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Opinion paper

Impacts of low-carbon power policy on carbon mitigation in Guangdong Province, China

Beibei Cheng [a,b], Hancheng Dai [c,*], Peng Wang [b], Yang Xie [d], Li Chen [a], Daiqing Zhao [b], Toshihiko Masui [c]

[a] School of Chemistry and Chemical Engineering, South China University of Technology, Guangzhou 510640, China
[b] Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, No. 2 Nengyuan road, Wushan Street, Tainhe District, Guangzhou 510640, China
[c] Social and Environmental Systems Division, National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305-8506, Japan
[d] Department of Social Engineering, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro-ku, Tokyo 152-8550, Japan

HIGHLIGHTS

- This study analyzes the low carbon policy in the power sector in Guangdong of China.
- The role of power sector in achieving carbon and energy intensity target is shown.
- Renewable energy and natural gas are very important for Guangdong Province.
- Additional efforts in other sectors are needed to achieve the intensity targets.
- The mitigation cost and economic impacts are assessed under various policy settings.

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ABSTRACT

This paper analyzes the impacts of the low-carbon policy in the power sector of Guangdong Province in China on its energy and carbon emission targets by 2020, as well as their costs and co-benefits, using a regional CGE model with seven scenarios: business as usual (BaU), renewable energy (RE), renewable energy and natural gas (RE–NG), CAP only (CAP), CAP and RE–NG (CAP–RE–NG), carbon emission trading (ETS), and ETS with RE–NG (ETS–RE–NG). Analysis results reveal that provincial energy and carbon intensity targets can be achieved in the assumed carbon mitigation scenarios with carbon cap, ETS, and clean energy development policies. While the carbon constraint exerts negative impacts on the economy, GDP loss could be lowered by the ETS and RE policies. The RE scenario is more economically efficient than the ETS scenario, and coupling the RE and ETS scenarios appears to be the most economically efficient scenario to achieve the desired carbon and energy intensity targets. One of the benefits of the low-carbon policy is its improvement of the energy security of Guangdong in terms of reduced reliance on external coal and oil; in particular, Guangdong coal consumption could peak in 2017–2019.

1. Introduction

China's "12th Five-Year Plan" (FYP) (2011–2015) introduced a national target to reduce the nation's carbon intensity by 17% over the period of 2011–2015 to address rising energy consumption and carbon emission concerns. This plan is in line with the nation's commitment at the 2009 Copenhagen Summit to reduce its carbon intensity by 40–45% over the period of 2005–2020 (Zhang et al., 2013). China has also pledged to achieve its carbon emission peak and increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030 (US White House Press, 2014). To achieve these goals, China must adopt tangible measures and realistic actions, such as setting targets at the provincial level, assigning responsibility for different levels of coal control, non-fossil energy development, and carbon intensity reduction in China's provinces.

As one of the most important economic powerhouses of China, Guangdong Province plays a key role in helping achieve the national goal. Guangdong was selected as one of China's low-carbon pilot provinces in 2010 and a pilot to implement a carbon cap and emissions trading (ETS) study in 2013 (Guangdong Provincial Government, 2012). Since then, the Guangdong government has

* Corresponding author.
E-mail addresses: chengbb@ms.giec.ac.cn (B. Cheng), dai.hancheng@nies.go.jp (H. Dai), wangpeng@ms.giec.ac.cn (P. Wang), xie.y.ab@m.titech.ac.jp (Y. Xie), celichen@scut.edu.cn (L. Chen), zhaodq@ms.giec.ac.cn (D. Zhao), masui@nies.go.jp (T. Masui).

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become more active in formulating low-carbon policies, such as developing renewable energy and natural gas for power generation and carbon cap and emissions trading. According to government plans, the carbon emissions per unit of GDP must decrease by 34% by 2020 compared with that in 2010 (GCCP, 2014), non-fossil energy consumption must account for 20% of the total primary energy consumption in 2015, and the share of renewable energy in total energy consumption must be within 20% by 2020 (GEDP, 2012). The cap and trade policy aims to achieve carbon reduction through a market-based policy instrument. In the first phase, the electricity, cement, iron and steel, and refinery sectors are obligated to participate. Implementation of these low-carbon policies would directly affect the energy consumption and carbon emissions in Guangdong Province and further contribute to the national mitigation target. With low-carbon policies that are more aggressive than the national policies, Guangdong is the front runner of China's efforts to mitigate climate change.

Given that energy plays a vital role in all economic sectors, such as industrial production, final consumption, and international trade, energy and climate policies will exert widespread effects on the entire economic system. A comprehensive assessment of the economic impacts of low-carbon policies from Guangdong, whether positive or negative, will greatly help the national government formulate more appropriate low-carbon policies.

Numerous studies have been conducted to evaluate how China's renewable energy plan and climate and environmental policies affect its energy consumption and carbon emissions as well as the macroeconomic impact of these policies on the industry structure at the national level (Lin et al., 2010; Li et al., 2012; Zhang et al., 2012; Zhou et al., 2012; Qi et al., 2014; Yuan et al., 2014). These studies have focused on topics, including assessment of long-term renewable energy deployment with an energy model (Chen et al., 2007; Jiang et al., 2008; Lu et al., 2010; Zhou et al., 2013), national intensity-based carbon limit policies (Wang, 2003; Dai et al., 2011), energy and climate innovation policies (He et al., 2010; Li, Wang et al., 2012), China's CO_2 mitigation abatement cost using the EPPA model (Paltsev et al., 2012), and carbon taxes on regional emission reduction (Li et al., 2009; Shi et al., 2010). Several studies have also assessed the effectiveness of the emission reduction policies at the provincial level (Liu et al., 2012; Wang et al., 2013; Zhang et al., 2013; Cui et al., 2014; Hübler et al., 2014; Tang and Wu, 2014). In these studies, system optimization or computable equilibrium (CGE) models were employed to evaluate the regional energy and carbon intensity targets on the impact of CO_2 emission reduction and economic welfare from multi-region and multi-sector perspectives.

Despite the relative availability of studies on these topics, however, very few studies have specifically focused on the consistency between non-fossil energy development policy and climate target at the provincial level in China. A study conducted by Wang et al. (2011) investigated the effects of two contrasting policies, i.e., developing nuclear power and energy saving, in meeting the provincial reduction target. Another study (He et al., 2010; Lu et al., 2010) investigated the impacts of energy investment policy on economic growth and carbon emissions based on the case of Shaanxi province in Western China. Jiang et al. (2008) evaluated the future natural gas consumption scenario in Beijing, Guangdong, and Shanghai using the MARKAL model. Yang et al. (2013) constructed a system dynamic model to determine how energy policies influence energy balance and CO_2 emissions in Qinghai Province, China. However, these studies did not focus on the impact of industry linkages and recent climate policies, such as ETS, or consider the electricity dispatch flow between interregional provinces.

A review of these studies would provide evidence of the effectiveness of renewable energy and other climate policies on carbon mitigation. To enhance understanding on the impacts of non-fossil energy development and carbon policy in Guangdong further, a regional CGE model was used in this study to (a) identify the contribution of the power sector to carbon reduction and (b) quantify the social and economic impacts of the energy and carbon reduction policies. The analysis results would be relevant for climate policymaking in Guangdong Province and provide a new perspective on renewable energy development.

The remaining parts of this paper are organized as follows: Section 2 describes the model and data, as well as how the scenarios were established, Section 3 introduces the results of the policy scenarios, and Section 4 discusses the implications of the simulation results. The paper ends with conclusions in Section 5.

2. Methodology and data

2.1. Overview of Guangdong's energy consumption

Guangdong consumes a large amount of energy because of its economic size. As shown in Table 1, in 2010, Guangdong consumed 5%, 10%, 6%, and 15% of the national total coal, crude oil, natural gas, and primary electricity consumption, respectively (NBS, 2011). Guangdong Province's primary energy consumption was 227.2 million tons of coal equivalence (Mtce), with shares of coal, crude oil, natural gas, and primary electricity totaling 48.1%, 29.1%, 3.7%, and 19.1%, respectively (Fig. 1). Guangdong's power sector consumed 82.1 mtce of fossil fuel in 2010, accounting for 33% of the provincial total energy consumption. Consequently, carbon emissions from the power sector totaled 220 million tons of CO_2-eq, accounting for 43.1% of the total emissions (NBS, 2011). Thus, the low-carbon policy in the power sector plays a very important role in emission reduction in Guangdong Province and is implicitly essential for carbon reduction in China.

2.2. The CGE model

This study uses a dynamic CGE model for Guangdong province (GD_CGE) jointly developed by Guangzhou Institute of Energy Conversion (GIEC) China and National Institute for Environmental Studies (NIES) Japan. The model is a two-region recursive dynamic CGE model that includes Guangdong (GD) province and the Rest of China (ROC). The technical description of the model is provided in (Wang et al., 2015). In order to provide an in-depth analysis of the power sector, seven power technologies are formulated in the model (Table 2) and we aggregate and disaggregate the 124 sectors to 33 sectors using the Guangdong input and output table in 2007 (NBS, 2010). The major model features are similar to the one-region dynamic version (Dai et al., 2012). It includes a production block, a market block with domestic and international transactions, as well as government and household income and expenditure blocks (Fig. A1). Activity output of each sector follows a nested constant elasticity of substitution (CES) production function. Inputs are categorized into material commodities, energy

Table 1
Primary energy consumption of China and Guangdong in 2010.

Energy carrier	China's primary energy consumption (Mtce)	Guangdong's primary energy consumption (Mtce)	GD's share in China (%)
Coal	2210	105	5%
Crude oil	617	64	10%
Natural gas	143	8	6%
Primary electricity	279	42	15%