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Policy and case study on heat and power cogeneration and industrial centralized heat supply in China

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ABSTRACT

Air pollution represented by haze in China has attracted great global attention in recent years. China has recently introduced a series of action plans to improve air quality and prevent air pollution. Remediation on small coal-fired boilers and the development of heat and power cogeneration (HPC) and centralized heat supply (CHS) are important measures for preventing air pollution. This paper introduces the above mentioned policies. An industrial park in Guangdong Province, China, is taken as an example to analyze the contributions of HPC-based industrial CHS to energy saving and environmental protection. The benefits to the heat supplier and user are also analyzed. Furthermore, this paper presents the difficulties and challenges in developing industrial CHS, including mismatching in the early phase, price dispute, measure dispute, and negative inter-effects. The reasons for these problems are analyzed and possible solutions are provided.

1. Introduction

Haze weather has frequently occurred in China in recent years. For example, in January 2013, four cases of haze affected 30 Chinese provinces. Beijing was only haze-free for five days that month. All these data indicate that air quality has deteriorated because of pollution, which not only threatens the living environment and health of Chinese people, but also influences China's international image. The accumulation of air pollutants and the poor meteorological condition for pollutant dispersion are direct reasons for haze weather. Various ideas about the pollutant emission source of haze, including factory emission, car exhaust, road dust, and cooking oil fume, are considered.

The coal-consumption industry, which releases air pollutants, is the most notable among the various pollution sources. The coal-dominant energy structure in China may be the major reason for air quality deterioration. The coal-consumption modes in different fields vary. For example, the iron and steel industry uses coke to directly take part in the chemical reaction for steelmaking. The cement industry utilizes coal combustion to provide a high-temperature condition for alkali–silicate reaction. Meanwhile, boiler combusts coal to generate steam or hot water to provide thermal energy. This paper mainly focuses on the coal-consumption mode of boilers. People use the thermal energy provided by boilers for two purposes, namely, power generation and heat supply. The purposes of heat supply are classified into two categories as follows: civil use and industrial use. The former refers to residential, public, or commercial heating requirements in cold days, while the latter covers industries, such as textile manufacture, printing, and dying, papermaking, and food industries. The case study of this paper focuses on the industrial heat supplied by heat and power cogeneration (HPC).

The coal consumption of China's thermal power generation industry accounts for about half of the national coal consumption. Its pollution control has attracted considerable attention for many years. Small power units below 100 MW with high energy consumption and heavy pollution have been almost shut down. Current and newly built power units are mostly subcritical, supercritical, and ultra-supercritical high-efficiency power units of 300, 600, or 1000 MW, respectively. These power units are equipped with desulfurization, denitration, and dust emission control equipment. The Ministry of Environmental Protection in China issued the *Emission Standard of Air Pollutants for Thermal Power Plants* (Website of the Ministry of Environmental Protection of the People's Republic of China, 2011) in 2011. This standard promotes the emission level of China's coal-fired thermal power units to be close to the nat-

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ural gas power unit. The No. 4 coal-fired power unit of Guohua Zhoushan Power Plant owned by the Shenhua Group started operations on June 25, 2014. This unit adopted a near-zero emission flue gas purification technology, and its emission concentrations of dust, sulfur dioxide, and nitric oxide have reached 1.80, 1.88, and 17.52 mg/Nm^3, respectively (Zhejiang News Network, 2014). These values are lower than the corresponding special limits of natural gas-fired unit emission standards, which are 5, 35, and 50 mg/Nm^3 (Website of the Ministry of Environmental Protection of the People's Republic of China, 2011). These data indicate that tough emission standards, effective supervisions, and advanced technologies can effectively control and decrease air pollutants from a large coal-fired boiler in the electric power industry. However, the pollution problem of small coal-fired boilers (SCFBs) in the heat supply field has still not been effectively solved.

The two modes in the heat supply field are decentralized heat supply (DHS) and centralized heat supply (CHS). The scale of DHS using SCFBs is relatively large in China. The DHS mode may cause more air pollution because of several reasons. First, the energy efficiency of SCFBs is lower than that of power station boilers, and so more coal is consumed; second, the flue gas purification systems of SCFBs are not very advanced as those of power station boilers, and so more pollutants are emitted; and third, the SCFBs are dispersedly located, which make government supervisions difficult to implement. Guangdong Province in China consumes 150 million tons of coal annually. Their power station boilers consume about 100 million tons, while the SCFBs consume 50 million tons. The pollutant emissions of SCFBs are over three times more than those of power station boilers. The remediation on SCFBs in the DHS field is suggested to be the emphasis of the next step of environmental control.

The types of CHS include various HPC units, distributed energy stations, and big boilers (i.e., coal-fired, natural gas-fired, or electric power). These types provide a relatively large HPC proportion in China. The HPC units include coal-fired extraction condensing, coal-fired backpressure, gas–steam combined cycle extraction condensing, and gas–steam combined cycle backpressure types. The coal-fired types are primarily used in China. HPC-based CHS provides energy saving and emission reduction to the environment. Korhonen provided comparative data showing that the fuel efficiency of an HPC plant is 85%–90%, whereas that of a condensing power plant is only 40%–45% (Korhonen, 2001a,b, 2002). Westner and Medlener indicated that a coal-fired HPC plant's energy-saving rate is between 5% and 25%, while its emission reduction is between 1% and 10% (Westner and Madlener, 2012). Celma et al. also found that the HPC in an olive-processing industry may achieve reductions of primary energy demand (49%) and CO_2 emissions (Celma et al., 2013). All these data indicate that the HPC-based CHS is an environment-friendly mode.

The DHS transition to CHS may be an efficient means of realizing cleaner production in the heat supply field. The present paper discusses this topic. Policies and measures on the SCFB remediation and CHS development in recent years in China are introduced. A typical industrial CHS case based on the coal-fired extraction condensing-type HPC unit is then provided. The energy-saving and emission reduction effects of CHS, as well as the various benefits to the heat supplier and user, are analyzed through this case. This paper also presents the difficulties and challenges in developing CHS and providing possible solutions. The measures taken in this case can be adopted by other industries to resolve similar problems.

2. Policy study

The Chinese government has issued a series of policies and measures to shut down small power units and remediation on SCFBs to reduce the influence of coal-fired boilers on the environment. All these policies support the development of HPC and CHS.

2.1. National policies on shutting down small power units

China began to shut down small power units in the 1990s. In May 1995, the State Council issued "*Opinions on Shutting-down Small Power Units* (110 legal advice net, 1999), which required that conventional coal-fired and oil-fired units with power per unit below 50 MW shall be shut down before the end of 2003. In January 2007, *Several Opinions on Accelerating the Shutting-Down Small Power Units* was issued (Website of the Central People's government of the People's Republic of China, 2007), which required that in the 11th five-year planning period (2006–2010), conventional thermal power units with below 100 MW per unit and over 20 years' service, various units with less than 200 MW per unit and service expiration, and other high energy consumption and excessive emission units should be shut down. The conventional units in the two above mentioned files refer to condensing power generation units. In other words, HPC units are not shut down, which indicates that the country is in favor of the HPC. Through shutting down small power units, the energy efficiency of China's coal-fired power industry was improved by 10% from 2006 to 2010 (Website of the National Development and Reform commission, 2012).

The government has provided clear standards on identifying HPC units. Four national ministries and commissions jointly issued '*Provisions on Developing Cogeneration*' (Website of the National Energy Administration, 2011a) in August 2000. The National Development and Reform Commission (NDRC) revised this provision in June 2011. The provisions stated that only when the unit conforms to the following indices shall it be regarded an HPC: (1) its annual mean gross thermal efficiency shall be more than 45%, and (2) its annual mean heat-to-electric ratio shall be more than 100% for units below 50 MW and more than 50% for units between 50 and 200 MW. Therefore, if the supplying heat amount of a generator unit is insufficient, the unit will not be regarded as an HPC unit and will not enjoy relevant preferential policies.

2.2. National action plan for air pollution control

The China State Council issued the "*Action Plan for Air Pollution Prevention and Control*" on September 10, 2013 in light of the air pollution typically represented by haze. As the Action Plan contains 10 specific items, it is popularly called the Ten Articles of Air (TAA). Relevant national ministries, commissions, and provincial governments issued work programs or implementation rules for the TAA thereafter (Table 1).

The TAA proposed that China would witness an overall improvement in air quality and a dramatic drop in seriously polluted days in five years. The air quality of three key areas will significantly improve. China will also strive to gradually eliminate the seriously polluted weather and improve the national air quality in another five years or more. The specific targets of the TAA are for inhalable particle concentration in cities at prefecture level or above to decline by over 10% in 2017 compared with that in 2012. Premium air quality days should also increase year by year. The inhalable particle concentration of three key areas, namely, Beijing–Tianjin–Hebei, Yangtze Delta, and Pearl River Delta, drops by about 25%, 20%, and 15%, respectively. The annual particle concentration in Beijing is controlled to 60 μg per cubic meter. The TAA brings forward many measures to achieve the stated goals. This paper will mainly focus on the measures that involve SCFB remediation and HPC and CHS development.

Article 1 of the TAA expresses the following: "To enhance the integrated control and decrease the release of multiple contaminants." This statement refers to the strengthening of the integrated