Future emissions of air pollutants in Indonesia: SO_2 and NO_x

Armi Susandi

Max Planck Institute for Meteorology
Bundesstrasse 53, D-20146 Hamburg, Germany
Phone: +49-40-82243-111 Fax.:+49-40-41173-298
email: susandi@dkrz.de

Abstract

This paper examines global and regional energy use which focusing in Indonesia and indication to emission in energy sector. Population and economy drivers as well as trends in energy and emission are evaluated. The trend of population and economic growth applied as driving force in energy use as suggested in IPCC scenarios. This paper presents estimates of emissions of two of the major pollutants in Indonesia: sulfur dioxide (SO_2), and nitrogen oxide (NO_x). Emissions are estimated for Indonesian region, based on energy consumption which covered by the MERGE (a **M**odel for **E**valuating the **R**egional and **G**lobal **E**ffects of greenhouse gas reduction policies) simulation model. Emissions project to 2100 under IPCC scenarios and one mitigation scenario.

Keywords: Indonesia; Air pollutant; Emission; MERGE model

Presented on the International Conference on Policy Modeling, June 30 – July 2, 2004, Paris - France

1. Introduction

Indonesia is the world's fourth most populated country with a population of 215 millions in 2003. More than 60% of the population lives on Java, covering only 7% of land area of Indonesia. Gross Domestic Product (GDP) has grown around 5-6% per year during the last decades, driven by government deregulation and market oriented policies. Manufacturing and modern service sectors are making up an ever-greater proportion of GDP. The share of oil in GDP fell from 11.6% in 1990 to 9.6% in 1995 (MOEROI, 1999). At the same time, Indonesia is also one of countries with high potential air pollution as consequences of continuing growth of Indonesia. Because of its huge potential impact, the study of Indonesia's energy development and related health effects and economic valuation on it is important not only for Indonesia itself but also for other developing countries. Furthermore, this problem is expected to grow in the near future as rapid growth outpaces efforts to reduce emissions.

In this study, a Model for Evaluating the Regional and Global Effects of greenhouse gas reduction policies (MERGE) was used for energy consumption projection. We applied the base scenarios as wrote in Intergovernmental Panel on Climate Change (IPCC) in the Special Report on Emissions (SRES) scenarios (IPCC, 2000) with assumes that no new measures are undertaken to control emissions, later can also investigate one mitigation scenario on energy demand. In its version 4.3 (Manne and Richels, 2001), we added some equation due to calculated emissions of air pollutants from energy consumption projection, directly from the MERGE model. The new MERGE model designed to analyze emission of sulfur dioxide (SO_2) and nitrogen oxide (NO_x) which are gases released when fossil fuels are burned.

2. Emission scenarios in MERGE

In 1996, the Intergovernmental Panel on Climate Change (IPCC) developed a new set of emissions scenarios as substitutes of IS92 scenarios. Special Report on Emission Scenarios (SRES) described the new scenarios and how they were used (IPCC, 2000). The scenarios cover different future developments that might influence energy sources. The set of scenarios includes anthropogenic emissions of all greenhouse gas (GHG) term, sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOCs). In this study, we focus of analyze only for SO_2 and NO_x emissions.

The major driving forces of future emissions are demographic patterns, economic development and environmental conditions. The next level of GHG emissions are driven by forces of population growth, socio-economic development, and technological progress among others. We investigate the population and GDP growth as driving force of emissions as wrote on SRES scenarios. There are four family (A1B, A2, B1 and B2) scenarios applied on MERGE, based on assumption about future socioeconomic conditions, have already been generated using the MERGE model. Please see Table 1.

Table 1. IPCC scenarios (resume for Indonesia)

Set	*A1B*	*A2*	*B1*	*B2*
Population growth	low	high	low	medium
GDP growth	very high	medium	high	medium

3. Economic and energy development of Indonesia

Indonesia's population grew from 175 million in 1988 to 207.4 million in 1998. Growth rate of population is 2.34% per year during 1970-1980, growth declined to 2% per year for 1985-1988, further declining to 1.5% per year during the last decade (The World Bank, 1997). In MERGE model, Indonesian population increased from 212 million in 2000 to 250 million by 2100 in the A1B and B1 scenarios (Figure 1), with annual growth rates dropping from 0.8% in 2000 to 0.2% in the end of century. These scenarios are based on a variant of the low population projection. The highest population trajectory in Indonesia reached 443 million by 2100 in the A2 scenario; the average Indonesian population growth rate over 100 years is 0.7% per year. Furthermore, Indonesian population with median population projections, in the B2 scenario, increased to 389 million in 2100, the average Indonesian population growth rate over 100 years is 0.6% per year, is lower than A2 scenario but upper than both A1B and B1 scenarios. See Figure 1.

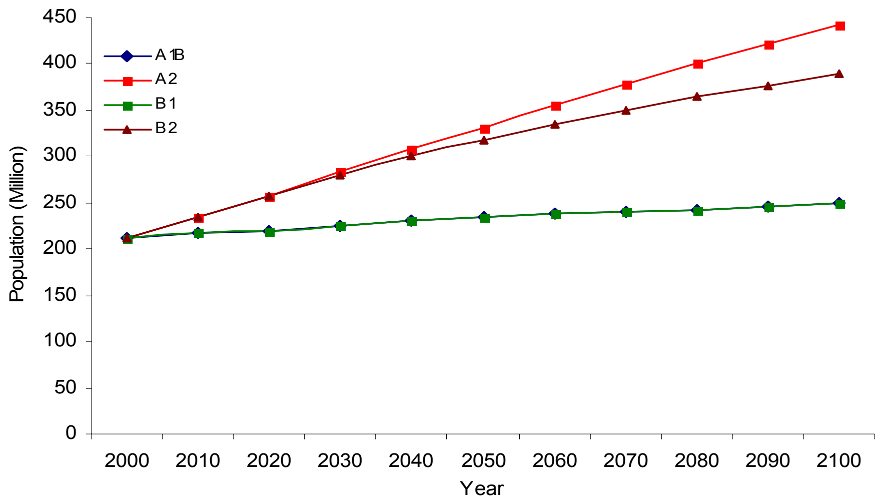

Figure 1. Population of Indonesia

In 1999, Indonesian economy began moving up reaching a positive GDP growth, after monetary crisis in 1997, although only 0.9% per year. Then, in 2000, the economy grew by a better than expected rate of 4.8% per year supported by a significant growth of domestic consumption (Datacon, 2003). In our model, the 2000 gross domestic product (GDP) of Indonesia was about US$ 153 billion increase exponentially to US$ 9,193 billion by 2100 in the A1B scenario, the Indonesian economy is projected to expand at annual rate of 3.4%

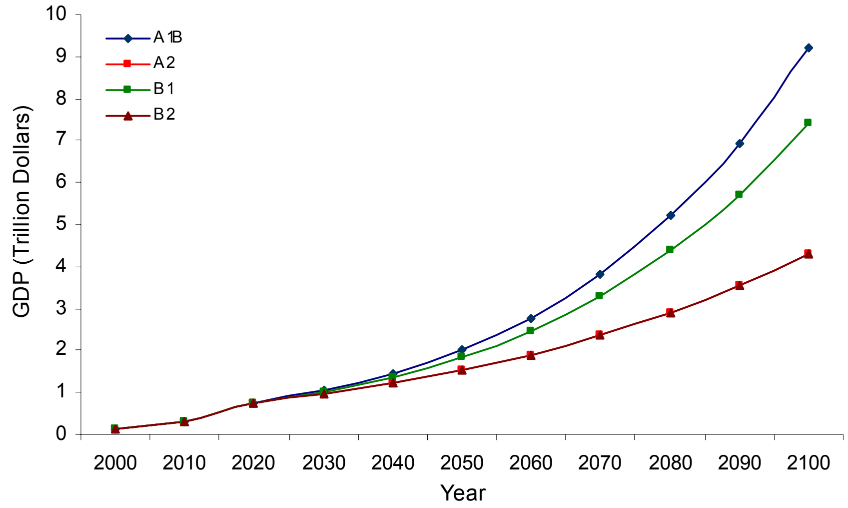

Figure 2. Growth domestic product (GDP) of Indonesia

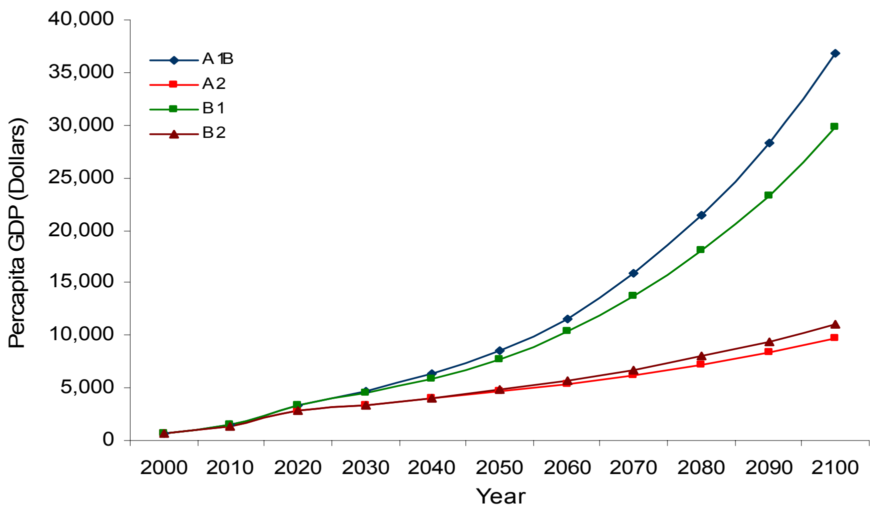

Figure 3. Percapita GDP of Indonesia

to 2100. See Figure 2. In A1B, per capita income of Indonesia increases from US$ 720 by 2000 to US$ 37,000 by 21000 (see Figure 3). The high growth scenario designed in family A1 search the highest future economic development. Free trade, continued innovation, and a stable political as expected on IPCC (2000), enable developing region such as Indonesia to access knowledge, technology and capital. This is assumed to lead to acceleration of economic growth to developing countries. The A2 scenario is distinguish by relatively slower productivity growth rates. The GDP average (2000-2100) growth rate is 1.9% per year reflect to the slow face of the demographic transition that underlines A2's high population growth trajectory. Per capita income in the A2 scenario is the slowest in the IPCC scenarios, achieve only to US$ 9700 (Figure 3). The B1 scenario assumes grand of social awareness, GDP reaches US$ 7,431 billion in 2100, which correlates to an average growth rate of 2.8% per year. Per capita GDP in B1 scenario is lower than A1B scenario, reaches US$ 30,000. Indonesian GDP in B2 is assumed to increasing at an average annual

Table 2. The International emissions reduction scenarios

Scenario	*Emission reduction*	*Start date*	*Emissions trade*
Reference (REF)	No		No
Kyoto all countries	Annex B countries	2010	All participating
with trade	China, India and Mexico+OPEC	2030	countries
(KAT)	Indonesia	2050	
	Rest of the World	2070	

Table 3. Emission coefficient of Indonesian pollutants

Emission type	*Oil*	*Gas*	*Coal*
SO_2 (kg/GJ)	0.6820	0.0002	1.3022
NO_x (kg/GJ)	1.2670	0.4433	1.2527

Source: Sasmojo *et al.*, 1997

growth rate of 2.4% and is similar to the median GDP growth in both the A2 and B1 scenarios. See Figure 2. Average per capita income reaches about US$ 11,000 by 2100. Nonetheless, per capita income in B2 scenario is lower than those in the A1B and B1 scenarios, but much greater than those in A2 scenario (Figure 3).

To analyze the impact of the international climate policy on air pollution in Indonesia with those IPCC base scenarios, we developed two scenarios, specified in Table 2. In the first scenario (baseline scenario), there is no GHG emission reduction policy on four IPCC scenarios. In the second scenario, we assume all countries, including Indonesia, accept some target to reduce their emissions by five percent per decade in the future.

4. Emission in Indonesia

To predict pollutant emission in Indonesia, these studies collected the emission coefficients of pollutants by different type of fuels. See Table 3. The simple method and popularly to calculate of pollutant emission is the emission coefficients of pollutants multiply by energy consumption (Changhong *et al.*, 2001). The emission coefficients of pollutants are used on this study based on different type of fuels in Indonesia, as reported by Sasmojo *et al.* (1997) on ALGAS Report. We assumed that emission coefficients fall gradually over time by 1 percent per decade in the years after 2000. This section provides emission prediction of sulfur dioxide (SO_2) and nitrogen oxide (NO_x) from fossil fuel energy consumption with one mitigation emissions scenario in MERGE. We simulated those scenarios on the IPCC base scenarios (A1B, A1, B1, and B2 scenarios).

a. Sulfur dioxide

In the energy sector, emissions of sulfur dioxide (SO_2) are mainly produced from burning of coal, oil, and a little emission of gas in power stations. In MERGE model, sulfur dioxide emissions calculating results of each fossil fuel energy-consuming sector indicated that SO_2 emissions of whole country in 2000 are 1.4 million tons, as shown in Figure 4, upper than Downing, Ramankutty, and Shah (1997) report, as 1.1 million tons in 2000.

In baseline scenario of the A1B scenario, sulfur dioxide emissions increase gradually, are the lowest in the IPCC scenarios, reached peak 4.5 million tons in the near term around 2080, thereafter, almost steadily to the end of century. In this scenario, coal consumption increases gradually while carbon-free technology more and more produce to meet domestic demand as substitute fossil fuel production; while per capita GDP increase is the highest to 2100.

The other IPCC scenario, A2 scenario, SO_2 emissions increase rapidly to the middle of century, are the highest emission in the IPCC scenario, reached at 5.4 million tons by 2050, then decrease slowly to 2100 while carbon-free technology will dominated in Indonesian energy sector within high growth of population. Sulfur dioxide emissions in B1 scenario, after 2040, produce closely during the middle of century, and then fall gradually to 4.3 million tons to the end of century (see Figure 4).

In B1 scenario, a decline in emissions are associated with increases of per capita incomes. As developing countries reach levels of US$ 3,500 per capita (IPCC, 2000), as Indonesia also, they start to apply tighter SO_2 controls that lead to reached the lower of emission levels.

In B2 scenario, emissions of SO_2 are still increase rapidly, in the beginning of century, even lower than A1 and B1 scenarios. Emissions reached pick before the middle of century then decrease gradually to 2100. In this scenario, Indonesian energy switched gradually from coal and oil to cleaner fuels, such as carbon-free technologies. Sulfur dioxide emissions in 2100 would be 4.1 million tons; these emission levels are higher than A1B scenario but lower than A2 and B1 scenarios.

Were all countries to accept emission reduction targets in the future, sulfur dioxide emissions increase gradually for all IPCC scenarios to the second half of century, and then falls substantially to the end of century. Emissions of SO_2 in B2 scenario are relative higher than other IPCC scenario (Figure 4) with growth of GDP and population is medium rate (Table 1). The highest emissions of SO_2 reached at 5.2 million tons in 2070.

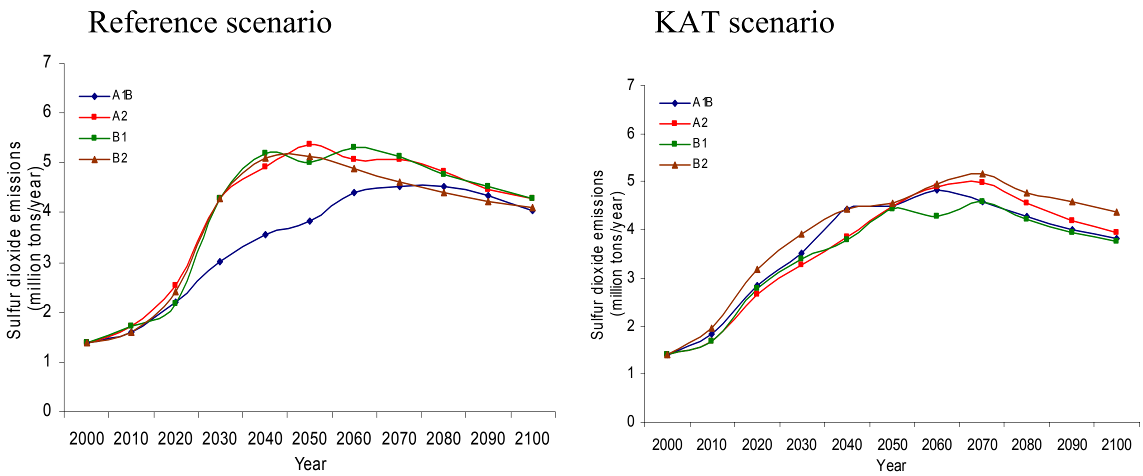

Figure 4. Sulfur dioxide emissions of Indonesia

b. Nitrogen oxide

Most of nitrogen oxide (NO_x) emissions trend unstable or increase thereafter as reflection of Indonesian energy use which dominated by coal. In baseline scenario, the trends of NO_x emissions are essentially the same as in the sulfur dioxide emissions. See Figure 5. Except that, nitrogen oxide emissions increase more rapidly to the middle of century in A2, B1, and B2 scenarios whereas A1B scenario increases substantially, and then all fall to 2100. All IPCC scenarios in the model show that NO_x rise from 2.4 million tons by 2000 to 7 million tons by 2050 in the A2 scenario while the others are lower, thereafter, fall to around 4.2 – 5.1 million tons in 2100.

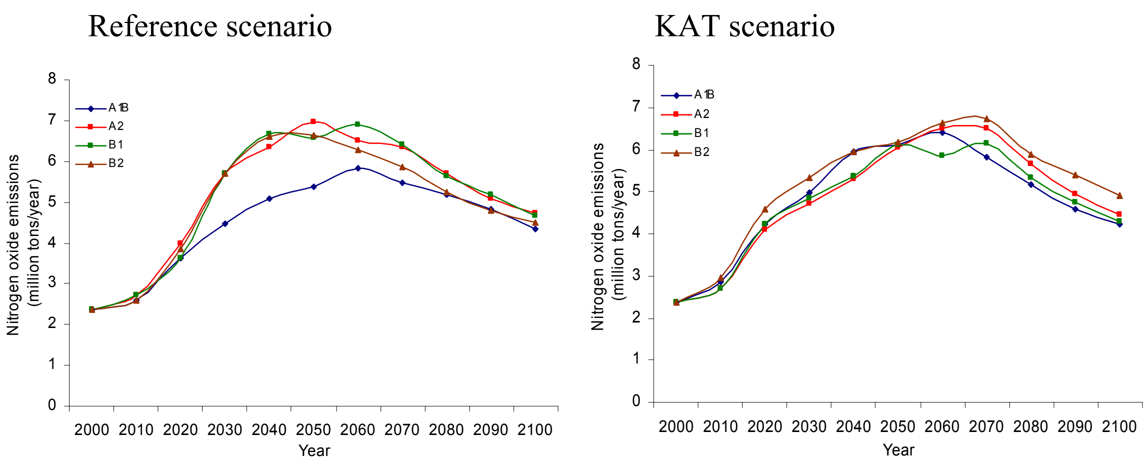

Figure 5. Nitrogen oxide emissions of Indonesia

In the second scenario, if all countries reduce their emissions, emissions of NO_x increase substantially to the second of century then falls thereafter. Decreasing of energy from coal consumption and limitation gradually of oil are indicated in this scenario. Start in 2060 fossil fuel energy gradual shift by alternative energy with low emission such as carbon-free technologies.

6. Conclusions

This paper has presented the results of Indonesia's air emissions prediction. We look at how policies intended to reduce emissions of greenhouse gas might simultaneously affect emissions of air pollutants. In this paper we concentrate on two air pollutants, sulfur dioxide (SO_2) and nitrogen oxide (NO_x). The analysis of the health effects of pollutants, are left for future work.

Current trends in energy production and consumption in Indonesia indicate that air pollutants emissions increase rapidly to the next fifty years. If 2000 trends continue, emissions of sulfur dioxide will more than triple throughout the region, and if all countries reduce their emission sulfur dioxide will increase slightly lower than baseline scenario. The trends of nitrogen oxide emissions are essentially the same as sulfur dioxide emissions.

References

Changhong, C., Bingheng, C., Qingyan, F., Chuanjie, H., Minghua, C., Haidong, K. 2001. The Integrated Assessment of Energy Options and Health Benefit, Shanghai Academy of Environmental Sciences, School of Public Health, Fudan University.

Datacon (PT. Data Consult). 2003. Indonesian Economic 2003: Trend and Prospect. Working Paper, Jakarta, Indonesia.

Downing, R. J., Ramankutty, R., Shah, J. J. 1997. RAINS-ASIA: An Assessment Model for Acid Deposition in Asia. The World Bank, Washington, D.C.

IPCC (Intergovernmental Panel on Climate Change). 2000. *Emission Scenarios: Special Report on Emissions Scenarios*, Cambridge, Cambridge University Press.

MOEROI. 1999. Economics of Greenhouse Gas Limitations: Indonesia Country Study. Ministry of Environment Republic of Indonesia.

Sasmojo, S., Winarno, O. T., Trianto, A., Wachjoe, C. K., Tasrif, M., Nasrullah, Soerawidjaja, T. H. 1997. Indonesian National Greenhouse Gas Emissions Inventory Status and Needs, Technical Report of ALGAS Project:

The World Bank. 1997. Indonesia Country Profile. World Bank, Washington, D. C.