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Analysis of achievable residential energy-saving potential and its implications for effective policy interventions: A study of Xiamen city in southern China

Fei Guo [a,*], Lado Kurdgelashvili [a], Magnus Bengtsson [b], Lewis Akenji [b]

[a] Center for Energy and Environmental Policy, University of Delaware, Newark, DE 19711, USA
[b] Institute for Global Environmental Strategies, Kanagawa 240-0115, Japan

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ABSTRACT

This paper explores opportunities for effective policy intervention for residential energy savings in southern China, by analyzing achievable potential of residential energy savings in the city of Xiamen as a case study. In contrast to static technical and economic potential analyses, the achievable potential analysis is based on dynamic energy consumption projections, which consider two real-world factors: (1) gradual ramping-up adoption process of advanced technical measures; and (2) consumers' adoption of these measures. A bottom-up type Residential Energy Consumption (REC) projection model specifically tailored for southern China was developed in this paper, based on the general logic and calculation principles utilized in the U.S. EIA's "National Energy Modeling System (NEMS)," and the adoption theory of advanced technical measures proposed by Kastovich. This REC projection model was then used as a policy analysis tool to quantitatively evaluate the impact of various policies on residential energy savings in the case study city of Xiamen. The analysis of the Xiamen case shows that although there is a significant technical potential for residential energy savings in the city (about 20.9–24.9%), the maximum achievable potential (MAP) in 2020 is only about 8.3–8.4% of that year's business-as-usual baseline consumption. Moreover, with existing policies only about one-fourth to half of the calculated MAP is likely to be achieved by 2020. These findings indicate that in order to realize a larger share of achievable potential for residential energy savings in China, additional and more effective polices are needed.

Contents

Abbreviations: AC, air conditioner; ACEEE, American Council for an Energy-Efficient Economy; AR, adoption rate; BAU, business-as-usual; BPI, Best-Policy-Intervention; EEG, energy efficiency gap; EEL, energy efficiency level; EES&L, Energy Efficiency Standard and Labelling schemes for appliances; EIA, Energy Information Administration of the U.S.; EPA, Environmental Protection Agency of the U.S.; FESL, Frozen Energy-Service-Level scenario; FSAC, fixed-speed air conditioner; IESL, Increasing Energy-Service-Level scenario; MAP, maximum achievable potential of energy savings; NEMS, National Energy Modelling System of the U.S. EIA; NREL, National Renewable Energy Laboratory of the U.S.; PAP, possible achievable potential of energy savings; PJ, petajoule; PPI, Possible-Policy-Intervention; REC, Residential Energy Consumption; RECS, Residential Energy Consumption Survey of the U.S. EIA; RDM, Residential Demand Module of NEMS; SPBT, simple payback time; TJ, terajoule; UEC, Unit Energy Consumption; VSAC, variable-speed air conditioner; XBS, Xiamen Bureau of Statistics

* Corresponding author. Tel.: +1 302 766 1869; fax: +1 302 831 3098.
E-mail addresses: guofei@udel.edu, guofei2003@gmail.com (F. Guo).

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1. Introduction

1.1. Research background

The residential buildings sector accounts for one-fourth of the world's total final energy consumption (excluding the consumption of non-energy use) [1]. China is the largest energy consumer and carbon emitter country in the world, and promoting residential energy savings in the country presents an urgent task. The urgency mainly relates to three aspects:

1.1.1. Enormous residential energy use

Owing to China's huge population, robust economic growth, and fast urbanization (from 19.4% in 1980 to 54.4% in 2012) over the past decades [2], residential energy consumption in China has become enormous. The consumption in 2012 was about 371 Mtoe (million tonnes of oil equivalent), which was almost the combined total final energy consumption by all sectors in Germany (221 Mtoe) and France (155 Mtoe) in the same year [1,3].

1.1.2. Increasing residential energy intensity

From 2007 to 2012, China's per capita residential energy use increased by 14.8%, while for the same period the country's industrial energy intensity (measured in energy use per 1000 Chinese Yuan industrial GDP output) experienced a sharp decrease of about 34.4% [1,4,5].

1.1.3. Critical need for policy intervention

Due to huge investments in the buildings sector, the floor space of China's building stock increased very fast in recent years by about 2.7 billion square meters on average annually (2007–2012) (over 80% were in residential buildings) [5,6]. This fast increase means that China is constructing the equivalent of total Japan's existing building floor space (about 8 billion square meters) about every three years [7]. Since building infrastructure tends to have a lock-in effect on user behavior and typically have a long lifetime (several decades), it is now crucial for policy intervention that address the unsustainable trends in residential energy use.

1.2. Research focus

With this background, the paper explores effective policy intervention opportunities through analyzing achievable energy-saving potential in residential buildings in southern China, using the city of Xiamen as a case study.

This research focuses on the urban residential buildings in southern China mainly because of the involvement of centralized space heating in northern China. The two parts of China are divided by a geographic line called "Qin Mountains and Huai River Line." Widely been viewed as an important government-provided social welfare, centralize space heating is usually treated as a separate area for residential energy consumption studies in China [6,8].

The selected city for the case study has less than 5 million residents. There are two prime reasons for selecting this type of city. Firstly, compared to megacities (with over 10 million in population) and regional hub cities (5–10 million) in China [9], cities with population less than 5 million usually lack the capacity (e.g., governance, financing, human resources) to design and issue their own policies for local energy-saving, depending mostly on implementation of national policies. Therefore, they present more appropriate showcases for analyzing national policies which are the focus of this study. Secondly, together these cities host the vast majority (about 80%) of Chinese urban population (about 740 million) [10].

The city of Xiamen, the case study for this paper, lies in the Fujian province of southern China, and in 2014 had a population of about 3.81 million [11]. The city has relatively complete statistical data, and thus presents a significant advantage for the data collection. In addition, Xiamen is among the top economically developed cities in China. Therefore, an analysis of Xiamen can help not only to observe currently developed areas in urban China, but also serves as an instructive example to the less developed areas in the nation, which are currently undergoing rapid economic growth. Moreover, it needs to be noted that the residential energy consumption excluding space heating (namely, cooking, lighting, water heating, plug-in appliances and space cooling) in China does not vary significantly between the north and the south [6]. This means that the research findings from Xiamen can be also representative of the final energy consumption in northern Chinese cities (excluding space heating).