

A survey on energy consumption status and characteristics of hotel buildings in Guangzhou

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Abstract. Existing hotel buildings are normally of high energy consumption and low energy performance in China. The implementation of energy efficient measures is an approach to improve this situation; but it is essential to have a thorough understanding of their energy consumption patterns beforehand. In this paper, a survey on energy consumption status and characteristics of 14 hotel buildings in Guangzhou was conducted. Through a comprehensive analysis of the annual, monthly and subentry energy consumption of different buildings, combined with an on-site inspection, it has been found that existing hotel buildings in Guangzhou have very good energy-saving potentials, especially in terms of the glazing of building envelope, air conditioning systems, hot water systems, and lighting systems.

1. Introduction

As sustained development of tourism, there are more and more hotel buildings built in China. However, the design of a large proportion of existing hotel buildings only focuses on grandeur, novelty style and luxurious decoration, leaving behind building energy efficiency. This leads to high energy consumption and low energy performance of the existing hotel buildings, especially for those built in 1980s and 1990s [1]. The ageing of equipment and the absence of building energy regulations even aggravate the waste of energy and resource consumption.

Fortunately, architects, engineers and governments have paid increasing attention to energy efficiency in hotel buildings. In 1987 and 1989, the EU countries such as Germany and Denmark initially put forward the concept of green energy-saving hotel buildings [2]. Such concept was introduced into the big cities in China such as Beijing, Shanghai and Guangzhou in the mid-1990s. After that, the Chinese government inaugurated “China Ecotourism Year” in 1999 [3]. From then on, the owners of different hotel buildings began to take the initiatives to energy efficient measures. In 2005, the State Council of China issued official documents to promote the use of energy efficient measures in hotel buildings, launching the activity of “Striving for Green Hotels” [4].

In order to reduce energy consumption in hotel buildings, it is critical to have a thorough understanding of its energy use status and characteristics [5]. By doing this, a comprehensive analysis can be conducted to find out the energy saving potentials. However, the energy consumption of hotel buildings depends on a range of criteria, among which the local climate and the local economic and technical conditions are the most essential. Guangzhou is located in South China and belongs to hot summer and warm winter zone. It has a summer as long as 5 months, while the winter is very short. Additionally, there is normally no need for heating in winter. The hot and humid weather in Guangzhou makes its building energy consumption quite different from that of other cities. Currently, there are previous studies about energy consumption analysis of hotel buildings in different locations. For



example, Zhao [6] studied on energy consumption status and energy saving of hotel buildings in Suzhou; Wang and Yang [7] analysed energy consumption and energy saving potential of star-rated hotels in Xi'an; Sun [8] researched on energy consumption and efficiency of hotel buildings in Chongqing. However, there is still an absence of study on energy consumption status and characteristics of hotel buildings in Guangzhou. Previous studies have been found only to analyse the energy consumption of office, commercial and residential buildings.

Therefore, in this paper 14 hotel buildings in Guangzhou are surveyed in order to discover their energy consumption status and characteristics, to identify current performance problems and to find out potential energy saving areas. Firstly, the selection of the surveyed buildings is introduced in section 2. Secondly, a detailed analysis of energy consumption status and characteristics of the surveyed buildings is conducted in section 3. The analysis involves the annual, monthly and subentry energy consumption. Lastly, an on-site inspection of energy performance problems of the buildings is carried out in section 4.

2. Selection of the surveyed buildings

2.1. Selection of hotel buildings with different features

Energy consumption of hotel buildings is impacted by various factors. Therefore, the selection of hotel buildings should take into account different features in order to facilitate the comparison. Totally, 14 hotel buildings are selected; such buildings have different star ratings and were built in different years. Table 1 lists the basic information of the surveyed buildings, including their service levels, number of rooms, built year, height, number of floors, total area and air conditioned area. It can be seen that the selected buildings are built from 1950s to 2010s. In addition, they have different service levels, including three stars, four stars and five stars. Moreover, the buildings also have different scales, represented by number of rooms, building height and area.

Table 1. Basic information of the surveyed buildings.

Number	Service level	Number of rooms	Built year	Height (m)	Number of floors	Total area (m ²)	Air conditioned area (m ²)
H1	3 stars	345	1968	86.0	27	36475	25000
H2	3 stars	645	1984	—	18	40000	—
H3	3 stars	212	1991	51.0	16	20000	16150
H4	3 stars	326	2006	57.8	17	38642	32000
H5	4 stars	310	1952	33.9	9	20451	15600
H6	4 stars	248	1972	32.8	8	60648	—
H7	4 stars	114	1994	30.0	10	11400	10400
H8	4 stars	152	2005	95.3	28	29900	20000
H9	5 stars	699	1961	—	—	147000	97000
H10	5 stars	828	1985	98.0	33	170000	120000
H11	5 stars	709	2006	150.0	39	122867	100504
H12	5 stars	460	2011	200.2	—	184000	110000
H13	5 stars	493	2011	99.8	30	77439	—
H14	5 stars	445	2011	132.0	35	59585	46500

The proportion of buildings constructed in different years and the distribution of different star ratings are respectively shown in figure 1 and figure 2. It can be seen that 29% of the buildings are constructed before 1980, 29% between 1980 and 2000, 21% between 2000 and 2010, and 21% after 2010. Meanwhile, there are 29% of the hotels having three stars, 29% having four stars, and 43% having five stars. The buildings with different features can facilitate energy consumption analysis through comparison and help finding out the energy patterns.

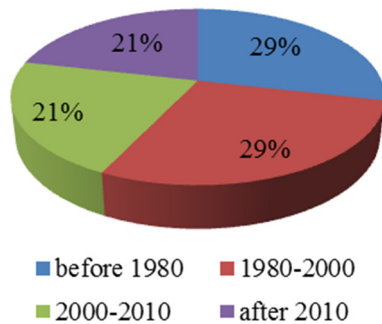


Figure 1. Distribution of the surveyed buildings constructed in different years.

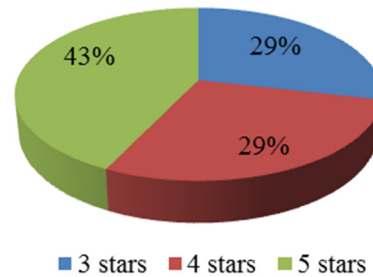


Figure 2. Distribution of the surveyed buildings with different star ratings.

2.2. Building function, envelope and energy use equipment

Hotel buildings commonly have many different functions. According to the survey, all of the buildings offer catering services and conference centres. The majority of the buildings provide services such as entertainment, business, spa, gym, laundry and so on. The five-star hotels have more service facilities than the other two star-rated ones. For instance, all of the five-star hotels have indoor or outdoor swimming pools.

The surveyed buildings are open 24 hours and all year round. The energy facilities of the halls and guest rooms also run without interruption; while the other functional zones have various operation schedules. The conference rooms normally open from 8:30 am to 22:30 pm, the dining hall from 7:00 to 23:30. In each zone, the number of occupants, energy facilities and indoor environment requirements are different, which results in the complexity of energy consumption in hotel buildings.

Table 2. Main construction features of the surveyed buildings.

Number	Orientation	Exterior wall	Exterior window	Glass type	Framework material	Shading
H1	South	—	Single glazing	Normal	Aluminum	Internal
H2	South	—	Single glazing	Normal	Aluminum	—
H3	South	Glass curtain wall	Single glazing, double glazing	Normal, coated	Aluminum	—
H4	Southwest	—	—	—	—	—
H5	South	Brick, stone	Single glazing	Brown	Aluminum	—
H6	Southwest	Glass curtain wall	—	—	—	—
H7	South	—	—	—	—	—
H8	South	Glass curtain wall	Single glazing	Coated	Aluminum	Internal
H9	South	Hollow clay brick, lime sand brick	Single glazing	Coated	Aluminum	Internal
H10	South	—	—	—	—	—
H11	South	Glass curtain wall, lime sand brick	Hollow double glazing	Coated	Aluminum	—
H12	Southwest	lime sand brick	Single glazing	Normal	Aluminum	Internal
H13	South	Glass curtain wall	Hollow double glazing	Coated	Aluminum	Internal
H14	Southwest	Glass curtain wall, aerated concrete	Hollow double glazing	Low-e	Aluminum	Internal

The main construction features of the buildings are investigated, as shown in table 2. The construction features directly impact the energy consumption of air conditioning systems. It can be seen that most of the buildings have an orientation of south; the exterior wall of some buildings is built with large-area glass curtain wall. Additionally, no exterior wall has insulation layer; only H14 uses aerated

concrete block, which is considered to have better thermal properties than others. Among the surveyed buildings, only three of them install exterior window of hollow double glazing, and only one uses low-e glass. Moreover, the window mainly has internal shading. Internal shading can block a part of solar radiation, but its effect is not as good as the external one. In short, the envelope of the surveyed buildings has a great space for improving.

Meanwhile, energy equipment in each building has also been surveyed. The main equipment used in the hotels include chillers, chilled/cooling water pumps, air conditioning units and fan coil units, lighting equipment, plugs, domestic hot water (DHW), kitchen equipment, office equipment and driving equipment such as elevators. The cooling mainly use screw or centrifugal chillers; also three buildings install absorption chillers, which use gas or steam as power. Due to the warm climate in Guangzhou, most of the buildings have no heating in winter, but there are also some four-star and five-star hotels consider the heating from December to February.

According to the survey, there are still 64.3% of the buildings using incandescent lamp, although it is known as low efficiency. Fluorescent lamps and metal halide lamps are also widely used. Only H14 install LED light. Therefore, it can be inferred that the lighting systems in the hotel buildings have considerable energy saving potential.

3. Analysis on energy consumption status and characteristics

In order to understand the energy consumption status and characteristics of hotel buildings, it is essential to analyse their annual, monthly and subentry energy consumption.

3.1. Annual energy consumption

Based on the survey, electricity, oil and gas are the main energy types consumed. Steam is also used in two buildings, primarily for absorption chillers and heat exchangers of hot water.

In order to compare the energy consumption of each building, different types of energy are converted into standard coal based on the equivalent coefficient listed in General Principles for Calculation of Total Production Energy Consumption (GB/T 2589-2008) [9]. As a result, the annual energy consumption index, which is calculated by annual energy consumption divided by total building area, is shown in figure 3. It can be seen that the index ranges from 18.83 kgce/m²a to 67.22 kgce/m²a; the difference is 3.57 times. According to Energy Consumption Limit of Hotels and Shopping Malls in Guangdong Province (Trial) [10], the energy consumption limit of three-star hotels is 27 kgce/m²a, four-star 31 kgce/m²a, and five-star 35 kgce/m²a. Therefore, only less than half of the buildings have met the limit requirements.

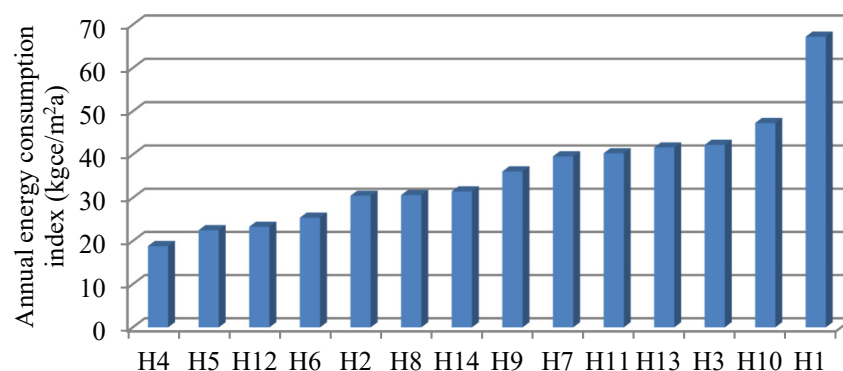


Figure 3. Annual energy consumption index of the surveyed buildings.

From this figure, it is hard to conclude that annual energy consumption has direct relation to star ratings. This is due to the many other criteria that influence the energy consumption; while the service level is not decisive. Among the surveyed buildings, H4 has the smallest energy consumption, and H1 has the biggest; both of them are three-star hotels. According to section 2.1, H1 is built in 1968. The building uses screw chillers for air conditioning and oil boilers for hot water. Such equipments are old

and no energy retrofitting has been conducted before. Hence, the aging, low efficient equipment could be the reason for this high consumption. However, H4 is a new building built in 2006. It has similar scale as H1, but it has less functional areas, dominated by guest rooms. This makes H4 consume the least energy. Additionally, the high consumption of H3 is due to the use of large-scale glass curtain wall with single glazing.

Among the four-star hotels, H5 is the oldest building, but it has the least consumption, because H5 has conducted a retrofitting in 2009. One of the chillers has been replaced; and the condensation heat of the chillers has been recycled for hot water production. This measure greatly decreases the energy consumption of H5. To the opposite, H7 uses electric heaters for hot water production, which makes it consume the most energy among all of the four-star hotels. Therefore, the recycle of condensation heat of chillers is a measure with great potential for energy saving in Guangzhou. Due to the long summer, the chillers usually run more than five months; meanwhile, hotel buildings need hot water all year around, both for showering and kitchen. Hence, the condensation heat can be fully used, saving a large amount of energy for hot water.

Comparing the five-star hotels, H10 has the highest consumption, while H12 has the lowest. H10 is built in 1985; its chillers and oil boilers has been used for a long time. The low efficiency of the equipment should be the reason of the high consumption. H9 is also an old building, but it uses the waste heat (steam) from the nearest power plant for absorption chillers, so its energy consumption level is lower than H10.

From the analysis above, it can be concluded that the aging of equipment is one of the main reasons for high energy consumption, so it is essential to maintain and replace the equipment regularly; in addition, the recycle of condensation heat of chillers is an effective energy saving measure in hotel buildings, while the use of electric heaters should be avoided.

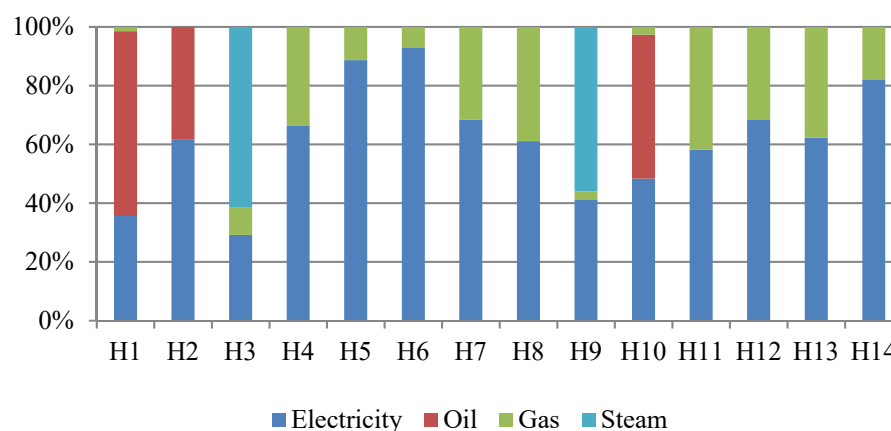


Figure 4. Proportion of electricity, oil, gas and steam consumption of the surveyed buildings.

In order to analyse the use of different energy types in the surveyed buildings, the proportion of electricity, oil, gas and steam consumption are shown in figure 4. It can be seen that electricity is the dominant type of energy consumed in the hotel buildings, its rate varies from 28.92% to 91.54%. Electricity is mainly used for air conditioning systems, lighting systems and driving systems. Another main energy type is oil and gas, which are used for hot water and kitchen equipment. The proportion of different energy types consumed in hotel buildings largely depends on the type of energy equipment used. In average, the distribution of different energy types is shown in figure 5. It can be seen that electricity accounts for 55.96% of the total consumption, gas and oil for 33.67%, and steam for 9.53%.

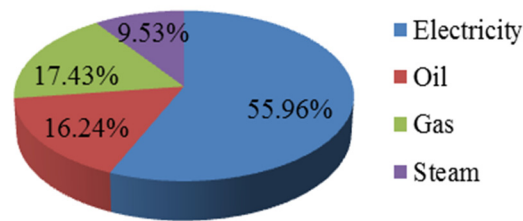


Figure 5. Distribution of different energy types in hotel buildings.

3.2. Monthly energy consumption

After analysing the annual energy consumption, monthly energy consumption of the hotel buildings is analysed in order to get a deeper understanding of the energy characteristics. Figure 6 shows the monthly electricity index of the surveyed buildings. It can be seen that July and August are the months with highest electricity consumption, because the hot weather increase energy use of air conditioning. In addition, June and September also have high electricity consumption. Generally, these two months are busy in tourism, which leads to the electricity use of some buildings in these two months even higher than July and August. In February and December, the electricity consumption in most of the buildings is the least, since there is no need for air conditioning. An exception is January; its consumption is higher than the other two months. This is because in January there are more tourists. Therefore, from the changes of monthly consumption, the room occupancy rate can be also inferred. Electricity consumption of hotel buildings is decided by both weather and room occupancy rate.

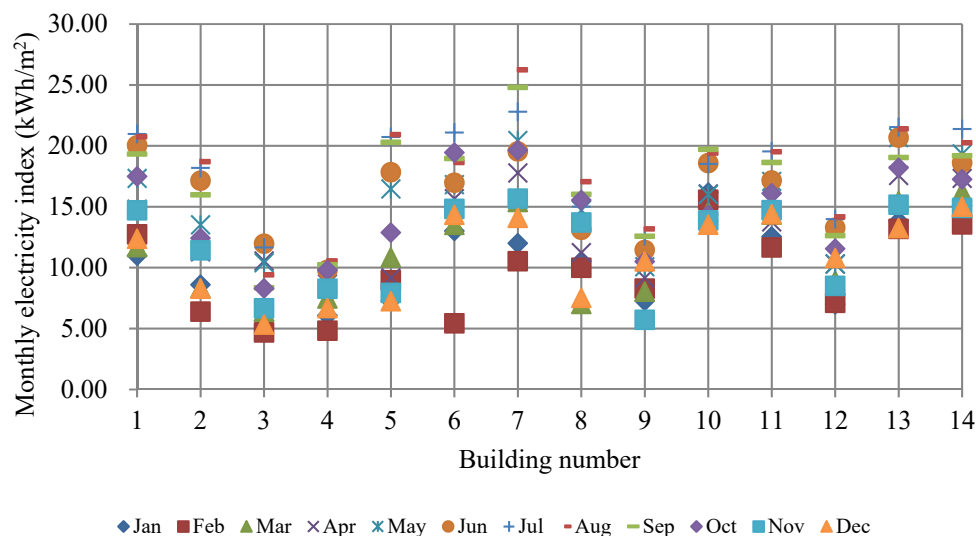


Figure 6. Monthly electricity index of the surveyed buildings.

Additionally, figure 7 presents the monthly gas consumption index of the surveyed buildings. It can be seen that the gas consumption indexes of the buildings are quite different. Gas is mainly used for hot water production and kitchen. In most of the buildings, January, February and December are the months with the most gas consumption; but there are also two buildings, e.g. H3 and H8, have the most consumption respectively in April and May. In addition, H2 has no gas consumption because it uses oil as alternative energy, H9 has little consumption because gas is only used for kitchen stoves. In general, the gas consumption has no obvious changes in law as electricity.

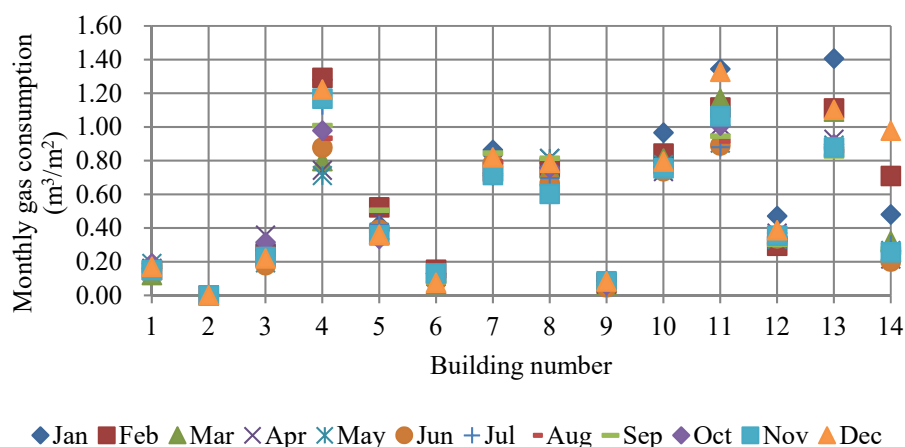


Figure 7. Monthly gas consumption index of the surveyed buildings.

3.3. Subentry energy consumption

The subentry energy consumption includes those from air conditioning systems, lighting systems, driving systems, DHW systems, and other indoor equipment. Based on the available data, figure 8 shows the electricity indexes of air conditioning systems of 12 surveyed buildings. It can be seen that the electricity indexes of air conditioning systems have significant variation, ranging from 36.32 kWh/m² to 194.11 kWh/m². The difference between the lowest value and the highest value is 5.39 times. Among the buildings, H1, H5 and H9 have relatively high consumption; a common point of such buildings is that they were all built before 1970s. The performance deterioration of equipment and the unsatisfied thermal properties of building envelop both increase the consumption. In addition, H3 and H8 also have high consumption in air conditioning systems; and a common point of such buildings is that their exterior walls are all built with large-area glass curtain wall with normal single-layer glazing. In comparison, H11 and H14 install glass curtain wall, but they use coated and low-e double glazing; thus, their consumption in air conditioning is much less than H3 and H8. Therefore, it can be known that the type of glazing is especially important for hotel buildings in Guangzhou, especially when large-area glass curtain wall is used.

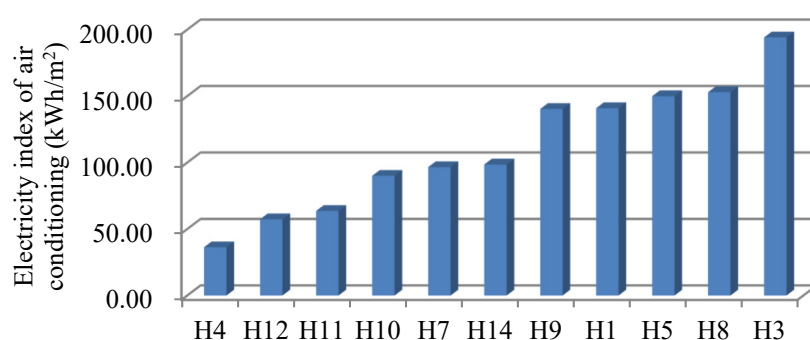


Figure 8. Subentry electricity consumption of air conditioning of the surveyed buildings.

Taking H14 as an example, the distribution of subentry energy consumption is shown in figure 9. It can be seen that the consumption of air conditioning systems account for 36.83%, lighting systems for 21.82%, driving and hot water systems for 14.15%, and indoor equipment for 27.12%. Air conditioning has the most significant energy consumption, but the other subentries are also important.

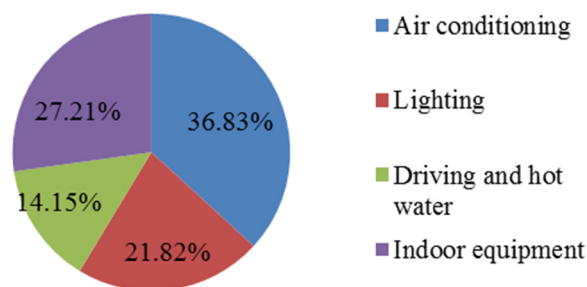


Figure 9. Distribution of subentry energy consumption in H14.

4. On-site inspection of energy performance problems

Except for the data analysis, an on-site inspection was also conducted in order to find the energy performance problems. Through the on-site inspection, it has been found that the energy systems in hotel buildings commonly have the following problems.

4.1. Building envelope

In most of the buildings, there is no consideration of insulation of exterior walls. Furthermore, the heat transfer coefficient and shading coefficient of windows and glass curtain walls do not meet the requirements of energy-saving design standards. The air penetration through doors, windows and curtain walls is large.

4.2. Air conditioning system

According to the test, the average temperature of the guest rooms in different buildings ranges from 21.7 °C to 25.5 °C, which is lower than the recommended 26 °C. In addition, some terminal equipment such as fan coil units run when the room is unoccupied; and the fresh air is not controlled on demand. There is also a common problem that the condensers and evaporators of the chillers have considerable fouling, which results to performance decrease of the chillers. The fouling also reduces temperature difference between the inlet and outlet chilled water, so the system should increase the water flow in order to meet the cooling demand. This also leads to more energy consumption of water pumps. Moreover, few pumps use frequency converters to adjust the flow.

4.3. Lighting system

There are still some buildings using incandescent lamps and traditional fluorescent lamps; LED lamps are rarely used. According to the test, the illuminance levels of the work areas in most buildings are higher than the recommended levels; while there are also some zones with illuminance levels lower than the recommended ones.

4.4. Domestic hot water

Electric water heaters are still used in some buildings. Additionally, improper insulation of water storage tanks, pipes, valves and water heaters has been found. In order to save energy for hot water production, the recycle of condensation heat of chillers is an alternative measure.

4.5. Energy management

Most of the buildings built before 2000s have no automated control for energy systems. For example, some of the buildings still need to start up and stop the chillers, cooling towers and pumps manually. Few buildings are installed with energy management systems, normally the consumption is recorded by hand monthly. Since there is no control system for air conditioning and lighting, unmanned areas are also provided with cooling and/or illumination. The air conditioning systems in hotel buildings normally

have a large number of terminal equipment; if the systems are controlled automatically and managed properly, a considerable number of energy consumption could be saved.

5. Conclusions

Based on the survey of energy consumption in this paper, it has been found that most of the hotel buildings in Guangzhou have very good energy saving potentials, especially for those built before 1990s. The aging of energy equipment and the unsatisfied thermal properties of building envelope are prominent problems in old hotel buildings. Therefore, energy retrofitting of such buildings is imperative in Guangzhou. Through a comprehensive analysis and an on-site inspection, five areas with great spaces for improving were identified, e.g. building envelope, air conditioning systems, lighting systems, domestic hot water systems, and energy management. Current buildings should replace single glazing in exterior window and glass curtain wall with low-e double glazing; external shading of the exterior wall could be added; the aging, low efficient equipment in energy systems should be replaced, and other equipment should be maintained regularly; the use of incandescent lamps should be substituted by LED lamps; electric heater should be avoid, and the recycle of condensation heat of chillers for hot water production is highly recommended; energy management in hotel buildings generally should be strengthened and use information technologies as assistance.

This survey offers a thorough understanding of the energy consumption status and characteristics of hotel buildings in Guangzhou and identifies the existing energy performance problems. This is extremely helpful for guiding future implementation of energy efficiency design or energy retrofitting in hotel buildings.

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