



Static analysis of technical and economic energy-saving potential in the residential sector of Xiamen city



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ABSTRACT

Based on a household energy use survey, this paper explores the technical and economic potential of residential energy savings in a Chinese city, Xiamen. The survey adopted a similar questionnaire used by the U.S. EIA's Residential Energy Consumption Survey (RECS), covering the end-uses of cooking, water heating, plug-in appliances, lighting and space cooling. The analysis shows that the technical potential of energy savings in Xiamen's residential buildings is significant, around 20%. Of the technical potential, about two-thirds to four-fifths are cost-effective from a whole society perspective. The cost-effectiveness was evaluated by comparing the Levelised Cost of Conserved Energy (LCOCE) of advanced technical measures with the actual cost of conserved energy. The actual cost of energy is defined by adding the carbon emission cost and hidden government subsidies over the retail prices of energy. About three-quarters of the technical energy-saving potential in Xiamen come from adopting efficient household appliances, therefore, further tightening the energy efficiency standards for key household appliances and promoting wide diffusion of efficient models of appliances by various effective financial incentives are essential for achieving residential energy savings in China's "Hot Summer and Warm Winter" region where Xiamen locates.

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1. Introduction

Being the largest carbon emitter in the world, China's CO₂ emissions closely relate to its energy consumption. This is mainly because of China's heavy dependence on the use of coal, about 70% in primary energy consumption [1]. Both China's total primary energy use and CO₂ emissions have been significantly increased from their 1990 levels, about six and four times respectively [2]. Although the deployment of nuclear, hydro, geothermal, solar and wind energy has been increasing very fast in the nation, they together still account only for a tiny share (around 5%) in China's primary energy supply [3]. Therefore, improving energy efficiency will remain crucial in the long run for China's commitments to climate change mitigation.

The residential building sector in China accounts for a significant share (approximate to 25%) of the nation's total final energy consumption [3]. In addition, owing to fast improvements of people's

quality of life, the residential energy consumption intensity (per capita) in China has been increasing (see Fig. 1). It increased by about 21% from 2005 to 2014, in sharp contrast with the significant drop of about 30% in China's industrial energy intensity (per 1000 Chinese Yuan industrial GDP, in 2005 Chinese Yuan) during the same period [1,3–5].

Given China's continuous economic growth and fast urbanization, its residential energy consumption and related CO₂ emissions are expected to have a substantial increase in the foreseeable future with the business-as-usual scenario. Promoting energy efficiency and conservation in China's residential building sector is, therefore, urgent. To address this issue, a fundamental step is to analyze the energy-saving potential in Chinese residential buildings.

Much research has been done on energy-saving potential analysis in buildings. However, the adopted analytical approaches vary among studies. In the research [6–11], the potentials were estimated based on the efficiency difference between existing technical measures in the building stock and anticipated advanced measures in the market. The studies [12–14] focused on the cost-effectiveness of energy-saving potential, while Broin et al. calculated the potential by assuming policy scenarios first [15].

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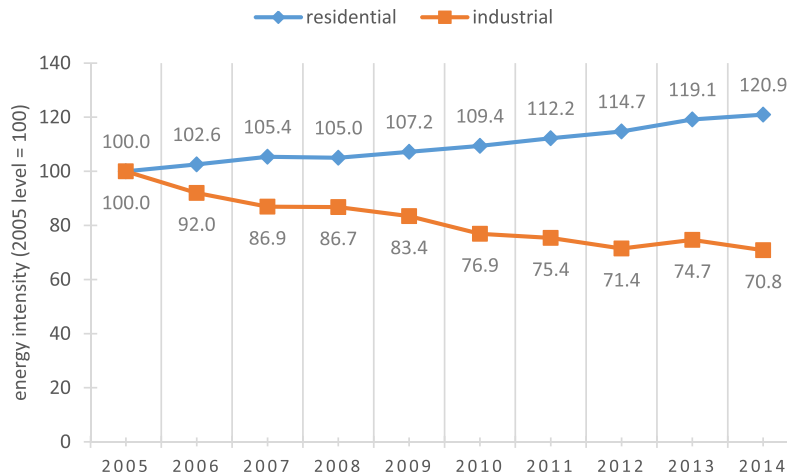


Fig. 1. Trends of energy intensities of industrial and residential sectors in China [1,3–5].

Nonetheless, the U.S. Environmental Protection Agency's "2007 Guide for Conducting Energy Efficiency Potential Studies" (hereafter referred to as the 2007 EPA Guide) suggests a conceptual framework of standard approaches for energy-saving potential analysis [16]. This framework could well cover the existing potential analysis approaches. By taking the view of efficiency as the supply-side alternative, the 2007 EPA Guide divided the energy-saving potential coming from energy efficiency improvements into four categories: technical, economic, achievable, and program potential.

In the 2007 EPA Guide, technical potential was defined as "the theoretical maximum amount of energy use that could be displaced by efficiency, disregarding all non-engineering constraints such as cost-effectiveness and the willingness of end-users to adopt the efficiency measures;" economic potential referred to as the "subset of the technical potential that is economically cost-effective as compared to conventional supply-side energy resources" [16].

Both the EPA's definitions of technical and economic potential assume "complete" and "immediate" replacement of existing technical measures by advanced ones, and they are, therefore, static potential analysis. In contrast, the achievable and program potential analyses involve a dynamic calculation process as they need to consider the real-world gradual adoption process of advanced technical measures (i.e., additions and replacements) within a certain time horizon as well as to take into account consumers' choices of efficiency-different appliances.

Different potential analysis serves different policymaking needs, and adopts different analytical approaches [16]. Static technical and economic potential studies target to help policymakers to design general energy policies for a sector. In comparison, dynamic achievable and program potential research is for assessing the impact of specific incentives on energy savings within a sector.

Using Xiamen city in China as a case study, this paper explores static technical and economic energy-saving potentials in Chinese urban residential buildings.¹ The analysis in this paper is based on a household energy use survey conducted in Xiamen in 2012, which adopted the same survey methods used by the U.S. Energy Information Administration's Residential Energy Consumption Survey

(RECS) [17].

Xiamen lies in southern China's Fujian province, belonging to the "Hot Summer and Warm Winter (HSWW)" climate zone according to the nation's classification in energy performance design of buildings. Owing to its warm climate (all-year-round average temperature of 21 °C) [18], space heating in the city is not needed. Hence, our surveyed household energy consumption in Xiamen includes the end-uses of lighting, cooking, water heating, plug-in appliances and space cooling.

Space heating is needed in northern China where district (or centralized) systems are dominant. These district systems widely lack household controlling measures. Consequently, the space heating energy consumption in China is usually out of the control of households themselves. Therefore, by studying Xiamen's household energy consumption, this paper principally focuses on the part of energy consumption in Chinese urban residential sector that can be substantially influenced by the household's own lifestyles or occupant behaviors. In fact, as the use patterns for the end-uses of lighting, cooking, water heating, plug-in appliances and space cooling do not vary much among Chinese cities [19], the Xiamen case can represent to some extent the residential energy consumption excluding space heating in northern Chinese cities as well.

In addition, being one of the most developed cities in China (with a per capita GDP of about 1.8 times the national average) [1,18], the overall efficiency levels of household appliances in Xiamen are relatively higher than the Chinese average. Therefore, exploring the residential energy-saving potential in Xiamen can be seen as a conservative (or "safe") choice for estimating the scale of potential in the nation.

2. Methodology

2.1. Analysis method for technical potential

According to the definition of technical potential given by the 2007 EPA Guide as well as referring to Swisher et al. [16,20], the general calculation principles of technical potential can be expressed as follows:

$$EEG_i = f\left(EE_{(i, new_h)}, EE_{(i, cur)}\right) \quad (1)$$

¹ The analysis of dynamic achievable and program residential energy-saving potentials in Xiamen city was presented in another paper [<https://doi.org/10.1016/j.rser.2016.04.070>]. These two papers adopt completely different analytical approaches suggested by the EPA [16], although they partly share the common data from our household energy use survey in Xiamen city.

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