ISSN : 114 - 1284

http://www.qir-ftui.com

THE 9th INTERNATIONAL CONFERENCE on QUALITY in RESEARCH (QiR)

PROCEEDING

Energy, Process and Environmental Engineering and Management

Depok, 6 - 7 September 2006

UNIVERSITY OF INDONESIA
FACULTY OF ENGINEERING

FOREWORDS from

Dean of Faculty of Engineering, University of Indonesia

The Conference on Quality in Research (QIR) is annual event organized by the Faculty of Engineering, University of Indonesia. Since started in 1998, it has become an excellent forum of discussion for all researchers from research institutions and universities all over the country of Indonesia. The 1st and 6th conference on QIR had been successfully organized as a high quality national conferences, and starting from 7th conference on QIR, the conference has been organized to invite presentations of research papers internationally.

The 9th International Conference on Quality in Research having a theme of "Gaining Competitive Advantages Through Engineering Research" is to provide an international forum for exchange of the knowledge, information, experience and results as well as the review of progress and discussion on the state of the art and future trend various issues and developments in the multifield of scientific and technology. The main purposes of this conference are to provide a forum for free discussion of new ideas, development and applications, including techniques and methods to stimulate and inspire pioneering work, to provide opportunities for students and young engineers to meet their experienced peer and to provide a meeting that will enforce progress, stimulate growth and advance the state of knowledge in the multifield of science and technology.

We would like to express our heartiest to thank to all authors and participants for their active participations in the 9th International Conference on Quality in Research – QIR 2006, and also to all the paper reviewers, member of the technical committees, and member of the organizing committees, for their support to the success of this conference. Last but not least, we would also like to invite all participants to the next conference on Quality in Research – QIR 2007.

Faculty of Engineering, University of Indonesia
Dean,

Rinaldy Dalimi, Ph.D

FOREWORDS

The 9th International Conference on Quality in Research (QIR) having a theme of "Gaining Competitive Advantages Through Engineering Research" being the third time to go internationally, has invited limited papers from other country like Japan and Malaysia. The conference is organized in parallel session focusing on the 6 (six) research areas such that many researchers and peer groups may focus their discussion on the relevant topics. All submitted papers had been reviewed by the technical committees appointed and had been arranged in to 6 (six) sub-themes according to the following fields:

- Energy, Process and Environmental Engineering and Management
  Energy and environmental issues, combustion technology, fluid mechanics and thermal fluid machinery, thermodynamics and heat transfer, geotechnical and environmental engineering, etc
- Industrial, Manufacturing, Material Engineering, and Management
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- Biomaterial, Biomedical Engineering and Biotechnology
  Biomedical numerical modeling, Biomaterial, Biosensor, Biocompatibility, Biomechanics, Biotechnology, Biomedical Instrumentation, Biomedical Imaging
- Design and Infrastructure Engineering and Management
  Product design and development, composite: materials and applications, structural dynamics, mechanics of materials, Construction Management, Public Infrastructures and Services, Structural Engineering, etc
- Information and Computation Engineering
- Nanotechnology
  Nano structured material, Nanotechnology, Nanocomposite, Nanoporous Materials, MEMS, Self Assembled Monolayer, Thin Film, Nanomagnetic Materials, Etc

The main purposes of this conference are to provide a forum for free discussion of new ideas, development and applications, including techniques and methods to stimulate and inspire pioneering work, to provide opportunities for students and young engineers to meet their experienced peer and to provide a meeting that will enforce progress, stimulate growth and advance the state of knowledge in the multifield of science and technology.

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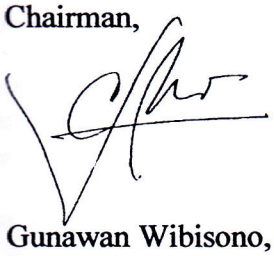

Gunawan Wibisono, Ph.D

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ISSN 1411-1284

Environmental and Utility Planning Implications Assessment of Sulfur Tax : The case of Indonesian Power Sector

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Abstract—**This paper presents the environmental and utility planning implications assessment of sulfur tax as an alternative instrument for SO_2 emission reduction from the Indonesian power sector. The implications were analyzed based on a long-term Traditional Resource Planning perspective. The methodology used to calculate the implication is least cost expansion model expanded by Integrated Resource Planning Model less Demand Side Management (DSM) option. Seven scenarios based on sulfur tax rate have been selected. The planning horizon period is 2006-2025. The environmental implication shows that SO_2 emission would decrease significantly i.e. 40% at sulfur tax rate of US$250/tS and 84% at sulfur tax rate of US$300/tS, while at the same rate CO_2 and NO_x emissions would decrease to 53% and 67% respectively. From generation system aspect, introducing sulfur tax to power sector would promote the selection of clean technology power plant for expansion planning. The generation plant mix would reduce the consumption of coal fuel and increase the consumption of gas.**

Keywords— **Environtmental, Utility Planning, Sulfur tax, IRPA Model**

I. INTRODUCTION

Sulfur dioxide (SO_2) is a harmful environmental emission. It produces acid rain i.e. the wet and dry deposition of acidic substances form the atmosphere. There are two effects of acid rain. Firstly, there is an acidification of natural water resources, and secondly, a leaching of nutrients in the soil which can lead to loss in productivity of crops and forests or a change in the natural vegetation which is finally destroy the sources of human life [1].

Emission of SO_2 from one country can affect the nature of rain in another country. Therefore controlling of SO_2 emission is very important. The controlling should be done in the whole countries since these types of horrendous impacts are felt globally and should not be considered one countries problem. Fortunately, United Nations (UN) has been concerning emission control by ratifying Kyoto Protocol [2].

Reducing of SO_2 emission and other pollutant is one of the controlling strategies. However, reducing emission of SO_2 is difficult because the emission come largely from the driver sectors of our economies and our lifestyles.

Power sector has been recognized as a major source of SO_2 emission as well as CO_2 because it fire fossil fuels that high sulfur, carbon, and nitrogen content to produce electricity. "Reference 3" analyzes and shows the level of total SO_2 emission from the Indonesian economy in year 1990 and 2000. The study shows that oil fired power generation and coal fired power generation are among the top six sectors in term of SO_2 production.

Installed capacity of Indonesian power generation is more than 18000 MW which is 77 % consist of thermal power plant that convert fossil fuel to electricity. The rest (23%) consist of hydropower plant and geothermal power plant [4]. Electricity demand has been increasing in last decade in line with the growing Indonesian economy. Since electricity consumption and demand is growing then consequently emission of SO_2 from the power sector is increasing. Based on those facts, measures regarding reduction SO_2 emission in Indonesia power sector need to be taken and implemented.

In order to avoid and minimize the effects, it is very important to carry out a study with an objective to analyze the policy options for mitigation of SO_2 emission and other harmful emission from Indonesia power sector.

"Refrence [5]" explains that tax on sulfur emission is part of environmental taxes. Environmental tax is an Indirect Economic Incentives instrument because this instrument does not require the regulator to monitor the emission and therefore may stand a better chance of being effective.

Many studies for implication of sulfur tax have been done in the world, for example [6], [7] and [8], however, most of the studies are for industrialized countries. Some lesson can be learned from those studies to analyze the implications of considering sulfur tax in power sector in developing countries like Indonesia

II. METHODOLOGY

2.1. Analytical framework

This study is carrying out by using an analytical framework as shown in Fig 1.. The integrated resource-planning model used in this study is based on The

Integrated Resources Planning Model (IRPA version 3) formulated & developed by Prof. Ram. M. Shrestha.

With the introduction of sulfur tax, the relative prices of fuel would increase. As a result, there would be changes in capacity and generation-mix of plants. The changes in capacity and a generation mix would result in reduction in SO_2 emission from the power sector. Algebraically, the SO_2 mitigation due to the changes capacity (here after denote as "ΔE") can be written as:

$$\Delta E = E(O, D_0) - E(T, D_0) \quad (1)$$

Where,

$E\ (O,\ D_0)$ =SO_2 emissions corresponding to the least cost fuel requirements in power generation to meet projected electricity demand D_0 without sulfur tax.

$E\ (T,\ D_0)$ = SO_2 emissions corresponding to the least cost fuel requirements in power generation with sulfur tax T for meeting the electricity demand D_0.

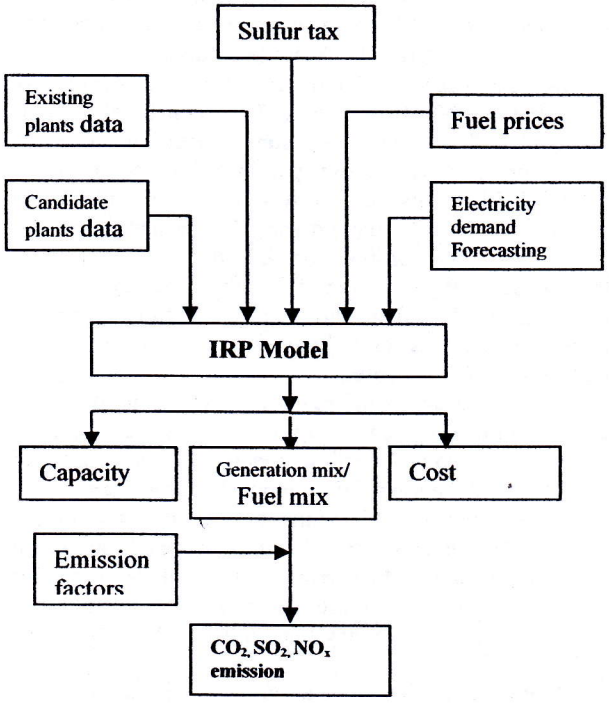

Fig 1. Analytical framework of Sulfur tax implication assessment based on IRP

2.2. Data Collection and Assumptions

Following the analytical framework, there are five types of input data required, they are: exiting plants data, candidate plants data, electricity demand forecasting, fuel prices, and sulfur tax. Secondary data for existing plants, fuel prices, are taken from PT.PLN (included the subsidiaries PT.PJB, Indonesia POWER,) and from DJLPE, while technical candidates DPG data was taken from [9].

The candidates of power plants for the future year are dominated by thermal power plant. Based on the resource availability advanced generating technologies, i.e. supercritical, AFBC, PFBC and IGCC based on coal fuel, and combine-cycle gas turbine (NGCC) based on gas fuel are also considered as candidate power plants. Plant candidates of Distributed Power Generation (DPG) based on biomass, solar and wind energy resources are also considered. The conventional power plants, which are considered, are steam coal power plants and gas turbine. The number of unit of all candidates are limited based on the resource availability. However, oil plant is excluded in electricity expansion plan based on Indonesia government policy. Nuclear power is excluded also since it likely fiercely opposed by environmentalists. Geothermal and hydro power plants are considered also as candidates but the number of its unit is limited.

Electricity demand forecasting data until 2006 is taken from PT. PLN and then extrapolating until 2025. The load factor is 87%, reserve margin 25%, and the chronological load curve (CLC) is divided into two periods and each period is divided into 7 blocks. Demand side management is not considered in this study.

In case of sulfur tax rate, six different sulfur tax rates are considered in this study. The selected sulfur tax rates are US$50, US$150, US$250, US$300, US$500 and US$1000 per ton of sulfur (hereafter "ton of sulfur" is denoted as "tS"). Base case is based on the absence sulfur tax. These rates are comparable to the tax rate implemented in other countries as reported in other studies. For example, sulfur tax in Sweden is 8.2 DM/kg Sulfur (= US$5186/tS); in Denmark is 2.6DM/kg Sulfur (=US$1644/tS); in France is 0.04DM/kg Sulfur (=US$25/tS) [8]. Hypothetical sulfur tax in Turkey is US$ 300/tS to US$ 500/tS [10]. Since different fuels have different sulfur content, the values of sulfur tax on the fuels in per Giga calories (denoted "Gcal") basis would vary from fuel to fuel. These are shown in Table 1.

TABLE 1.
SULFUR TAX RATE BASED ON FUEL TYPE, IN ($/GCal)

	Sulfur tax rate, US$/ton sulfur					
Fuel type	50	150	250	300	500	1000
Oil	13.89	41,67	69.44	83.30	138.89	277.77
Natural gas	1.97	5.91	9.86	11.83	19.72	39.43
Coal/ bituminous	5.12	15.35	25.58	30.70	51.17	102.33
Geothermal	0.02	0.054	0.090	0.108	0.18	0.36
Biomass	0.77	2.31	3.85	4.62	7.70	15.41

Source: Own calculation using energy conversion factors.

III. Results and Discussion

Study results of the implications of sulfur tax as instrument for SO_2 reduction from Jamali system could be grouped into 3 major aspects i.e. environmental, utility

planning, and economic aspect. This paper presents the environmental and utility planning implications only.

3.1. Environmental implication

Table 2 presents the total emission of CO_2, SO_2 and NO_x as implication of introducing sulfur tax at selected rate. Introduction of sulfur tax at selected rate would decrease total SO_2 emission as well as CO_2 and NO_x emissions as shown in Table 2. Mitigation rate of SO_2 emission will increase if sulfur tax rate is increased.

TABLE2.
TOTAL SO_2, NO_X, AND CO_2 EMISSIONS AT SELECTED SULFUR TAX RATE

Sulfur tax rate	Total emissions at selected sulfur tax rate		
US$/tS	CO2 emission (Mton)	SO2 emission (Mton)	NOx emission (Mton)
0	5,555,302.8	30,616.6	20,737.9
50	5,198,861.2	22,733.2	19,526.2
150	4,936,670.3	20,870.3	18,429.2
250	3,768,813.1	12,266.3	12,574.1
300	2,624,755.3	3,767.2	6,797.6
500	2,508,078.9	2,930.8	6,211.5
1000	2,931,932.9	2,931.9	6,169.4

Fig 2 shows the pattern of annual SO_2 emission in 2006-2025 periods at selected sulfur tax rate. It is shown that SO_2 emission would increase annually at sulfur tax rate lower than US$300/tS, but it would decrease annually at sulfur tax rate US$300/tS or higher. Mitigation rate of SO_2 emission is only 6%, 16%, and 40% due to Sulfur tax US$50/tS, US$150/tS, and US$250/tS respectively, but increase to 84% due to Sulfur tax rate US$ 300/tS.

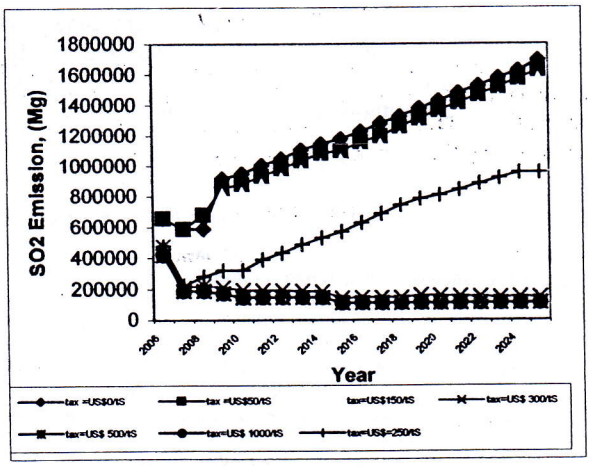

Fig2. Annual SO_2 emission at selected sulfur tax rate

The implication of sulfur taxes rate US$ 1000/tS would reduce also 88% of SO_2 that is almost the same implication with sulfur tax rate US$ 500/tS. This indicates that sulfur tax at low rate is less significant as instrument for reduction SO_2 emission. However, if introduced sulfur tax rate at or higher than US$300/tS the SO_2 emission would decrease significantly.

The results reflect that sulfur tax is an environmental friendly instrument for reduction of SO_2 emission as well as CO_2 and NOX emissions. Sulfur tax rate in range of US$250/tS to US$ 300/tS would give high significant mitigation of SO_2 emission.

Further, introduction of sulfur tax also affected NOx and CO_2 emissions as shown in Fig.3 and Fig.4. Mitigation rate of NOx would be 6%, 11% due to sulfur tax rate US$50/tS and US$150/tS respectively. The mitigation Nox emission would be sharply increased to 69% due to sulfur tax rate US$250/tS. Mean while mitigation of CO_2 emission would be 6% due sulfur tax US$ 50/tS, 11% due to sulfur tax US$ 150/tS and would be peaking to 68% due to sulfur tax US$ 250/tS.

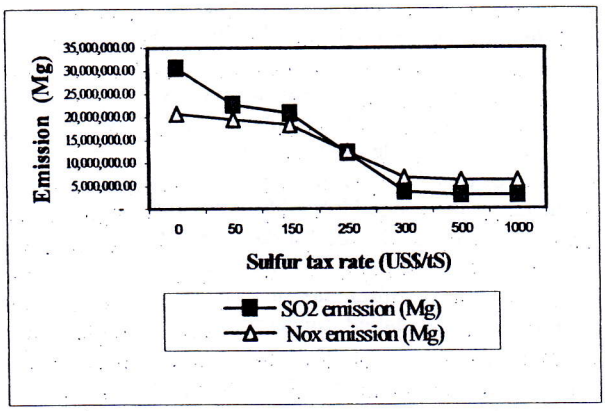

Fig.3. SO_2 and NOX Emission and its mitigation due to Sulfur tax Year 2006-2025

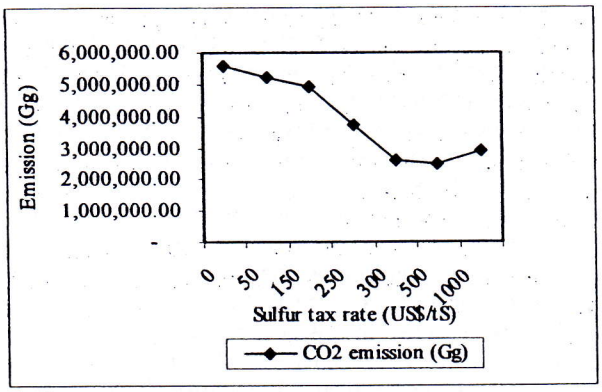

Fig.4. CO_2 emission and its mitigation due to sulfur tax, Year 2006-20025

3.2. Utility Planning Implication

The capacity mix based on plant types at generation planning horizon year 2006-2025 as the implication of introducing sulfur tax at different rate shows that in the absence of sulfur tax there would be additional around 46% new coal power plant based on supercritical

technology to mix with existing capacity. Oil power plant has retired during the planning horizon. At sulfur tax rate US$150/tS, the coal plant based PFBC technology would be selected 53%. However, at sulfur tax rate US$250/tS the selection of plants would shift from PFBC to Natural Gas Combine Cycle. The selection of NGCC would drastically increase at sulfur tax rate US$300/tS or higher and no more selection of coal power plants. At sulfur tax rate US$300/ts or higher the share of NGCC would dominate more than 65% of total install capacity.

Further, implication of sulfur tax in the generation system would be directed to utilize more candidates DPG, which consist of renewable energy resources. At sulfur tax rate US$50/tS there would be 180MW of biomass selected and increase to 750MW at sulfur tax rate US$1000/tS. While solar power plant would be selected 10 MW. The shifting of candidate selection and capacity mix from coal based to gas based plant is because there is no other plant type of less sulfur intensive candidate than NGCC. This reflect that the sulfur tax is an appropriate instrument to promote clean technology and able to push the utilization of renewable energy.

It is interesting to analyze the implication of sulfur tax to the total installed capacity at the end of planning horizon. Total installed capacity would be 46209 MW at the absence of sulfur tax, but it will decrease if introduced sulfur tax at the range US$50/tS to US$300/tS. At sulfur tax rate US$300/tS the total install capacity would be the lowest, which is 1000 MW lower than at without sulfur tax. However if sulfur tax introduced is higher than US$300/tS the installed capacity would increase again. This reflects that the implication of sulfur tax rate to total install capacity is the lowest at range of US$250 to US$300/tS.

What would be the implication of sulfur tax to electricity generation? Electricity produced by hydro plant would be only 57,5 GWh at the absence of sulfur tax and increase to 311,3991 GWh at sulfur tax rate US$300/tS and the same at sulfur tax rate US$500 and US$1000/tS. Electricity produced by Oil plant decline from 50363 GWh at the absence sulfur tax to 21981 GWh at sulfur tax rate US$300/tS, and the same amount at sulfur tax rate US$500 and US$1000/tS.

Total electricity generation by existing steam coal plant would decrease if the sulfur tax rate were increased. That means the utilization factor of conventional coal plants will decrease. However, it is contra with the total electricity generated by gas power plant (gas turbine, and NGCC). Electricity produced by Natural gas Combine Cycle (NGCC) power plant will increase if selected sulfur tax rate is increased. Further, solar plant selected, which is free from fuel, would operate at full capacity to produce electricity. In other word, introducing sulfur tax to power sector will reduce consumption of fuel that high sulfur content and increase the consumption of fuel that low sulfur content. This reflects also that sulfur tax is a good instrument to promote clean technology.

Since Indonesia country has affluent of coal and natural gas resource, it is important to know at what sulfur tax rate the amount of electricity generation by coal-based power plant will same with the amount of electricity generation by gas based power plant is. Figure 5.4 shows that at sulfur tax rate US$250/tS electricity generation by coal based power plant would be 1,476,440 GWh, while the electricity generation by gas based power plant would be 1,913,620 GWh. At this sulfur tax rate SO_2 emission would mitigate 40%.

IV. Conclusion

In this study has been assessed the environmental, generation system, and economic implications of sulfur tax as instrument for reduction of SO_2 emission from Indonesia power sector i.e. Jawa Madura Bali system. The assessment based on the framework of Traditional Expansion Plan (TEP) year 2006-2025. Seven scenarios have been introduced that reflect without sulfur tax, and with sulfur tax US$50, US$150, US$250, US$300, US$500, US$1000 per ton sulfur. Integrated Resource Planning Model and CPLEX software have been used in this study.

Introducing Sulfur tax to power sector would not only decrease SO_2 emission significantly but CO_2 and NO_x emissions as well. It is found that SO_2 emission would decrease 40% at sulfur tax rate US$250/tS and 84% at sulfur tax rate US$300/tS or higher. Therefore sulfur taxes at high rates are environmental friendly instrument.

From utility planning aspect, sulfur tax will promote clean technology of power plants. It is found that capacity mix and fuel mix will change from coal-based plants, which has high sulfur content to gas based plant, which has low sulfur content. It is also found that sulfur tax is able to push utilization of renewable resources like solar power plant and biomass as distributed power generation (DPG) plants, which are low sulfur content.

Acknowledgment

The authors wish to express gratitude and appreciation to Prof. Ram M. Shrestha and Swdish International Development Coordiantion Agency (SIDA) for awarding the authors fund to carry out the study.

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