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ScienceDirect

Energy Procedia 83 (2015) 10 – 20

Energy Procedia

7th International Conference on Sustainability in Energy and Buildings

Cutting air pollution by improving energy efficiency of China's cement industry

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Abstract

In this study, the energy conservation supply curves (ECSC) combined with the GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies) was used to estimate the co-benefits of energy savings on CO_2 and air pollutants emission for implementation co-control options of energy efficiency measures and end-of-pipe options in the china's cement industry for the period 2011-2030. Results show the cost-effective energy saving potential (EEP1 scenario) and its costs is estimated to be 3.0 EJ and 4.1 Billion $ in 2030. The technical energy savings potential (EEP2 scenario) and its costs amounts to 4.2 EJ and 8.4 Billion $ at the same time. Energy efficiency measures can help decrease 5-8% of CO_2, 3-5% of PM, 15-25% of SO_2, and 12-20% of NOx emissions by 2030. Overall, the average marginal costs of energy efficiency measures will decrease by 20%, from 1.48 $/GJ to 1.19 $/GJ, when taking into account avoided investments in air pollution control measures. Therefore, implementation of energy efficiency measures is more cost-effective than a solely end-of-pipe based policy in China's cement industry. The plant managers and end users can consider using energy efficiency measures to reach new air pollutants emission standards in China's cement industry.

Peer-review under responsibility of KES International

Keywords: Co-benefits; energy efficiency; air pollution; GAINS; Cement industry

1. Introduction

China's cement industry has attracted attention worldwide. Despite several efforts, such as increasing the new dry process application, closing obsolete plants, and using various best practice technologies, that have been made by

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Peer-review under responsibility of KES International

doi:10.1016/j.egypro.2015.12.191

Chinese government in the past two decades, recent studies indicate that there is still a large opportunity to improve energy efficiency, reduce emissions of GHGs and air pollutants [1–3]. Comparing the disparity between the current energy efficiency level in China and best practice, indicates a cumulative energy savings potential of 5.0-37.5 EJ in the period 2011-2030, under different scenarios [2,3]. Likewise, if all Chinese cement plants adopted energy efficiency improvement measures, alternative fuels, and clinker substitution (to reduce the clinker-cement ratio), 2.5-4.7 Gt or 53% CO_2 would be saved up to 2050 [1,4]. Lei [5] evaluated local air pollutants, such as PM, SO_2, and NOx in China's cement industry using the proportion of different types of kilns to produce cement and air pollutant emission standards for the Chinese cement industry, and they found that PM and SO_2 emissions would decrease, by shifting from wet to dry process. NOx emissions would decrease because of the increase of precalciner kilns [5]. Furthermore, many studies have shown that the co-benefits (including direct co-benefits and indirect co-benefits) of health effects of energy efficiency improvement and CO_2 mitigation can be substantial [6,7]. For instance, Xi [8] estimated the interaction between carbon mitigation and air pollutant control measures in China's cement industry during the 12th Five Year Plan period, and found significant co-benefits of 18 energy saving technologies. However, most of these studies usually do not monetize the co-benefits when assessing the best available technologies and end-of-pipe options. Therefore, synergies between policies to address energy efficiency and air pollutant emissions mitigation have been neglected by policy makers. The aim of this paper is to address this gap by assessing the co-benefits of energy efficient technologies and air pollutant control in the China's cement industry and quantify how co-benefits would affect the cost effectiveness of energy efficiency technologies.

The structure of this paper is as follows, section 2 gives an overview of China's cement industry. The methodology, data collection, and scenarios construction is given in section 3. The results of energy saving potential and emission mitigations of GHGs and air pollutions and associated costs for different scenarios are discussed in section 4. Finally, the conclusion is given in section 5.

2. Overview of China's cement industry: production, energy consumption and emissions

As the largest cement market in the world, China's share in cement production has surged from 20% in 1990 to 59% by 2012. Although the annual growth rate of cement and clinker production fluctuated drastically between 1990 and 2012, the total production of cement and clinker increased rapidly from 210 Mt and 157 Mt in 1990 to 2210 Mt and 1278 Mt in 2012, respectively [9]. The annual growth rate of cement production was 18% from 1990 to 1996, and slowed down to 4% by 2000. Between 2001 and 2012 (except 2008), it resumed rapid growth at an average of 9% per year. The cement produced from dry process increased slightly from 6% share of total cement production in 1990 to 10% by 2000, however, it was increased at an average of 7.6% per year, from 14% in 2001 to 92% in 2012, which was caused not only by the expansion of dry process for cement production and retrofitting but also by the elimination of wet process, closing of obsolete vertical shaft kilns, and the decrease of the clinker to cement ratio.

The energy consumption of China's cement industry generally kept pace with the growth of China's cement output. The total amount of energy consumption of China's cement industry increased about 6 times from 1200 PJ to 6961 PJ in 2011, which equals 7% of Chinese total energy consumption [10]. The annual growth rate of energy consumption was 8.7% between 1990 and 2011, lower than the annual growth rate of cement production, which was 11.6% during this period. This may be due to the decrease of the clinker to cement ratio from 74.9% in 1990 to 62.5% in 2011 and 57.9% in 2012 and improved efficiency of new NSP kilns [2].

CO_2 emissions in cement production come from calcination, fuel combustion, and indirect emissions of electricity consumption. The overall CO_2 emissions increased at an average of 8.9% per year, from 591 Mt in 2000 to 1380 Mt in 2010. In 2010, approximately 43.8% was due to process emissions, 47.6% due to fuel combustion, and 8.6% due to electricity consumption. One main reason for the CO_2 emissions reduction is the lower ratio of clinker to cement (63%) that was adopted through utilizing alternative materials such as blast furnace slag, and fly ash, compared to the weighted average world level (76%) [11,12].