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Evaluating the effectiveness of urban energy conservation and GHG mitigation measures: The case of Xiamen city, China

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ABSTRACT

To assess the effectiveness of urban energy conservation and GHG mitigation measures, a detailed Long-range Energy Alternatives Planning (LEAP) model is developed and applied to analyze the future trends of energy demand and GHG emissions in Xiamen city. Two scenarios have been designed to describe the future energy strategies in relation to the development of Xiamen city. The 'Business as Usual' scenario assumes that the government will do nothing to influence the long-term trends of urban energy demand. An 'Integrated' scenario, on the other hand, is generated to assess the cumulative impact of a series of available reduction measures: clean energy substitution, industrial energy conservation, combined heat and power generation, energy conservation in building, motor vehicle control, and new and renewable energy development and utilization. The reduction potentials in energy consumption and GHG emissions are estimated for a time span of 2007–2020 under these different scenarios. The calculation results in Xiamen show that the clean energy substitution measure is the most effective in terms of energy saving and GHG emissions mitigation, while the industrial sector has the largest abatement potential.

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1. Introduction

Energy consumption is the major contributor to the rising concentrations of greenhouse gases in the earth's atmosphere (IPCC, 2006, 2007), which in turn is resulting in climate change with significant negative impacts on both natural and socio-economic systems (Parks, 2009; Roger et al., 2008; Solomon et al., 2009). In addition, cities, with their high concentrations of both population and economic activities, have become the hot spots for energy demand and GHG emissions. Currently more than half of the world population lives in cities, and this population shift is increasing. Cities are estimated to account for about 75% of the global total GHG emissions (The-Climate-Group, 2009). In China, the 35 largest cities contain 18% of the population, and compose 40% of China's energy uses and CO_2 emissions (Dhakal, 2009). With the importance of energy-related GHG releases from cities, many governments and organizations are seeking measures to reduce these emissions, and cities are becoming the loci for innovative solutions (Bai, 2007a, 2007b; Grimm et al., 2008; Kennedy et al., 2009). A better understanding of the effectiveness of city-level measures will help devise a much needed integrated management framework, as well as to design and implement policies for addressing urban development, energy, and climate-change concerns collectively (Clinton et al., 2005; Kadian et al., 2007; Schmidt and Helme, 2005; WRI, 2005).

Policy changes are easier when the impacts of various measures can be properly quantified and analyzed (Dhakal, 2009; Yan and Crookes, 2009). Several energy-modeling approaches have been used to analyze the future trends of energy demand and GHG emissions and to develop GHG-reduction strategies; these can be categorized into three types: top-down, bottom-up, and hybrid models (Bohringer and Rutherford, 2009; Lin and Huang, 2009; Turton, 2008). Babiker developed a multi-regional general equilibrium model for climate policy analysis based on the MIT Emissions Prediction and Policy Analysis (EPPA) model (Babiker et al., 2009). Bollen performed an integrated assessment of the long-term conundrum of climate-change mitigation and the short-term challenge of reducing local air pollution using the MERGE model (Bollen et al., 2009). Strachan used the MARKAL model to discuss the iterative provision of modeling insights on long-term decarbonisation scenarios for UK energy policy makers (Strachan et al., 2009). MARKAL has also been applied to analyze energy systems and GHG reduction scenarios in many other works (Contaldi et al., 2007; Cosmi et al., 2009; Kannan and Strachan, 2009). Liu used the MESSAGE model to analyze the trends of new key power-generation technologies

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and their contributions to GHG mitigation in China (Liu et al., 2009). The EPPA and MERGE models are widely-used top-down models and the MARKAL and MESSAGE belong to bottom-up. Top-down models examine the broader economy and incorporate feedback effects between different markets triggered by policy-induced changes in relative prices and incomes, but they typically do not provide technological details of energy production or conversion. Bottom-up models describe current and prospective technologies in detail, so they are well suited to the analysis of specific changes in technology or command-and-control policies such as efficiency standards (Bohringer and Rutherford, 2009).

The Long-range Energy Alternatives Planning system (LEAP) is a bottom-up scenario-based energy/environment modeling tool. With a flexible data structure, LEAP allows for an analysis rich in technological specifications and end-use details that allows the user many choices in setting parameters (SEI, 2006; UNFCCC, 2008). It is widely used to project energy supply and demand situations, in order to forecast future patterns, identify potential problems, and assess the likely impacts of energy policies on various areas at the local, national, and global scales. Huang and Lee used the LEAP model for estimating the future trends for energy-related carbon dioxide emissions, and then evaluated potential problems with the 2006 Greenhouse Gas (GHG) Reduction Bill for Taiwan (Huang and Lee, 2009). Cai employed the LEAP model to study the emissions reduction potential and mitigation opportunities in the major five emission sectors in China (Cai et al., 2008). Zhang used LEAP to evaluate the impact of several energy efficiency and environmental abatement policy initiatives in reducing the total energy requirements and external costs of electricity generation in China under various scenarios (Zhang et al., 2007). Kadian applied the LEAP system for modeling the total energy consumption and associated emissions from the household sector of Delhi (Kadian et al., 2007). However, there are few works using LEAP to comprehensively evaluate the efficiency of city-level policies and measures aimed at reducing energy demand and GHG emissions, which cover all urban sectors (Dhakal, 2004; Kadian, 2007; Kadian et al., 2007).

This study consists of five steps: (a) collecting information on local urban policies and measurements; (b) designing the corresponding scenarios; (c) constructing and applying the LEAP model to generate and analyze a reliable future trend of energy demands and GHG emissions in the Xiamen city area from 2007 to 2020, under several different scenarios; (d) assessing the effectiveness of various measures aimed at energy savings and GHG emission reductions; and finally (e) discussing implementation of current measures, future reduction measures, and implications for other cities. The results can provide valuable input for Xiamen's future energy planning and policy making, and it may provide some general insights on the effectiveness of urban-level energy conservation and GHG reduction for other cities as well.

2. Methodology

2.1. The principles for calculating reduction potentials

LEAP is a scenario/energy simulation model, which can provide a platform for structuring data, developing energy balances, projecting demand and supply scenarios, estimating associated emissions and evaluating alternative policies (Huang and Lee, 2009; SEI, 2006). With a powerful accounting ability, it can describe in detail how energy is consumed, converted, and produced in a given region or economy under a range of alternative assumptions for population, economic development, technology, price, etc. Furthermore, through comparing the results derived under different scenarios, the energy-saving potential and the CO_2 reduction potential under different scenarios in a specific target year or period can be obtained. In this study we focus on assessing the effectiveness of local control measures at the city scale. The calculation process, based on LEAP, consists of three parts: identification of energy consumption trends, estimation of greenhouse gas emissions, and estimation of energy savings potential. The analytical procedure in the LEAP model is described in Fig. 1. In this process, the baseline scenario (business as usual) and the integrated scenario are considered, which correspond to different control policies and measures, respectively. The total energy consumption and greenhouse gas emissions for both scenarios are calculated, and the potential energy savings and emission reductions are derived by comparing the results of the two scenarios.

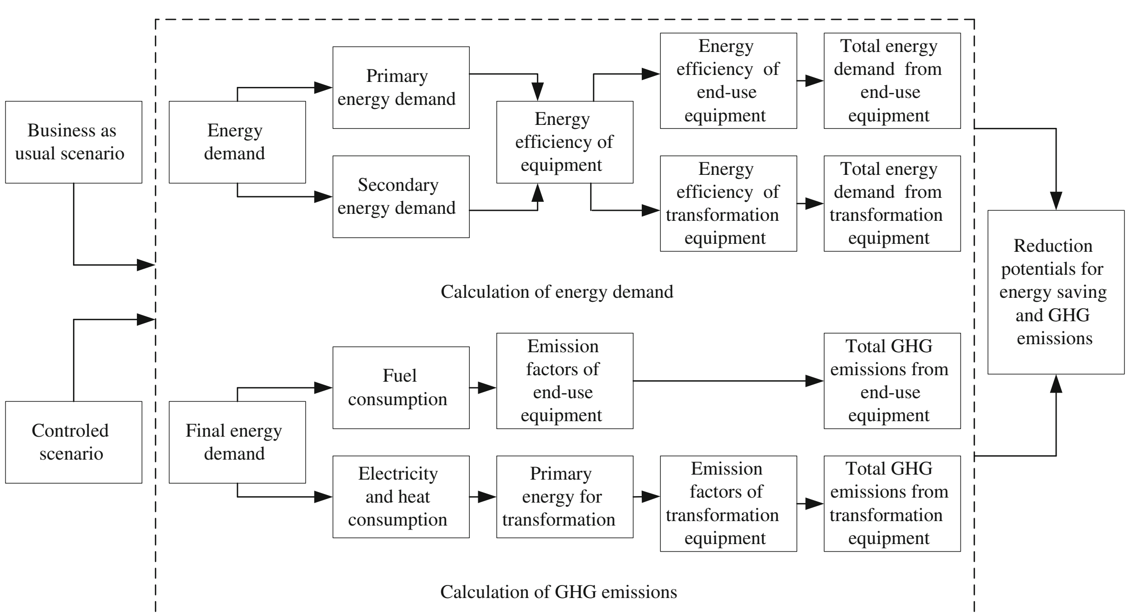

Fig. 1. Research processes based on the LEAP model.

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