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Evaluation on the impacts of the implementation of civil building energy efficiency standards on Chinese economic system and environment

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ABSTRACT

In this paper, in contrast to the usual rough estimation, we present a model to simulate and evaluate the direct, indirect economic and environmental impacts of the implementation of building energy efficiency standards on Chinese economic system and environment by 12 indicators in two scenarios. Four indicators are used to evaluate the direct economic impact degree, five indicators are used to evaluate the direct environmental impact degree, three indicators are used to evaluate the indirect economic impact degree of 34 sectors and the whole Chinese economic system. This research makes it possible to link developments in the implementation of building energy efficiency standards with environmental and economic structure change. The most important finding is that the implementation of building energy efficiency standards can reduce a large amount of pollutants emissions and increase the GDP at the same time.

1. Introduction

China is facing a major challenge posed by increasing energy requirement and greenhouse gas emission. From 2000 to 2020, the national planning targets call for quadrupling the value of China's GDP with a concomitant doubling of energy consumption, implying an energy elasticity coefficient should be 0.5. However, in the last three years, the coefficient was estimated at more than 1.3, suggesting that future energy levels (absent any major conservation efforts or significant improvements in efficiency) will be far higher than those estimated by the current planning's forecast. Furthermore, China's development has entered into the heavy industry stage. According to the development experience in the rest of the world, the stage of rapid growth in energy requirement of China seems to be insurmountable [1].

According to preliminary estimations, over the period from 2001 until 2006 the energy consumed by residential buildings in urban areas accounted for 20–27% of the total annual energy consumption in China. In 2006, the total energy consumption of residential buildings in urban areas is 539.75 million tce, which accounted for 24.5% of the total energy consumption in China (Table 1). If the energy consumption in the building materials production and in construction is added, the total energy consumption of the construction industry accounts for about 46.7% of China's total energy consumption.

Due to strong capital investment, the large population, urbanization, and heavy reliance on coal, Chinese GHG emissions are high. The IEA has estimated that China's GHG emissions for 2005 were 7527 MMTCO2e. Of these emissions, about 78% were CO_2. By most estimates, China is now or soon will be the largest emitter of GHG globally [2]. The world bank, working with the Chinese government and other experts, in 2007 estimated that the cost of outdoor air and water pollution to China's economy totaled around US$100 billion annually, or 5.8% of China's GDP. Related to such findings, the Chinese government put environmental protection into its 11th-Five-Year-Plan (2006–2010) as a high priority. Chinese central government officials have over the past decade pursued a combination of measures to control air, water and soil pollution, and are struggling to build a recycling industrialized economy to ease environmental pressures. These efforts have met with mixed success. The greenhouse gas emission incurred by building energy consumption accounted for about 25% of the total greenhouse gas emission. Along with the population and economic growth, and the associated expansion of the building stock, if there have no major conservation efforts or significant improvements in energy efficiency, the overall energy use and the energy use in buildings and the greenhouse gas emission in China will be on an up-rising trend [3].

Energy used by air-conditioning and heating in buildings account for 65% of the total buildings energy consumption. Practice in China has proved that energy-efficient residential

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Table 1
National urban building energy consumption data in 2006 in China.

District	Total building energy consumption (10,000 tons of standard coal)	The proportion to the national urban building energy consumption (%)	The proportion to the total national energy consumption (%)
National urban district	53975	100	24.5
Freezing and cold district	27530	51	23.3
Hot summer and cold winter district	18496	34.3	25.8
Hot summer and warm winter district	7949	14.7	26.8

Data source: 2006 Building Energy Conservation Special Inspection of the Ministry of Housing and Urban-Rural Development of the People's Republic of China reported data.

buildings can reduce the use of energy by air-conditioning in summer, can also reduce about half of the energy consumption in heating at the same heating effects in winter. By the end of 2002, there were only 230 million m^2 existing floor spaces of residential energy-efficient buildings in China, which accounts for 0.86% of the Chinese total existing floor space of residential buildings [21,22]. With great efforts of Chinese government to promote the building energy efficiency, the ratio increased to nearly 5.3% until 2007 October.

Obviously, improvements of building energy efficiency are urgently needed. As an effective way, the implementation of building energy efficiency standards can achieve the goal. However, studies reveal that the effort made to improve the efficiency and effectiveness of using energy in buildings remains limited [4,5].

In China, there are mainly 17 building energy efficiency standards, codes and technical specifications that had been enacted by the MOHURD (Ministry of Housing and Urban–Rural Development of the People's Republic of China) until 2007 [6]. JGJ26-95, JGJ134-2001, JGJ75-2003 and GB50189-2005 are the core of these standards. The other items play support and complementary roles to the above four. We call all 17 items in Table 2 as the building energy efficiency standards (BEES) commonly in the later analysis for their same aim to improve building energy efficiency.

China is divided into three climate zones which are freezing and cold zone, hot summer and cold winter zone, and hot summer and warm winter zone (see Fig. 1). For each climate zone, there have a design standard of residential building JGJ26-95, JGJ75-2003, JGJ 134-2001. There is a design standard for energy efficiency of public buildings GB50189-2005 (see Table 2). In each standard, it gives the weather condition of the climate zone, the outdoor design temperature in summer, the cooling load of the building, etc. For example, COP of the chiller is 2.2 in hot summer and warm winter climate zone, and in hot summer and cold winter climate zone. COP of the electric heating is 1.0 in hot summer and warm winter climate zone, and in hot summer and cold winter zone. These standards in Table 2 were published. The detailed parameters can be checked from them. Especially, in GB 50189-2005, the parameter of ventilation for acceptable indoor air quality is referred to [7]. In GB50365-2005, the rate of hydraulic disorder and the rate of airflow disorder are referred to ASHRAE standards and made some adjustment according to the specific condition in China. The newly designed standards in China will treat [8] as minimum acceptable outdoor air supply rate, follow ASHRAE standard for thermal comfort.

Most standards in Table 2 require civil buildings adopt the 50% kind of BEES. Some require civil buildings adopt the 65% kind of BEES. The meaning of the 50% kind of BEES can be explained as this. Regard buildings built in 1980s as baseline, overall heat transfer coefficient of building envelope, index of design load for heating of building and other parameters are set according to buildings at that time. Then calculate the energy consumed by the baseline when the indoor environment was kept the same as that set in the design standard for energy efficiency of buildings. Assumed the result as 100%, adjust the parameters of the baseline to the parameters that set in the 50% kind of standard, the energy consumption of the baseline will be 50% of the primal result. The meaning of the 65% kind of building energy efficiency standard is similar.

We have the energy consumption data of the non-energy-efficient buildings, assumed all the parameters of the buildings are set according to the corresponding building energy efficiency standard, according to the meaning of the building energy efficiency standards, we can evaluate how much energy could be saved after the building energy efficiency standards are implemented.

China has made more mandates on implementing BEES in the recent years. It was ordained that all the newly built residential buildings must be adopted the 50% kind of BEES strictly, those in large cities and developed districts should adopt the 65% kind of

Table 2
Main standards, codes and technical specification that are being implemented in China until 2007.

No.	Name of standards, codes and technical specification	Corresponding serial number
1	Energy conservation design standard for new heating residential buildings	JGJ26-95
2	Design standard for energy efficiency of residential buildings in hot summer and cold winter zone	JGJ134-2001
3	Design standard for energy efficiency of residential buildings in hot summer and warm winter zone	JGJ75-2003
4	Design standard for energy efficiency of public buildings	GB50189-2005
5	Thermal specification for energy conservation reconstruction of existing heating residential building	JGJ129-2000
6	Standard for energy efficiency inspection of heating residential buildings	JGJ132-2001
7	Thermal design code for civil building	GB50176-93
8	Code of acceptance for construction quality of ventilation and air-conditioning works	GB50243-2002
9	Code for design of heating ventilation and air-conditioning	GB50019-2003
10	Technical specification for external thermal insulation on walls	JGJ144-2004
11	Standard for lighting design of buildings	GB50034-2004
12	Technical specification for floor radiant heating	JGJ142-2004
13	Technical code for solar water heating system of civil buildings	GB50364-2005
14	Code for operation and management of central air-conditioning system	GB50365-2005
15	Technical code for ground-source heat pump system	GB50366-2005
16	Evaluation standard for green building	GB/T50378-2006
17	Code for acceptance of energy-efficient building construction	GB50411-2007