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Coal use for power generation in China

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ABSTRACT

Coal holds dominant position in China's primary energy mix, and roughly 45% of China's coal consumption is used for power generation. In this paper, we study the prospective of coal used for power generation in China into 2030 by testing three interrelated factors, namely electricity demand, fuel mix and generation efficiency of coal power. We find that, under the 'new economic normal', electricity demand growth would slow down; under the effort of low-carbon transition, coal power is expected to reach the peak at around 970 GW by 2020; and coal used for power generation will reach the peak at around 1280 million ton coal equivalent (Mtce) under the clean coal power plan declared by the Chinese government.

1. Introduction

China's social and economic development has long been puzzled by inadequate electric power supply (Yuan et al., 2012). However, impressive growth of China's electric power industry has been witnessed in the new century. New records on annual capacity installation have been constantly set, and the power industry made firm contribution to China's prompt economic growth. According to China Electricity Council (CEC) (China Electricity Council 2015a), China's per capita generation capacity has reached 1 KW at the beginning of 2015, which has achieved global average level.

The domination of coal consumption leads to serious environmental damages in China. The outburst of nationwide severe air pollution haze has become a stubborn threat to public health (Pan et al., 2012; Deutsche Bank, 2013). As the largest coal consumer, the electric power industry contributed to more than 23%, 45% and 64% of national emissions of particle material (PM), SO_2 and NO_x, and 44% of CO_2 emissions as well (Yuan et al., 2015). Since 2013, controlling the growth of primary energy consumption (coal in particular) has become the major issue of China's national energy and environment policy (State Council of China, 2013a). Meanwhile, in the end of 2014, a Sino-US Climate Change Communiqué was declared during the APEC and the Chinese government announced its determination to peak CO_2 emissions by 2030 (Xinhuanet, 2014).

Electric sector plays a major role in global sustainable transition (Pacala and Socolow, 2004). China is one of the largest developing economies with high potential in future electricity demand. Therefore, a sustainable energy pathway shall be explored for the electric power industry, which is currently confronted with double red-line constraints of air quality improvement and greenhouse gases (GHG) peak. The prospective of coal power is critical to this pathway, which calls for a systematic and detailed review on China's future electricity demand and power generation planning.

In literature, many studies have explored China's electricity demand and power generation planning (Zhou et al., 2013; Hu et al., 2010, 2013; Yuan et al., 2014b; Zheng et al., 2014). However, most were conducted before 2014 and could not capture the new state of China's macro economy. China's new leadership has dedicated to pursue a new economic normal, and people had witnessed a structural change in electricity consumption in 2014 (China Electricity Council, 2015b). There were three influential studies published in 2015, among which two are prepared by authoritative industry institution or think tank. The first study, a China Electricity Council (2015a) report presented comprehensive analysis on the sector in 2014 and concluded that total electricity consumption is expected to reach 7700 TWh while per capita electricity consumption would reach 5570 KWh by 2020. The second study elaborated the assumptions for GDP electricity consumption elastic coefficient based upon international comparison study and concluded that total electricity consumption would reach 7600–8000 TWh by 2020 (Wang and Wu, 2015). The consensus of these two studies is that coal power capacity would reach beyond 1100 GW by 2020 and 1350 GW by

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2030 under business-as-usual (BAU) projection. The third report by China Coal Cap Group (2015) concentrated on China's electricity demand and power generation planning into 2050, without providing clear near future predictions. Appendix A is a summary on prediction of China's 2030 electricity consumption in literature. As illustrated, the prediction of China's 2030 electricity consumption is distributed broadly, ranging between 7000 TWh and 11000 TWh; the average prediction of approximately 60% fossil power share is expected in terms of power generation.

The interest of this paper is to explore a different but feasible electric power pathway for China into 2030 and thus shed new insight on China's power sector policy. The future pathway of coal use for power generation is determined by three factors, firstly electricity demand, secondly fuel mix for power generation which is largely determined by generation capacity planning, and thirdly generation efficiency of coal power. As illustrated by Fig. 1, our study starts with an overview China's power sector (Section 2). Then electricity demand scenarios are projected based upon various assumptions of key social & economic variables (Section 3). With recommended demand scenario, a low-carbon power planning will be outlined in Section 4. Next, generation efficiency improvement potential led by Chinese government's official clean and efficient coal power plan will be estimated in Section 5. With the above work done, the pathway of coal use for power generation in China can be projected in Section 6. Finally Section 7 concludes with policy implications.

2. Electric power sector in China

2.1. Electricity demand

China's prompt economic growth is fueled by energy supply. As indicated in Fig. 2, during 1980–2014, China's GDP grew by 25 folds. Primary energy consumption grew by 7 folds. Electricity consumption grew closely with economic growth by 18 folds.

Electricity consumption has increased steadily since 1980. The annual growth was around 8% during 1980–2000 (China Electricity Council, 2014a). The process was speeded up during 2000–2010, with nearly 12% annual growth rate. After 2010, electricity consumption growth slowed down remarkably, due partly to slowing-down economic growth and restructuring in economic output (National Bureau of Statistics of the People's Republic of China, 2015). A noticeable observation is that in 2014 electricity consumption grew by merely 3.8% while GDP grew by 7.4% (National Bureau of Statistics of the People's Republic of China, 2015). Most of the electricity consumption was used for production in China. However, household consumption is on a steady increase and by the end of 2014 it accounted for 12.5% of total electricity consumption in China (China Electricity Council, 2015a).

2.2. Generation capacity and fuel mix

Power supply capacity has expanded substantially along with China's growing electricity demand. Generation capacity increased from merely 66 GW in 1980 to 1360 GW in 2014 (Fig. 3). Although power shortage was persistent in China before 2000, China managed to provide firm power supply since 2012. By the end of 2014, per capita capacity was 1 kW, which reaches the global average level. Though an important milestone in China's power sector, it still lagged behind the average of developed countries, implying the vast growth potential in the future.

Due to relative resource abundance, China's power generation has been dominated by coal. Starting from 69% in 1980, coal power persistently accounted for more than 70% in total generation capacity (China Electricity Council, 2014a). Nuclear power was initiated in China from 1990s, but its contribution was rather limited. Renewable energy, wind power in particular, gains growth momentum only since the turn of new century. By the end of 2014, the share of coal in overall generation capacity was 62%, as contrast to 74% in 2005. Fuel mix experiences similar change. Coal steadily accounted for 80% during 1980–2010 and began to decline after 2010 (Fig. 4).

2.3. Coal power mix and generation efficiency

China is a late comer in clean coal technologies. 300 MW subcritical units were imported in the late 1980s. The first imported super-critical (SC) unit was commissioned in 1992 in Shanghai and took nearly twenty years to adopt the SC technology. China began to develop its own SC technology in 2000 and spent 3 years to realize commercialized operation of domestic SC technology. And then it only took 4 years to realize the commercialized commission of domestic 1 GW ultra super-critical (USC) technology from project research & development. Technology learning is accompanied by radical improvement in China's coal power fleets. By the end of 2012, units sized at 600 MW and above accounted for 40.15% of installed coal power plants, up by 20 percent points than in 2006, while units sized less than 300 MW only accounted for 25%. As a contrast, in 1995, units sized at less than 300 MW accounted for more than 70% of total thermal capacity. Combined heat and power generation (CHP) development and retrofitting also makes great progress. A total of 60 GW CHP units were added during the 11th Five-Year-Plan (FYP) period (2006–2010). By the end of 2011 total CHP capacity was 141.3 GW in China. Then in 2012 it amounted to 220.7 GW, accounting for 27.5% of total thermal units (see Table 1 for the breakdown of thermal units in 2012 and Fig. 5 for changes in thermal units mix from 1995 to 2012).

Along with the deployment of high-parameter and high efficiency units, generation efficiency in China's thermal power units has made continuous improvement. According to official data from the China Electricity Council (2015a, [China Electricity Council, 2009]2009–[China Electricity Council, 2009]2015), the heat rate of power supply in 2014 was 318 g coal equivalent per kWh

Table 1
statistics of thermal power units in China, 2012.

Unit type		Capacity (GW)	Capacity share (%)
CHP units		220.75	27.49
Pure Condensing units	unit ≥ 1000 MW	58	7.22
	600 ≤ unit < 1000 MW	264.41	32.93
	300 ≤ unit < 600 MW	216.57	26.97
	200 ≤ unit < 300 MW	20.01	2.49
	100 ≤ unit < 200 MW	14.45	1.80
	unit < 100 MW	8.83	1.10
	Sub-total	582.27	72.51
Total		803.02	100

Source: China Electricity Council (2015a); Forward Industry Institute (2013).

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