only energy consumed by occupants in the subject building is electricity. So in this paper, "energy" refers in particular to "electricity".

![Fig.2. Research Flowchart](image)

The purposes for consuming electricity can be divided into three groups: (1) basic load (i.e. lighting, amusement, etc.), (2) heating load (i.e. mainly space heating, water heating), (3) cooling load (i.e. mainly space cooling). The electric appliances for space heating and cooling are air-conditioners, assisted by fans in summer and heating equipment in winter.

In order to record electricity consumption, the electricity department of the city installed ammeters for all households on the walls of stairwells in the subject building. (see Fig. 3.) Generally, the staff of the electricity department goes to record electricity consumption from ammeters and sends bills to every family once every two consecutive months. Considering that the data from the electricity department is not sufficiently detailed or accurate, the authors themselves recorded the monthly electricity consumption directly from ammeters on the first day of every month from April, 2007 to March, 2008.

![Fig.3. Photos of Ammeters](image)

| Time           | Average electricity consumption |
|----------------|---------------------------------|
| March, 2007    | 203.7                           |
| April, 2007    | 181.2                           |
| May, 2007      | 202.3                           |
| June, 2007     | 225.2                           |
| July, 2007     | 451.9                           |
| August, 2007   | 393.7                           |
| September, 2007| 210.3                           |
| October, 2007  | 172.4                           |
| November, 2007 | 203.0                           |
| December, 2007 | 291.8                           |
| January, 2008  | 380.9                           |
| February, 2008 | 295.5                           |

The subject building has 28 households and there are no vacancies. But some occupants are not the owners of apartments in the subject building, only tenants who might be living there for less than one year, therefore...
the electricity consumption data of such households might be anomalous. From the records, twenty-two valid samples were determined and the six invalid ones were deleted. The average monthly electricity consumption of the valid samples in the twelve consecutive months is shown in Table 2.

### 3.2 Climatic attribute and Assumptions

To decrease heating and cooling loads by 50% and to improve indoor thermal comfort are both objectives of the national (2001) and regional (2003) standards for residential energy saving. When speaking of the heating and cooling loads of residential buildings, it is essential, first, to make clear the outdoor climatic attributes, affecting them directly.

The following is a description of the climate of Hangzhou city from the climatic web (2007). There are four distinct seasons in the city: spring, summer, autumn and winter.

1. Spring begins in March and ends in May. The temperature is a little cold in early March and a little hot in late May. The climate is comfortable on almost all days in March.

2. Summer begins in June and ends in August. The yearly temperature is the hottest in late July.

3. Autumn begins in September and ends in November. The temperature is a little hot in early and mid-September and a little cold in late November. The climate is comfortable on all days in October.

4. Winter begins in December and ends in February of the following year. The yearly temperature is the coldest in January. In January 2008 there was an especially heavy snow that lasted for more than twenty days. Such harsh weather conditions had not occurred in the city in the last several decades.

Variations in outdoor temperatures over one year in the city can be shown in Fig.4. Temperatures in the range between Ta and Tb are considered comfortable in theory.

Considering that the heating and cooling loads of residential buildings obviously change, while basic load changes little with outdoor climate, various assumptions can be made about climatic attributes of Hangzhou city (shown in Fig.5):

1. Electricity consumption is at its lowest during the months of April and October. Electricity consumption in these two months is only for basic load and such load remains the same throughout the twelve months of the year. The value given is the average electricity consumption in April and October. The basic load of the subject building is 176.8 kWh/household/month or 2121.8 kWh/household/year calculated as shown in Table 2. Basic load is not the cause of decrease in the relative energy saving standards, but it must be excluded from further studies.

2. Electricity consumption from May to September can be divided into two groups: cooling load and basic load. By subtracting basic load from all electricity consumption over the five months, the residual is for cooling load. The cooling load of the subject building is 599.3 kWh/household/year.

(3). Electricity consumption from November to March of the following year can be divided into two groups: heating load and basic load. By subtracting the basic loads from all electricity consumption over the five months, the residual is for the heating load. The heating load of the subject building is 490.7 kWh/household/year.

By comparing Fig.5. with Table 2., the above assumptions are clearly proven. Similarly, Li et al. (2006) had proven that this method is rational and can be applied to the analysis of the cooling and/or heating load of residential buildings in China.

### 3.3 Data Analysis and Comparison

According to the above three assumptions, the original data is processed further and the results of investigation are shown in Table 3. The total heating and cooling load is 12.28 kWh/(m²·yr), 33.94% of the total electricity consumption of the subject building, which is very consistent with the results of Q. Wu (2005).

The proposed standard (2002) is that the heating and cooling load of a given energy saving residential building should be less than 56.40 kWh/(m²·yr). Although the value of the subject building meets the request of standard, the building cannot be thought of as an energy saving residential building. The value (56.40 kWh/(m²·yr)) recommended in the standard is misleading, and it is therefore necessary to understand the difference between the value in actuality and in theory.
Table 3. Comparison of the Heating and Cooling Loads of the Subject Building in Fact and in Thermal Simulation

|        | Heating load kWh/yr | Heating load kWh/(m²·yr) | Cooling load kWh/yr | Cooling load kWh/(m²·yr) | Total kWh/yr | Total kWh/(m²·yr) |
|--------|---------------------|--------------------------|---------------------|--------------------------|--------------|------------------|
| In simulation | 160,426             | 64.52                    | 65,282              | 26.26                    | 225,737      | 90.79            |
| In fact | 13,740              | 5.53                     | 16,782              | 6.75                     | 30,521       | 12.28            |
Table 4. Revision of Energy Saving Effects of the Measures

| Plans | Heating load kWh/yr | Heating load kWh/(m²·yr) | Cooling load kWh/yr | Cooling load kWh/(m²·yr) | Total kWh/yr | Total kWh/(m²·yr) |
|-------|---------------------|--------------------------|---------------------|--------------------------|--------------|-------------------|
| 1     | In simulation       | 152,522                  | 63,409              | 215,932                  |              |                   |
|       | Ratio (R)           | -4.93%                   | -2.87%              | -3.80%                   |              |                   |
|       | After revision      | 13,063                   | 5,26                | 16,300                   | 6,53         | 29,363            | 11.78         |
| 2     | In simulation       | 134,851                  | 61,613              | 196,411                  |              |                   |
|       | Ratio (R)           | -15.94%                  | -5.62%              | -10.27%                  |              |                   |
|       | After revision      | 11,550                   | 4.65                | 15,839                   | 6.34         | 27,389            | 10.99         |
| 3     | In simulation       | 160,426                  | 50,271              | 210,697                  |              |                   |
|       | Ratio (R)           | 0.00%                    | -22.99%             | -10.06%                  |              |                   |
|       | After revision      | 14,527                   | 5.84                | 12,924                   | 5.18         | 27,451            | 11.02         |
| 4     | In simulation       | 135,498                  | 60,906              | 196,429                  |              |                   |
|       | Ratio (R)           | -15.54%                  | -6.70%              | -10.68%                  |              |                   |
|       | After revision      | 11,605                   | 4.67                | 15,658                   | 6.27         | 27,262            | 10.94         |
| 5     | In simulation       | 136,904                  | 60,195              | 197,125                  |              |                   |
|       | Ratio (R)           | -14.66%                  | -7.79%              | -10.88%                  |              |                   |
|       | After revision      | 11,726                   | 4.72                | 15,475                   | 6.20         | 27,200            | 10.92         |
| 6     | In simulation       | 164,102                  | 57,080              | 221,236                  |              |                   |
|       | Ratio (R)           | -2.29%                   | -12.56%             | -5.88%                   |              |                   |
|       | After revision      | 14,055                   | 5.66                | 14,674                   | 5.88         | 28,729            | 11.53         |
| 7     | In simulation       | 87,081                   | 34,189              | 121,271                  |              |                   |
|       | Ratio (R)           | -45.72%                  | -47.63%             | -46.77%                  |              |                   |
|       | After revision      | 7,458                    | 3.00                | 8,789                    | 3.52         | 16,247            | 6.52          |

Table 5. Revision of Final Reductions of CO₂ Emission of the Measures in the Next 40 Years

| Plans | Initial embodied CO₂ emission [kg] | Reduction of CO₂ emission [kg/yr] | Duration [yr] | Renovation times | The final reduction of CO₂ emission [kg] |
|-------|------------------------------------|-----------------------------------|---------------|------------------|----------------------------------------|
| 1     | In simulation                       | 4,639.57                          | 9,314.36      | 20               | 61,107                                 | 363,295.26                           |
|       | After revision                      |                                   | 1,101.07      | 2                |                                        | 34,763.83                            |
| 2     | In simulation                       | 68,159.7                          | 27,859.05     | 20               | 27,966.64                              | 571,122.16--552,810.16                |
|       | After revision                      |                                   | 2,976.64      | 2                |                                        | 978,042.48                           |
| 3     | In simulation                       | 91,569.8                          | 14,287.21     | 10/20            | 2,917.62                               | 116,338.67--98,026.67                 |
|       | After revision                      |                                   | 15,475        | 4               |                                        | 116,338.67--98,026.67                 |
| 4     | In simulation                       | 15,115.6                          | 27,842.17     | 40               | 3,096.61                               | 1,098,571.14                         |
|       | After revision                      |                                   | 27,810.79     | 2               |                                        | 108,748.36                           |
| 5     | In simulation                       | 14,698.03                         | 3,155.52      | 20               | 4,275.36                               | 1,083,035.54                         |
|       | After revision                      |                                   | 1,703.51      | 4               |                                        | 96,824.81                            |
| 6     | In simulation                       | 1,463.08                          | 4,275.36      | 10               | 1,703.51                               | 165,162.08                           |
|       | After revision                      |                                   | 1,703.51      | 4               |                                        | 165,162.08                           |
| 7     | In simulation                       | 190,476.62~208,788.62             | 99,242.44     | 40               | 13,561.43                              | 3,799,203.38~3,760,891.38             |

Table 6. Revision of Final Cost Reductions of the Measures in the Next 40 Years

| Plans | Initial Cost [Y] | Energy saving [¥/yr] | Duration [yr] | Pay back year [yr] | Renovation times | Final reduction of cost [¥] |
|-------|------------------|-----------------------|---------------|--------------------|------------------|--------------------------|
| 1     | In simulation    | 20,000                | 5,193         | 20                 | 3.85             | 2                        | 167,737                               |
|       | After revision   |                       | 614           | 20                 | 3.85             | 2                        | 15,429                                |
| 2     | In simulation    | 140,000               | 15,542        | 20                 | 9.01             | 2                        | 341,696                               |
|       | After revision   |                       | 1,600         | 20                 | 9.01             | 2                        | 2,135,574                             |
| 3     | In simulation    | 22,890~               | 7,080         | 10/20              | 3.23~20.05      | 4/2                      | -213,574                             |
|       | After revision   |                       | 1,628         | 10/20              | 3.23~20.05      | 4/2                      | -26,451~218,729                      |
| 4     | In simulation    | 84,810                | 15,533        | 40                 | 5.46             | 2                        | 536,510                               |
|       | After revision   |                       | 1,728         | 40                 | 5.46             | 2                        | 100,517                               |
| 5     | In simulation    | 180,000               | 15,162        | 40                 | 11.87            | 2                        | 246,480                               |
|       | After revision   |                       | 1,760         | 40                 | 11.87            | 2                        | 2,09,582                              |
| 6     | In simulation    | 75,537~               | 2,385         | 10                 | 21.7             | 4                        | -2,06,740                             |
|       | After revision   |                       | 950           | 10                 | 21.7             | 4                        | -2,06,740                             |
| 7     | In simulation    | 856,370~              | 55,368        | 40                 | 15.47~18.94      | 1                        | 1,358,310~1,166,034                   |
|       | After revision   |                       | 7,566         | 40                 | 15.47~18.94      | 1                        | -553,736~746,012                      |
heating and cooling loads in the thermal simulation and in authentic situation, though the relative values of the actual energy saving effects are assumed to be the same as those in the thermal simulation.

(2). The largest energy saving potential can still be achieved by upgrading the insulation performance of the existing building's envelope. But the total energy saving effects of Plans 2, 4, and 5 on reducing the heating and cooling loads in actuality are a little less than those in the thermal simulation.

(3). Contrary to the thermal simulation, the cooling load is more than the heating load in fact. Thus, the total effects of plans 3 and 6 on reducing cooling and heating loads, in fact, are more than those in the thermal simulation, whereas the total effects of plans 1, 2, 3, 4, and 5 on reducing cooling and heating loads, in fact, are less than those in the thermal simulation.

(4). Reducing the shadow coefficient of exterior windows in summer is very important. The energy saving effect of Plan 3 is almost the same as those of Plans 2, 4, and 5.

Because the absolute values of the energy saving effects of the plans are much less than those in the thermal simulation, it is worth further evaluating the actual environmental and economic effects of the plans from the LCA viewpoint.

4.2 Revision of reduction of CO2 emission and cost
With the absolute values of the energy saving effects of the plans decreasing by revision, the absolute values of final reduction of CO2 emission and cost will also decrease. The results after revision are shown in Tables 5 and 6 for easy comparison with those in the thermal simulation.

From an environmental perspective, it is surprising that the effect on reducing CO2 emission of Plan 2 following revision is non-beneficial, while that in the thermal simulation is so remarkable. But substituting plastic double windows for old ones is still recommended as an important measure of Plan 7, after all, its effect in reducing CO2 emission is still very beneficial in the next 40 years.

From an economic perspective, it is very disappointing that the effects of cost reduction of all plans (including the suitable plan) are negative following revision. This finding reveals again the importance of the investigation of the factual electricity consumption of the subject building.

5. Comparison and Discussion
From the viewpoints of reducing energy consumption and CO2 emission, the suitable plan is worth implementing to renovate the subject building, but the result of economic analysis following revision may discourage investors or ultimate decision makers from investing in such actual projects.

There are two reasons for this: (1) the prices of the measures are too expensive; (2) the price of the electricity in China is too cheap. P. Lam (2004) has proven the latter regarding the monopoly of the electricity industry in China, and B. Wang (2007) also attributed China's inefficient use of energy to the too low electricity price. This implies that the too cheap electricity price will hamper implementation of the energy saving renovation measures for the subject building at present. Should the government increase the price of electricity in order to implement energy saving renovations of existing residential buildings? This, indeed, is an important question needing addressing.

According to some researchers, raising energy prices to boost the efficiency of energy consumption is an effective policy tool (F. Birol and J. Keppler, 2000, R. Amstalden et al., 2007, A. Joelsson and L. Gustavsson, 2008). If the government of China increased the electricity price, it would accelerate the development and implementation of energy savings in China, and energy saving renovation of existing buildings with bad thermal quality as soon as possible would maximize the effects of reducing energy consumption, and CO2 emissions, and meanwhile shorten the pay back years of investment, together with improving indoor air quality. However, the impacts of raising energy prices are multidimensional (L. Huang and M. Tu, 2007). Indeed increasing prices will improve energy efficiency and increase energy supply in China, but it will also add a greater burden on vulnerable households because of the big gap between the poor and the rich in China. Additionally, the unique features and important position of electricity, long history of electricity shortage and great pressure from interest monopoly groups, and so on, are great challenges for the state government concerning the raising of the electricity price. Given the strong social sensitivity regarding energy prices as well as the possible shocks to the Chinese economy, it is necessary for policymakers to raise electricity prices gradually through economic schemes.

The government can request real estate developers to pay for the construction of new buildings with energy saving measures based on relative building standards, but in the case of the renovation of existing buildings with energy saving measures, the possible bill-payers are the owners of the corresponding buildings and the governments. If there are no new technological advancements and reforms to provide more effective and cheaper energy-saving measures, it should be the mission of governments to provide certain subsidies to bridge the investment gap of energy saving renovations under current conditions, in order to make them attractive so that they will be implemented.

6. Conclusion
This study demonstrates that it is very important and necessary to revise and reevaluate the simulative outputs based on the factual electricity consumption
of the subject building when studying the energy performance or advancing energy saving measures for it.

(1) From the investigation, the overall electricity consumption of the subject building is 89932.3 kWh/yr, of which the heating and cooling loads are 13740 and 16872 kWh/yr respectively. The total heating and cooling loads are 12.28 kWh/(m²·yr), 33.94% of the overall electricity consumption.

(2) The simulated energy saving effects of the measures are too exaggerated regarding the great discrepancy of the heating and cooling loads between the factual and the thermal simulation.

(3) The cooling load of residential buildings is greater than the heating load in the hot summer and cold winter region. When evaluating the performance of energy saving measures, the effect on reducing cooling load should be taken more seriously than that on reducing heating load. So, reducing the shadow coefficient of exterior windows in the summer is very important, together with upgrading the insulation performance of the existing buildings' envelope.

(4) With the absolute energy saving effects of the plans decreasing, the corresponding effects on reducing CO₂ emission and cost will also decrease. The comparison of the results in thermal simulation and after revision shows the indispensability of the revision process.

(5) From the viewpoint of reducing energy consumption and CO₂ emission, the suitable plan is worth being implemented to renovate the subject building, but the economic benefits following revision are negative in terms of the too cheap electricity price in China. The government should provide certain subsidies for energy saving renovations of those existing residential buildings.

Thermal simulation is a very important tool to study building energy conservation, but we should be more practical and realistic, and check the simulated results further by combining them with factual information of the buildings, then the outputs can be more realistic and meaningful.

References
1) J. Ouyang et al., T. (2008) The reduction potential of energy consumption, CO₂ emissions and cost of existing urban residential buildings in Hangzhou city, China, Journal of Asian Architecture and Building Engineering, 7(1), pp.139-146.
2) O. Arslan and R. Kose, T. (2006) Thermo economic optimization of insulation thickness considering condensed vapor in buildings. Energy and Buildings, 38 (12), pp.1400-1408.
3) H. Tommerup and S. Svensden, T. (2006) Energy savings in Danish residential building stock. Energy and Buildings, 38 (6), pp.618-626.
4) A. Papadopoulos et al., T. (2002) Feasibility of energy saving renovation measures in urban buildings: The impact of energy prices and the acceptable pay back time criterion. Energy and Buildings, 34 (5), pp.455-466.
5) T. Siller, T. (2007) Long-term energy savings and greenhouse gas emission reductions in the Swiss residential sector. Energy Policy, 35 (1), pp.529-539.
6) M. Jakob, T. (2006) Marginal costs and co-benefits of energy efficiency investments: The case of the Swiss residential sector. Energy Policy, 34 (2), pp.172-187.
7) J. Lam, T. (1998) Climatic and economic influence on residential energy consumption, Energy Conversion and Management, 39(7), pp.623-629.
8) P. Hu et al., T. (2004) Investigation of thermal environment and energy consumption for HuBei residences, Heating Ventilating & Air Conditioning, 34(6), P21-22, 71. (In Chinese)
9) T. Zhong and W. Long, T. (2003) The survey on room air conditioners in Shanghai and the calculation of energy consumption in summer. Building Energy & Environment, 1,3, P22-24. (In Chinese)
10) J. Ren et al., T. (2003) Investigation of air conditioning energy consumption in residential buildings in Guangzhou, Wall Material Innovation & Energy Saving in Buildings, 4, P34-37. (In Chinese)
11) Q. Wu, T. (2005) Study on the energy-consumption problem and energy-efficiency technologies of residential buildings in Hangzhou. Dissertation submitted for the Degree of Master of Zhejiang University. (In Chinese)
12) Hangzhou Statistics Bureau, T. (2006) Hangzhou Statistical Yearbook. China Statistical Press. (In Chinese) http://www.hzstats.gov.cn/webapp/more01.aspx?id=0_1_69
13) Ministry of Construction P. R. China et al., T. (2001) Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone (JGJ134-2001). Chinese Construction Industry Publication. (In Chinese)
14) Zhejiang Province Architectural Design and Research Institute et al., T. (2003) Design standard for energy efficiency of residential buildings in Zhejiang province (DB33/1015-2003). Chinese Construction Industry Publication. (In Chinese)
15) The climatic bureau of Hangzhou city, T. (2007) Hangzhou city's climatic web. (In Chinese). http://www.hzqx.com/gzhfw/index.asp
16) Z. Li and Y. Jiang, T. (2006) Investigation methods of air conditioning energy consumption in residential buildings in summer, Heating Ventilating & Air Conditioning, 36(9), 35-37. (In Chinese)
17) P. Lam, T. (2004) Pricing of electricity in China, Energy, 29(2), pp.287-300.
18) B. Wang, T. (2007) An imbalanced development of coal and electricity industries in China, Energy Policy, 35(10), pp.4959-4968.
19) F. Birol and J. Keppler, T (2000) Prices, technology development and the rebound effect, Energy Policy, 28(6-7), pp.457-469.
20) R. Amstalden et al., T. (2007) Economic potential of energy efficiency retrofitting in the Swiss residential building sector: The effects of policy instruments and energy price expectations, Energy Policy, 35(3), pp.1819-1829.
21) A. Joelsson and L. Gustavsson, T (2008) Perspective on implementing energy efficiency in existing Swedish detached houses, Energy Policy, 36(1), pp.84-96.
22) L. Huang and M. Tu, T (2007) The impacts of energy prices on energy intensity: Evidence from China, Energy Policy, 35(5), pp.2978-2988.