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Model projections and policy reviews for energy saving in China's service sector

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HIGHLIGHTS

- Government energy saving target cannot realize with current policies in services.
- Energy savings policies for new buildings are crucial than building retrofitting.
- Cooling energy use increases significantly to reach equal weight as heating.
- CO_2 tax can contribute to change in fuel mix, and thus emission reductions.
- Low compliance rate limits further energy saving, hence green fund is required.

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ABSTRACT

Energy efficiency of buildings in the service sector is becoming increasingly important in China due to the structural shift of the economy from industry to services. This paper employs a bottom-up cohort model to simulate current energy saving policies and to make projections for future energy use and CO_2 emissions for the period 2000–2030 in the Chinese service sector. The analysis shows that energy demand in the service sector will approximately triple in 2030, far beyond the target of quadrupling GDP while only doubling energy use. However, it is feasible to achieve the target of emission reduction by 40% in 2020 even under the poor state of compliance rate of building standard. This paper also highlights four crucial aspects of designing optimal energy saving policies for China's service sector based on the model results.

1. Introduction

China as the largest and fastest growing non-OECD economy consumed 18% of world energy in 2009 (IEA, 2010). The service sector accounts for 7% of China's total energy consumption. From the data reported in the China Statistical Yearbook (2010) and the China Energy Statistical Yearbook (2010), its primary energy use increased from 89 million tonnes of coal equivalent (Mtce) in 2000 to 150 Mtce in 2006. With an average growth rate of more than 10%, energy use in the service sector expands much faster than the energy consumption on the aggregate level which grows at annual rate of 6.4%.

Due to a high dependence on coal, China emitted 8.33 billion tonnes CO_2 in 2010, accounting for a quarter of global emissions (BP, 2011). Moreover, total CO_2 emissions in China increased by more than a factor of four in the past 30 years due to rapidly growing energy demand. In the same period, CO_2 emissions in the service sector grew even faster, reaching a rate of 7.2% per year, which is almost 38% larger than the aggregate emission growth rate.

Moreover, the structural change of China's economy makes it appealing to explicitly examine service energy use not only for stabilizing future energy demand but also for cutting emissions. The service sector is the dominant economic sector in developed countries, and its importance is rising greatly in China. In 2006, the service sector contributed 40% of the GDP in China, lower than many other countries. The USA has 76% of GDP coming from the service sector in 2003 (World Bank, 2006). Lin et al. (2008) predicted that China's energy intensity would drop by 31% if the contribution of the service sector to GDP reached the levels of USA. Hirschhausen and Andres (2000) predicted that the structural change of China's economy would lower the electricity demand by 10%. The central government of China recently has announced a strategy to accelerate the development of the service sector in the next decade. Hence the service sector will contribute substantially to energy reduction in the future if treated properly.

China has set a standard of 50% reduction of energy consumption compared to buildings built in the 1980s (Standard-2005). By employing a bottom-up cohort simulation model—the SERVE-China model, this paper provides a sectoral analysis of energy use and emission trends when the Standard-2005 is implemented in China. It contributes to a better understanding of future trends and underlying factors influencing energy and emission intensity. Since

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most of the activities in the service sector take place in buildings, the model calculates the energy consumptions from the perspective of building energy use.

Several papers have studied the significance of the impacts of the service sector on energy consumption and emission reduction. Rosenblum et al. (2000) investigated the case of USA; Alcantara and Padilla (2009) provided analysis for Spain, Catenazzi (2009) for Switzerland. For the case of China, Cai et al. (2009) summarized the situation and challenges of building energy consumption in general. More than 20% of the total national energy consumption comes from building energy consumptions. Low efficiency and huge energy waste of public buildings offer large potential for future energy consumption reduction. Zhou and Lin (2007) explored the reality and future trends of commercial building energy consumption. Also, some studies discussed barriers to energy efficiency in policies towards buildings (IPCC, 2007; Yao et al., 2005). Zhou et al. (2009) highlighted the difficulties of implementation of the building codes in small provincial cities.

This paper differs from above contributions in several aspects. First, most of the papers restrict their attention to the technology level. This study incorporates the economic indicators – GDP growth and energy price – to reflect the future energy consumption from macroeconomic level. Second, existing studies only discuss the barriers for energy saving policies. Information on poor implementation of energy saving policies is integrated into model parameters to illustrate the real impacts of low compliance rate. Finally, this paper synthesizes the Standard-2005 with the government targets, providing a concrete evidence of the weakness of current energy saving policies.

I find that the standard can reduce heating use by 32% and electricity consumption by 8%. This analysis also shows that economic growth contributes largely to the energy consumption. High GDP growth will leads to 17% more heating use and 29% electricity consumption compared to the reference growth. I assess the possibilities of achieving two energy and emission targets announced by the government—(i) quadrupling GDP while only doubling energy use between 2000 and 2020, and (ii) emission reduction by 40–45% in 2020 compared with 2005 level. With current building and energy efficiency standards, target (i) cannot be achieved while target (ii) is feasible. This paper finally highlights four aspects which are crucial for policy makers on designing an optimal energy efficiency policy.

The rest of the paper is organized as follows. Section 2 introduces the SERVE-China model. Section 3 describes policy scenarios and the dynamics of key variables. Section 4 presents the simulation results and the assessment of government targets. Section 5 comments current energy saving policies in China based on the model simulation results, and identifies several crucial factors to be considered in policy design. Section 6 concludes the paper.

2. The model

The SERVE model, developed by the Center of Energy Policy and Economics, is a bottom-up cohort-based model which is used to simulate energy consumption in the service sector. It is a technology-based simulation model, in which the calculation of energy consumption is modeled as a complex dynamic aggregation of data. "Cohort-based" means energy use changes with the construction year and/or retrofitting year. Detailed description of the original model can be found in Aebischer (1996), Aebischer et al. (2007) and Catenazzi (2009).

The service sector refers to the production of services rather than tangible goods. Examples of specific service sectors include hotel, retail, banking, health, education, etc. The model takes the existing trends as a base line to model future energy use. To make prediction as precise as possible, many factors have been taken into consideration. Technological factors such as diffusion of technologies, improvement of efficiency, together with macroeconomic factors contribute to the dynamics of main variables described in the model equations.

In this paper, I use a modified version of the SERVE model (SERVE-China) to simulate the service energy use in China. The model version is rich in bottom-up, technological details and covers all sub-sectors of China's service sector.

Energy use in China differs significantly across regions. For simplicity, the whole country is divided into three regions: North, Central, and South. Within each region, the service sector is disaggregated into five sub-sectors. A sub-sectoral breakout includes hotel, retail, office, school, and others. For each of the sub-sectors, total energy use consists of two parts: energy use in heating and energy use in electricity. They are further broken out by end use or technologies. The heating use is based on the existing heating technologies. Seven technologies are included: CHP (combined heat and power), boilers with gas, boilers with coal, district heat with gas, district heat with coal, electric heating, and heat pumps. The electricity consumption is calculated based on the final consumption of different uses, namely electricity for cooling purpose, lighting, work related equipment, elevators and other supplementary uses. Total energy use in the service sector is the aggregation of the two parts.

The intra-structural changes within the service sector are modeled by different growth rates of value added GDP and the change of market shares in total services. The substitution among different technologies is projected by exogenous predefined substituting behaviors under different policies.

Energy use (final energy) in heating in period t includes heating in the North region and Central region, which can be calculated by the equation below. The south region is not heated due to relatively high average temperature. Energy use for hot water in the three regions is also included in the final heating use.

$$E_t^{heating} = \sum_b \sum_i E_{t,b,i}^{heating} = \sum_b \sum_i \sum_r \frac{h_{t,b,r}}{\eta_{t,b,i}} (A_{t,b,r} \cdot P_{t,i}), \qquad (1)$$

- b: construction year of building or technology;
- i: technology used for heating;
- r: regions in the model;
- $h_{t,b,r}$: average unit energy consumption (useful energy) for sub-sector r constructed in year b at time t, the unit is kWh/m^2, including heating and hot water;
- $\eta_{t,b,i}$: overall efficiency of technology i installed in year b at time t, including efficiency for heating production, conversion and end use;
- $A_{t,b,r}$: floor area for heating in sub-sector r constructed in year b at time t;
- $P_{t,i}$: share of fuel and heating technology i on total heating supply at time t;
- $E_t^{heating}$: total energy use for heating at time t.

Electricity use in service buildings is similar to the heating part. The only difference is that electricity use varies substantially within sub-sectors. To make projections more precise, the model differentiates buildings of the same sub-sectors into three classes: low electricity use class, median electricity use class, and high electricity use class.

$$E_t^{elec} = \sum_b \sum_{gr} (A_{t,b,gr} \cdot h_{t,b,gr}), \qquad (2)$$

- b: cohort, the construction year of the buildings;
- gr: electricity classes of buildings in sub-sectors (regions) of the model;