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Sulfur dioxide emission reduction of power plants in China: current policies and implications

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ABSTRACT

Electricity generation by conventional fossil fuel power plants have caused severe environmental problems worldwide. Besides greenhouse gas emissions which has global impacts on the climate, there are also pollutant emissions like sulfur dioxide which endanger the local environment. In particular, for developing countries who often highly rely on coal for power generation due to their resource endowment and the competitive costs of coal, the issue of environment pollution caused by coal-fired power plants is getting increasingly severe. Therefore, various solutions should be combined and implemented to address the issue, including environmental regulation, and economic and financial incentives. This study conducted an industry survey in 7 coal-fired power plants in China to collect detailed data in the field to examine the costs and benefits of flue gas desulfurization. Currently, coal-fired power plants in China which install and properly operate flue gas desulfurization equipment can receive 15 Yuan/MWh premium tariff on top of their on-grid tariffs. However, this study shows that this incentive is insufficient to cover the flue gas desulfurization costs of most of the sample plants. More solutions, both regulatory and market-based, should be considered to address this issue. Firstly, under China's current regulated power plants dispatch scheme, allocating generation hour based on the pollutant emission would provide strong incentive for sulfur dioxide mitigation. Secondly, it is suggested to provide more supportive financial environment for flue gas desulfurization industry by fiscal supports, diverse financing accesses, and innovation financial and business models. Thirdly, more environmental regulation tools such as emission cap and emission discharge fees should be set properly and examined carefully, to optimize their impacts on economy, society and environment. Finally, the analysis and results of this study can also be applied in other fields such as denitration and dedusting of coal-fired power plants.

1. Introduction

Electricity generation by conventional fossil fuel power plants have caused severe environmental problems, such as greenhouse gas emissions which has global impacts (Lin and Moubarak, 2013; Lin et al., 2014; Li and Lin, 2013), and other pollutant emissions which mainly endanger local environment such as sulfur dioxide (SO_2) emissions (World Bank Group, 2008). For developing countries like China, who often highly rely on coal-fired power generation due to its resource endowment and competitive costs of coal, the issue of environment pollution caused by coal-fired power plants is even more significant (Zhang et al., 2015; Du and Mao, 2015; Lin and Liu, 2010). Therefore, systematic solutions are needed to tackle this challenge by integrating environmental regulation and economic and financial incentives.

Currently, China is at its industrialization and urbanization stage with relatively fast growth in both GDP and energy consumption. Large amount of energy and natural resources are required to support China's economic and social development at this stage (Jiang et al., 2013). Further, China's coal-dominated energy mix will have to last in mid-term and even long-term to provide sufficient support for its large-scale and fast-growing energy demand.

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However, severe environmental damages have been caused by the large amount of coal consumption, e.g., CO, NOx and SO_2 make up the major components of haze (Wang et al., 2002), and NOx is also the major cause of ozone reduction (Li et al., 2013). According to the Ministry of Environmental Protection of China, power plants account for 40% of the country's NOx emissions and around 50% of SO_2 emissions. The Government of China has implemented several measures to promote the denitration and desulfurization of coal-fired power plants.

SO_2 emission from coal-fired power plant is charged at 0.63 Yuan per ton in China,[1] yet SO_2 emissions and their damage continue to grow rapidly. Among the top 5 cities where total non-accidental and cardiopulmonary mortality are mainly caused by SO_2 emission in Asia, there are three in China: Hong Kong, Shanghai and Wuhan (Kan et al., 2010). Chen et al. (2012) study the relationship between short-term exposure to SO_2 and daily mortality in 17 Chinese cities, they find that short-term exposure to SO_2 is correlated with a higher mortality risk. 65% of all sulfur input enters into products while the rest 35% ends up wastes (Tian et al., 2012). Wei et al. (2014) assessed the agricultural losses caused by 2069 enterprises (located in 899 counties) in China, and identified US$1.43 billion losses of agricultural value added in 2008 due to SO_2-associated pollution, which represents 0.66% of the total agricultural value added of the 899 counties. SO_2 emission is also a major cause for acid rain. In 2009, acid rain covered over 1.20 million square kilometers of area in China, and about 5% of these places suffered severe acid rain (Ministry of Environmental Protection of People's Republic of China, 2010).

Thermal power plants account for half of the coal consumption, and emit about half of total SO_2 emissions in China. A series of national and local policies have been issued and implemented to control SO_2 emissions, one of which is the on-grid tariff premium policy (Jiang et al., 2013). This policy is implemented to compensate the coal-fired power plants for the cost of desulfurization – according to NDRC (National Development and Reform Commission), coal-fired power plants which implement desulfurization can raise their on-grid electricity tariffs by 15 Yuan/MWh.

After the SO_2 mitigation policy mentioned above, China's SO_2 emissions in 2009 were 22.14 million tons, down by 4.60% and 13.14% compared to the figures in 2008 and 2005, respectively. Therefore, the SO_2 mitigation target of 11th Five Year Plan[2] has been accomplished already. Specifically, the SO_2 mitigation during the 11th Five-year is mainly attributed to the mitigation of coal-fired power plants. Firstly, the flue gas desulfurization (FGD) installation on coal-fired generators increased by more than 0.10 MW, much higher than Government's requirement of 0.05 MW increment issued at the beginning of 2009. Secondly, more than 0.26 MW of small coal-fired power generation capacities were shut down due to their low operation efficiency and high pollutant emissions.

Other policies favorable to FGD-equipped power plants are implemented, e.g., priority given to be connected to grids, and being allowed to operate longer than those plants that do not install desulphurization capacity (Zhang, 2014). Meanwhile, The State Council of China published Guidance on Further Promoting Compensation for the use of Pollutant Emission Right and Trading Pilot in August 2014, which in principle forbids the pollutant emission trade between thermal power plants and other industries, thus power plants have to install and operate FGD equipment themselves to meet the emission reduction targets. In addition, local governments in different provinces have also issued and implemented complementary policies to promote desulfurization. For example, Shanghai set a special award for coal-fired power plants which exceeded the SO_2 emission reduction target and provided them monetary award from Shanghai Special Funds for Energy Conservation and Emission Reduction.

Although various policies have been used to reduce the SO_2 emissions in China, it is expected to continue to rise to 24 to 31 million tons by 2020 (Xu and Masui, 2009). In 2012, China's SO_2 emission was 21.76 million tons and increased to 20.44 tons in 2013. SO_2 emission pollution leads to large amount of economic cost – 20,000 Yuan/ton (Ministry of Environmental Protection of People's Republic of China, 2006). Public health damage caused by SO_2 emissions attributed to energy consumption will increase rapidly in the coming decade (Wang, 2010). Therefore, it is necessary to seek for more efficient SO_2 mitigation methods to solve the serious pollution issues in China.

Among all the SO_2 emission sources, coal-fired power plants should take the major responsibility, and FGD system should be their important tool as it is widely available and applicable for most of the coal-fired power plants. Because of strict regulatory rules on coal-fired power plants, almost all the plants have installed the FGD systems, however, the challenge is to keep them running the FGD equipment constantly. It is often revealed that some plants insufficiently operate the FGD system to save operation costs, even though SO_2 abatement cost has largely dropped in China due to technological improvement (Kaneko et al., 2010).

Many of the existing studies on environmental efficiency of production aim to seek for solutions to reduce industrial pollutant emissions, e.g. Schreifels et al. (2012) and Lin et al. (2012) tried to address China's emission problems by examining the national policies in this field. Song et al. (2013) used the provincial data to study the environmental efficiency of provinces in China. Song et al. (2014) studied the environmental efficiency of the coal-fired power plants by using overall company performance data across the power plants. Although these studies have covered national, regional and power plant levels of the environmental efficiency analysis, none of them have collected or examined detailed data on pollutant emission and mitigation in the field. However, field survey is critically important to analyze and understand the issue of pollutant emission reduction of power plants, as well as helpful to explore effective solutions. Further, among the large number of studies on FGD costs of power plants, many have identified the key factors which impact the FGD costs most significantly, including project investment, sulfur content of coal, and electricity consumption of FGD systems (Yan, 2003; Sun and Zheng, 2004; Wang, 2005; Xue et al., 2006; Hao, 2006).

Coal-fired power plants have adopted various FGD technologies which are usually classified as wet, dry, and half-dry methods. "In wet processes, wet slurry waste or by-product is produced, and flue gas leaving the absorber is saturated with moisture" (Srivastava, 2000), while dry waste material that is produced in dry process is not. In half dry process, the reaction takes place in gaseous, solid, and liquid scrubbing (Li et al., 2015).

Wet process has been dominant in the FGD industry, and the most popular deployment are Wet Limestone (lime)/gypsum FGD (WFGD) and Seawater FGD technologies. In China, about 90 percent of coal-fired power plants uses the wet technology of WFGD due to its high economic and SO_2 removal efficiency. Flue gas is brought in contact with limestone slurry in an absorber to dissolve in and reacts with the absorbent. WFGD is also the most widely used method across the world, its SO_2 removal efficiency can reach 95 percent or even higher. Power plants which are located close to

[1] Ministry of Environmental Protection of People's Republic of China, 2007, The Eleventh Five Year Plan of Regulation of Sulfur Dioxide Existing in Coal-fired Power Plants in China. And this price is the nominal price in 2007.

[2] According to China's Outline of '11th Five-year Plan', sulfur dioxide emissions in 2010 should be reduced by at least 10% comparing with the 2005 level, that is, 22.94 million tons, of which 42% will be accomplished by the power industry. Meanwhile, emission performance standards of sulfur dioxide for coal-fired power plants nationwide will be reduced from 6.4 g/kWh in 2005 to 2.7 g/kWh in 2010 - a 57.8% reduction.