ENVIRONMENTAL SCIENCE & POLICY 31 (2013) 1–12

Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.elsevier.com/locate/envsci

Emissions trading in Hong Kong and the Pearl River Delta region—A modeling approach to trade decisions in Hong Kong's electricity industry

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ARTICLE INFO

Article history:
Received 18 October 2011
Received in revised form
5 March 2013
Accepted 19 March 2013
Published on line 23 April 2013

Keywords:
Air pollution
Regional emissions trading
Emission control
Modeling

ABSTRACT

In 2002, the Hong Kong government and the Guangdong provincial government agreed to reduce emissions of sulfur dioxide, nitrogen oxides, respirable suspended particulates, and volatile organic compounds by 40%, 20%, 55%, and 55%, respectively. There was strong public demand for the power stations in Hong Kong to reduce emissions. Emission caps were introduced, with allowances for the trading of emission credits. However, local power stations were using equipment built in the 1980s and 1990s, making it difficult for them to meet the new emissions requirements. The situation presented a new challenge, which involved a choice of either improving the existing equipment, or using emissions trading to meet the emission caps. This study reviews the background on emissions in Hong Kong and the surrounding regions, the "cap and trade" system, and the technologies used for power generation and emission reduction. A modeling approach is adopted to simulate the equipment, the electricity dispatching requirements, and the costs of either reducing emissions or trading emission credits. Data from a power station in Hong Kong was chosen for the simulation. Different options were simulated in the model to identify the optimal strategy. The results were then compared with the plan for emission reduction. This study demonstrates that a modeling approach using linear programming can analyze the complicated options involving emission reduction and investments to achieve an optimized business solution.

1. Introduction

Air pollution in Hong Kong (HK) has worsened since the early 2000s. The number of hours of reduced visibility increased from 480 h in 1997 to 1490 h in 2003 (HKO, 2007). Hong Kong faces two major air pollution problems: street-level and region-wide air pollution. In 2002, the Hong Kong government commissioned a study of the air quality in the surrounding Pearl River Delta region (PRD). The PRD comprises an area of 42,794 km^2 with a population of 38.7 million around the estuary of the Pearl River, whereas Hong Kong comprises only 1000 km^2 and a population of 7 million. The report, entitled "Final Report – Study of Air Quality in the Pearl River Delta Region" (CH2M HILL, 2002), revealed that the main sources of pollution in the region came from the energy, industry, and transportation sectors. Electricity generation contributed most of the pollution in the energy sector.

The report considered four major air pollutants to be important in the region: sulphur dioxide (SO_2), nitrogen oxides

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1462-9011/$ – see front matter
http://dx.doi.org/10.1016/j.envsci.2013.03.010

(NO_x), respirable suspended solids (RSP), and volatile organic compounds (VOC) from hydrocarbons. In 1997, the total emissions of SO_2, NO_x, RSP, and VOC in the region were 585,900, 643,000, 256,400, and 480,600 tons respectively, of which Hong Kong produced 65,960, 123,000, 11,400, and 68,900 tons respectively. The energy sector in Hong Kong contributed approximately 64,300, 59,700, and 6500 tons of SO_2, NO_x, and RSP respectively, from generating 23,574 GWh of electricity. The region has been one of the fastest growing economic development areas in China, with an annual GDP growth rate of more than 4.5% in Hong Kong (Census and Statistics Department, 2007) and 11–12% in the PRD. Thus, the report predicted increasing energy consumption and worsening emissions problems in the region.

In 2002, the Hong Kong government and the Guangdong provincial government agreed to reduce, on a best-endeavor basis, the regional emissions of sulfur dioxide, nitrogen oxides, respirable suspended particulates, and volatile organic compounds by 40%, 20%, 55%, and 55% respectively, by 2010, using 1997 as the base year (HK Government news, 2002). There was a strong demand for power companies to reduce their emissions. Based on the agreement, the required emission targets for Hong Kong's electricity generation in 2010 were estimated at 25,000, 42,600, and 1260 tons of SO_2, NO_x, and RSP respectively. These reduction targets were substantial. Emissions trading was proposed as a solution for the electricity generation industry to achieve the targets in 2002 (Liao, 2002). Emissions trading was completely new and quite different from the emission controls that were in use at that time. This option presented a new challenge for power station managers who had to choose between improving their existing equipment and/or using emissions trading to meet the emission targets. The aim of this study was to explore a modeling approach that would facilitate power station managers in making such decisions.

Many different emissions trading systems have been reported around the world (Leung et al., 2009). However, only two major popular emissions trading programs have been actively implemented: the Acid Rain Program based on Title IV of the Clean Air Act adopted in the US (US EPA, 2006), and the EU emissions trading program based on Directive 2003/87/EC and Council Directive 96/61/EC (EC Directive, 2003) in Europe. Both programs were developed from the ''cap and trade'' system. In HK, a pilot scheme for emissions trading among the power stations based in HK and the PRD was also based on a ''cap and trade'' system (EPD HK, 2007a).

2. "Cap and trade" system

The ''cap and trade'' system is a means of preventing emissions from exceeding government-set limits through the trading of emission credits among the major emission sources. An *emissions monitoring station*, usually the government's environmental protection agency, sets the air quality objectives based on public expectations and assigns emission caps to *emissions permit holders*, i.e. the power stations, who either own or operate the *emission sources*. The *emissions permit holders* must meet emission caps, either by improving their equipment or by trading emission credits in the emissions trading market. The *emissions monitoring station* monitors the emissions from the *emission sources*, oversees the operation of the emissions trading program, and enforces public policy by imposing heavy penalties for any exceedance of emission standards.

An effective ''cap and trade'' program requires legislation so that it is enforceable by the authorities. The emission caps must meet the air quality objectives and be respected by all of the parties concerned. There should also be a global allocation plan for emission caps, supported by agreement between the *emissions monitoring stations* and the *emissions permit holders*. The important rules in an allocation plan must be fair and equitable and should allow for the new entry of permit holders. The system requires a comprehensive emissions measuring, monitoring, and reporting system. Continuous emissions monitoring supplemented by an agreed calculation system is commonly adopted, with heavy penalties for exceeding limits to deter noncompliance. The pricing of emission credits depends on the market and the cost of the emission reduction work. Most credit trading is done through agreed contracts that must be scrutinized by the *emissions monitoring stations*.

To meet the emission caps, the *emissions permit holders* can use cleaner fuels, or remove pollutants in the flue gas before emitting it into the atmosphere. Alternatively, the permit holders can buy emission credits to meet their emission caps, or sell their emission credits to others when they have a surplus. The *emissions permit holders* must strike a balance between investing in emission-reduction equipment and paying the price of emission credits. In the electricity industry, the main concerns of the *emissions permit holders* are the operating and maintenance costs, the capital investments and the return on investment.

3. Technologies for electricity generation and pollution reduction

The emissions levels from power plants depend heavily on which technologies the plants use for electricity generation. The main fuels used for conventional power plants are coal and oil. Natural gas is used in combined cycle generating power plants.

In coal-fired or oil-fired power plants, fuels are burned in the boiler to produce heat energy that is then converted into mechanical energy for electricity generation. The energy conversion efficiency for a power plant is the ratio between the useful output of the power plant and the input in energy terms. The theoretical energy conversion efficiency of this process is between 35 and 42%, depending on the operating conditions of the plant (Eastop and McConkey, 1986). With the latest developments in technology and materials, it is possible to achieve actual conversion efficiency of 42% at full load (Alstom Power, 2011b).

In combined cycle plants, air is compressed in the air compressor and gas fuel is injected into the combustion chamber to burn with the compressed air. The combustion process produces heat. Residual heat from the gas turbine is used to heat water into steam in the heat-recovery steam generator. The heat energy from the compressed air and