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China's urban residential carbon emission and energy efficiency policy

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ABSTRACT

With China's urbanization, issues relating to emission reduction of buildings have become more prominent. Based on the latest data, we estimate total area of China's buildings, total housing area, and residential elevator stock. And also, we estimate energy consumption and carbon emission from the fossil fuel during building operation phase. Two index decomposition analysis on changes of urban residential carbon emissions and emissions intensity have been applied. The major findings of the study are: firstly, there has been a significant shift from primary energy consumption to electricity and heat in urban residential during the periods of 1996–2012, and the proportion of direct CO_2 emission to residential emission declined. Secondly, residential energy intensity, per capita housing area, total number of households are the main driving factors affecting the change in carbon emissions, with contribution rates of −39%, 77%, 67% respectively, and the decline of energy intensity is the most important factor of decreasing carbon intensity (contribution rate of 89%). Thirdly, reduction of carbon intensity is conducive to the decline of CO_2 and decrease in emission intensity of urban residential. Residential energy efficiency policy lessons learned from rethink of economic and social policies during the study period were concluded finally.

1. Introduction

Climate change is one of the greatest challenges facing the international community, and China is no exception. After more than 30 years of rapid economic development, China is now the world largest CO_2 emitter with its increasing energy consumption. China's fossil fuel carbon emissions was 9.5 billion tCO_2 in 2013, 4.2% higher than that of in 2012, and shared 27.1% of the global carbon emissions. While the United States accounted for 16.9% of global carbon emissions at the same time.[1] Thus, in addition to the contradiction between supply and demand of energy, China has serious environmental problems and pressures on addressing climate change.

According to statistical evaluation, the share of building energy consumption in total final energy consumption is about 21%–24% in China currently, while, the share is about 35–40% in developed countries [1]. With the further development of urbanization, issues on energy and emission reduction in buildings will become more prominent in China since construction sector is a major energy consuming one. For example, the residential electricity consumption accounted for 13.3% of final electricity consumption in 2012, compared with 10.7% in 1996 in China, per capita residential electricity is annual 459 kWh in 2012,[2] which is about ten percent of that in U.S. in 2011 (4560 kWh).[3]

Current research literature concerning energy consumption in China's building sector mainly consists of two parts, one is the study on characteristics of energy consumption and carbon emissions of the building systems [2–4], defining the appropriate statistical indicators [5], or forecasting energy consumption in the phase of construction [6]. The other is to study on carbon emission from buildings during the phase of construction and operation with life cycle analysis [7–9]. These studies lack in-depth analysis of the energy consumption and carbon emissions by fossil fuel during building operation. Taking into account the great difference between China's urban and rural residential buildings, as well as the differences in living standards, it is necessary that the issue of carbon emissions from rural houses and urban houses be separately analyzed. This paper tries to study urban residential carbon emissions in the operation of buildings, including the estimation of residential energy consumption and carbon emissions by fuel

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[1] Data source; BP Statistical Review of World Energy June 2014, http://www.bp.com/statisticalreview.

[2] Data source: China Energy Statistical Yearbook 2013.

[3] Data source: IEA website http://www.iea.org/.

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types, and the evolution patterns of urban residential energy consumption and its impact on carbon emissions during the operation of buildings, analyzing the driving factors of the changes of carbon emissions and emission intensity using the Divisia index models. Finally we conclude residential building energy efficiency policy recommendation and lessons learned from our analysis.

2. Methodology and results

Based on currently available statistical data published by China Statistics Press, we can only evaluate the building energy consumption by fuel type, but cannot directly get building energy consumption by different use from the final usage of the energy, such as cooking and lighting, due to the lack of statistical data that require social sample survey data. We select study period from 1996 to 2012,[4] using the data sourced from "China's energy balance tables (physical quantity, standard quantity)" from China Energy Statistics Yearbook (2009–2013), and the China Statistical Yearbook (1997–2013), as well as data sourced from the literature [1,10–12], and estimate urban resident stock building area, residential building energy consumption and CO_2 emissions by fuel type, total elevator stock, residential elevators, central heating energy consumption of residential buildings in urban area of Northern China, as well as other indicators.

2.1. Carbon emission factors estimation

This calculation method to estimate residential emissions is based on the IPCC's formulas of national greenhouse gas emission.[5] We also take into account Chen Shiyi's study [12], as well as the availability of China's energy consumption statistics data. The following emissions formula is applied in our study to simplify the estimation:

$$C = \sum_i C_i = \sum_i EQ_i \times TEF_i \times CEF_i \quad (i \text{ denotes fuel type}) \qquad (1)$$

where, C is carbon emissions, EQ_i is energy *i* physical consumption (unit: million tons or 10^8 cu m), TEF_i is conversion coefficient from physical unit to coal equivalent, CEF_i is carbon emission factors. According to classification in China's Energy Balance Tables, we classify 20 types of energy including raw coal, and cleaned coal, and other washed, and briquettes, and coke, and coke oven gas, and BF gas, and converter gas, and other gas, and crude, and gasoline, and kerosene, and diesel, and fuel oil, and LPG, and refinery gas, and natural gas, and LNG, and heat, and electricity. Other coal products and petroleum products for non-fuel purposes are not included in the estimation. The conversion coefficients and emission factors are shown in Table 1.

2.1.1. The carbon emission factor estimation for heat and electricity

As a secondary energy, the heat and electricity do not directly emit carbon dioxide. But the carbon emission factors for heat and electricity need to be provided while calculating indirect CO_2 emissions. Based on the data of "thermal power generation" and "heat supply" from the table of "intermediate inputs and transform" in Energy Balance Sheet in CHINA ENERGY STATISTICAL YEARBOOK 2013, the aggregate CO_2 emission from the use of fossil fuels is estimated according to the Formula (1), and the evaluated emission is the carbon emissions of heat and electricity. Then, the emission factor for heat is defined as the ratio of the estimated CO_2 emission from heat to the heat value in balance tables, and we use the average annual ratios as emission factor of heat in this study.

The emission factor of electricity is defined as the ratio of estimated CO_2 from electricity to the total electricity consumption in China including hydropower, nuclear power and other "zero carbon" renewable power (Table 2). Because of fast increasing consumption of nuclear and renewable power in recent years, China's annual carbon emission factor of electricity decreases, where the estimated emission factor is average annual carbon emission factor of electricity supply according to the definition.

2.2. Building stock area and residential building area estimation

Total buildings stock include residential and public buildings (such as hotels, office buildings, government offices and other buildings), residential building can be classified as urban houses and rural houses. The proportion of rural public buildings (such as schools and hospitals) is very small so that it is not separated estimated. According to Jiang Yi [1], China's buildings stock area is 40.1 billion m^2, with urban residential and public building areas for 11.29 billion m^2 and 6.16 billion m^2 respectively by the end of 2006. Based on the data of annual urban and rural new buildings area published in China Statistical Yearbook, and annual demolition area proportions of residential buildings, which we assume that urban residential annually demolished 100–130 million m^2 and rural residential annually demolished 500–550 million m^2 [1], we estimate building stock area and residential building area from 1996 to 2012 (Table 3).

Table 3 shows that the China's buildings stock area increases at 3.6% annually, along with the rapid development of the real estate market from 1996 to 2012, in particular, the quick development of urban houses and public buildings. Due to the scarcity of arable land in China, experts suggest that China's building stock area should be controlled within 60 billion m^2 in the future [1].

2.3. Elevator energy consumption estimation

In this section, we firstly estimate China's elevator stock from 1996 to 2012 (Table 4) according to the data provided in the reference [11], we assumed urban residential elevators accounted for 60% of the total elevators, and civil residential elevator operations consume electricity of average 50 kW h (kWh) daily, i.e., annual electricity consumption of 18250 kWh. According to Table 1 and Table 2, we estimated the annual energy consumption and carbon emissions of residential elevators as shown in Table 4.

Obviously, China's residential elevators in operation consumed electricity 26.7 billion kWh in 2012 with18.7 $MtCO_2$ carbon emission. If we assume that energy conservation rate is 30%, residential elevators operation in 2012 could save 8 billion kWh, which was about 5.6 $MtCO_2$ emissions reduction. The total saved electricity is also equal to the total electricity consumption (8.16 billion kWh) of Hainan Province in 2005. So the energy-saving potential of elevator operation should not be neglected.

2.4. Estimation of heating system energy consumption of residential in North China

China is the country with big difference in urban and rural residence, meanwhile, the impact of different climate zones on residential lives is different. At present, China's central heating system is available only to urban households in 15 provinces and

[4] Energy statistical data of 1996–2008 are corrected in "China energy Statistical Yearbook 2009", so this paper does not refer to previous yearbooks, and it is why 1996 is taken as the starting year of study period.

[5] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, 1.1 introductions.