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Energy savings and cost-benefit analysis of the new commercial building standard in China

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Abstract

In this paper, a comprehensive comparison of the commercial building energy efficiency standard between the previous 2005 version and the new proposed version is conducted, including the energy efficiency analysis and cost-benefit analysis. To better understand the tech-economic performance of the new Chinese standard, energy models were set up based on a typical commercial office building in Chinese climate zones. The building energy standard in 2005 is used as the baseline for this analysis. Key building technologies measures are analyzed individually, including roof, wall, window, lighting and chiller and so on and finally whole building cost-benefit analysis was conducted. Results show that the new commercial building energy standard demonstrates good cost-effective performance, with whole building payback period around 4 years
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Keywords: commercial building, energy efficiency standard; reference building, cost-benefit, simulation

1. Introduction

The issue of energy and environment is increasingly prominent. Industry, transportation and building energy consists of the main consumption factor, among which building-related energy consumption contributes to 48% of the total social energy consumption (Pérez-Lombard et al. 2008). Commercial building accounts for a great part of the total building floor area. In China, the total floor space of commercial buildings increased from 2.8 billion m2 to 7.1 billion m2 from 1996 to 2008, with approximately 0.5 billion m2 of new commercial building floor space built annually (Fridley 2008; Zhou et al. 2012). From 2001 to 2011, the area of commercial buildings increases by 0.8 times and the average energy consumption per unit floor area increases from 17.9 kgce/m^2 to 21.4 kgce/m^2 (Hong 2009).

To improve the indoor environment & energy efficiency and promote the utilization of renewable energy in commercial buildings, China has issued its own standard on commercial building energy conservation in 1993 and an upgrade in 2005 (Zhao et al. 2009). The 2005 version mandated that commercial buildings be 50% more efficient than a 1980's baseline defined by the 1980s building characteristics (Feng et al. 2014). It was estimated that the commercial building energy standard in China can produce 249 mtce savings from 2010 to 2030 (Hong et al. 2014). In this paper, a comprehensive cost-benefit analysis comparison between the previous 2005 version and the new proposed version is conducted for cost-benefit purposes.

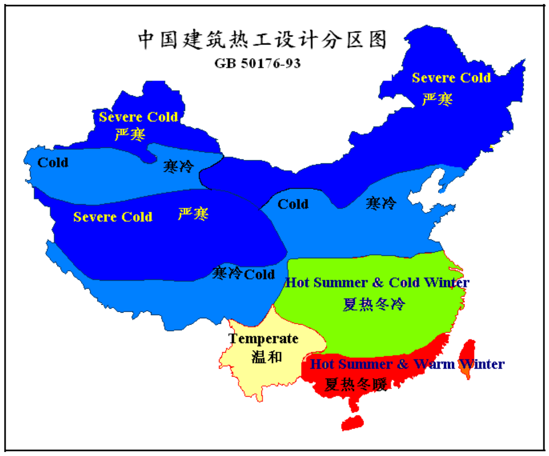

Figure 1. Chinese climate zone Figure

2. Methodologies

There are five climate zones in China: Severe cold, cold, hot-summer & cold-winter, hot-summer & warm-winter and temperate (seen in Figure 1), among which cold, hot-summer & cold-winter and hot-summer & warm-winter climates consist of the majority of building floor space and energy consumption. Beijing, Shanghai and Guangzhou are chosen as the typical cities for the energy and cost-benefit analysis in these three climate zones respectively.

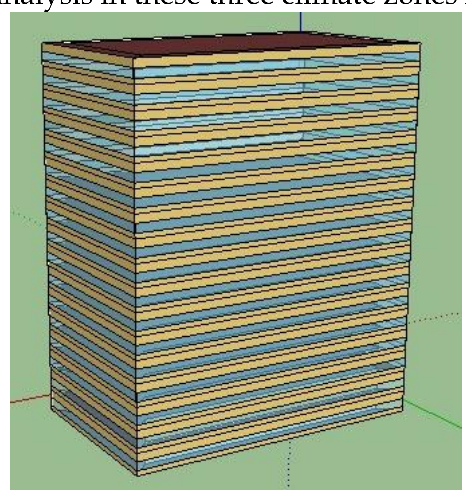

Figure 2. Chinese reference office building geometry

To better understand the tech-economic performance of the new standard, energy models were set up based on a typical commercial office buildings in the above three cities (Feng et al. 2014). The building energy standard in 2005 is used as the baseline for this analysis. Basic information of the building model and general technologies measures are presented in Table 1. Key building technologies measures are analyzed individually, including roof, wall, window, lighting, building air-tightness, chiller, plug load and so on and finally whole building cost-benefit analysis was conducted (the energy saving from infiltration and air-tightness is attributed to window system improvement). The models were developed in EnergyPlus and simulated to get whole year performance.

Table 1. Reference office building model information

	GB50189-2005	GB50189 - new proposed
Shape	50m*30m	
Floors	18 floors(no basement)	
WWR	0.4	
HVAC system	VAV with reheat; terminal hot water radiator (only in cold and severe cold climates)	
Lighting power density	11 W/m^2	9 W/m^2
Plug load power density	20 W/m^2	15 W/m^2
Occupancy density		
Chiller COP	4.7	5.2
Boiler efficiency	0.89	
Air tightness	7.5 $m^3/(m^2\ hr)$	3 $m^3/(m^2\ hr)$
OA rate	3 $m^3/(hr\ person)$	
pumps	Variable speed	

3. Results:

Whole year's energy consumption simulation was calculated separately for Beijing, Shanghai and Guangzhou. The 2005 standard and the new standard are used to obtained key technologies parameters. Building operation information is also obtained from the proposed standard and can be seen in Figure 3. The simulated results are compared between the standard 2005 and the new proposed standard, with results shown in Figure 4.

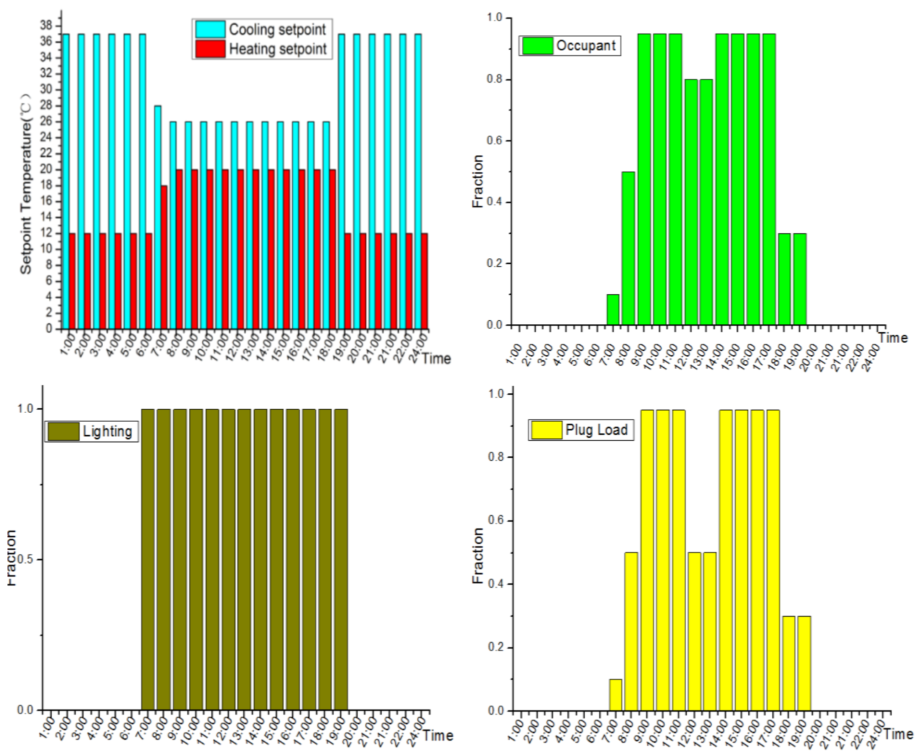

Figure 3 cooling and heating setpoint, occupant, lighting and plug load fraction in a typical weekday

The simulation results from EnergyPlus indicate that Beijing, Shanghai and Guangzhou can respectively achieve a site energy consumption deduction of 28.8%, 20.9% and 19.4% with overall national weighed average savings 23.9%. It is noticed that the plug load improvement is not taken into account in the results mentioned above, otherwise, the site energy saving percentage results would be 27%, 23% and 24% with plug load improvement included (Feng et al. 2014), and national weighed average savings 24%. When it comes to the source energy, the results are 22.8%, 19.6% and 19.6% (Table 2) respectively in Beijing, Shanghai and Guangzhou excluding plug load and national weighed average savings 21.0%. It is also found that North climates demonstrate higher savings than Transition and South climates in China in site energy, while in source energy, the savings are very close. The conversion factors from site energy to source energy is used in the paper and kept the same across all the climates as shown in Table 3, even though in reality the conversion factor could be different.

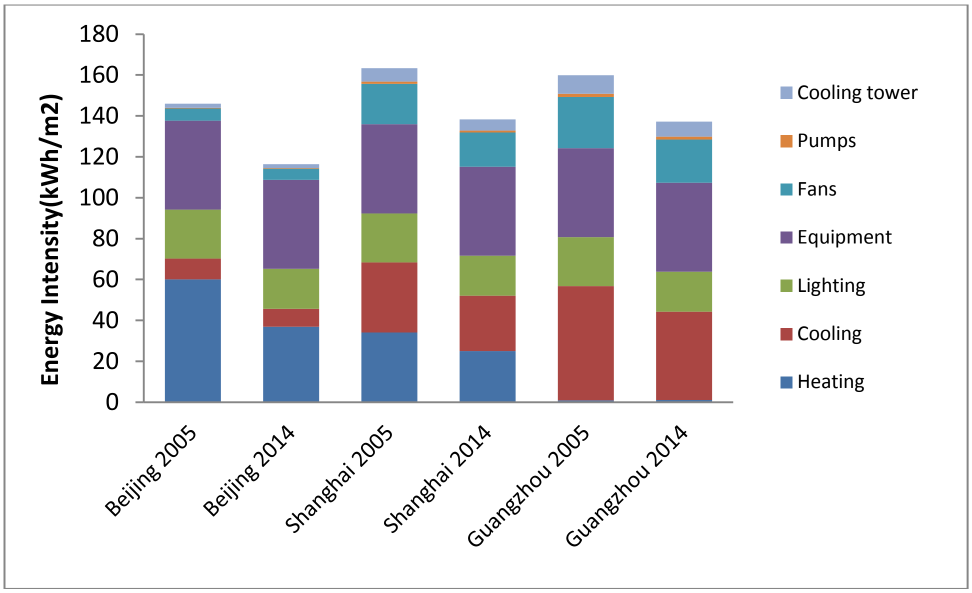

Figure 4. Energy Intensity of Chinese office reference buildings in three cities

Table 2. Site and Source Energy Savings for Beijing, Shanghai and Guangzhou without plug load

City	site energy(kWh/m2)			source energy(kWh/m2)		
	2005	new proposed	Saving percentage	2005	new proposed	Saving percentage
Beijing	102.39	72.87	28.83%	199.21	153.78	22.81%
Shanghai	119.86	94.79	20.92%	308.63	248.21	19.58%
Guangzhou	116.29	93.7	19.43%	366.47	294.48	19.64%

Table 3. Site-to-Source Energy Conversion Factor for Different Energy Types

Energy type	Electricity	Natural Gas	District Cooling	District Heating	Steam	Gasoline	Diesel	Coal
Factor	3.167	1.084	1.056	3.613	0.300	1.050	1.050	1.050

To analyze the cost-benefit of new standard, a survey of energy conservation measures' cost is conducted. The survey included energy price such as gas, electricity, and district heating price, and technologies investment cost such as insulation materials, windows, lights, chillers and so on. Insulation materials and their prices are obtained from major insulation material retail websites. Lighting technology costs are collected from lighting manufactures, and chiller costs are obtained by surveying major chiller manufacturers in Chinese market. Building glazing system cost data is obtained from the pilot fenestration system labelling database in

China (CFEEPL 2015). The incremental investment cost of one technology is calculated by the technology cost difference between the model developed by the 2005 standard and the one developed by the new proposed standard. Technology capital cost is only used for incremental cost calculation. Labor and Operation and Maintenance (O&M) cost not used in the incremental cost analysis and are assumed the same between the 2005 standard and the new proposed standard.

Energy prices are kept the same for 2005 and the new proposed standard. Time of use (TOU) electricity price in different cities are used, and two different heating tariff are used to calculate heating energy cost: floating heat metering tariff (plan A) and the floating and fixed heating tariff (plan B), calculated as follows:

Plan A: full floating heat metering tariff (calculated as the amount of natural gas consumption)

$$Cost_A=V_{NG}*P_{NG}=E_A/\alpha*P_{NG} \quad (1)$$

where:

E_A	Energy consumption	kilocalorie
α	calorific capacity	Kilocalorie/m^3
P_{NG}	Natural Gas price	RMB/m^3

Plan B: floated + fixed tariff:

$$Cost_B=A*P_2+E_B*P_1 \quad (2)$$

where:

A	Heating floor area	m^2
E_B	Energy consumption	kWh
P_1	Energy consumption based tariff	RMB/kWh
P_2	Floor area based fixed tariff	kWh/m^2

For Beijing: floating tariff P_1 is 0.25 RMB/kWh, and floor area based fixed tariff P_2 is 18 RMB/m^2

Table 4 shows the tech-economic calculation results. The payback periods for Beijing, Shanghai and Guangzhou are 3.4 years or 4.1 years, 3.9 years and 2.9 years respectively. Lighting's payback period is generally the same across different zones. Chiller efficiency retrofit enjoy a shorter payback time in south and transition zones mainly because of the relative longer cooling season in these two climates compared with North China. Figure 5 further illustrates the payback period for different technologies in different climate regions.

Table 4. Payback time calculation for Beijing, Shanghai and Guangzhou

City	technology	△EUI (kWh/m2)	△saving (RMB/m2)	Incremental Cost (RMB/m2)	Pay back time year
Beijing A[1]	Roof	0.36	0.16	0.49	3.06
	Wall	0.77	0.27	2.77	10.26
	Window	22.03	6.81	36.4	5.35
	Lighting	4.16	4.71	8.7	1.85
	Chiller	1.02	1.09	6.5	5.96
	Combined	28.21	14.74	50.51	3.43
Beijing B[2]	Roof	0.36	0.14	0.49	3.50
	Wall	0.77	0.19	2.77	14.58

1 Beijing climate using heating tariff A
2 Beijing climate using heating tariff B

	Window	22.03	5.13	36.4	7.10
	Lighting	4.16	4.74	8.7	1.84
	Chiller	1.02	1.09	6.5	5.96
	Combined	28.21	12.34	50.51	4.09
Shanghai	Roof	1	0.78	1.32	1.69
	Wall	0.77	0.41	5.6	13.66
	Window	15.31	8.08	48.58	6.01
	Lighting	4.79	4.76	8.7	1.83
	Chiller	4.04	3.76	6.5	1.73
	Combined	25.08	16.92	66.34	3.92
Guangzhou	Roof	1.18	1.5	1.09	0.73
	Wall	0.85	0.78	4.9	6.28
	Window	8.3	7.53	42.51	5.65
	Lighting	5.87	5.35	8.7	1.63
	Chiller	7.48	6.75	6.5	0.96
	Combined	22.58	20.51	59.34	2.89

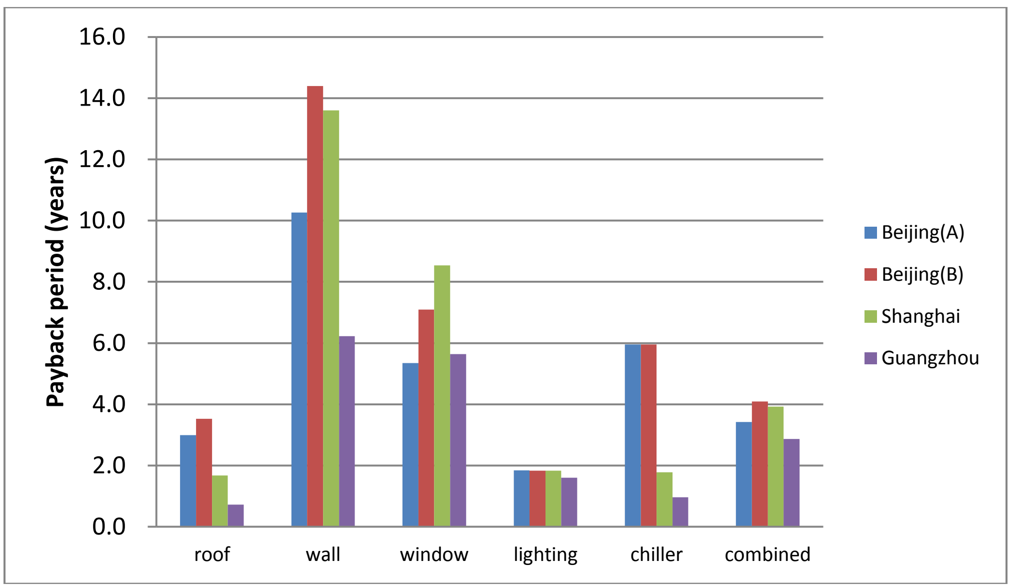

Figure 5. Payback period for Beijing, Shanghai and Guangzhou

4. Conclusions:

This paper conducted a quantitative and cost-benefit analysis of the newly proposed Chinese commercial building standard GB 50189 compared with its previous 2005 version. The new proposed commercial building codes can achieve good cost-benefit performance. Building technology measures influence the performance of the new proposed standard differently. In summary, following conclusions can be drawn based on analysis above:

- The new proposed standard demonstrates site energy savings of 24% and source energy savings 21% on national average, without considering plug load efficiency improvement.
- Cost-benefit analysis shows that the payback periods for Beijing, Shanghai and Guangzhou are 3.4 years or 4.1 years, 3.9 years and 2.9 years.

Though a comprehensive analysis has been done in this paper using large size office building models, there are still certain limitations need to be addressed in the future:

- Only the large office building type is analyzed while some more types need to be considered in the future, such as retails, hospitals, government office buildings, schools and so on.
- Only three representative climate cities are studied and more cities could be imported in China's five climate zones.
- Limited cost data access makes the calculation relatively rough and a more comprehensive cost-benefit analysis could be conducted.

5. Acknowledgement

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