Energy Consumption Status and Analysis of Public Buildings in Qingdao*

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Abstract. Based on Qingdao energy consumption monitoring platform of public buildings, basic information and energy consumption data are analyzed. Energy consumption intensity, features of different types of public buildings and the effect of each subentry energy consumption system on building energy consumption are summarized. Results show that range of energy consumption intensity is 28.4~254 kWh/m^2•a in Qingdao, and the average value of 87.7kWh/m^2•a. There is great difference between different type of building and difference among same type of building are also obvious, which shows the energy efficiency potential of some buildings. Lighting system and air conditioning system are the major energy consumption system of office buildings and business building, while hotel buildings should also pay attention to the effect of special electricity system.

Keywords: Public buildings, Qingdao, Subentry energy consumption, Energy consumption characteristic.

1. Introduction

With the rapid development of China's economy, the area of public buildings increases year by year and the energy consumption intensity keeps increasing. In 2012, the energy consumption of public buildings reached 182 million tce, and the energy consumption intensity was 21.9 kgce/m^2. Public buildings were the highest energy consumption building of all [1]. Therefore, study on energy consumption and energy efficiency of public buildings has become vital for social energy efficiency work. Scholars have analyzed the current situation of energy consumption of many public buildings in China. Wan [2] analyzed the energy consumption characteristics of public buildings in Wuhan, and concluded that the rational design and optimization of lighting and air conditioning system is the key to reduce building energy consumption. Xu [3] sorted out and counted the data of Shanghai public building energy consumption surveillance platform to explore the influencing factors of energy consumption of different types of buildings. Wu [4] investigated and measured the energy consumption of various types of public buildings in Chongqing, and put forward the technical measures for energy efficiency reconstruction from the aspects of enclosure structure, energy using equipment, energy management and so on.

Based on Qingdao energy consumption monitoring platform of public buildings, this paper analyzes the energy consumption of existing public buildings of Qingdao, and discusses the current status and characteristics of energy use in various public buildings, which can provide a reference for the energy efficiency operation and reconstruction of the system.

2. Basic Information of Public Buildings

General situation and energy consumption status of all buildings in the energy consumption monitoring platform of public buildings are investigated. 20 representative buildings with reliable and complete energy consumption data are selected as samples for detail analysis, including 10 office buildings, 6 business buildings and 4 hotel buildings. The basic building information is shown in Table 1:

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Table 1 The basic building information

No.	Year	Area(m^2)	Type	Cold source	Exterior wall	Exterior windows
1	2008	21836	Office	Chiller	Aerated concrete block	Low-e insulating glass
2	2003	57600	Office	Chiller	Hollow clay brick	Low-e insulating glass
3	2004	38800	Office	Chiller	Hollow clay brick	Low-e insulating glass
4	2009	19000	Office	VRV	Aerated concrete block	Hollow double glazing
5	2007	26391	Office	Water source heat pump	Aerated concrete block	Hollow double glazing
6	1990	4421	Office	Chiller	Clay brick	Single glass
7	2014	39588	Office	Chiller	Aerated concrete block	Low-e insulating glass
8	2002	33000	Office	Chiller	Aerated concrete block	Double glazing
9	2005	15786	Office	Chiller	Aerated concrete block	Double glazing
10	2007	11880	Office	Chiller	Aerated concrete block	Double glazing
11	1998	44781	Business	Chiller + heat pump	Aerated concrete block	Single glass
12	2007	72069	Business	Chiller	Aerated concrete block	Double glazing
13	2005	36000	Business	Chiller	Aerated concrete block	Single glass
14	2008	48000	Business	Direct-fired absorption chiller	Aerated concrete block	Single glass
15	2008	99125	Business	Chiller	Aerated concrete block	Hollow double glazing
16	1990	7348	Business	VRV	Hollow clay brick	Single glass
17	1990	13800	Hotel	Chiller	Clay brick	Double glazing
18	2010	8762	Hotel	VRV	Aerated concrete block	Double glazing
19	2010	18200	Hotel	Water source heat pump	Aerated concrete block	Single glass
20	2006	9261	Hotel	Direct-fired absorption chiller	Aerated concrete block	Double glazing

3. Energy Consumption Intensity of Public Buildings

The energy use equipment of public buildings includes air conditioning, ventilation, lighting, domestic hot water, office equipment, elevators, etc. Considering that most public buildings use electricity as the main energy source, the total building energy consumption is converted to equivalent electricity index to analyze building energy consumption [1][5]. The energy consumption intensity of public buildings does not include heating energy consumption in winter [6]. Energy consumption intensity of the 20 buildings is shown in Fig. 1.

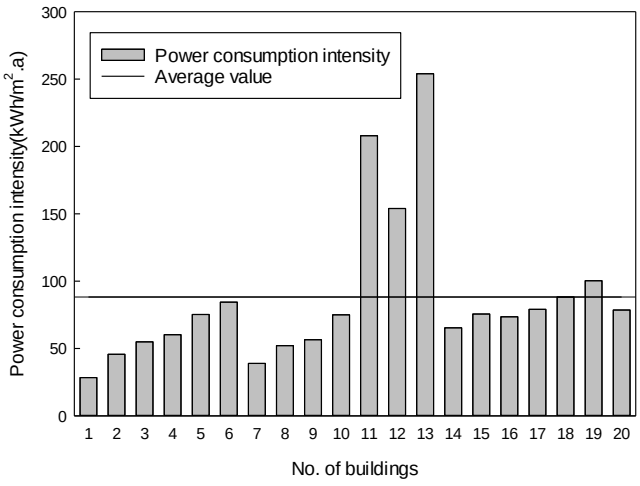

Fig. 1 Total energy consumption intensity of public buildings

As can be seen from the figure, range of the energy consumption intensity is 28.4~254 kWh/m^{2}a , and the average value is 87.7 kWh/m^{2}a . Building energy consumption has the following characteristics:

The energy consumption intensity of different types of buildings varies greatly. The average energy intensity of office buildings (1~10) is the lowest, and the average energy consumption intensity of business buildings (11~16) is higher than that of hotel buildings (17~20). This is related to the service characteristics of different types of buildings. The business buildings and hotels have long business hours and high energy consumption.

The difference of energy consumption among the same type of buildings is obvious. In office buildings, the highest energy consumption is 2.9 times of the lowest. The highest energy consumption of business buildings is 3.8 times of the lowest.

Building 13 is a shopping mall, and the energy consumption intensity is significantly higher than that of other buildings. The reason is that the shopping mall has long business hours, the lighting lamps are fully open during the daytime, and the lighting illumination of some regions is far higher than the national standard, which results in a certain waste of energy consumption.

Building 14 is a shopping mall too. Compared with building 13, the energy consumption intensity is lower. The reason is that in 2010 the building carried on the energy efficiency reconstruction to the air conditioning system and the lighting system. The ordinary energy saving lamp were replaced by the LED lamp, the chilled water pumps, and the cooling water pumps were reselected and replaced. By comparison of building 13 and 14, we can find that many high-energy-consuming public buildings have great energy-saving potential.

Compared building 6, 7, 8 and 11, it can be found that the energy consumption of buildings varies greatly in different construction year. According to the statistical data, the thermal insulation performance of the building enclosure structure was poor before the year 2000. Clay bricks and ordinary glass windows were widely used, did not adopt new energy efficiency materials. Most energy-using equipment is old and aging, the efficiency is reduced, and the energy consumption is increased.

The energy consumption intensity of public buildings has no directly relationship with the building area. The energy consumption depends mainly on the demand for energy of air conditioning, lighting and equipment in the building.

Compared with the literature, the energy consumption intensity of the public buildings in Chongqing is 45~339 kWh/m^2·a [7], Shanghai is 79.5~355.3 kWh/m^2·a [8], and Xi'an is 31.72~266.84 kWh/m^2·a [9]. Comparatively speaking, the energy consumption intensity of public buildings in Qingdao is at a lower level in the country.

4. Energy Consumption Analysis of Different Types of Public Buildings

4.1 Office Building

The 10 office buildings discussed in this paper include office buildings of government, general office buildings and so on, with a total building area of 268 thousand m^2. Individual building area range from 4.4 thousand m^2 to 57.6 thousand m^2. The minimum energy consumption intensity is 28.4 kWh/m^{2}a , the highest value is 84.4 kWh/m^{2}a , and the average value is 58 kWh/m^{2}a .

Office buildings have the characteristics of regular working hours, fixed personnel occupancy and daily flow, and the energy consumption is concentrated in the working hours. The main energy consumption systems throughout the year include the air conditioning system, lighting socket system (including office equipment), power system and special power system.

Take a typical office building as an example. The power consumption intensity of each subsystem is shown in Fig. 2.

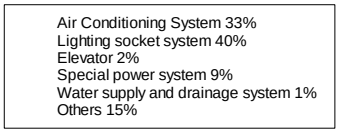

Fig. 2 Power consumption intensity of office building

The energy consumption intensity of lighting socket system is 30 kWh/m^2·a, accounting for 40% of the total energy consumption of the building. The energy consumption of air conditioning system is 24.8 kWh/m^2·a, accounting for 33% of the total energy consumption. The main reason is that the office buildings have a lot of office equipment which runs for a long time, and the air conditioning system serves the indoor temperature and humidity regulation.

Power system consists of an elevator and a water supply and drainage system, energy consumption intensity is 2.3 kWh/m^2·a, which accounts for 3%. Special power system is mainly used for dining room and electronic information room, the energy consumption intensity is 6.75 kWh/m^2·a, accounting for 9%. Others are electricity used in unmonitored equipment in the building, accounting for 15%.

It can be seen that, for office buildings, the air conditioning system and lighting socket system are the main energy-using systems, and refrigerator of the air conditioning system has the highest energy consumption ratio. Reducing energy consumption of lighting socket system and improving operation efficiency of air conditioning system are the key points of energy efficiency reconstruction of this kind of buildings.

4.2 Business Building

The 6 business buildings include shopping malls, supermarket and bookstore. Total building area is 307 thousand m^2 and individual building area range from 7 thousand m^2 to 99 thousand m^2. The minimum energy consumption intensity of the building is 67 kWh/m^2·a, the highest value is 254 kWh/m^2·a, and the average value is 138 kWh/m^2·a.

Compared with other types of buildings, business buildings have the characteristics of long business hours, high passenger flow rate, large building space and high energy consumption.

According to the analysis of a typical shopping mall building, the power consumption intensity of each subsystem is shown in Fig. 3.

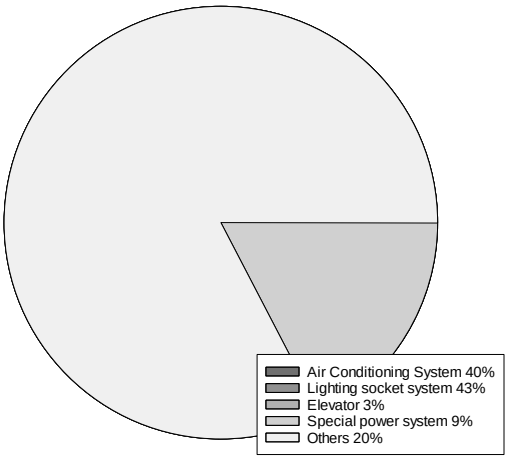

Fig. 3 Power consumption intensity of shopping mall building

The energy consumption intensity of the lighting socket system is 89.8 kWh/m^2·a, which accounts for 43% of the total energy consumption of the building. The energy consumption intensity of the air conditioning system is 83.2 kWh/m^2·a, accounting for 40%. The elevator is 6.3 kWh/m^2·a, accounting for 3%. The energy consumption intensity of the special power system is 18.7 kWh/m^2·a, accounting for 9%. Because the building space is airtight and the windows can not be opened, the lighting service time is long. Most of the lamps are traditional light source, and some shops' illumination is obviously higher than the standard, which results in the highest energy consumption of the lighting socket system. It can effectively reduce the power consumption of buildings by replacing energy-saving lamps and enhancing lighting management.

4.3 Hotel Building

There are 4 hotel buildings, including star hotels and normal hotels. The total building area is 50 thousand m^2, and the individual building area range from 9.2 thousand m^2 to 19,2 m^2. The maximum energy consumption intensity is 103kWh/m^2·a, the lowest value is 71 kWh/m2·a, and the average value is 89 kWh/m2·a.

Due to the particularity of its application, hotel buildings are opened all year round. The energy consumption intensity is obviously related to the star level, hotel with higher star level usually has the higher energy consumption intensity. At the same time, the energy consumption of such buildings has a great relationship with the occupancy rate. Most of the equipment in the hotel works under partial load condition.

Taking a typical hotel building as an example, the power consumption intensity of each subsystem is shown in Fig. 4.

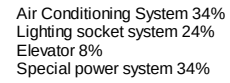

Fig. 4 Power consumption intensity of hotel buildings

The maximum energy consumption intensity is of air conditioning system, 34.5 kWh/m^2·a, accounting for 34% of the total energy consumption of the building. The energy consumption intensity of the lighting socket system is 23.6 kWh/m^2·a, accounting for 24%. The special power system includes domestic hot water, kitchen equipment and electricity consumption, its energy consumption intensity is 34.2 kWh/m^2·a, accounts for 34%. The energy consumption intensity of elevator is 8 kWh/m^2·a, accounting for 8%.

It can be seen that because of the large demand for hot water in hotel buildings, and this part of energy consumption is classified into the special power system, which makes the energy consumption of hotel special power system obviously higher than that of other types of buildings. Similarly, the hotel business time is longer, which makes the air conditioning system consumes more energy. Air conditioning system and special electricity system has significant impact on building energy consumption of the hotel.

5. Conclusion

The energy consumption intensity of concerned public buildings in Qingdao is in the range of 28.4~254 kWh/m^2·a. Different types, same type of buildings with different functions and working hours, and different demands for air conditioning and lighting are the main reasons for the obvious difference in building energy consumption.

There are obvious differences in energy consumption between the same type of buildings. The existing cases show that some public buildings in Qingdao have great energy efficiency potential.

From the analysis of different types of public buildings, the air conditioning system and the lighting socket system are the main energy consumption systems for public buildings. Hotel buildings should also pay attention to the energy efficiency of special power system. The user can effectively improve the efficiency of building energy utilization by rationally control the operation mode of the air conditioning and the lighting socket system, and improve the energy saving consciousness.

Acknowledgements

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