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An energy system model for Hong Kong in 2020

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ABSTRACT

Climate change and energy security are forcing Hong Kong to shift from a fossil fuel-based to a clean and low-carbon energy structure. In this article, a simulation model for Hong Kong's energy system is developed to examine the present energy structure and analyse alternative future sustainable energy strategies. First, a reference model is established and validated based on year 2009 data. Secondly, three scenarios are modelled. The BAU (business-as-usual) scenario for Hong Kong's energy system in 2020 is presented and simulated. To address the energy security and environmental sustainability challenges posed by the BAU outcomes, two alternative scenarios are then studied. The first alternative is a fuel mix for 2020 proposed by the government which is characterized by importing more nuclear power from the mainland. As a result of the Fukushima nuclear incident, however, this proposal has been held in abeyance. Therefore, a second alternative for Hong Kong in 2020 is proposed in this study, using more RE (renewable energy) to replace nuclear power. The results show that both the governmentally proposed scenario and the RE scenario can achieve the carbon reduction target. However, the RE scenario would be much better than the government scenario in terms of environmental, social benefits and long-term sustainability.

1. Introduction

Climate change, the defining challenge of our time, brings about more severe weather and affects each and every one of us. In recent years, there has been growing worldwide consensus to combat climate change, reduce GHG (green-house gas) emissions and more specifically to lower the carbon footprint. Being part of the international community, Hong Kong has set a target to achieve a reduction in energy intensity of at least 25% by 2030 corresponding to the APEC (Asia–Pacific Economic Cooperation) target and a reduction of carbon intensity by 50–60% by 2020 corresponding to the Copenhagen Accord, with 2005 as the base year [1].

In order to meet this goal, the Hong Kong government proposed optimizing the fuel mix for power generation, significantly reducing the reliance on fossil fuels, phasing out existing coal-fired generation units, and increasing the use of non-fossil, cleaner and low-carbon fuels, including RE (renewable energy) and imported nuclear energy. Specifically, natural gas should account for about 40% of electricity production, coal no more than 10%, renewable energy about 3–4%, and the balance of about 50% by nuclear energy [2,3].

Recently, the study on Hong Kong's energy system and government policy has generated considerable scholarly interest. The primary and final energy consumption in the five sectors (industrial, commercial, residential, transport, and export) of Hong Kong has been reviewed [4,5]. The growth pattern of the electricity consumption of Hong Kong has also been analysed [6]. Furthermore, an outlook of Hong Kong's electricity market beyond 2008 has been investigated in Ref. [7], and an overview of building energy research and efforts in Hong Kong is presented in Ref. [8]. A critical review of the governmentally proposed climate change strategy and action agenda was performed in Ref. [9], which indicates that the Hong Kong carbon reduction target is too modest for a developed economy, and suggests that mitigation and adaptation measures should be integrated and comprehensive.

A study of the RE potential for power generation in Hong Kong was conducted by the government in 2002 [10], suggesting targets of RE contribution to annual power demand would increase gradually, with 1% by 2012, 2% by 2017 and 3% by 2022 against the baseline year of 1999. The future policy on RE was assessed by Close et al. [11], demonstrating a greater support from the public for RE than was previously envisaged. The feasibility and energy-saving potential of solar PV (photovoltaics), wind farms, landfill gas and

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hydrogen for energy supply in Hong Kong has also been examined [12–15]. In addition, the potential application of RE resources to achieve zero emission on the island of Hong Kong has been studied by Bağcı [16].

However, regarding the previous research on Hong Kong's energy system, little attention has been devoted to examining the regional energy system as a whole or investigating the performance of the governmentally proposed fuel mix for power generation by 2020. There is clearly a need for research on developing a model integrating the entire energy system and also proposing future scenarios to identify how Hong Kong can work towards its 2020 emission reduction targets and beyond. That is the motivation of this article.

The main objective of the present study is to develop an energy system model for Hong Kong which integrates all the energy production, conversion and consumption sectors. Initially, a reference model based on the year 2009 is established and compared to the actual data to ensure the model is valid for further use. After validating the reference model, the models for three future scenarios, i.e. the APEC BAU (business-as-usual) scenario for 2020 (referred to as BAU 2020 in this article), the governmentally proposed fuel mix scenario for 2020 (referred to as Gov 2020) and the renewable energy scenario without nuclear power for 2020 (referred to as RE 2020), are developed and investigated in detail to identify whether the carbon reduction targets can be achieved and which significance the scenarios will bring to Hong Kong. Finally, the three future scenarios are compared to identify the strategy with the best potential to implement and contribute to the reduction of carbon emissions. In addition, the feasibility of using RE to replace nuclear power was explored.

2. The present energy system in Hong Kong

This section details the current Hong Kong energy system as well as policy goals of Hong Kong in order to establish context and reference scenario.

2.1. Background

Hong Kong, a special administrative region of China, is a well-known world-class financial, trading and business center of about 7.2 million people [17], located at the southeastern tip of China. As Hong Kong has no domestic energy reserves or fossil energy resources, it imports all of its primary energy needs [18]. According to the IEA (International Energy Agency) [19], the total PES (primary energy supply) in Hong Kong was 173.7 TWh in 2009, in which coal had the highest share (51%), followed by oil (27%), gas (17%) and net-import electricity (5%). The TFC (total final consumption) of Hong Kong in 2009 was 103.7 TWh. The residential and commercial sectors accounted for the largest share at 49.3%, followed by the industry (25.9%), transport (22.4%) and other (2.4%).

The total electricity consumption of Hong Kong in 2009 was 46.6 TWh. Hong Kong has a total installed electricity generating capacity of 12,624 MW, including 1378 MW nuclear power plant and 300 MW pumped storage plant in mainland China. All locally generated power is thermal fired. Electricity is supplied by two local power companies: CLP (China Light & Power) Power Hong Kong Limited (CLP) and PAH (Power Assets Holdings Ltd). In 2009, coal dominated the fuel mix for power generation in Hong Kong (about 54%), followed by natural gas (about 23%) and nuclear power imported from the mainland (about 23%). The electricity consumption of Hong Kong from 2000 to 2010 is presented in Fig. 1, which shows that the commercial sector in Hong Kong (including offices, retail stores, restaurants, hospitals, schools, and public buildings) is the largest energy consumer congruent with Hong Kong's status as a service-oriented economy. Residential demand grew slowly over the decade, reflecting Hong Kong is focused on improving energy efficiency, such as the mandatory/voluntary energy efficiency labelling schemes for appliances and the adoption of high-efficient lighting systems.

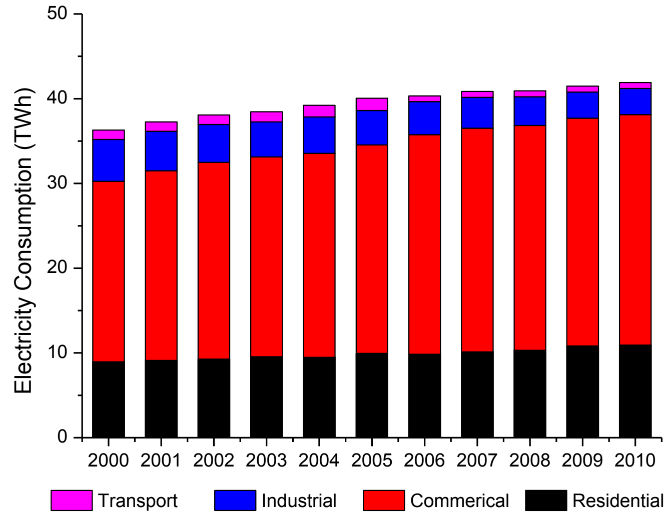

Fig. 1. Hong Kong's electricity consumption from 2000 to 2010.

2.2. Climate change strategy and carbon intensity reduction target of Hong Kong

Combustion of fossil fuel to generate electricity is Hong Kong's major contributor of CO_2 emission, accounting for some 68% of total emissions in Hong Kong. Reducing carbon emissions relating to power generation is, therefore, an indispensable element of the strategies to combat climate change. To tackle the carbon emissions, starting from 1997, power companies in Hong Kong have not been allowed to build new coal-fired power plants. The government also proposed to increase nuclear power to 50%, natural gas to 40% and RE to 3–4%, but reduce coal to 6–7% by 2020 [1]. By implementing this strategy, Hong Kong expects to reduce its carbon intensity by 50–60% by 2020, compared with the 2005 level, decrease its greenhouse gas emissions by 19–33% compared with 2005, and lower its greenhouse gas emissions per capita from 6.2 tons in 2005 to 3.6–4.5 tons [2,3], which will be far lower than the levels of the United States, the European Union and Japan. By adopting this ambitious target, Hong Kong will set a good example as a responsible international city making an effort to combat climate change.

3. Methodology

3.1. Energy system simulation tool

In order to develop future scenarios of the energy system in Hong Kong, and identify how Hong Kong can transform from a mainly fossil fuel-based to a low carbon based energy system, the first step is to create a simulation model of the energy system of Hong Kong. Based on the review results of 37 simulation tools [20], the EnergyPLAN model was employed for this study. The feasibility of this simulation model for energy system modelling has been widely reported and verified in literature; for instance, it has been used to analyse and simulate the national energy systems of Denmark [21,22], United Kingdom [23], Ireland [24], Romania [25] and Macedonia [26], and municipal energy systems [27–29]; to