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Study on Energy Use Characteristics of Hotel Buildings in Shanghai

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Abstract

This paper presents statistical energy use characteristics of hotel buildings in Shanghai. Building information and energy consumption data had been collected by field survey of 45 star hotels. The results show that the hotels were mostly built after 1990s, and the area of guest room accounts for more than half of the gross floor area. The breakdown of energy use shows that electricity is the main energy source, which accounts for 75% of total energy consumption. The annual average energy use intensity (EUI) for 3-star, 4-star and 5-star hotels are 61.95 kgce/m^2, 73.18 kgce/m^2 and 86.64 kgce/m^2 respectively by converting all consumed energy into equivalent coal. In addition, some other factors were also reviewed such as occupancy rate and hotel's class. Some suggestions are put forward to improve energy performance of hotel buildings.

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Keywords: Hotel building; Energy use intensity (EUI); Energy audit

1. Introduction

Compared to other types of commercial buildings, hotel building is a particular one that has many different functional areas, such as guest room, business center, restaurant and laundry room. Exploring the energy use characteristics of hotels helps to understand the building energy consumption level and figure out the possible countermeasures to improve building energy efficiency of hotel buildings. There have been several investigations of energy performance of hotel buildings in various regions across the world. For example, Santamouris et al. [1] investigated the energy performance of 158 hotels in Greece, and found that the annual average energy use intensity (EUI) was 612 kWh/m^2. Bohdanowicz et al. [2] collected energy consumption data from 73 Hilton hotels and 111Scandic hotels in Europe, which were 364kWh/m^2 and 285kWh/m^2 respectively. Priyadarsini et al. [3] reported

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an annual average EUI of 427kWh/m^2 by studying energy performance of 29 Singapore hotels, including 3-star, 4-star and 5-star hotels. Meanwhile, researchers tried to subdivide hotel types, e.g. the British benchmark established by CIBSE, approaching to the differences of any types. In China, the annual average EUIs were different, e.g. Hong Kong [4], Shenzhen [5], Hainan [6] were 564kWh/m^2, 229kWh/m^2 and 150kWh/m^2. The EUI not only varied in different cities, but also did within one city. Fu et al. [7] presented the annual maximum, minimum and average EUIs in 12 Chongqing hotels, which were not the same as Zheng et al. [8]. Hotels located in hot areas consumed more electricity, ranging from 45% to 91% [4, 9]. While in the cold areas, gas would be used as same as electricity, e.g. in Ottawa [10], the percentage of electricity, gas and steam were 28.9%, 26.4% and 44.7% respectively. In addition, some studies analyzed the factors that influenced the EUI of hotels. For example, Zmeureanu et al. [10] divided factors into temperature-dependent and temperature-independent. Priyadarsini et al. [3] considered the relationships among EUI, star level, occupancy rate and retrofit measures.

Despite of many studies on energy performance of hotel buildings, there is still a lack of study on energy use characteristics of hotel buildings in Shanghai, which is one of the most representative international metropolis and finance centers in China. Therefore, a detailed survey on hotel building energy consumption had been carried out in this study. The investigated items covered energy use information and building energy related factors. This study aims to achieve a fully understanding of energy use characteristics.

2. Investigation method and data processing

In this study, quantitative and qualitative data was obtained through questionnaire survey and field investigation. The questionnaire survey collected architectural and structural information, such as year of construction, gross floor area, energy use, equipment and management measures, as listed in Table 1. The energy consumption data and other related information were accomplished through statistical survey of 15 3-star hotels, 15 4-star hotels and 15 5-star hotels locating in various regions of Shanghai.

Table 1. The survey summary of all hotels.

No.	Item	Parameter included
1	Building information	Building construction year, gross floor area, building shape coefficient, window to wall ratio, wall and window types.
2	Function and service level	Hotel rating, worker density, percent of GFA for each function region, number of guest rooms, swimming pool (Y/N), laundry room(Y/N), occupancy rate, total revenue
3	Equipment and management	HVAC, lighting, elevator type and capacity, operation management regime(Y/N), energy monitoring(Y/N), energy efficiency technology conducted.
4	Energy use	Monthly bills of electricity, gas, diesel oil, steam and LPG used

3. Hotel characteristics and statistical analysis

The results of the survey are summarized in Table 2. It is found that the hotel samples are heterogeneous in terms of size. Fig.1 shows the years of construction for 3-star hotels, 4-star hotels and 5-star hotels. Most of the hotels were constructed in 90s and after 00s. The 5-star and 4-star hotels were built earlier than 3-star hotels in general.

Table 2. The statistical summary of all hotels

Items	Min.	Max.	Average
Year of construction	1934	2009	1994
Number of rooms	67	714	293
Number of workers	90	990	383
Gross floor area (GFA)(m^2)	5679	112606	42749

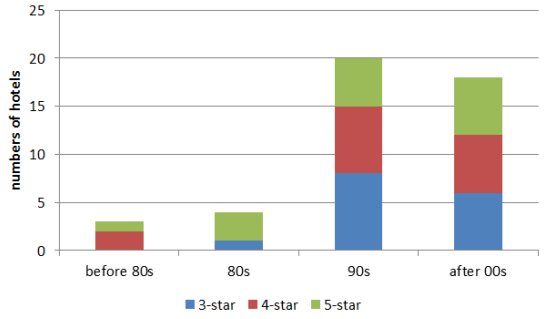

Fig. 1. The construction year for each kind of star hotels

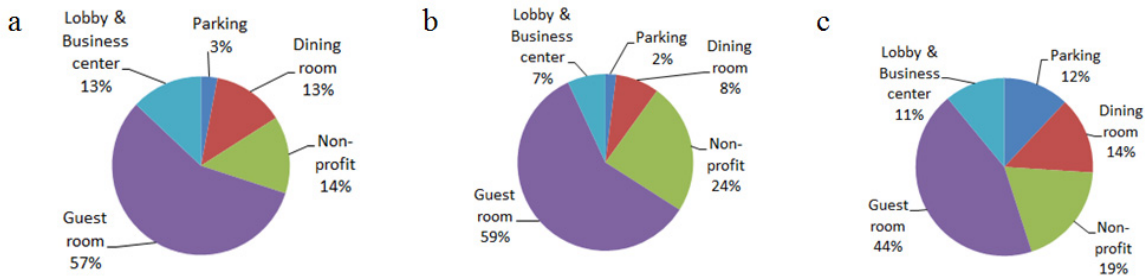

Fig. 2. Percent of building area in hotels (a) 3-star; (b) 4-star; (c) 5-star.

The proportions of different functional areas are shown in Fig. 2. It can be seen that the ratios of guest room area to the total area are 57% in 3-star hotels, 59% in 4-star hotels and 44% in 5-star hotels. The ratios of indoor parking area to the total area are 3% in 3-star hotels, 2% in 4-star hotels and 12% in 5-star hotels.

It can be seen from Fig.3 that the percentage of air-conditioned area to GFA in 3-star hotels is greater than those of 4-star and 5-star hotels. In some 3-star hotels, almost all the areas are air-conditioned. Possible explanation for this might be that the indoor parking area of 5-star hotels is larger than that of the other hotels, and the percent of GFA for guest rooms in 3-star and 4-star hotels are higher than that of 5-star hotels.

In 3-star hotels, the ratio of the average energy cost to the total revenue is 22.6%, and those of 4-star hotels and 5-star hotels are 11.0%, 7.6% respectively. Several reasons may cause this phenomenon. One is that the total revenue of the 3-star hotel is lower than that of other hotels, and another is that the percent of GFA for air-conditioned area in the 3-star hotels is larger than those of the 4-star and 5-star hotels.

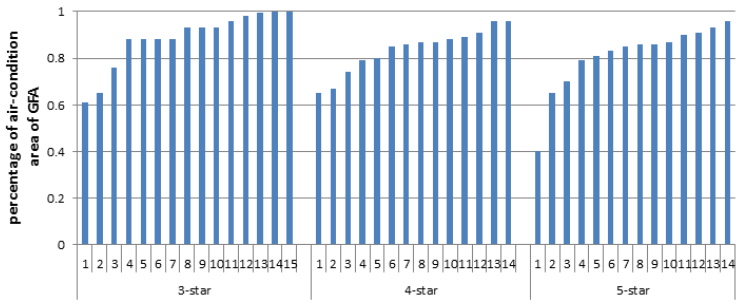

Fig. 3. Percentage of air-conditioned area of GFA.

4. Energy consumption discussion

4.1. Energy use intensity

There are different energy types used in different hotels. Energy consumed by hotels includes electricity, gas, diesel and so on. Electricity is primarily used for cooling, lighting and equipment. Gas and diesel are used as fuel for heating, hot water and cooking. In order to facilitate statistical analysis and comparison, all types of energy are converted into the equivalent coal with the unit-kgce and equivalent electricity with the unit-kWh respectively. The distributions of the EUI conform to the normal distribution. These energy use intensities vary significantly from one building to other, as shown in Table 3. The annual average EUIs for 3-star, 4-star and 5-star hotels still gradually increase with the values of 61.95 kgce/m^2, 73.18 kgce/m^2 and 86.64 kgce/m^2 respectively.

Table 3. Statistical results of energy use intensity

Type	EUI(kgce/m^2)			EUI(kWh/m^2)		
	Minimum.	Maximum	Average	Minimum.	Maximum	Average
3-Star	39.4	110.2	62.0	133.2	314.8	215.7
4-Star	51.7	104.8	73.2	84.0	340.2	234.8
5-Star	52.4	112.1	86.6	159.4	360.2	279.8

4.2. Hotel class

In general, the higher the hotel class is, the more service the hotel provides and then the more energy the hotel may consume. In Fig.4, energy use intensities are plotted against the star ratings of hotels. It shows that the low class hotel may have high EUI and the EUI difference among the same class hotels is also obvious. It can be concluded that the energy use intensity for individual building is not strictly correlated with hotel's star rating due to many factors affecting EUI. In order to reasonably evaluate energy performance of hotels, there is a need to further classify the hotel sample into certain types beyond the star classification.

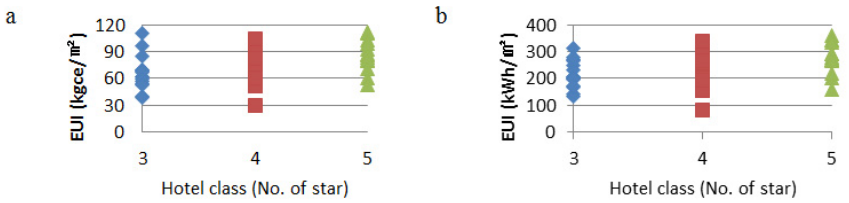

Fig. 4. EUI vs. hotel star class (a) EUI (kgce/m^2); (b) EUI (kWh/m^2)

4.3. Weather conditions

Shanghai locates in the hot-summer and cold-winter architecture thermotechnical design zone in China. Fig. 5 plots the profile of monthly mean outdoor temperature against the monthly mean EUIs among the same period. It can be seen that the energy consumption intensity (EUI) generally follows the fluctuations of outdoor temperature between April and November. From December to March, the EUI is in negative correlation with outdoor temperature. The main reason is that the energy consumption of air conditioning systems dominates the total energy consumption and the operation of air conditioning systems is obviously climate-related. In contrast, the energy use for other systems such as lighting is relatively stable all over the year.

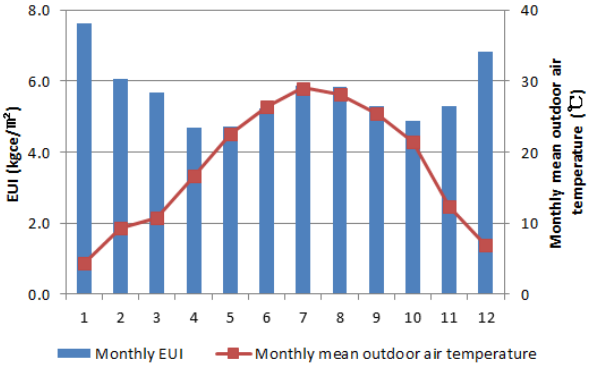

Fig. 5. Relationship between monthly EUI and outdoor temperature.

4.4. Breakdown of energy use by fuel type

Six types of energy are used in these hotels including electricity, gas, LPG, fuel oil, steam and diesel oil. In these hotels, the average energy use percentages of electricity, nature gas, diesel oil, gas, steam and LPG are 75%, 11%, 9%, 3%, 0.8% and 0.15% respectively based on the equivalent coal conversion method. Electricity is the primary energy source, which is mainly used for HVAC, lighting and other equipments. Gas is mainly used for cooking and hot water.

4.5. Hotel occupancy

Fig. 6 compares the EUI against the annual average hotel occupancy rates for the 45 hotels. However, the relationship between them is difficult to identify. As the occupancy rates vary significantly from time to time over a year and in many hotels even when only a guest room is occupied, air conditioning will be provided to prevent discomfort. This explains why hotel occupancy level does not directly influence the whole energy use. This phenomenon is especially obvious for high-class hotels.

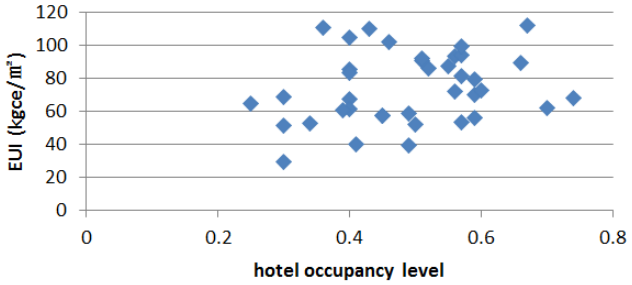

Fig. 6. EUI vs. annual average hotel occupancy rate.

4.6. Energy efficiency technology

Energy efficiency technologies applied in these hotels were also investigated. Among the 45 hotels, 34 hotels had established the energy statistics regime and 23 hotels had set up energy consumption monitoring system. Table 4 gives the summarized results. In the past ten years, 30 hotels had been retrofitted, and 50% installed energy-efficient lights. The variable frequency pump and condenser heat recovery technologies were also widely used.

Table 4. Energy efficiency projects in last ten years

No.	Energy efficiency technology	Number / Percentage
1	Installing energy efficient lamps	15/50.0%
2	Using variable frequency pump	6/20.0%
3	Condenser heat recovery	5/16.7%
4	Using solar collector for hot water	3/10.0%
5	Reformation of cooling tower	1/3.3%
6	Replacing coal boilers by heat pump or gas boiler	4/13.3%

5. Conclusions

In this study, the energy use characteristics of hotel buildings in Shanghai were preliminarily studied by investigating building information, function and service level, equipment and management, energy use from 45 hotels. The following findings can be obtained by analysis.

(1) The hotels were mostly built after 1990s with guest rooms, taking up more than half of the gross floor area.

(2) The breakdown of energy use shows that electricity is the main energy source, which accounts for 75% of total energy consumption.

(3) The annual average energy use intensity (EUI) for 3-star, 4-star and 5-star hotels are 61.95 kgce/m^2, 73.18 kgce/m^2 and 86.64 kgce/m^2.

(4) The relationship between occupancy rate and EUI is difficult to identify.

(5) The energy use intensity for individual building is not strictly correlated with hotel's star rating due to many factors affecting EUI.

To further understand the energy performance in hotel buildings, classifying all hotels into different sub-groups to reveal homogeneous features is suggested, which can be conducted by cluster analysis in the next step.

Acknowledgements

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