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Scenario analysis of energy-based low-carbon development in China

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ABSTRACT

China's increasing energy consumption and coal-dominant energy structure have contributed not only to severe environmental pollution, but also to global climate change. This article begins with a brief review of China's primary energy use and associated environmental problems and health risks. To analyze the potential of China's transition to low-carbon development, three scenarios are constructed to simulate energy demand and CO_2 emission trends in China up to 2050 by using the Long-range Energy Alternatives Planning System (LEAP) model. Simulation results show that with the assumption of an average annual Gross Domestic Product (GDP) growth rate of 6.45%, total primary energy demand is expected to increase by 63.4%, 48.8% and 12.2% under the Business as Usual (BaU), Carbon Reduction (CR) and Integrated Low Carbon Economy (ILCE) scenarios in 2050 from the 2009 levels. Total energy-related CO_2 emissions will increase from 6.7 billion tons in 2009 to 9.5, 11, 11.6 and 11.2 billion tons; 8.2, 9.2, 9.6 and 9 billion tons; 7.1, 7.4, 7.2 and 6.4 billion tons in 2020, 2030, 2040 and 2050 under the BaU, CR and ILCE scenarios, respectively. Total CO_2 emission will drop by 19.6% and 42.9% under the CR and ILCE scenarios in 2050, compared with the BaU scenario. To realize a substantial cut in energy consumption and carbon emissions, China needs to make a long-term low-carbon development strategy targeting further improvement of energy efficiency, optimization of energy structure, deployment of clean coal technology and use of market-based economic instruments like energy/carbon taxation.

Introduction

China has abundant energy resources in terms of total reserves. According to British Petroleum (BP, 2012), by the end of 2011, proven coal, oil and natural gas reserves in China accounted for 13.3%, 0.9% and 1.5% of the world total, respectively. The rapid economic growth in China over the past decades has been accompanied by a significant increase in energy consumption. China is now the largest energy producer and consumer in the world. The share of China's primary energy consumption in the world total rose from 4.8% in 1965 to 21.3% in 2011 (BP, 2011, 2012). Resource endowment of "rich in coal and poor in oil and natural gas" has made China's energy consumption structure heavily dependent on coal, accounting for around 70% of the energy share. China consumed almost half of the world coal in 2011 (BP, 2012).

Burning coal produces more pollution than other energy sources. Burning one ton of raw coal emits 2.77 tons of CO_2, which are 0.62 and 1.13 tons higher than burning 1 ton of crude oil and natural gas, respectively. Chen and Xu (2010) estimate that coal combustion is responsible for 90% of SO_2, 70% of CO_2, 67% of

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NOx, and 70% of dust emissions in China. China's increasing energy consumption and the over-dependence on coal comes at the cost of the environment and human health. China is now the world largest SO_2, CO_2 and NOx emitter (China Council for International Cooperation on Environment and Development, 2007; BP, 2012; Vennemo et al., 2012). The annual mean value of PM_{10} in 114 key environmental protection cities is more than two times of the European Union's (EU) standards and more than four times of the World Health Organization (WHO) standards (WHO, 2006; Ministry of Environmental Protection, 2012; European Commission, 2012). According to the China Council for International Cooperation on Environment and Development (CCICED, 2007), economic losses caused by air pollution account for 3% to 7% of China's GDP and by 2020, the losses from diseases caused by burning coal could take up 13% of GDP if the current trends are not changed.

China is facing dual challenges of solving its worsening domestic environmental problems without impeding economic development and the ever increasing international pressures to curb CO_2 emissions. With the further development of industrialization and urbanization, energy consumption and energy related CO_2 emissions are expected to continue to increase in the foreseeable future. Decoupling carbon and pollution emissions from economic development and moving to a low-carbon development path are a must for China to ease domestic pollution problems, tackle global climate change and achieve its long-term development goal.

1. Energy consumption and CO_2 emissions in China

China has made remarkable achievements since launching the economic reform and open-up policy in the late 1970s, with an average annual GDP growth rate of almost 10% over the past three decades. Total energy consumption has also increased sharply along with the rapid economic development. According to the National Bureau of Statistics of China (NBSC, 2012), total primary energy consumption rose from 586 million tons of coal equivalent (tce) in 1980 to 3.48 billion tce in 2011.

One of the unique features of China's energy structure is the dominance of coal. The coal-based energy structure makes China very different from other countries. Coal accounted for 68.4% of the total energy consumption in 2011, compared with 22.1% in the USA, 17% in EU, 21.2% in Japan and 5.2% in Brazil and the world average of 30.3% (NBSC, 2012; BP, 2012).

The increasing energy consumption and coal-dominant energy structure have made China's CO_2 emissions grow very fast over the past 45 years. CO_2 emissions from fossil fuel combustion have increased from 0.48 billion tons in 1965 to 8.7 billion tons in 2011, accounting for 25% of the world total (BP, 2012). With further population growth and economic development, it is anticipated that China's increasing energy consumption will continue to drive up its energy-related CO_2 emissions.

2. Environmental consequences and health impact associated with energy use in China

China's increasing energy consumption and excessive use of coal have resulted in severe environmental pollution, ecological deterioration, profound human health impacts and huge economic losses.

Urban air quality degradation caused by burning coal and automobile exhaust has been identified as one of the most pressing environmental problems in China. Ministry of Environmental Protection's (MEP) statistics (2012) show that in 2011, only 3.1% of 325 cities monitored reached grade I national ambient air quality standards, accounting for only 0.9% of the 114 key environmental protection cities.

China's SO_2 emissions account for 25% of the world total, being almost as high as the EU and the US combined, and China is the 3rd largest acid rain area in the world after North America and Europe (CCICED, 2007; Lu et al., 2010; Vennemo et al., 2012). Acid rain, which is mainly the result of SO_2 and NOx emissions from thermal power plants and mobile sources, was recognized as a potential environmental problem in China in the late 1970s and early 1980s (Zhao and Sun, 1986; Menz and Seip, 2004; Larssen et al., 2006). Many studies have found correlations between SO_2 concentration and damage to crops, forests and severe corrosion of metals (Cao, 1988, 1989; The World Bank, 1997; Larssen et al., 1999; Feng et al., 2002; Chinese Academy of Engineering, MEP, 2011). The study of Feng et al. (2002) showed that the area of crops damaged by acid rain was 12.9 million hm^2, with the economic loss of 4.26 billion yuan per year from 1991 to 2000 in 10 Chinese provinces. Forest decline due to the direct effects of acid rain was observed in areas with high concentrations of SO_2, including Emei Mountain of Sichuan Province, Nanshan Mountain of Chongqing, the suburban area of Liuzhou, Guangxi Province and Wan county of Sichuan Province in the early 1980s (Chinese Academy of Engineering, MEP, 2011). Larssen et al. (1999) point out that the corrosion rates of metals in Shanghai and Chongqing were 1.5 to 4.5 times faster than the Japanese average due to high SO_2 emissions.

Human health is closely linked to environmental conditions. Air quality has significant impacts on the potential exposure of people to health risks. Many epidemiologic studies have confirmed the associations between ambient air quality and human health (WHO, 2002, 2008, 2012). Environmental degradation caused by coal combustion has contributed to the declining health in China. A recent study by Cheng et al. (2013) shows that the total number of premature deaths attributable to PM_{10} pollution increased from 418,000 in 2001 to 514,000 in 2011.

Since the 1980s, many Chinese and western researchers have conducted research on the economic losses caused by air pollution in China. Air pollution has become a huge burden on China's economy, and costs the Chinese economy from 1% to 7% of GDP each year according to different studies (Xu, 1988; Guo and Zhang, 1990; Smil, 1996; Xia, 1998; the World Bank, 1997, 2007). Matus et al. (2012) estimate that the economic cost of health damage due to air pollution alone accounted for 5% of total GDP in 2005 in China.

Global concern about climate change is also closely linked to the increasing CO_2 emissions in the atmosphere, which will most likely lead to global climate change, resulting in rising of sea levels, increasing risks of species extinction, more extreme climate events, damage to crops, and threats to human settlements and health.

The Information Office of the State Council of China (2008) reports China's average surface air temperature increased 1.1°C from 1908 to 2007, which was 0.36° higher than the global average rise. The Ministry of Science and Technology et al. (MOST, 2011)