Energy Audit of Building: A Case Study of A Commercial Building in Shanghai

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***Abstract*—The paper presents a detailed study of building energy audit through a case study about a commercial building in Shanghai. Recorder data of energy consumption of each building service system are used to diagnose the weak points of the building energy-usage system, tap latent power and then a detailed energy audit study are presented. By conducting an investigation of the energy consumption, the energy audit focuses mainly on the equipment consumption, especial on air-conditioning system, electronically equipments, lighting system, and elevators, etc. During the energy audit investigation, field-measurement of the indoor environment has been carried out in winter. Indoor temperature, relative humidity and CO_2 concentration have been measured during the field-measurement. Based on the energy audit results on the total energy consumption of the building from 2005 to 2008, outer climate and office occupancy rate are two leading factors for the change of the total energy consumption. The energy consumption of the air-conditioning system is at the first place, which accounts for about 45%. The energy consumption of the lighting system is just less than 10%. Some measures are put forward to increase energy efficiency.**

Keywords: energy audit, energy consumption recorder data, field-measurement, outer climate, office occpancy rate

I. INTRODUCTION

Energy crisis and greenhouse effect are the impetus behind energy audit. The energy audit is used to "diagnose" the weak points of the building energy-usage system, tap latent power and to build up energy-saving responsibility.

The Energy audit focuses mainly on total energy consumption of the equipments, especially on air- conditioning system, electronically equipments, lighting, and elevators, etc.

The paper presents the energy consumption of a commercial-building in Shanghai as a case study, which is used to discuss the consumption standard of non-renewable resources of the normal commercial-building in Shanghai. By conducting a survey on the energy use, the equipment load in the building is gathered for the analysis. Some measures to increase energy efficiency are put forwards.

Field investigation of the energy audit on the commercial -building have been carried out from December, 2008 to Juanary, 2009. It took nearly two months to investigate the energy consumption from 2005 to 2008, including the running recorders of the air-conditioning system, lighting system, charter business, outer climate of the typical seasons and the equipment loads.

II. A CASE STUDY

A Introduction of the commercial-building

The commercial-building was built at 1998. There are 28 floors of the building in all, 20 floors of which are used as office zone. The building height is 106.5m. And the building area is 26000 m^2, as well as the air-conditioned area. The working time is 12 hours every day, from 7:00am-19:00pm.

The envelop area of the building is 12,000m^2, in which the proportion of the glass curtain wall is 50%. The area of the openable window is 300m^2.

B Lighting system

The hall, lobby and public lavatory can be considered as the public zone of the commercial- building. The lighting system of the public zone can be basically divided into two types:1) 9w eco-lamp; 2) 36w fluorescent light. Except this, different companies have installed other different lighting systems to meet their own demands in the office zone.

According to the specials of the companies in the building, the total lighting system can be defined as 3 types:1）design corporation：45w fluorescent lamps are installed for the special demands of the Engineering Design; 2）Beauty Salon: Ornamental lighting are added to make a more comfortable and relax indoor environment; 3）Government Functional Department: 9w eco-lamp and 36w fluorescent lamp are used commonly as the main lighting equipments without other lighting system.

Power and quantity of each type of lamp were investigated firstly, and the energy consumption of the lighting system is the product of the power and the quantity. In conclusion, the total energy consumption per year of the lighting system is the product of the above energy consumption and the yearly running time of the each type of lamp.

C Air-conditioning system

8 air-source heat pumps are used as the cooling-supply source in summer, in which 7 heat pumps are also used in winter. The performances of the heat pumps are shown in

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TABLE I. Both of the public and the office zones are the serviced zone of the 8 heat pumps.

Cooling system is used in the office-zone from the end of May to the end of October each year. During the cooling-supply period, 3 or 4 air source heat pumps are enough to supply cooling capacity during May, June, September and October. Considering the outer temperature rising up to the top value, all of the heat pumps should be used in July and August.

Heating system is used in the office-zone from January to March each year. Considering the much colder climate, all of the heat pumps must be used in January. 3 or 4 air source heat pumps are enough to supply heating capacity in February and March.

Out-flowing water temperature is monitored to check the equipments working normally.

TABLE I PERFORMANCE INFORMATION OF THE HEAT PUMP

	Num.	Rated refrigerating output/kW	Rated heat output/kW	Rated power/kW
Heat pump (for summer and winter)	7	1129.68	878.64	90
Heat pump (Only for summer)	1	2259.36	-	180

D Office facilities

The audited building is a moderately business building. The office leasers can be classified as 5 types by the nature of company: 1) Government Functional Department; 2) Engineering Design Company; 3) Beauty Salon; 4) Consulting & Investment Company; 5) Machinery Manufacturing Company. So the office facilities of the mentioned company types can be considered as routine necessities without large energy-used equipment, such as computer, printer, and communication equipment.

E Elevator and pump system

There are 4 elevators in the commercial building. Operation information of the elevators is shown in TABLE II, including the power, running-time and function, etc.

To get the energy consumption of the elevator system per year, the energy consumption of one elevator is measured hourly in one day firstly, and then the total energy consumption per year is the product of the energy consumption per day and total running-time per year.

There are 8 pumps in the commercial –building, except cooling water pump. Operation information of the pumps is shown in TABLE III， including power, running-time and function ,etc. The calculation method of the pump system is similar to the elevator system.

TABLE II PERFORMANCE INFORMATION OF THE ELEVATOR

	power	running-time	function	Num.
elevator	22 kW	24hours	Client	2
elevator	22 kW	7:00-19:00	Client	1
elevator	15 kW	24hours	sight-seeing	1

F Energy management contract

Property management centre of the commercial building is responsible for air-conditioning system operation recorder, lighting and elevator system operation recorder every day and office occupancy rate recorder update.

TABLE III PERFORMANCE INFORMATION OF THE PUMP

	power	running-time	function	Num.
pump	37kW	1.2h	life	2
pump	15kW	1.2h	life	2
pump	110kW	/	fire fighting	1
pump	110kW	/	spraying	2

III. Energy Consumption Analysis

Energy utilization situation from 2005 to 2008 is analyzed by audit field investigation and recorder data.

A Analysis on total energy consummption per annum

Total energy consumption is illustrated in TABLE IV. By the energy audit investigation, the indoor heat source generated by office facilities and company staff are stable. Hence outer climate and office occupancy rate are two leading factors for the change of the total energy consumption.

From the recorder data shown in Fig.1, the extreme climate appeared respectively during the summer of 2007 and the winter of 2008. More cooling (heating) capacity was needed to fight against the bad weather. Therefore, the energy consumptions of 2007 and 2008 are larger than the energy utilizations of 2005 and 2006.

Due to financial crisis in 2007, the office occupancy rate dropped to the bottom point. However, the total energy consumption was still at the peak, because that the building envelops and equipments were maintained and reconstructed at the end of 2007.

In 2005, the office occupancy rate was the top value. The energy consumption increased with the incensement of occupancy rate. So it can be concluded that office occupancy rate made an efficient impact on the total energy consumption in 2005 and 2006. However, the total energy consumptions in 2007 and 2008 are still larger, compared with 2005 and 2006. Therefore, the outer climate is the key factor of the energy consumption, compared with the office occupancy rate.

TABLE IV THE TOTAL ENERGY CONSUMPTION PER YEAR

	2005	2006	2007	2008	average
Electrical (kWh)	2759730	2627758	2963661	2842905	2798514
energy consumption (tce)	1114.9	1061.6	1197.3	1148.5	1130.6

remark：tce—ton Standard coal

B Analysis on total energy consummption per unit area

Considering the office occupancy rate, the office area for the energy audit changes every year in TABLE V. Nevertheless, the change of the energy consumption per unit area is the same as the total energy consumption per year. The energy consumption per unit area of 2007 is still at the peak point, as well as the total energy consumption in Fig.2.

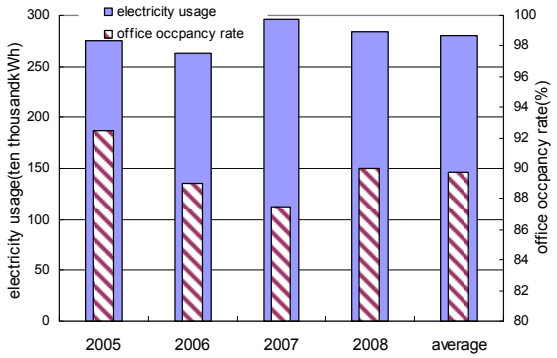

Fig.1 electircity usage and office occpany rate per year

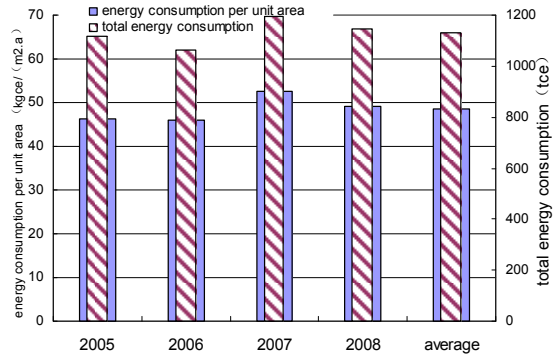

Fig.2 the energy consumption per unit area

TABLE V THE TOTAL ENERGY CONSUMPTION PER UNIT AREA

	2005	2006	2007	2008	average ve
office occpancy rate%	92.5	89	87.5	90	92.5
energy consumption (tce)	46.4	45.9	52.6	49.1	48.5

By the energy audit investigation, it can be concluded that the office occupancy rate determines the energy consumptions of lighting system, elevator system, office facilities and person activity. And the outer climate is the key point to the energy consumption of the air-conditioning system. Therefore, the total energy consumption is generated by the outer climate and office occupancy rate working together.

C Analysis on energy consumption per month

The electricity consumption recorder data from 2007 to 2008 in detail were used to analyze the change of energy consumption per month in Fig.3.

From January to March, heating system is used to make a more comfortable environment in the office-zone every year. In the transitional seasons, the total energy consumption reduces correspondingly, because the air-conditioning system is being taken off. And in summer, the energy consumption reaches the peak to lighten the heat burden.

Difference of the energy consumption distribution between 2007 and 2008 focuses on the energy utilization in February. In February 2008, snow storms weather appeared unexpectedly in Shanghai. More heat capacity was needed to fight against the hard climate. Hence, the energy consumption increased by 30%, compared with the same period last year.

In July 2008, outer temperature of more than 31days temperature climbed to 35℃ in Fig.4. In July 2007, the recorder data shows that the outer temperature increased to 35℃ naturally during only 15 days in Fig.5. So the energy consumption increased by 18.1% in July 2008. It can be concluded that the outer climate seems getting extremely worse, the temperature was much lower in winter, and the temperature was much higher in summer in 2008.

D Analysis on components of the energy consumption

Recorder data of each system in the commercial building in January and July of 2007 are used to analyze the components of the total energy consumption in summer and winter respectively.

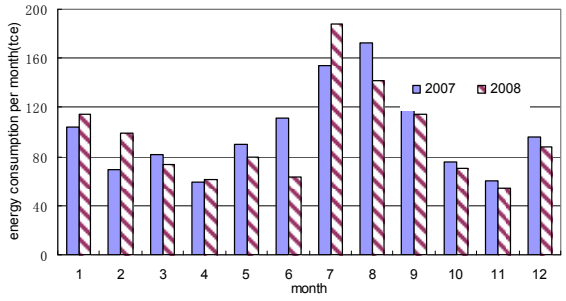

Fig.3 energy consumption per month

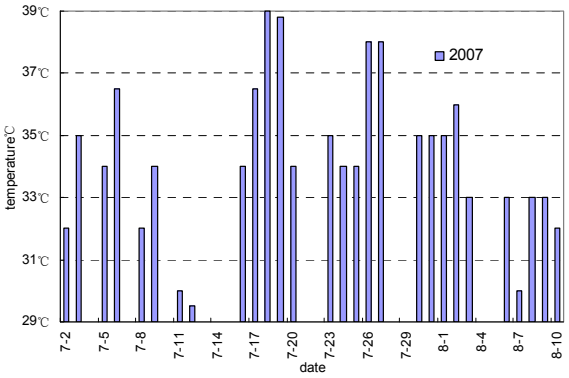

Fig.4 outer temperature distribution in 2007

From Fig.6 and Fig.7, it is described that the energy consumption of the air-conditioning system is at the first place, and it accounts for 45% of total energy consumption.

Ornament of the lighting system is relatively concise, so the energy consumption of the lighting system is just less than 10%.

E Analysis on indoor environment of office zone in winter

During the energy audit investigation, field-measurement of the indoor environment has been carried out on 19th January 2009. Two office rooms on 8th floor and 23th floor were chosen to measure the indoor temperature, relative humidity and CO_2 concentration in winter. The indoor temperature and the relative humidity were tested by E+E automatic thermograph simultaneously, and the CO_2 concentration was tested by auto tester. On the test day, the outer temperature was 8.8℃, the relative humidity was 54.5%, and CO_2 concentration was approximately 380ppm. There were 12 testing points in the tested rooms.

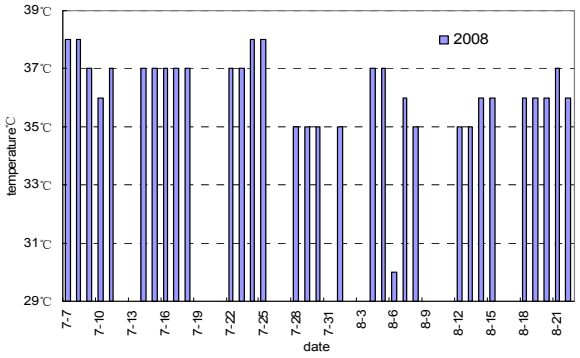

Fig.5 outer temperature distribution in 2008

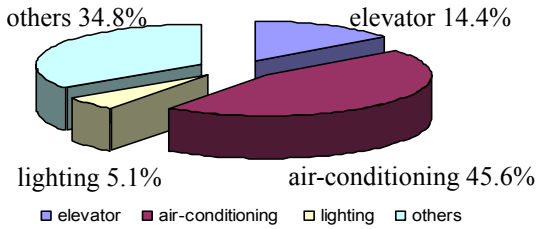

Fig.6 components of the energy consumption insummer

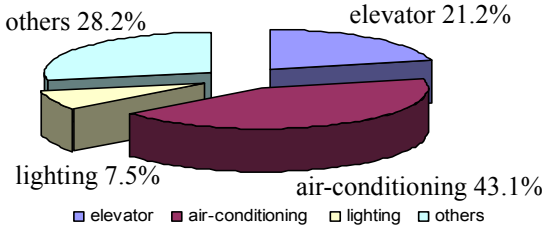

Fig.7 components of the energy consumption inwinter

In Fig.8, it is shown that the average indoor temperature was 21.2℃, and the average relative humidity was 36.8%. The work area per capita is 27.5m^2 on the 8th floor, which is a comparatively narrow space, compared with the office room on the 23th floor. Hence, the temperature on the 8th floor was higher by 1.1℃, and the relative humidity was lower by 3.6%. From the testing data in Fig.9, the indoor CO_2 concentration was 600PPM fluctuant.

F Analysis on energy-saving potential of the glass curtain wall reconstruction

The building glass curtain wall was maintained and reconstructed in 2007, including that the thickens of 1,400m2 glass curtain wall was reconstructed and broadened from 6mm to 8mm. Energy charge before and after reconstruction were compared to analyze the energy-saving potential and to increase the energy efficiency.

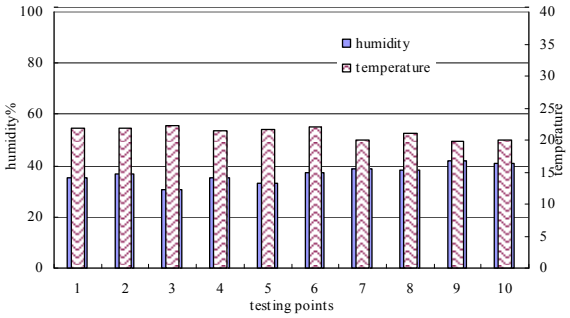

Fig.8 measured data of indoor temperature

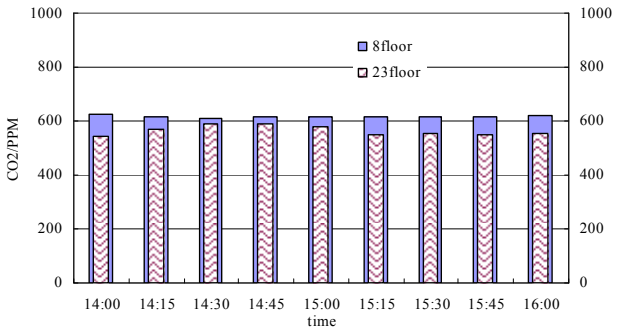

Fig.9 measured data of CO_2 concentration

Energy charge before and after reconstruction are illustrated in TABLE VI. After reconstruction, building envelop power consumption each month can be decreased by 869.41 kWh, which is account for 9.64% of the energy consumption before reconstruction if COP=4.0. It can be concluded that broadening the thickness of the glass curtain wall has notable saving electric energy effect.

TABLE VI ENERGY-SAVING POTENTIAL OF THE GLASS CURTAIN WALL RECONSTRUCTION

Glass	Cooling load /W	Power /W	energy consumption per month /kWh
6mm	150335.8	37583.96	9020.15
8mm	135845.6	33961.41	8150.74

I. Conclusion

The energy consumption of a commercial building in Shanghai is used to discuss the consumption standard of non-renewable resources of the normal commercial building in Shanghai. From 2005 to 2008, the average total energy consumption of the commercial building is 1130.6 tce, and the average energy consumption per unit area is 48.5 tce. The energy consumption of the air-conditioning system is at the first place, and it accounted for about 45% of total energy consumption. As to the audited commercial building, outer climate and office occupancy rate are two leading factors for the change of the total energy consumption.

II. Acknowledgements

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