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Building energy saving potential in Hot Summer and Cold Winter (HSCW) Zone, China—Influence of building energy efficiency standards and implications

Luyi Xu, Junjie Liu, Jingjing Pei*, Xu Han

Tianjin University, School of Environmental Science and Engineering, China

HIGHLIGHTS

- ▶ Building energy efficiency standards were compared among China, UK and the US.
- ▶ Heating energy consumption takes 1/3 of that of the residential building in HSCW Zone, China.
- ▶ Building energy saving in Chongqing is 30–70% applying various building standards.
- ▶ Public and residential buildings are most sensitive to LPD and COP respectively.
- ▶ Building energy standards should be improved and implementation should be enforced.

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ABSTRACT

Hot Summer and Cold Winter (HSCW) region plays an important role in China's building energy conservation task due to its high consumption in recent years for both climate and social reasons. National and local building energy standards according to which the buildings are built and operated can affect the building energy consumption to a great extent. This study investigated the energy saving potential in Hot Summer and Cold Winter Zone under different level of energy efficiency standards (China local, China national, and UK standard). Chongqing was taken as an example, and the commercial energy simulation tool eQuest was applied to analyze the building end-use energy. With the existing situation as a baseline, the building energy saving for residential section could achieve 31.5% if the Chinese national standard were satisfied, and the value would further increase to 45.0% and 53.4% when the Chongqing local and UK standard were met. For public buildings, the corresponding energy saving potentials were 62.8%, 67.4% and 75.9%. Parameter sensitivity analysis was conducted. The analysis was able to provide suggestions on energy saving implementation priorities for residential and public buildings. Indications to improve building energy standards and their implementation were also discussed.

1. Introduction

Driven by economic resurgence, the global energy consumption increased significantly in recent years. The world's total energy consumption growth reached 5.6% in 2010, which was the highest rate since 1973 (BP plc, 2011). Sharing 20.3% of the global energy consumption, China exceeded the US as the largest energy consumer in the world. The report from British Petroleum Company (BP) in 2012 (BP plc, 2012) indicated that China would account for 67% of global coal growth to 2030 and remained the largest coal consumer. China's building section accounts for 23% of the country's total energy consumption (Building Energy Conservation Research Center of Tsinghua University, 2010). With this trend, the building energy consumption will be 1.3 times higher than the current situation by 2020 (Jiang, 2008). Therefore promoting building energy conservation and carbon emission reduction is crucial and urgent for sustainable social and economic development.

The climate condition varies greatly from region to region in China, leading to different regional characteristics of building energy consumption. The Chinese national regulation "Thermal Design Code for Civil Building" (GB 50176-93, 1993) (China Construction Ministry, 1993) defined five climate zones in China according to the mean temperature of the coldest month (tcm)

* Correspondence to: Building 14, Room 240C, School of Environmental Science and Engineering, Tianjin University, 92 Weijin Road, Nankai District, Tianjin 300072, China. Tel.: +86 2227403416, mobile: +86 18622407076; fax: +86 22 27401561.
E-mail address: jpei@tju.edu.cn (J. Pei).

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and the hottest month (thm): Severe Cold (SC) Zone (tcm ≤ -10 °C), Cold (C) Zone (tcm $= -10$–0 °C), Hot Summer and Cold Winter (HSCW) Zone (tcm = 0–10 °C, thm = 25–30 °C), Hot Summer and Warm Winter (HSWW) Zone (tcm ≥ 10 °C, thm = 25–29 °C) and Temperate (T) Zone (tcm = 0–13 °C, thm = 18–25 °C).

Compared with other climate zones, the Hot Summer and Cold Winter (HSCW) Zone showed special significance in energy conservation task of China due to the following reasons: This area covers 16 provinces, which is nearly half of the nation's total provinces; more than 40% of Chinese population lives in this area, which is less than 20% of Chinese total area, leading to much higher population density than other regions; the economy growth is more rapid than other region, and takes up 48% of the gross domestic product (GDP). The weather data of Typical Meteorological Year (Meteorological information center of China meteorological administration and Tsinghua University, 2005) showed that the average outdoor temperature is 0–10 °C in the coldest month and 25–30 °C in the hottest month. The relative humidity is 70%–80% or even higher all over the year. Together with the long period of summer and winter (summer: from early May to late September, winter: from mid-December to mid-February next year), the building energy consumption in HSCW Zone takes about 45% of the whole country (Yu, 2009). According to China design regulation (GB 50176-93, 1993) and local traditional habits, no central heating system was designed for buildings in the HSCW climate zone. However, people's increased requirement for thermal comfort aggravates the increase of building energy consumption, especially for the heating part. According to the data from China National Bureau of Statistics, energy consumption for heating in HSCW Zone raised 30.6% from 2003 to 2007 (National Bureau of Statistics of China, 2003, 2004, 2005, 2006, 2007). Furthermore, the insulation performance of the building envelope was generally very poor. A survey showed that 54% of the existing urban dwellings in HSCW Zone only installed 370 mm depth brick wall with 20 mm cement plaster on both internal and external face of the wall (Fu, 2002), with the heat transfer coefficient of 1.53 W m^{-2} K^{-1}. These social, climate and policy factors lead to the high building energy consumption and poor indoor thermal comfort in HSCW Zone.

The serious building energy consumption situation had raised the government's attention. Researchers and experts from thirteen provinces in China gathered together for an ''Integration and demonstration on the key technologies of building energy conservation in Hot Summer and Cold Winter Zone'' project, which is a research project funded by ''The Twelfth Five Year'' national key technology program in 2011 aimed to improve this situation. It was vital to understand the current building energy consumption status and the effect of the national and local energy efficiency standards on energy saving potential in this area. Here, energy saving potential is a percentage value that is calculated between the energy consumption of existing situation and energy consumption of buildings satisfying various levels of standards. Chinese building energy efficiency standards can be divided into three grades, namely national standards (standard number start with GB, which is short for ''national standard'' in Chinese) released by the departments of standardization administration under the state council; industrial standards (standard number start with JGJ, which is short for ''building industry construction'' in Chinese) released by Ministry of Housing and Urban–Rural Development of the People's Republic of China and local standards (standard number start with DB, which is short for ''local standard'' in Chinese) released by local Urban–Rural Development Office. The scope of application decreased from national standard to local standards. National standard fit for the whole country. The industrial standards (JGJ134-2010, 2010) in this study were applied to a specific region and local standards were released for a province or a city. Industrial standards and local standards are generally sticker and are in more detail than national standards. The industrial and local standard must ensure the agreement and consistency with national standard. The specifications in those standards significantly influence the energy consumption of buildings designed accordingly. Therefore the building performance in terms of energy consumption under design requirements should be evaluated to study the effect of different energy standards.

There were several approaches in estimating building energy saving potential. Energy audit and energy consumption simulation are the most commonly used methods. In China, the annual energy use per unit area in large scale public buildings with centralized HAVC systems ranged from 119 to 158 kWh/m^2 (converted into electricity consumption) (Lam et al., 2008a) by computational simulation with DOE-2.1E. Chen et al. (2009) compared energy consumption characteristics between new and old residential buildings in Shanghai by statistical methods, and the results showed energy consumption by HVAC system took up 11.6% and 16% for new and existing dwellings separately. Wang et al. (2010) used Simplified Building Energy Model (SBEM), the recommended simulation tool in UK building regulation (Building Regulation Approved Document L1A & L2A, 2006), to estimate the energy use of a virtual commercial building in the Severe Cold Zone of China. The results showed that, the building had 29% saving potential according to the UK standard (Building Regulation Approved Document L2A, 2010) compared with Chinese building energy conservation standard (GB 50189-2005, 2005).

It was shown that the standard according to which the building was designed presents significant influence on the building energy consumption characteristic. However, most of the literature studies were mostly limited to the energy consumption status of a specific case of residential buildings, without analyzing energy saving potential in detail when different energy saving standards was applied. This paper aimed at estimating the influence of different energy saving standards on building energy consumption in China's HSCW Zone. The energy audit method is significantly time and effort consuming, and is impossible for the current purpose as no buildings was built according to the standards to be discussed. The computer simulation costs less time and is suitable for comparing different scenarios and was used in current study.

2. Method

2.1. Target city

Building energy consumption in Chongqing is investigated in current study. Chongqing is one of the two municipalities in the HSCW Zone in China. Chongqing's specific characteristic of climate, building thermal environment and energy consumption made it more representative for this case study.

Located in Sichuan Basin in the west part of HSCW Zone (east longitude 105°11′–110°11′ and northern latitude 28°10'–32°13'), Chongqing is well known as a ''furnace city''. The summer here was extremely hot and uncomfortable. An investigation showed there were 60–90% people who complained that they were sleepless at summer night due to the sweltering and sultry weather (Fu, 2002). In winter, Chongqing did not benefit too much from the lower latitude compared with north China. People felt cold in buildings without heating. As no central heating and cooling facilities were available in most dwellings in Chongqing, the majority local residents adopted split air-conditioning and electric furnace to improve the thermal comfort, which was quite energy inefficient. According to a survey data carried out in 1997, average daily electricity consumption during summer season could reach 20 kWh per household in Chongqing. Heating power