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China's energy systems transformation and emissions peak

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ABSTRACT

From 1990 to 2013, China's energy intensity (EI) declined from 1.587 (oil equivalent kg/2005$) to 0.63 (kg oil equivalent/$), while the share of clean energy (CES) rose from 4.18% to 9.61%, which played an important role in emissions reduction. The economic growth in increasing emissions exceeded the technical progress and energy structural upgrades in reducing emissions, Chinese emissions have shown a steeply rising trend since 1990. Three variables, economic growth, EI, and multiple emission intensity (MI) representing energy utilization per unit, were set to the combinations of high, medium and low levels. The annual total emissions index (TEMI) was calculated for each combination. If gross domestic product (GDP) keep growing at 7.6% per year (high level), the results show that TEMI will not have peaked by the end of 2035. If GDP growth decelerates at an annual rate of 0.05% (medium level), TEMI will exhibit three emissions peaks in 2032 and 2034. By then, the CO_2 peak will have reached 11,155–13205.6 million tons, which is 9.01–29.05% higher than the 2013 baseline. Other emissions will be 5–30% higher than the 2013 baseline. The range of EI was 0.219–0.26 (kg oil equivalent/$), and the range of CES was 17.75–20.54%. More peaks will appear before 2035 if GDP growth decelerates at an annual rate of 0.1% (low level). The emissions-reducing effect of technical progress (declines in EI) is far greater than that of structural change. Comparing with developed countries, China has a great potential for energy conservation and emissions reduction. China will achieve peak emissions by 2035 with actively creating the conditions for transforming its energy system.

Contents

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1. Introduction

China's rapid economic growth has improved people's living standards with high energy consumption, which has caused a series of problems. First, it aggravates the long-term shortage of domestic energy and mineral resources [1]. According to China customs administration data, China's degree of dependency on external coal, oil and natural gas rose significantly in 2013, reaching 8.13%, 57.39%, and 30.5% respectively [2]. It constitutes an increased energy security risk [3]. Second, energy consumption generates several negative environmental effects [4]. China's per capita primary energy consumption was only 2578.2 kg oil equivalent in 2013, but the total energy consumption ranks highest in the world with the highest total emissions. In recent years, more foggy and hazy weather has become apparent in central and eastern regions of China because of the air pollution. Concentrations of air pollutants, sulfur dioxide (SO_2), nitric oxide (NO_x) and fine particulate matter (PM), are higher than the safe levels established by the World Health Organization [5]. Third, social and economic costs for energy use are increasing. China's commercial energy prices have risen rapidly over the last decade, increasing the costs of energy use and the burden on consumers. Gasoline prices rose by 126% from 2005 to 2014. China has entered the ranks of middle-income countries with the gross domestic product (GDP) per capita of 6807.4$ (current dollars) in 2013, which is about one-fifth of the mean value in the Group of Seven countries [6]. There are still many low-income people in central and western China.

To address the dilemma of economic development and environmental protection, China established a green development strategy and target objectives. During the 11th Five-Year Plan (2006–2010), China achieved a 17.2% reduction in energy intensity compared to 2005 levels. During the government's 12th Five-Year Plan (2011–2015), China set targets to reduce the energy intensity by 16% and carbon intensity per unit of GDP by 17% over 2010 levels [7]. In 2014, APEC Economic Leaders' Meeting held in Beijing, the United States and China issued a Joint Announcement on Climate Change. China officially stated for the first time it intends to achieve peak CO_2 emissions around 2030 and increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030 [8]. To achieve these goals, China implemented a series of energy conservation and emissions reduction measures: (1) promoting the development of clean energy and adjustment of the energy structure. The use of cleaner, non-renewable natural gas and nuclear power increased from 23.74 billion m^3 and 44.194 billion kW h in 2000 to 156.29 billion m^3 and 290.75 billion kW h in 2013, respectively, which grew rapidly. Hydroelectric power grew from 639.65 billion kW h in 2000 to 2399.27 billion kW h in 2013. Wind electricity, solar photovoltaic power and biomass-generated power grew from 8.14 billion kW h to 498.93 billion kW h during the same period [9]. (2) Accelerating technological upgrades of existing energy sectors. The desulfurization and ash-removal equipment was installed in most coal-fired power plants, and thousands of low-efficiency generators and power plants were closed or upgraded [7]. Massive reconstruction of power grids was carried out [10], and ultra-high-voltage, large-capacity, long-distance transmission lines were built [11]. (3) Improving the energy efficiency. Energy-saving technology was popularized actively in the industrial, transportation and construction sectors [12]. More projects involving clean development mechanisms (CDM), reuse and recycling were implemented in the provinces. Energy-intensive industries were transformed to optimize their economic structure [13]. China has been active in the development of new-energy vehicles [14], the use of thermal insulation materials in buildings [15], experimentation with and demonstration of low-energy-consumption buildings. (4) Changing patterns of household energy use. Central heating systems were built or renovated in urban areas to replace coal stoves in households and small boilers in communities. Household heat metering was implemented for residential buildings [16]. The use of biogas and solar energy was popularized in rural areas [17]. To improve the energy efficiency of end-use electrical products, the government encouraged and supported production and use of energy-efficient household appliances by implementing subsidies in 2012 [18]. (5) Strengthening the management of energy supply and demand using multiple methods of planning, policy, and pricing. Low-carbon governance was supported by policy instruments, such as laws, regulations, industry standards, finance and taxation [19]. The development of wind, biomass and solar PV power were promoted by renewable-energy power subsidies [20]. Energy price reforms were carried out using market-oriented mechanisms to enhance the efficiency [21].

China has made great efforts in energy saving and emissions reduction, but it is difficult to change a coal-dominated energy structure. Coal accounted for 67.5% of the total energy demand in 2013 [6], and its utilization efficiency is still low. How can China "lighten up" [22]? How does China achieve green development [23]? When will the CO_2 emission Kuznets curve reach the highest point in China [24]? These questions have received much attention from China and elsewhere. Sustainable, low-carbon development boils down to two main aspects: the energy structural adjustment and technical innovation involving research [24–28]. China needs to increase the share of low-carbon or carbon-free energy by replacing coal and oil with cleaner energy sources, such as hydropower, nuclear power, biomass energy, wind power, solar energy and geothermal energy [4,29,30]. Wind and solar generation could achieve substantial health, environmental and climatic benefits. Ten percent wind penetration would result in 12% reduction in CO_2 emissions, 13% reduction in NO_x, 8% reduction in SO_2 and 11% reduction in PM [31]. The development potential is great and the application prospects are broad for wind power [32–35], photovoltaic power and other uses of solar energy [36–38], biomass power generation and clean energy use [39,40]. Energy