2014

Comparative Analysis on Energy Consumption of Commercial Buildings Based on Sub-metered Data

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Comparative analysis on energy consumption of commercial buildings based on sub-metered data

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ABSTRACT

With energy use growing rapidly around the world, building energy conservation is becoming a great concern especially for large commercial buildings. Therefore, it is of great significance to develop appropriate methods for energy use assessment of commercial buildings. In recent years, energy monitoring system (EMS) has been applied in some large-scale commercial buildings, which has laid the foundation for exhaustive and authentic evaluation. However, most of the current studies are only focused on annual or monthly aggregated energy consumption. Though end-use data are monitored in some buildings, only major categories or equipment are included. Little has been done to analyze the energy performance of numerous buildings with detailed hourly end-use data.

With the access to hourly sub-metered data of detailed end uses, this study aims to introduce a comparing method to evaluate building energy performance through a case study. Information on selected buildings in the case was introduced. The research intends to compare energy use intensity (EUI) of the 19 malls based on a uniform energy data model, from total energy to detailed end-uses. It was shown that there is a significant discrepancy on the total energy use among these buildings, mainly due to HVAC (Heating, Ventilation and Air Conditioning) and public lighting. Then an in-depth comparative study was conducted on the energy consumption of public lighting and HVAC respectively. An unexpectedly remarkable discrepancy was illustrated on the EUI of public lighting. Thus the daily and hourly energy of public lighting were compared to identify the discrepancy in management mode. The study on HVAC was focused on the comparison of daily and hourly EUI in terms of four subordinate end uses (chillers, chilled water pumps, fans and cooling systems). The result showed that chillers accounts for larger proportions of total energy use, and the daily and hourly data were compared between buildings with similar climate. At last, the methods were summarized and challenges were discussed.

1. INTRODUCTION

With the energy use rapidly growing, building energy conservation is becoming a great concern especially for large commercial buildings. According to statistics, energy use intensity (EUI) of large commercial buildings ranges from 120 to 180 kWh/ m^2 , which is much higher than that of residential buildings, at the level of 50 kWh/ m^2 (Tsinghua Building Energy Research Center, 2013). Therefore, it is of great significance to gain extensive knowledge on the key factors of commercial building energy use and to propose effective approaches and policies to improve the energy performance.

Though a lot of efforts have been made in this area, some problems have emerged, as the two listed below (Wang, 2010).

1) Although large amounts of energy efficiency technologies have been developed to enhance the building energy

performance, an absence of their application conditions and unpredictable external factors leads to poor operation of many so-called energy efficient buildings.

2) Researchers and managers of the buildings have made an attempt to deal with the real energy data from utility bills. The data are usually annual or monthly total energy consumption, failing to provide an explicit view of energy performance. There were researchers trying to estimate the hourly data, or data on detailed end-uses by applying a series of predetermined coefficients (Fumo et al. 2010), which is arduous and incredible.

Based on the problems mentioned above, building energy monitoring system (EMS) has been applied in some large-scale commercial buildings, which brings exhaustive and authentic evaluation of energy performance of commercial buildings to fruition and simultaneously challenges the researchers on how to utilize the data properly. With the access to hourly sub-metered data from 19 shopping malls, this study aims to discuss the characters and influential factors of energy consumption in commercial buildings through systematic comparisons as well as a close-up on public lighting and HVAC.

2. METHODOLOGY

2.1 Energy Data Model

Building information in the case study including location and area is collected in the first place. As the data are sub-metered by end-uses, an understanding of the energy data model is necessary. There is a general energy data model certified in the ISO Standard 12655, while there is a slight modification specifically for this case. Figure 1 shows the energy data model for the shopping malls in the case.

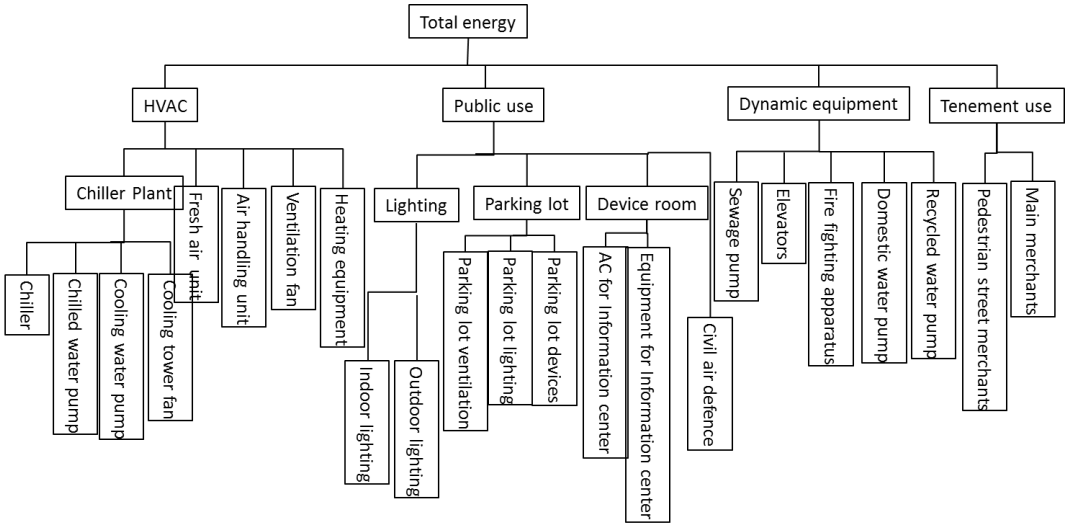

Figure 1: Energy data model

2.2 Data Clean-up and Analysis Methods

The data from the EMS are received as raw data. To ensure the quality, elaborate data clean-up is carried out. Two kinds of data, including those with default or zero values and exceptionally high or low values, need to be replaced with new ones which are randomly generated according to the mean and variance of the adjacent data.

Energy comparative analysis is based on three levels according to the energy data model:

1) Total energy.
2) Major end-uses, including HVAC, public use, dynamic equipment and tenement use.
3) Subordinate end-use of public use, mainly on public lighting; subordinate end-uses of HVAC, including chillers, chilled water pumps, fans and cooling systems. These two end-uses are chosen as the focus because they are two main contributions to the total energy consumption.

In terms of the specific methods, energy profiling is the essential part, containing the profiling for cumulative annual EUI, average daily EUI and hourly EUI on the three levels of end-uses mentioned above.

3. CASE STUDY

3.1 Information of Buildings

The case includes 19 shopping malls of the same design which are located in different cities across China, from Severe Cold Zone to Hot Summer & Warm Winter Zone. Energy data to be analyzed are by hour from July 16th, 2012 to April 5th 2013. The buildings are named after their location in the following analysis.

3.2 Comparative Analysis

The total EUI aggregated from July 16th 2012 to April 5th 2013 was compared among 19 buildings in the first place. To obtain an explicit view of the proportions of public use, HVAC and dynamic equipment, the part of tenement use was eliminated, as shown in Figure 2.

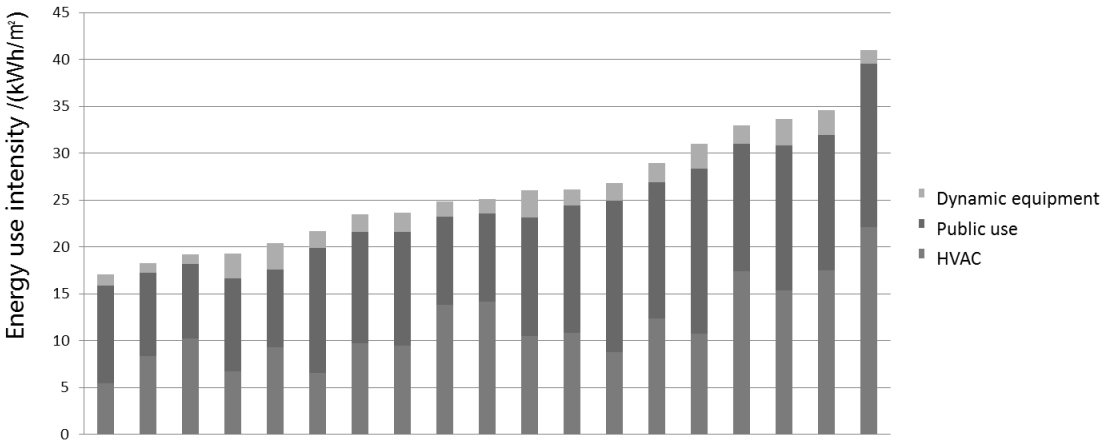

Figure 2: Comparison on EUI of aggregated total energy(07/16/2012 ~ 04/05/2013)

As can be seen from Figure 2, there is a remarkable discrepancy on total EUI, with a large proportion of HVAC and public use. Therefore, comparison on EUI of public use and HVAC was conducted respectively.

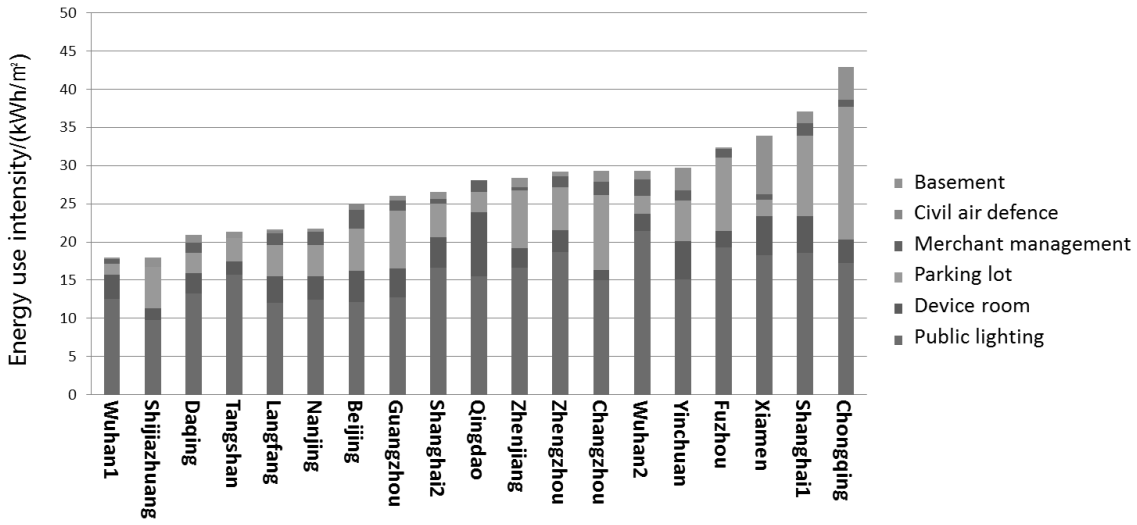

Figure 3: Comparison on EUI of aggregated public use (07/16/2012 ~ 04/05/2013)

As can be concluded from Figure 3, public lighting plays an important role in public energy use and is an unexpectedly discrepancy on EUI of public lighting. Therefore the comparative analysis moved on to public lighting. Because the shopping malls have the same design and operation, the energy use of public lighting is supposed to be similar, which conflicts with the actual results. To gain a better understanding of public lighting energy use, the hourly data were analyzed. Average daily EUI curves for each building were plotted, as shown in Figure 4. Each curve shows the hourly EUI of public lighting for one building for one day.

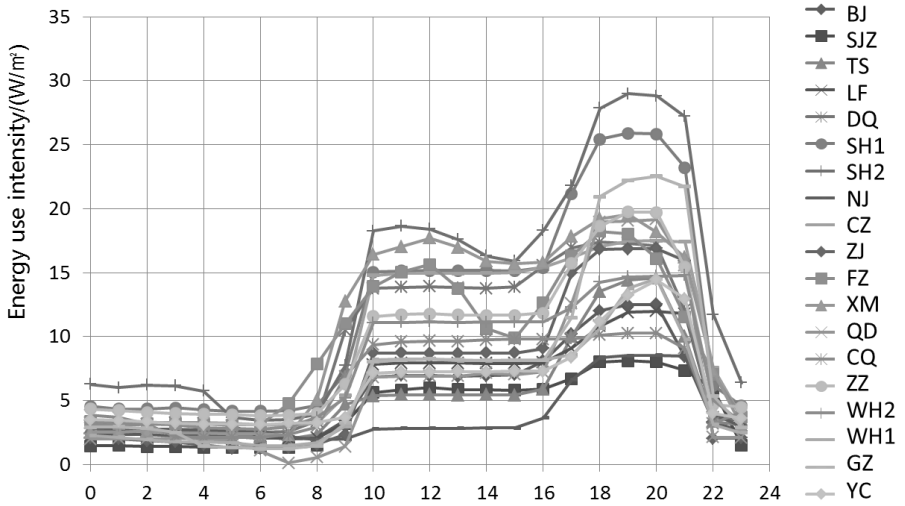

Figure 4: Average daily EUI curves of public lighting

The figure shows that the daily curves for all the buildings have a similar *three step* shape, while intensity and time span for each step differ among the buildings. Through analysis on daily pattern, management mode is concluded to play an important role in public lighting energy use.

As for the EUI of HVAC, it is necessary to compare the average daily data instead of the aggregated for a period of time because the operating time for HVAC equipment differs among buildings. The average daily EUI for each building in Figure 5 was calculated according to corresponding operating time.

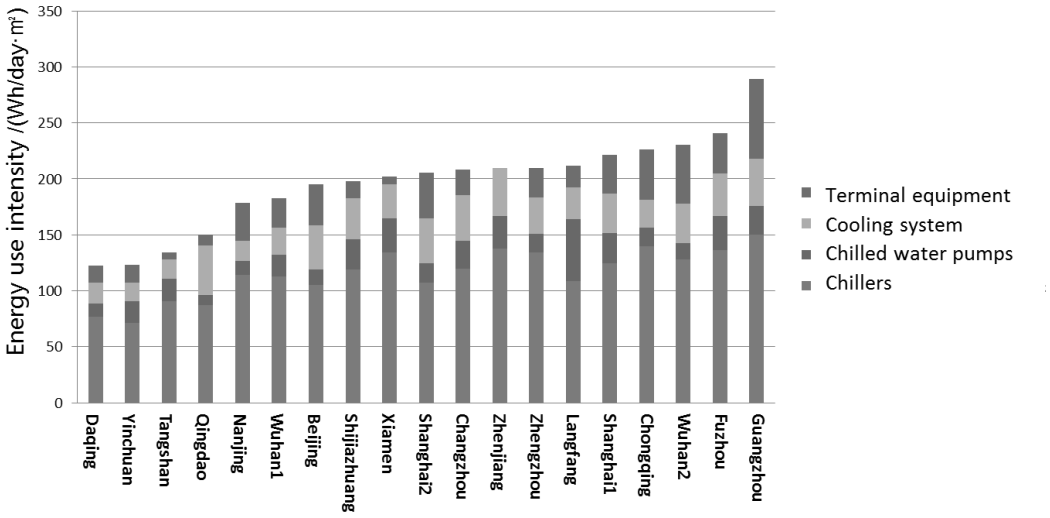

Figure 5: Comparison on average daily EUI of HVAC

Chillers are demonstrated to be the largest contribution to HVAC energy use in Figure 5. Therefore, aggregated EUI of chillers was compared in the similar way as public lighting. Meanwhile, hourly EUI of chillers for buildings with similar climate was then compared to obtain more information. It is proved that the key factors could be identified by delving into the energy data for HVAC.

4. CONCLUSION AND DISCUSSION

The comparative methods based on sub-metered data are proved to be applicable to building performance analysis. Through hierarchical comparison, the average level of energy use for the targeted buildings is demonstrated as well as buildings with excellent or poor energy performance. In addition, main factors for good or bad building energy performance are diagnosed effectively, which is conducive to the following specific measures. Both an overall perception and extensive knowledge on energy use of end uses are obtained with this method. What calls for attention is that clean and elaborate data from EMS is the foundation of this method. The data in this study are hourly metered by detailed end uses, which allows conducting various comparison and extracting different indexes to evaluate energy performance.

In terms of challenge, as energy use of HVAC is related to many factors, it is essential to develop more methods to evaluate the HVAC energy properly, for instance, weather normalization. There are varieties of weather normalization methods by using dry-bulb temperature, wet-bulb temperature, CDD etc. But how to utilize these parameters to evaluate HVAC energy is still a great challenge. In addition, more information needs to be collected, in order to achieve more effective and reasonable evaluation on building energy performance.

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