ELSEVIER

Energy Policy 33 (2005) 815–825

ENERGY POLICY

www.elsevier.com/locate/enpol

Supply- and demand-side effects of power sector planning with demand-side management options and SO_2 emission constraints

Ram M. Shrestha*, Charles O.P. Marpaung

School of Environment, Resources and Development Energy Program, Asian Institute of Technology, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand

Department of Electrical Engineering, Faculty of Engineering, Christian University of Indonesia, Jalan Mayjend Sutoyo, Jakarta 13630, Indonesia

Abstract

This paper examines the implications of SO_2 emission mitigation constraints in the power sector planning in Indonesia—a developing country—during 2003–2017 from a long term integrated resource planning perspective. A decomposition model is developed to assess the contributions of supply- and demand-side effects to the total changes in CO_2, SO_2 and NO_x emissions from the power sector due to constraints on SO_2 emissions. The results of the study show that both the supply- and demand-side effects would act towards the reduction of CO_2, SO_2 and NO_x emissions. However, the supply-side effect would play the dominant role in emission mitigations from the power sector in Indonesia. The average incremental SO_2 abatement cost would increase from US$ 970 to US$ 1271 per ton of SO_2, while electricity price would increase by 2–18% if the annual SO_2 emission reduction target is increased from 10% to 25%.

Keywords: Supply-side effect; Demand-side effect; Sulphur dioxide mitigation

1. Introduction

Developing countries in Asia have experienced fast growing emission of regional air pollutants during the last years of the 20th century. Streets et al. (2000) noted that between 1990 and 1997, the regional annual average growth rate for SO_2 emission in Southeast Asia was 6.0%, 5.2% in the Indian subcontinent and 1.1% in East Asia. Shrestha and Marpaung (1998) estimated that between 1990 and 2000, the annual average growth rate for SO_2 emission in Indonesia was about 5.7%. Without additional control measures, Shah et al. (2000) predicted that in 2020, the SO_2 emission in Asia would be 111 million tonnes, i.e., about three times the 1990 level. The rapid growth rates of the SO_2 emissions were mainly due to the heavy usage of fossil fuels (i.e., about 80% of energy consumption in Asia), such as coal and oil. Of the total SO_2 produced in 1990, the contribution of power sector was about 30% in Asia as a whole (Shrestha et al., 1996). Hence, development of the power sector to contain local and regional level pollutant emissions within a predetermined level is becoming an increasingly interesting issue for countries in the region.

There are few studies examining the implications of constraining SO_2 emissions in the power sector (see, e.g., Malcolm and Anandalingam, 2000; Spens and Lee, 1997; Zhijun and Kuby, 1997; Chowdury, 1996; Cooper et al., 1996; Hobbs and Centolella, 1995; Hobbs, 1993; Amagai and Leung, 1989). However, none of them discussed the relative importance of supply- and demand-side effects on total changes in pollutant emissions. Shrestha and Marpaung (2002) examined the supply- and demand-side effects in power sector development in Indonesia from a long term integrated resource planning (IRP) perspective considering both supply- and demand-side options. However, the study focused on effects of CO_2 emission constraints in the power sector and did not consider SO_2 emission targets.

This study analyzes the implications of SO_2 emission reduction targets for power sector planning in Indonesia—a developing country—during 2003–2017 in terms of generation-mix, capacity-mix, demand-side management (DSM) mix, overall thermal generation efficiency, and reliability of the power system from a long term IRP perspective. It also examines the supply- and demand-side contributions to total changes in CO_2, SO_2 and

*Corresponding author. Tel.: +662-524-5406; fax: +662-524-5439.
E-mail addresses: ram@ait.ac.th (R.M. Shrestha), elektuki@centrin.net.id (C.O.P. Marpaung).

0301-4215/$ - see front matter © 2003 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2003.10.007

NO_x emissions due to annual SO_2 emission targets in the power sector. Furthermore, it computes SO_2 abatement costs and electricity prices in the presence of SO_2 emission constraints.

This paper is organized as follows: A brief description of the power sector in Indonesia is presented in Section 2, followed by a description of the methodology in Section 3. Section 4 discusses input data and assumptions used. Utility supply-side planning and demand-side implications of SO_2 constraints are discussed in Sections 5 and 6, respectively. The roles of supply- and demand-side effects on CO_2, SO_2 and NO_x emission changes due to SO_2 mitigation targets are assessed in Section 7, followed by a discussion of economic implications (Section 8). Key findings and final remarks are presented in Section 9.

2. Power sector in Indonesia

Power demand in Indonesia recorded an annual average growth rate of over 8% during 1997–2002 (PTP, 2003). The Java-Bali Islands account for approximately 80% of the total electricity generation and 70% of the total generation capacity in the country.[1] The total installed capacity in the Java-Bali Islands in 2002 was 18,608 MW which comprised of 86.4% thermal power plants and 13.6% hydro-power plants. Of the total thermal generation capacity, coal based power plant had the largest share (41.4%), followed by gas-, oil- and geothermal-based power plants with shares of 27.5%, 26.4% and 4.7%, respectively (PTP, 2003).

Candidate power plants for the Java-Bali Islands are mainly those based on gas and coal. Geothermal- and hydro-power plants are also considered in the candidate power plants although their potentials are limited. Oil-based power plants would not be considered as a matter of national policy. Nuclear power is likely to be fiercely opposed by environmentalists and is not yet considered as an option (PTP, 2000).

In 2002, the industrial, residential and commercial sectors accounted for about 42.1%, 39.4% and 13.5% of total electricity demand, respectively, in the Java-Bali Islands, with the public sector accounting for the rest (PTP, 2003). In 1996, approximately 58% of electricity consumption in the residential sector was for lighting. Approximately, 59% of lamps used were incandescent while the rest used fluorescent tubes. In the industrial sector, about 70% of total electricity consumption was used by standard motors (IIEC, 1997). Clearly, this indicates significant potential for electricity savings from the residential and industrial sectors through energy efficiency improvement programs.

[1] These figures do not include captive generation. According to BPS (2002) the share of captive generation in total electricity generation in Java-Bali Islands is only 2.1%.

3. Methodology

3.1. Integrated resource planning model with SO_2 emission constraints

The framework for analyzing IRP with SO_2 emission constraints is shown Fig. 1. The IRP model based on mixed integer linear programming is at the heart of the methodology (see, e.g., Shrestha and Marpaung, 2002; Hobbs, 1995). The model determines the least cost supply- and demand-side options during a planning horizon. The model is also able to determine whether the candidate steam coal plants should be installed with flue gas desulfurization (FGDs) or not. The number of power generators added during the planning horizon are represented by integer variables while the electricity generation and the stock of end-use electricity using devices are represented by continuous variables.[2]

The objective function of the IRP model represents the sum of supply- and demand-side costs. The supply-side cost consists of capacity costs of candidate power plants, as well as fuel-cost and operation and maintenance-costs of existing and candidate power plants. The demand-side cost represents the cost of energy efficient end-use appliances/equipments net of the cost of the end-use appliances/equipments that would be replaced. Though least cost planning has been traditionally been employed for vertically integrated utilities, the basic issues are essentially the same for utilities in the competitive environment. Thus, it has been argued that least cost planning may be all the more important to deal with the issues in the deregulated environment (Majumdar and Chattopadhyay, 1999; Merrill, 1995).

The constraints of the IRP model are as follows:

(a) *Power demand constraints*: Total power generation from all existing and candidate power plants, and power generation avoided by energy efficient end-use appliances/equipments cannot be less than the sum of total power demand and transmission and distribution losses in all periods ("blocks"),[3] seasons and years of the planning horizon considered.

[2] The use of continuous variables for end-use devices may be justified because of large number (e.g., in thousands) of these devices involved. From the modeling perspective, the use of the continuous variables is desirable for end-use devices instead of integer variables as it would greatly reduce the computational complexity of the model.

[3] The daily chronological load curve is divided into several "blocks" (i.e., time intervals) in the model in order to adequately capture the effect of variations in power demand over different periods of a day.