Energy Consumption Investigation and Energy Saving Potential Analysis of an Office Building in Xiamen

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Abstract. An analysis of the energy consumption data of an office building in Xiamen in the past three years compared with both a year and a month earlier. At the same time, the corresponding energy consumption indexes of various types of energy consumption systems are calculated. The analysis results show that the air conditioning system and lighting system are the two largest energy consumption systems in the office building. Office building energy conservation should be prioritized in-depth excavation and analysis from these two systems to find the best energy-saving retrofit solution.

1. Introduction
With the development of economy and society, building energy consumption accounts for more and more of the total energy consumption in our country. It has become one of the three energy consumption giants along with transportation and industrial energy consumption [1]. According to relevant research, the annual energy consumption per square meter of public buildings is more than 10 times that of ordinary residential buildings. Although the total area of public buildings accounts for only 5%, the total power consumption accounts for 30% [2]. Due to the complexity of structure and function of public buildings, especially large public buildings, different types of public buildings have different energy consumption priorities and large differences in energy consumption structures. Therefore, it is necessary to conduct energy audits on different types of public buildings to tap the energy-saving potential of buildings and reduce energy consumption. This paper takes an office building in Xiamen as an example, conducts an energy audit on it, finds out the problems and deficiencies of the building in actual operation and energy management, analyzes its energy-saving potential and proposes corresponding reconstruction suggestions.

2. Project overview
The project is located in Huli District, Xiamen City. The total building foot print of the project building is 1051.3m\textsuperscript{2}, and the total building area is 26112.744m\textsuperscript{2}. The ground area is 21898.01m\textsuperscript{2}, the underground area is 421.7434m\textsuperscript{2}, and the total building height is 91.5m. The fourth to tenth floors are leased to a design institute for external use, and the rest floors are for their own use. The architectural structure of the building is frame-shear structure, the exterior wall adopts glass curtain wall, the main wall adopts horizontal concealed vertical glass curtain wall & light gray aluminum alloy single plate curtain wall, and the podium adopts dry hanging dark gray clay plate curtain wall & hanging full glass...
curtain wall. The air-conditioning system of the building adopts fan-coils and fresh air system, which is only for cooling in summer and isn’t for heating in winter. The air-conditioning operation time is from April to November.

3. Building energy consumption analysis

The energy consumption of the building is dominated by electrical energy. The energy-consuming systems include air-conditioning systems, lighting systems, ventilation systems, elevator systems, power supply and distribution systems, kitchen equipment systems and other equipment systems. The air-conditioning system adopts a central air-conditioning system, and the electrical appliances using electricity are used in the power distribution room, pump room, office equipment and kitchen equipment.

According to the energy bill, the annual power consumption of the building from 2014 to 2016 is shown in Figure 1. In 2014, 2015 and 2016, the total electricity consumption was 1858440kwh, 1823920kwh and 2253900kwh, respectively. After calculation, the energy consumption per unit area of the building from 2014 to 2016 is 69.85-86.31kwh/m², which is less than the limit value of 91 kwh/m² of energy consumption index of non-state office buildings proposed in Xiamen public building energy consumption quota. At the same time, the total annual power consumption in 2015 decreased by 34520kWh compared to 2014, a decrease of 1.85%. In 2016, the total power consumption increased by 429980kWh compared to 2015, an increase of 19.07%. It can be seen that in 2014 and 2015, the overall electricity consumption level of the building did not change much, and it was slightly reduced in 2015 compared to 2014, which is likely to be affected by natural weather and other factors, such as more rainy days in Summer 2015, so the power consumption of air conditioning decreased accordingly, resulting in the decrease of total power consumption. Compared with 2015, the energy consumption in 2016 increased significantly, which may be due to the increase of occupancy rate of buildings in 2016.

It can be seen from Figure 2 that the total electricity consumption of buildings in the same month from 2014 to 2015 did not change much, and showed a sharp decline in 2015, but a significant increase occurred in 2016 (a preliminary judgment is due to the increase in building occupancy), the small peaks of building electricity consumption for the three consecutive years all appeared in July, reaching 225,900 kWh, 225,400 kWh, and 292,900 kWh, respectively. The total power consumption of buildings also shows a trend of rising first and then declining with time. The trend of monthly total power consumption of buildings shows a significant positive correlation with the trend of air conditioning system power consumption. It can be seen that the increase of energy consumption of the building is mainly due to the opening of air conditioning in summer/winter, and the energy saving of air conditioning system should be focused on.

![Figure 1. Histogram of annual total power consumption in 2014~2016.](image)
Figure 2. Monthly power consumption in 2014–2016.

4. Composition and proportion analysis of energy types
The energy consumption of this project is mainly electrical energy. The building sub-system mainly includes air-conditioning system, lighting system, power system, special system, and other system. Table 3-1 summarizes the power consumption of each sub-system and the proportion of total power consumption in 2016. Figure 3-1 concisely shows the power consumption proportion of each sub-system in 2016.

Table 1. Power consumption proportion of each sub-system in 2016.

| Number | System               | Energy consumption (kWh) | Proportion (%) |
|--------|----------------------|--------------------------|----------------|
| 1      | Air-conditioning system | 419066                  | 19             |
| 2      | Power system         | 75453                    | 3              |
| 3      | Lighting system      | 452675                   | 20             |
| 4      | Special system       | 116216                   | 5              |
| 5      | Other system         | 1190490                  | 53             |
| 6      | Total                | 2253900                  | 100            |

Figure 3. Pie chart of each sub-system electricity consumption in 2016.

It can be clearly seen from Figure 3. that the power consumption of each sub system of the building is in order of other energy consumption, lighting energy consumption, air conditioning energy...
consumption, special energy consumption and power energy consumption from more to less. Among them, the air conditioning system and lighting system are the main power consumers of the project, accounting for 39% of the total, which is consistent with the judgment results of the previous chapter.

In order to better understand the operating status and energy consumption of the building air-conditioning system, the energy consumption data of the building air conditioning system will be analyzed below. The central air-conditioning system designed in this project only provides cooling in summer and no heating in winter. The operating time of the air-conditioning is from April to mid-November. The building runs 7 days a week and runs for 10 hours a day from 8:00 am to 18:00 pm. The start and stop time of the air-conditioning system is 8:00 am and 17:30 pm. Table 2. Shows the monthly electricity consumption during the operation of the air conditioning system. The monthly electricity consumption curve of the air conditioning system in the air conditioning season is shown in Figure 4.

**Table 2. Monthly electricity consumption of the air conditioning system in the air conditioning seasons.**

| Month    | 2016 | 2015 | 2014 |
|----------|------|------|------|
| May      | 27258| 15185| 10516|
| June     | 62450| 43879| 33502|
| July     | 82668| 52611| 53691|
| August   | 80809| 62032| 55344|
| September| 70572| 46908| 56080|
| October  | 51874| 31510| 28778|
| November | 43215| 20998| 9535 |
| December | 220  | 2197 | 1369 |
| Total    | 419066| 275320| 248815|

(Notes: Air-conditioning energy consumption data provided by the property)

![Figure 4. Monthly electricity consumption curve of the air conditioning system.](image)

From Figure 4, it can be seen that the monthly power consumption of the building’s air conditioning system shows obvious seasonal characteristics. The air conditioning power consumption in the air conditioning season shows a trend of first rising and then declining with time, and the peak value appears in July-September, which is proportional to the outdoor air temperature.
5. Analysis of energy saving potential and suggestions for transformation

5.1. Energy-saving analysis and suggestions for air-conditioning system

Through the audit, it is found that the energy consumption of the air conditioning system of the building accounts for a large proportion. Combined with the review of the operation records of the air conditioning unit of the building and the on-site inspection, it is found that the air conditioning system of the building operates well, the equipment selection is reasonable, the indoor temperature and humidity of each floor are basically controlled within the standard range, and the windows of each floor are closed when the air conditioning system operates, which effectively saves the energy consumption of the air conditioning system. However, problems such as severe scaling of the cooling tower on the roof have also been found. The cause of this scaling is mainly due to the fact that there are more ash and dust in the atmosphere during the heat exchange process of the cooling tower, which will form a layer of comprehensive dirt on the water separator and tower surface of the cooling tower. The dirt generated by long-term operation cannot fall off and enters the system with water, which may cause low heat exchange and cause equipment failure. It is recommended to periodically clean and descale the cooling tower.

5.2. Energy-saving analysis and suggestions for lighting system

Through on-site inspection, it is found that T5 fluorescent lamps are used in the underground garage and the machine room of the building, and all lamps are kept fully open when no one is around, resulting in unnecessary energy waste. In order to maximize energy conservation and emission reduction, it is recommended to transform T5 fluorescent lamp of underground garage into LED lamp, and set different induction devices according to different positions of garage. For example, adjustable light induction lamp can be installed in the lane, when the garage is unmanned and no cars, the lamps are in a state of 20% -30% brightness to provide monitoring lighting. When someone or car enters the garage, the lamps can be fully lit automatically, with the brightness state of 100%. When the person or car leaves for one minute, the lamps can return to the brightness state of 20%. The infrared induction system of human body shall be installed at the parking space. When there are people and cars, the lights will be on completely. When the car and people leave the parking space, the lights will be dark and standby state.

The audit team conducted inspections of the building's lighting power during the day and the audit results showed that the building's lighting management was good overall. In public spaces such as corridors and elevators, property managers were arranged to inspect the building every day and turn off some area lighting equipment unnecessary in time, causing better energy saving effect. However, in some office areas, it is also found that the indoor illumination in many office areas during the day can be satisfied without turning on the lights, but the lights are still on.

For the entire building lighting system, it is recommended to install intelligent lighting control systems in offices, corridors and other areas. The specific functions can be controlled in different areas according to different spaces. The office area can adjust the brightness of the light to use of natural lighting and artificial lighting better according to the indoor environment. By detecting the illuminance of the relevant indoor area (such as the envelope near glass window), the adjustable optoelectronic ballast is adjusted to reduce the power of the lamps, and the energy is saved when the indoor illuminance is basically constant.

5.3. Energy-saving analysis and suggestions for other systems

Through on-site inspections of the building, the audit team found that human negligence in daily work will also cause a certain amount of energy waste intentionally or unintentionally. For example, the door is still open when the air conditioner is turned on, and the office lights are still fully open when there are no or few people and other waste phenomena.

Suggestions: Strengthen energy saving and emission reduction into the daily life of employees, try to make sure the lights off when there is no one. If there is no one next to the desk for a long time, turn
off the computer or put the computer into hibernation, and do not make office equipment in a standby state for a long time, such as printers, copiers, etc.

6. Conclusion
According to the energy audit of the office building, it can be known that the energy consumption characteristics of the office building, that is, the air conditioning system and the lighting system account for most of the electricity, accounting for 19% and 20%, respectively. In the future audit of similar buildings, the audit of these two systems should be strengthened, the energy consumption characteristics of similar buildings should be analyzed based on the energy consumption data, the weak points of energy use should be found and suggestions for improvement should be put forward.

References
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