Energy Policy 88 (2016) 278–288

Contents lists available at ScienceDirect

Energy Policy

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

Impact of a national plan for future electricity supply on ambient air quality in South Korea

Changsub Shim*, Jiyoun Hong

Korea Environment Institute, 370 Sicheong-daro, Sejong, South Korea

HIGHLIGHTS

- Air quality impact assessment of future electricity supply plan was conducted.
- Future emissions changes by expansion of electricity capacity was estimated.
- Future coal-powered plants can cause intense NO_x emissions over Seoul, Korea.
- Consequent NO_2 level will increase significantly over Seoul Metropolitan Area.

ARTICLE INFO

Article history:
Received 3 June 2015
Received in revised form
22 October 2015
Accepted 24 October 2015

Keywords:
Air pollutant emission
Air quality
Coal
Electricity power generation
Seoul metropolitan area

ABSTRACT

South Korea has recently chosen coal as the major energy source for the future national electricity power supply, mainly due to economic reasons. This has raised concerns about national air quality, considering the serious air pollution associated with the long-range transport of Chinese air pollutants. In the present study, we simulated air pollution levels for 2027 considering the changes in electricity power plants of South Korea proposed by the sixth Basic Plan for Long-Term Electricity Supply and Demand (6th BPE, 2013–2027). Compared to the emissions in 2010, the emissions of CO, NO_x, SO_x, and PM_{10} from electricity supply in the Incheon, Gyunggi, Gangwon, Chungnam, and Gyeongnam regions will increase by 20–50% in 2027. The resulting number of days on which pollution levels exceeded the national air quality standards for O_3 and PM_{10} will increase by fewer than 6 days in all regions, which seems to be a minor increase. However, that of NO_2 over the Seoul metropolitan area (SMA, including Incheon, part of Gyunggi, and Seoul) showed a marked increase of more than 21 days. Therefore, an impact from secondary air pollution, such as acid rain and $PM_{2.5}$ formation, can be expected, although this requires quantification.

1. Introduction

Air pollution in the Seoul metropolitan area (SMA) of South Korea is more severe than in metropolitan cities of other continents based on the concentration of air pollutants such as nitrogen oxides (NO_x) and particulate matter (PM) (Organization for Economic Co-operation and Development (OECD), 2008)). The introduction of emissions reduction technologies and the use of clean energy have reduced some primary air pollutants such as CO and SO_2 for the past 10 years (Korean Ministry of Environment (KMOE), (2012)). However, despite such efforts, a continuous increase in the number of motor vehicles and industrial facilities is interrupting significant mitigation of NO_x and PM_{10} as well as ozone (O_3) in Korea (KMOE, 2012). In particular, the annual mean $PM_{2.5}$ concentration over most Korean cites has recently exceeded 25 μg/m^3, which is much higher than that recommended by the guideline of the World Health Organization (WHO, 10 μg/m^3) (Interagency of the Korean government, 2013).

The electricity consumption of South Korea has increased rapidly over the past 10 years. In 2011, total domestic electricity consumption was about 450,000 GW h, which was about a 61% increase compared to that of 2002 (280,000 GW h). This consumption ranks in the top eight of the world (Korean Ministry of Knowledge & Economy (KMKE), 2013). Korean electricity consumption is also relevant to national greenhouse gas emissions. Currently, Korea is ranked seventh in CO_2 emissions (Le Quéré et al., 2014).

Korea has built new power plants that use coal, nuclear power, and natural gas (i.e., liquefied natural gas [LNG]) to meet the

* Corresponding author. Fax: +82 44 415 7866.
E-mail address: marchell@gmail.com (C. Shim).

http://dx.doi.org/10.1016/j.enpol.2015.10.033

increasing demand. In particular, electrical power generation using coal and LNG has dramatically increased. The share of electricity generation by fossil fuels (mostly coal and LNG) in terms of final energy increased from 51% in 2002 to 64% in 2012 (KMKE, 2013). This trend could worsen domestic air quality despite various mitigation policies that have been put in place.

In February 2013, the Korean government announced the sixth Basic Plan for Long-Term Electricity Supply and Demand (6th BPE, 2013–2027), which is a biennial plan to guide national electricity policy based on long-term predictions of electrical supply and demand associated with the projection of the national economy (KMKE, 2013). According to this plan, South Korean electricity consumption is expected to increase to 770,000 GW h in 2027, which is an increase of more than 60% compared to 2012. Moreover, coal and LNG will provide a major portion of the energy sources for the electrical supply. Therefore, it is necessary to quantitatively assess the future impact of air pollutant emissions on domestic air quality.

According to the Second National Energy Master Plan of South Korea, a higher-level plan of the BPE announced in January 2014, total final energy consumption in the country is expected to increase about 21% by 2035 (254.1 MToe [million tonnes of oil equivalent]) compared to 2011 (205.9 MToe). In particular, the final energy consumption by electricity is expected to rapidly increase by 80% (Private–Public Working Group of Korean Ministry of Trade, Industry & Energy (MOTIE), 2014). Intense dependency on electricity generated from fossil fuels can cause an increase in air pollutant emissions from combustion in energy industry sector.

In the present study, we assessed the potential impact of the aforementioned electricity supply plan on ambient air quality in the SMA, which has a population of nearly 20 million. Considering the impact of future increases in the number of national electrical power facilities, we have discussed the energy and environmental policies of South Korea. In particular, we quantitatively analyzed the plan's potential impact on future changes in O_3, O_3 precursors (e.g., NO_x), and PM_{10} (PM less than 10 μm in diameter), which influence human health. We estimated the changes in 2027, the final year of the sixth BPE. The remainder of this paper is organized as follows. The methodology is described in Section 2, and Section 3 reports the results of air-quality model simulations.

2. Data and methodology

2.1. Sixth BPE (2013–2027)

The Korean Ministry of Trade, Industry, and Energy (KMOTIE, previously Korean Ministry of Knowledge & Economy [KMKE]) establishes a 15-year action plan every 2 years (Korea Electricity Business Act Enforcement Ordinance Article 15) aimed at developing a stable national power supply (Korea Electricity Business Act Article 25). In February 2013, the KMKE officially announced the sixth BPE (2013–2027) and reported demand management goals, proper reserve rates, power mixes, proportions of renewable energy, and power plant construction plans until 2027 (KMKE, 2013; Lee et al., 2015a). According to the plan, Korea's electricity demand is expected to increase ~4% annually, reaching 770,000 GW h in 2027, which is about a 60% increase compared to 2012.

As shown in Fig. 1, future energy sources of the electrical power supply are expected to include a higher proportion of renewable energy (12.6%) in 2027 compared to the current level. Although dependency of fossil fuels (including coal and LNG) for electricity generation in terms of final energy will slightly decrease from 60% in 2012 to 50% in 2027, total fossil fuel consumption for electrical generation in terms of primary energy is expected to increase

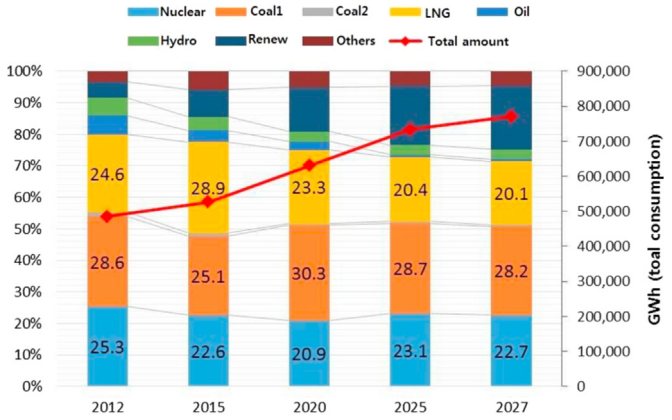

Fig. 1. Projections of future national electricity consumptions (unit at the right axis) and the power mix for electricity generation (unit at the left axis) according to the sixth National Plan for Electricity Supply (BPE) of Korea. (sources: KMKE, 2013). "Coal2" denotes anthracite coal. "Renew" denotes the renewable energy excluding hydro energy.

rapidly by 58% in 2027 compared to 2012. This is because the total electrical consumption is expected to significantly increase (KMKE, 2013), despite the government's effort to reduce the emissions of greenhouse gases.

To satisfy future demand for electricity, the Korean government has planned to install 18 additional electrical power plants by 2027 (totaling 15.8 million kW). Six facilities by four public enterprises (4.04 million kW) and twelve facilities by eight private power generation companies (11.76 million kW) will be installed by 2027.

2.2. National emissions of air pollutants

The National Institute of Environmental Research (NIER) of Korea has operated the Clean Air Policy Support System (CAPSS), which has calculated the emissions of air pollutants since 1999. It estimates air pollutants such as CO, NO_x, SO_x, PM_{10}, and volatile organic compounds (VOCs). According to CAPSS data for the year 2010, South Korean emission of NO_x exceeded 1 million tonnes (Table 1), which made it the largest pollutant emission. Although NO_x emissions have decreased continuously since the year 2000, the rate of decrease has not been sufficient, mainly due to the rapidly increasing number of motor vehicles. The second largest pollutant emission was VOC (860,000 tonnes), followed by CO (766,000 tonnes).

Fig. 2 shows the emissions sources for each pollutant. NO_x and CO, which can be relevant to the formation of O_3, are mainly

Table 1
Korean air pollutant emissions by major sources classification in 2010 (sources: NIER, 2012) (unit: tonne).

Sources	CO	NO_x	SO_x	PM_{10}
Combustion in energy industry (electricity supply)	46,679	138,355	70,923	2,695
Combustions in energy industry (heat supply)	3850	15,086	10,657	121
Non-industrial combustion plants	83,435	96,480	57,810	2421
Combustion in manufacturing industries	17,706	164,942	103,733	76,011
Production processes	19,719	49,022	93,365	6451
Road transport	520,386	382,226	798	15,255
Other mobile sources and machinery	66,793	208,878	62,919	13,401
Waste treatment and disposal	955	6062	1528	165
Other sources & sinks	6645	158	0	288
Total	766,268	1,061,209	401,742	116,808