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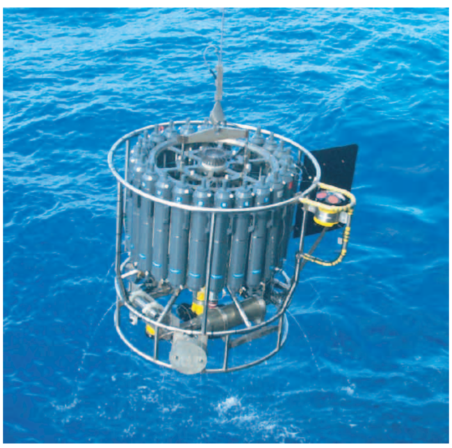
The Impact of International Greenhouse Gas Emissions Reduction on Indonesia

Armi Susandi


Berichte zur Erdsystemforschung 4/2004

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The Impact of International Greenhouse Gas Emissions Reduction on Indonesia

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im Fachbereich Geowissenschaften der Universität Hamburg
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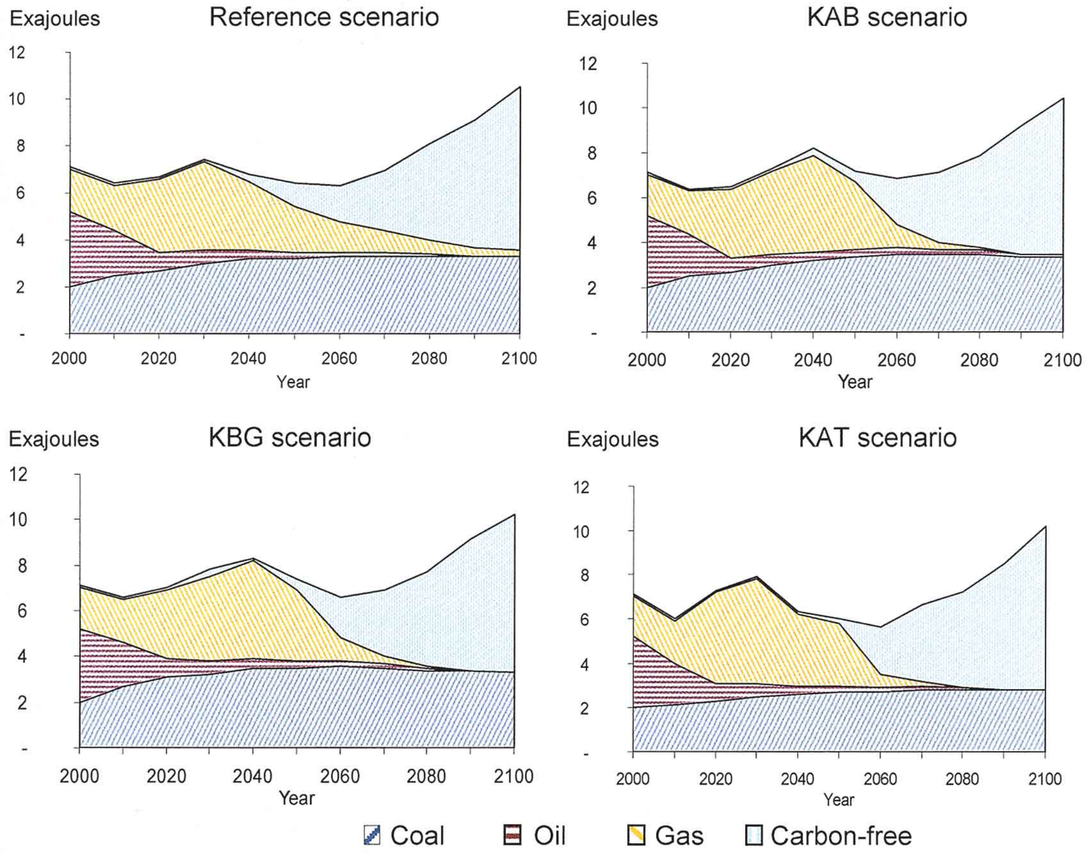

Primary energy production of Indonesia

Armi Susandi

Hamburg 2004

Contents

Zusammenfassung

Diese Dissertation präsentiert die Ergebnisse dreier Veröffentlichungen zu den Auswirkungen von Klimapolitik auf Indonesien. Eine erweiterte Version von MERGE (Model for Evaluating the Regional and Global Effects of Greenhouse Gas Reduction Policies) wurde benutzt, um Erzeugung, Verbrauch und Export von Energie in bzw. aus Indonesien jeweils für ein Referenz- und verschiedene Reduktionsszenarien bis zum Jahr 2100 zu projizieren. Zusätzlich zum internationalen Energiehandel wurde in dieser Modellversion Kohle berücksichtigt. Im zweiten Teil der Arbeit werden die gegenseitige Beeinflussung von Forstwirtschaft und internationalem Handel sowie die direkten Auswirkungen der internationalen Klimapolitik auf die Entwaldung in Indonesien untersucht. Schliesslich wurde MERGE erweitert, um Luftschadstoffe analysieren zu können. Das Modell benutzt die Basisszenarien des IPCC (2000) und erweitert diese um Reduktionsszenarien, in denen die Konzentration von Luftschadstoffen und deren Einfluss auf die Gesundheit der Bevölkerung und die Wirtschaft projiziert wird.

Im Referenzszenario wächst die Kohleproduktion im indonesischen Energiesektor allmählich und die Gasproduktion schnell, während die Ölproduktion sehr rasch abnimmt. Ölimporte steigen, während Kohleexporte abnehmen; später wird auch Gas importiert. Wenn alle Länder inklusive Indonesien ihre Emissionen verringern steigt die Kohleproduktion gegen Ende des Jahrhunderts etwas langsamer an als im Referenzszenario. Ölimporte sind größer und Gasimporte etwas geringer als im Referenzszenario.

Wenn Emissionen aus fossilen Brennstoffen reduziert werden sind die Auswirkungen auf die Entwaldung etwas geringer als im Referenzfall. Eine

Verlangsamung der Entwaldung verursacht exponentiell wachsende Kosten, die bis 2100 auf etwa das zwanzigfache wachsen. Dennoch würde Indonesien davon profitieren, denn diese Kosten sind geringer als der Ertrag der langsameren Entwaldung.

Die Gesundheitsprobleme, die von den Konzentrationen von Schwefeldioxid (SO_2) und Stickstoffdioxid (NO_2) bei der Verbrennung fossiler Brennstoffe herrühren, sind höher wenn die OECD-Länder ihre Emissionen reduzieren, weil dann die indonesischen Ölimporte steigen. Wenn jedoch alle Länder einschließlich Indonesiens das Kyoto-Protokoll übernehmen, sind die Gesundheitsprobleme geringer als im Referenzfall.

Abstract

This dissertation represents a summary of three papers addressing impacts of climate policy on Indonesia. The extended version of MERGE (Model for Evaluating the Regional and Global Effects of Greenhouse Gas Reduction Policies) has been used to project Indonesian's energy production, consumption and export to the year 2100, for a reference scenario and mitigation scenarios. In addition to the international trade of energy, coal has been included in this version. The study also analyzes the interaction between the forest sector and energy policy and finally analyzes the direct effect of international climate policy on deforestation in Indonesia. Then, MERGE has been extended to analyze emissions of air pollutants. The model uses the base scenarios from IPCC (2000), with extensions to include mitigation scenarios, to project concentrations of air pollutants and their impacts on human health and the economy.

In the Indonesian energy sector, coal production grows gradually and gas production more strongly in the reference scenario, whereas oil production falls rapidly. Oil imports increase, while coal exports decrease; gas is imported later. If all countries reduce their emissions, including Indonesia, coal production increases slightly less than in the reference scenario towards the end of century. Oil imports are higher and gas imports slightly lower than in the reference scenario.

The effects of fossil fuel emission reduction on deforestation are slightly less than in the reference case. The cost of slowing deforestation in Indonesia increases exponentially by a factor of approximately 20 by the year 2100.

Indonesia would gain the profits from slowing deforestation since the revenue from slowing deforestation is higher than the costs.

The health problems associated with sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) concentrations resulting from fossil fuel use reach higher levels if OECD countries reduce their emission, since Indonesian oil imports increase. However, if all countries, including Indonesia, adopt the Kyoto Protocol, the health problems are lower than in the reference case.

Chapter 1

Introduction

Human activities are increasingly modifying the Earth's climate. These effects add to natural influences that have been present over Earth's history. Human impacts on the climate system include increasing concentrations of atmospheric greenhouse gases (e.g., carbon dioxide, chlorofluorocarbons and their substitutes, methane, nitrous oxide, etc), air pollution, and land alteration.

Atmospheric carbon dioxide concentrations have increased since the mid-1700s through fossil fuel burning and changes in land use, with more than 80% of this increase occurring since 1900. Moreover, research indicates that increased levels of carbon dioxide will remain in the atmosphere for hundreds of years. It is virtually certain that increasing atmospheric concentrations of carbon dioxide and other greenhouse gases will cause global surface climate to be warmer.

The 1992 United Nations Framework Convention on Climate Change states as an objective the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". Annex I countries (that is, developed countries and countries with economies in transition) are required to reduce their aggregate net emissions. Indonesia has the fourth biggest population in the world, and is one of the countries prepared to meet its commitment as a Party to the Convention.
Furthermore, Indonesia has significant reserves of coal, natural gas, and oil as sources of energy and also as emissions. The emissions from forestry and land use change can also affect climate change be significantly.

Scientists' understanding of the fundamental processes responsible for global climate change has greatly improved during the last decade, including better representation of carbon, water, and other biogeochemical cycles in climate models. Yet, model projections of future global warming vary, because of differing estimates of population growth, economic activity, greenhouse gas emission rates, changes in atmospheric particulate concentrations and their effects, and also because of uncertainties in climate models.

The MERGE (Model for Evaluating the Regional and Global Effects of Greenhouse Gas Reduction Policies) model of Manne *et al.* (1992, 1995, 1996, 1998, 1999, 2001) is a powerful tool for analyzing mitigation policies to deal with the global climate change issues. For more on the model code, see web site: http://www.stanford.edu/group/MERGE. MERGE consists of four major parts: (1) economic model, (2) energy model, (3) climate model, and (4) climate change impact (damage) model. In the MERGE model, Indonesia is included only in the Rest of the World (ROW) region. However, an analysis of the individual role of Indonesia in relation to international climate policies is important for the country to develop a meaningful national climate policy. The main question is whether Indonesian national policy has a significant impact on international climate policies and global climate change.

To study this question, we add a separate region for Indonesia in MERGE as a tenth region (the originally MERGE model has nine regions). We also extended the MERGE model to include coal as a tradable good and added a new forest model to analyse forest change, especially for Indonesia. Finally, we applied the reference scenarios from the Intergovernmental Panel on Climate Change (IPCC, 2000) and we extended the IPCC scenario with various mitigation scenarios, in order to estimate air pollution. Figure 1.1 illustrates the framework of models and linkages.

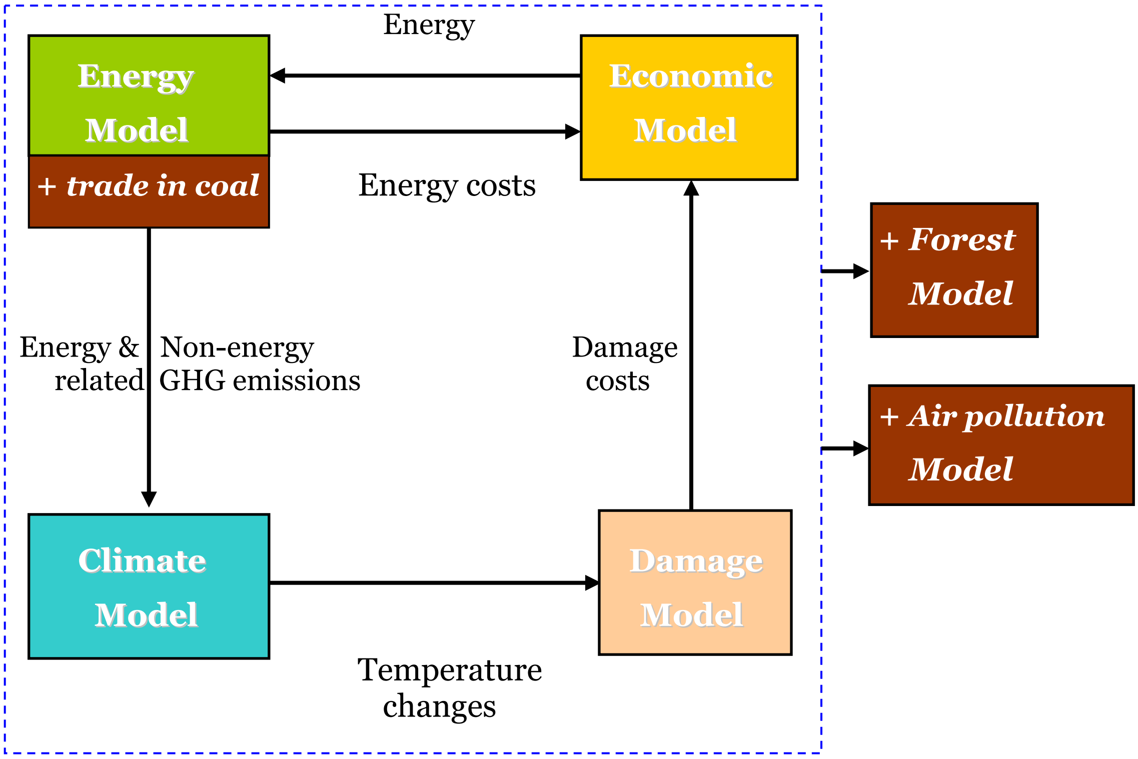

Figure 1.1 The framework of models and linkages

In the following we summarize the chapters of this thesis. Chapters 2 to 4 represent independent papers that have been submitted or accepted for publication in international reviewed journals. Hence some repetitions with regard to the introduction to the MERGE model are unavoidable.

1.1 Contents of the Ph.D. Thesis

Chapter 2 presents an analysis of international climate policy and its impact on the economy and the energy sector of Indonesia. The chapter describes first the extension of MERGE to include Indonesia as an additional region separated from the ROW region. To project Indonesia's energy development until the year 2100, a reference and various mitigation scenarios are applied.

In the chapter 3, coal trade is added to the international trade of energy (the original MERGE model has no trade of coal), including oil, gas, and some others sources of energy. As a further application, we study the implication of emission reduction policies on the deforestation rate in Indonesia and estimate the cost of slowing deforestation in Indonesia.

Following an analysis of the emissions from fossil fuel consumption, the chapter 4 presents an investigation of the impacts of greenhouse gas emission reduction on air pollution. The MERGE model is applied to estimate the emissions of air pollutants, the impacts on human health, and the economic costs.

Chapter 5, finally, summarizes the conclusions of the study, discusses some implications and presents an outlook.

1.2 Publications

Chapter 2 to chapter 4 are based on manuscripts which are either published or submitted for publication.

Chapter 2: Susandi, A. and R. S. J. Tol, 2002. Impact of International Climate Policy on Indonesia. *Pacific and Asian Journal of Energy* **12** (2): 111 – 121.

Chapter 3: Susandi, A. and R. S. J. Tol, 2004. Impact of international emission reduction on energy and forestry sector of Indonesia, submitted to *Energy Policy*.

Chapter 4: Susandi, A. and R. S. J. Tol, 2004. Air Pollution, Health, and Greenhouse Gas Emissions Reduction in Indonesia, will be submitted to *Ecological Economics*.

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Manne, A. S. and R. G. Richels, 1992: Buying Greenhouse Insurance - The Economic Costs of CO2 Emission Limits, Cambridge: The MIT Press.

Manne, A. S., R. O. Mendelsohn, and R. G. Richels, 1995: MERGE - A Model for Evaluating Regional and Global Effects of GHG Reduction Policies, *Energy Policy* **23**(1):17-34.

Manne, A. S. and R. G. Richels, 1995: The greenhouse debate: economic efficiency, burden sharing and hedging strategies, *Energy Journal* **16**(4): 1–37.

Manne, A. S. and R. G. Richels, 1996: The Berlin mandate: the costs of meeting post-2000 targets and timetables, *Energy Policy* **24**(3): 205–10.

Manne, A. S. and R. G. Richels, 1998: On stabilizing CO_2 concentrations: cost-effective emission reduction strategies, *Environmental Modelling and Assessment* **2**: 251–65.

Manne, A. S. and R. G. Richels, 1999: The Kyoto Protocol: a cost-effective strategy for meeting environmental objectives? *Energy Journal* [Special Issue on the Costs of the Kyoto Protocol: A Multi-Model Evaluation]: 1–24.

Manne, A. S. and R. G. Richels, 2001: An alternative approach to establishing trade-offs among greenhouse gases, *Nature* **410**: 675–77.

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

Chapter 2

Impact of international climate policy on Indonesia

Abstract

This paper studies the impact of international climate policy on the economy and structure of the energy sector in Indonesia. We use an extended version of MERGE – Model for Evaluating the Regional and Global Effects of Greenhouse Gas Reduction Policies – to project Indonesia's energy development till the year 2100, for a reference and various mitigation scenarios.

If the Organisation for Economic Co-operation and Development countries were to reduce emissions, Indonesia would export more gas but less oil and its per capita income would fall slightly. With international trade in emission permits, Indonesia would be an exporter of carbon permits as energy export sectors are almost the same as without emission abatement, but Indonesia would suffer a minor loss of income. If the country anticipates emission reduction targets relative to some future emissions, then it should increase its emissions in the short run. It should postpone exploiting its gas reserves and initially rely more on coal and imported oil. It could then become a substantial exporter of internationally tradable emission permits. If it anticipates emission reduction targets relative to currently projected emissions, then the optimal exploitation of coal gets shifted forward in time while gas exploitation moves backward, but to a lesser extent. Economic losses will be greater, but still not very large. International trade in emission permits would make the exploitation of Indonesia's coal reserves economically unattractive.

2.1 Introduction

Indonesia holds a special position in international climate policy. Being tropical, poor, crowded, and an archipelago, it is extremely vulnerable to climate change (Smith, Schellnhuber, Mirza *et al.,* 2001). However, Indonesia is also a member of OPEC (Organization of Petroleum Exporting Countries) and holds large coal reserves (some 39 billion tonnes according to DGEED 1998). As an energy exporter, Indonesia is also vulnerable to international climate policy. Its industry is inefficient and deforestation continues unabated, making the country a potentially big supplier of projects under the CDM (clean development mechanism)—a prospect Indonesians may welcome if urban air quality were to improve as a by-product.

Despite all this, Indonesia and its role in international climate policy is not well studied, perhaps because the country has had various other problems on its mind. This paper studies part of the complexity sketched above. We analyse the implications of emission reduction in the OECD (Organisation for Economic Co-operation and Development) on the economy and energy sector of Indonesia, the implications of international trade in emission permits, and the effects of Indonesia adopting an emission reduction target in the future.

Emission reduction in the OECD would lower their demand for oil and coal, but increase the demand for gas (Babiker, Reilly, and Jacoby 2000; Bernstein, Montgomery, and Rutherford 1999; Tulpule, Brown, Lim, *et al.*, 1999). Having reserves of all three, can Indonesia reduce its coal exports, increase its gas exports, and use coal to satisfy its domestic needs? (Other OPEC members do not enjoy this luxury.) This would mitigate the pain of the export losses, but increase emissions of carbon dioxide, making it an even more attractive target for CDM projects (note the moral hazard). Would the CDM substantially affect Indonesia's energy production and consumption, or even development, as suggested by Rose, Bulte, and Folmer (1999)? And how would all this change, were Indonesia to commit itself to emission reduction? Analyses of questions like this would help Indonesia position itself better in international climate negotiations.

As such, Indonesia requires a model with three properties. First, the model has to have a reasonably detailed energy sector. Second, the model has to cover the entire world, with Indonesia treated as a separate region. Third, the model must be calibrated to real data. There is one model that almost satisfies these criteria: MERGE (Model for Evaluating the Regional and Global Effects of Greenhouse Gas Reduction Policies) developed by Manne and Richels (1992; 1995; 1996; 1998; 1999; 2001) and Manne, Mendelsohn, and Richels (1995). The only problem is that MERGE includes Indonesia in its Rest of the World region. We, therefore, developed a new version of MERGE that singles out Indonesia.

The following section gives an overview of the MERGE model and specifies the changes we made in it. Later, the reference scenario is presented, followed by cases in which only the OECD has emission reduction targets. We also cover cases with emission reduction targets for non-Annex B countries, including Indonesia.

2.2 MERGE 4.3 model

MERGE is an inter-temporal general equilibrium model, which combines a bottom-up representation of the energy supply sector with a top-down perspective on the remainder of the economy (see Manne and Richels 1992; Manne, Mendelsohn, and Richels 1995 for a description). Our starting point is MERGE, version 4.3 (Manne and Richels 2001).

MERGE consists of four major parts: (1) economic model, (2) energy model, (3) climate model, and (4) climatic change impact model. The model is benchmarked with energy and economic statistics for the year 2000. It runs in

10-year intervals up to 2050 and, subsequently, in 25-year steps for the following century-and-a-half. The first commitment period of the Kyoto Protocol is represented as 2010 in the model.

The economic model is used to assess the economy-wide cost of alternative emission constraints at the regional and global level (Hourcade, Halsneas, Jaccard, *et al.*, 1996). The economy is modelled through nested constant elasticity production functions, which determine how aggregate economic output depends upon the inputs of capital, labour, and electric and non-electric energy. A social planner governs each region; alternatively, the economy is represented as a perfect market with long-lived economic agents. The social planner sets consumption and investment so as to maximize the discounted utility of consumption, subject to an inter-temporal budget constraint. Capital depreciates and expands with investment. A region's wealth not only includes capital, labour, and exhaustible resources but also its negotiated international share in emission rights, thus allowing regions with high marginal abatement cost to purchase emissions rights from regions with low marginal abatement costs. Oil and gas are viewed as exhaustible energy resources; this option can be switched off. The model also provides for international trading of gas and energy-intensive goods. International coal trade will be added in a later version of the model.

The energy model distinguishes between electric and non-electric energy. There are 10 alternative sources of electricity generation, as listed.

1 Hydro
2 Nuclear
3 Oil
4 Gas: current technology
5 Gas: advanced combined cycle
6 Gas: advanced
7 Coal: current technology

8 Coal: pulverized coal without CO_2 recovery
9 Coal: integrated gasification combined cycle with capture and sequestration
10 Coal: advanced.

The advanced gas and coal technologies are not specified in detail but could, for example, include fuel cells (with capture and sequestration of CO_2), plus two 'backstop' technologies: high- and low-cost advanced carbon-free electricity generation.

The model has five alternative sources of non-electric energy (gas, oil, coal [for heating and other purpose], renewables [like commercial biomass], and synthetic fuels [like tar, sand, and oil]), and two carbon-free backstop technologies (one at low cost and supply and the other at high cost and supply). The latter are available in unlimited quantities and do not emit GHGs (greenhouse gases). Technological progress is partly exogenous, with specified rates of improvement by way of labour productivity and energy efficiency; and partly endogenous, as the optimization programme determines the turnover of the capital stock and chooses which energy technologies to apply.

The climate sub-model is limited to the three most important anthropogenic GHGs: CO_2 (carbon dioxide), CH_4 (methane), and N_2O (nitrous oxide). The emissions of each gas are divided into two categories: energy-related and non-energy-related. The model includes not only net emissions from land use and forestry, but also the effect of changes in GHG concentrations on the global mean temperature. However, in this paper, we shall consider only the emission reduction of CO_2.

The 'damage assessment' model is divided into market and non-market damages, which determine the regional and overall welfare development. Market effects reflect categories that are included in conventionally measured national income and can be valued by using prices and observed demand and supply functions. Non-market effects have no observable prices and so can be valued by using alternative revealed preferences or attitudinal methods (Pearce, Cline, Achanta, *et al.*, 1996). Climatic change impacts play no substantial role in the analyses of this paper.

The original MERGE model has 9 regions. We separated out Indonesia to form the tenth. This required changes in databases and various scenarios but no conceptual changes were needed.

To analyse the impact of international climate policy on Indonesia, we analysed eight scenarios, as specified in Table 2.1. In the first scenario (reference) there is no GHG emission reduction policy. In the other seven scenarios, we assume that all Annex B countries will adopt the Kyoto Protocol, and that Kyoto will be succeeded by emission reductions of five per cent per decade in the years after 2010. In three of the seven policy scenarios, there are no emission targets for non-Annex B countries. These three are differentiated by the amount of international trade in emission permits: none, Annex B only, and global.

In four of the seven policy scenarios, we assume that non-Annex B countries adopt binding targets of a similar nature as the Annex B but at a later date. For instance, we assume that Indonesia accepts a target of 2050. After 2050, Indonesia's emissions fall by five per cent per decade. These four scenarios are differentiated by whether or not international trade in emission permits is allowed, and whether emission reduction targets are relative to the policy scenario or to the reference scenario.

Note that these scenarios are neither predictions nor policy advisories. They are simply projections that may or may not occur, but may be more or less desirable. This paper is limited to the implications of certain scenarios for Indonesia.

Table 2.1 Different scenarios of the impact of the international climate policy on Indonesia

Scenario	*Emission reduction*	*Start date*	*Emissions trade*
Reference	No	–	No
Kyoto Annex B	Annex B countries	2010	No
Kyoto Annex B with trade	Annex B countries	2010	All participating countries
Kyoto Annex B with global trade	Annex B countries	2010	All countries
Kyoto all countries	Annex B countries	2010	No
	China, India, Mexico and OPEC (Organization of Petroleum Exporting Countries)	2030	
	Indonesia	2050	
	ROW (Rest of the World)	2070	
Kyoto all countries relative to reference scenarios	Annex B countries, relative to reference scenario	2010	No
	China, India, Mexico, and OPEC, relative to reference scenario	2030	
	Indonesia, relative to reference scenario	2050	
	ROW, relative to reference scenario	2070	
Kyoto all countries with trade	Annex B countries	2010	All participating countries
	China, India, Mexico and OPEC	2030	
	Indonesia	2050	
	ROW	2070	
Kyoto all countries relative to reference scenarios	All Annex B countries, relative to reference scenario	2010	All participating countries
	China, India, Mexico and OPEC, relative to reference scenario	2030	
	Indonesia, relative to reference scenario	2050	
	ROW relative to reference scenario	2070	

2.3 Reference scenario

After China, India, and the US, Indonesia is currently the fourth most populous nation in the world. Its population was about 212 million in 2000. The growth rate of the population was 1.6% over 1990–2000. In 1994, the per capita gross domestic product was about 930 dollars at the market exchange rate. Although growing rapidly at that time (seven per cent or so annually), Indonesia's growth slowed down due to the East Asian crisis, political instability, and global economic recession. In the MERGE model, growth has picked up again in the current decade, and continues strongly throughout the century. By 2100, Indonesia's population is projected to fall to 389 million, a rate of -0.1% per year, and the per capita income is projected to grow to 20,000 dollars, at the rate of three per cent per year.

Households, transport, and industry accounted for approximately 35%–60% of CO_2, CH_4, and N_2O emissions between 1990 and 1994 as reported by SME-ROI (1999b). The uncertainty is due to Indonesia's instability on the one hand, and difficulties measuring CO_2 emissions from land-use change and CH_4 emissions from agriculture on the other. The forestry sector was the second largest contributor, responsible for 20%–50% of the emissions. Agriculture contributed around 15%. In the MERGE model, without emission reduction policies, current CO_2 emissions rise from 64 million tonnes in 2000 to 197 million tonnes in 2100. The energy intensity falls by 74% over the century at 0.3% per year.

In the energy sector, Indonesia currently produces primarily oil and some natural gas. Gas production is to increase substantially by the middle of the century and then begins to fall gradually. After an initial decrease up to 2010 – a continuation of current trends (EUSAI 2001) – oil production stays more or less constant through the first half of the century before beginning to fall gradually. In the second half of the century, coal production increases dramatically to cover domestic energy demand, as more and more oil is exported, and renewables are not yet competitive. As of 2020, carbon-free energy technologies begin to make inroads into the Indonesian market, but as these are still relatively expensive, their role is limited initially. After 2060, carbon-free energy technologies expand rapidly, first to make up for the decline in oil production and later to cover the expansion in energy demand. Carbon-free energy technologies are dominant at the end of the century. Oil exports are negligible for the coming 30 years, but pick up as international oil prices increase due to depleting oil reserves. Gas exports vary little over the century. Although the demand for gas gradually increases, Indonesia's limited reserves restrict expansion.

2.4 Emission reduction in the Organisation for Economic Co-operation and Development

If the OECD countries were to reduce their emissions as specified above, Indonesia can hope to increase the production of gas and, to a lesser extent, that of oil (Figure 2.1). More gas is exported, but oil exports begin to fall sharply; the falling oil price on international markets forces Indonesia to import some oil (Figure 2.2). Our prime welfare measure – the total per capita consumption in Indonesia – falls by a maximum of 0.6%. However, by the end of the century, the gap in the reference scenario becomes smaller (Figure 2.3), as international economy adjusts itself to the emission abatement policies. The net present value which 5% discount factor of the consumption loss is about 21 billion dollars (Figure 2.4).

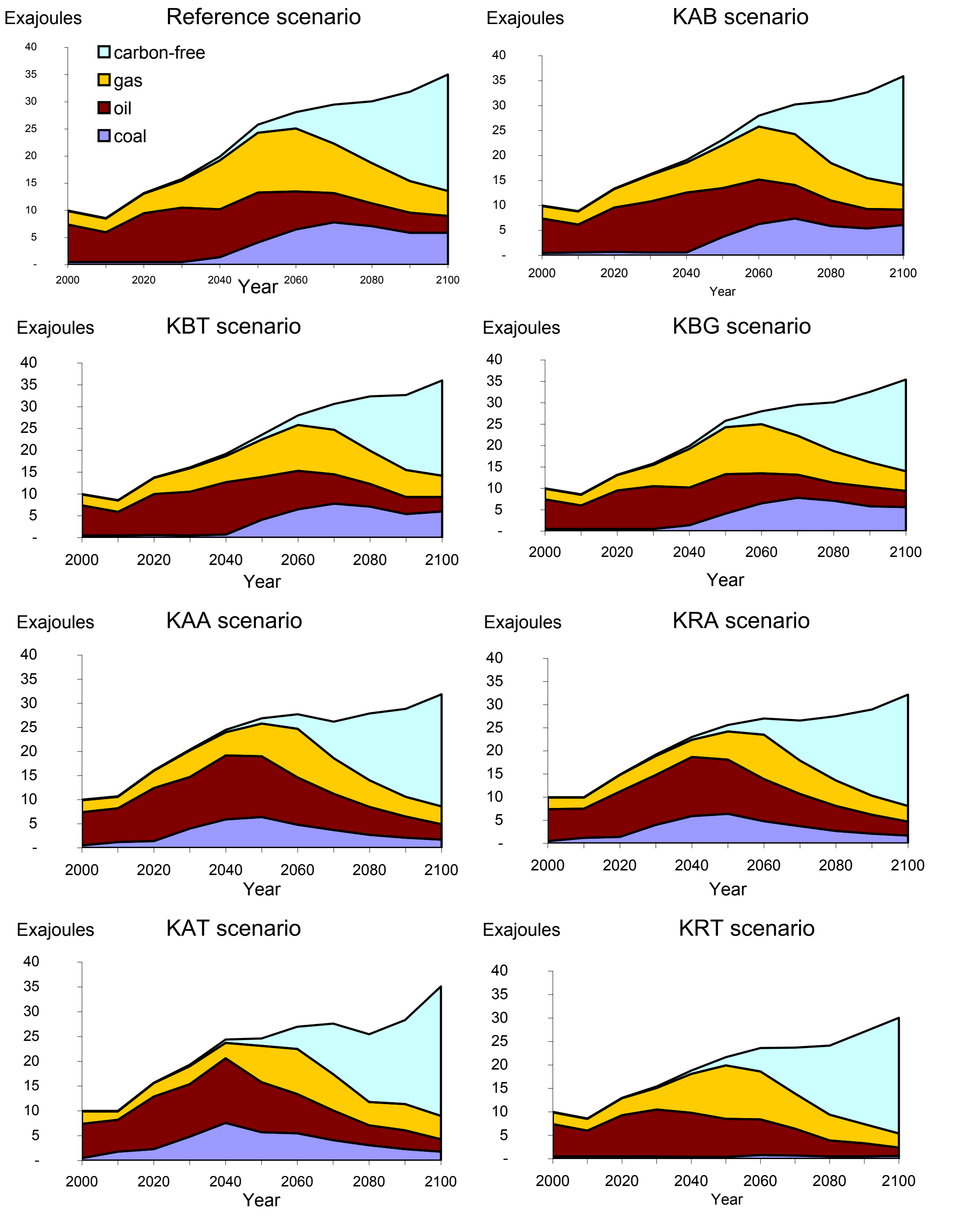
International trade in emission permits among Annex B countries hardly affects these results. The loss of income in Indonesia is less (Figure 2.3) because the costs of emission reduction in Annex B fall; the net present value consumption loss drops to 23 billion dollars (Figure 2.4). If all the countries engage in trade in emission permits with non-Annex B countries allotted their reference emissions, then the income loss of Indonesia is small (Figure 2.3); the net present consumption loss is only 2 billion dollars (Figure 2.4). This is partly because total emission reduction costs fall, and partly because Indonesia sells emission permits. The country reduces its CO_2 emissions by limiting its coal consumption (Figure 2.1).

2.5 Emission reduction in Indonesia

In the fifth scenario, not only the OECD countries but all other countries also have emission reduction targets, set relative to the current scenario: say, targets in 2050 depend on emissions in 2030 in the same scenario. As agents in MERGE are forward-looking (in 2030, they are aware of the target to be achieved in 2050), it implies that there is an incentive to increase emissions in the pre-regulation period so that absolute emission allowances are higher in subsequent years. Under this scenario, Indonesian fossil energy production peaks earlier than in the other scenarios, but begins falling sharply after 2060 (Figure 2.5). Coal production is shifted forward in time, while gas production is postponed. Oil is imported, as oil demand falls sharply in the rest of the world (Figure 2.1). Per capita income increases, relative to the scenario in which only Annex B countries force emission reduction obligations in the first half of the century, but falls thereafter (Figure 2.3). The latter periods dominate; the net present consumption loss is estimated to be 27 billion dollars (Figure 2.4).

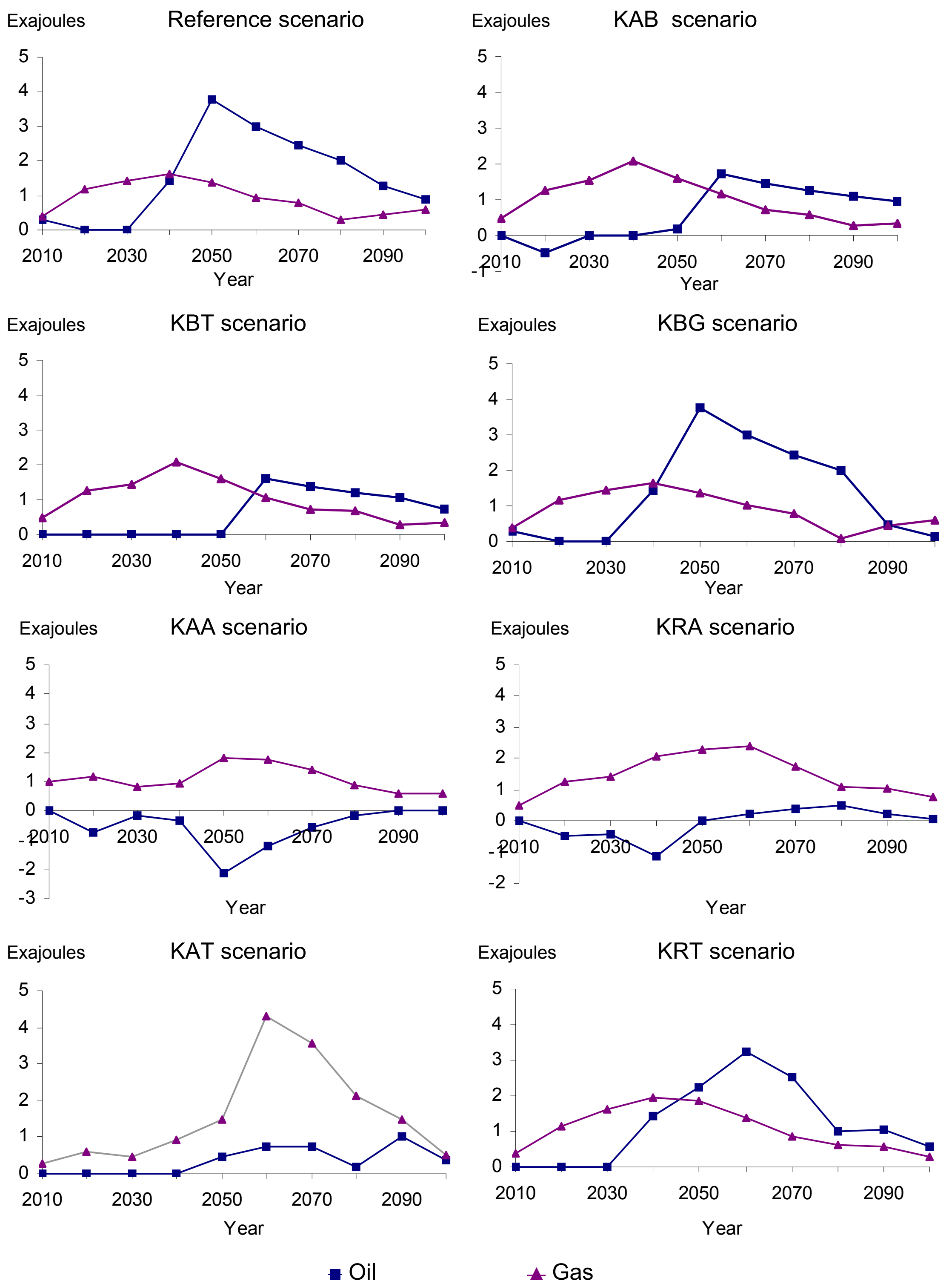
With international emission permit trade, Indonesia's fossil fuel production falls more rapidly after 2040, as the country becomes a net exporter of emission permits. Indeed, the expansion of CO_2 emissions provide for plenty of cheap emission reduction opportunities (Figure 2.1). Gas exports increase, as other developing countries sell emission permits as well, and oil is again exported, as oil prices increase (Figure 2.2). The per capita income increases (Figure 2.3), while the net present consumption losses fall to 15 billion dollars (Figure 2.4).

In the sixth scenario, emission reduction targets are set relative to the reference scenario, taking away the incentives to increase pre-regulation emissions (Figure 2.5). Nonetheless, Indonesia increases its pre-regulation fossil fuel production and shifts coal consumption forward in time, so as to reduce emission reduction costs later on (Figure 2.1). Gas exports increase slightly,



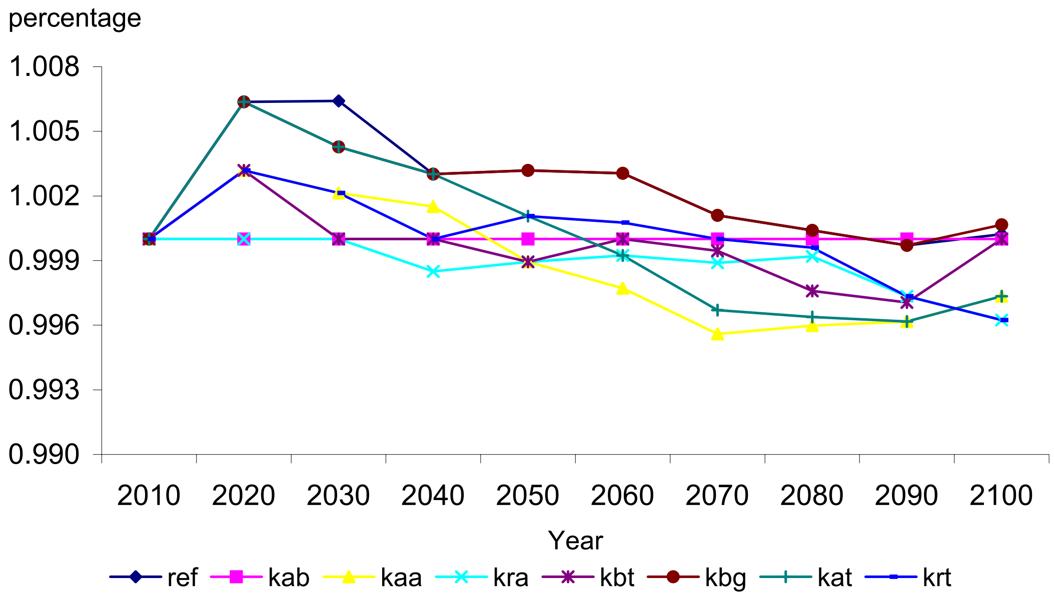
KAB – Kyoto Annex B scenario; KBT – Kyoto Annex B with Trade scenario; KBG – Kyoto Annex B with Global trade scenario; KAA – Kyoto All countries scenario; KRA – Kyoto All countries relative to Reference scenario; KAT – Kyoto All countries with Trade scenario; KRT – Kyoto All countries relative to Reference scenario with Trade

Figure 2.1 Primary energy production of Indonesia



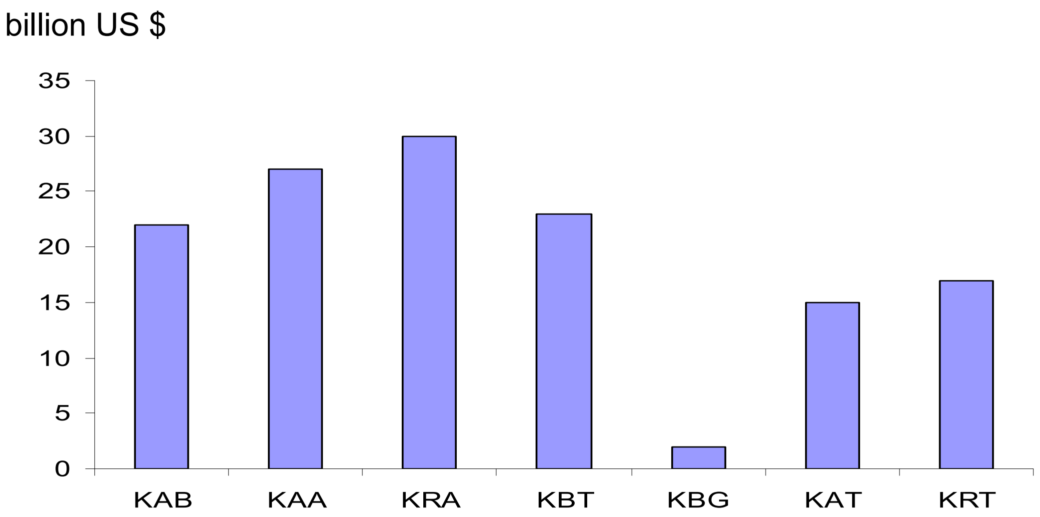
KAB – Kyoto Annex B scenario; KBT – Kyoto Annex B with Trade scenario; KBG – Kyoto Annex B with Global trade scenario; KAA – Kyoto All countries scenario; KRA – Kyoto All countries relative to Reference scenario; KAT – Kyoto All countries with Trade scenario; KRT – Kyoto All countries relative to Reference scenario with Trade

Figure 2.2 Net exports of Indonesia



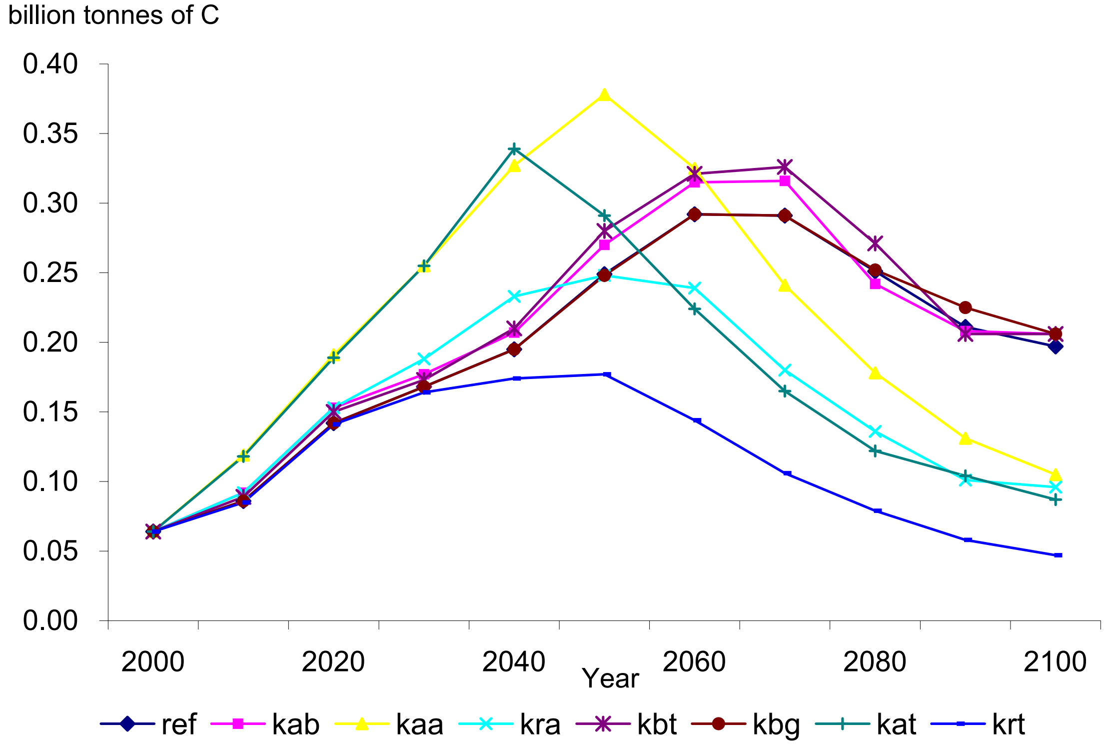
REF – Reference scenario; KAB – Kyoto Annex B scenario; KBT – Kyoto Annex B with Trade scenario; KBG – Kyoto Annex B with Global trade scenario; KAA – Kyoto All countries scenario; KRA – Kyoto All countries relative to Reference scenario; KAT – Kyoto All countries with Trade scenario; KRT – Kyoto All countries relative to Reference scenario with Trade

Figure 2.3 Per capita consumption relative to the Kyoto Annex B scenario



KAB – Kyoto Annex B scenario; KBT – Kyoto Annex B with Trade scenario; KBG – Kyoto Annex B with Global trade scenario; KAA – Kyoto All countries scenario; KRA – Kyoto All countries relative to Reference scenario; KAT – Kyoto All countries with Trade scenario; KRT – Kyoto All countries relative to Reference scenario with Trade

Figure 2.4 Net present value of consumption losses relative to reference scenario (five per cent discount rate)



REF – Reference scenario; KAB – Kyoto Annex B scenario; KBT – Kyoto Annex B with Trade scenario; KBG – Kyoto Annex B with Global trade scenario; KAA – Kyoto All countries scenario; KRA – Kyoto All countries relative to Reference scenario; KAT – Kyoto All countries with Trade scenario; KRT – Kyoto All countries relative to Reference scenario with Trade

Figure 2.5 Total carbon emissions of Indonesia

while oil imports drops as compared to the previous scenario (Figure 2.2). The per capita income falls first, but then is more than that in the previous Indonesian emission reduction scenario (Figure 2.3). However, net present consumption loss is larger, as the emission constraint is more (Figure 2.4).

With international emission permit trade, coal production remains virtually negligible (Figure 2.1). It is more economic not to use coal and export the resulting emission permits. As a result, less gas is exported. Oil exports increase, however, as the switch from coal to gas yields emission permits for exporting elsewhere in the developing world (Figure 2.2). The per capita income rises (Figure 2.3) but the net present consumption falls to 18 billion dollars (Figure 2.4).

2.6 Conclusions

We adopted the MERGE model, taking Indonesia as a separate region. The revised model allows us to investigate the implications of GHG emission reduction in Annex B countries and elsewhere for the Indonesian economy. The following results emerge.

Emission reduction in the OECD reduces economic growth in Indonesia, primarily through suppression of the country's oil exports. Gas exports increase, but only slightly, and are not sufficient to offset the loss of oil revenue. The total loss of income is small, as the total per capita consumption is never less that 99% of what it would have been without emission reduction. With global emissions trade, Indonesia would export permits, but the revenues would not be enough to offset the loss of fossil fuel revenues.

Were Indonesia to accept emission reduction targets in the future, its economy would grow slowly. However, emission reduction by five per cent per decade would lead to per capita income losses of less than one per cent when compared to the reference scenario. However, to anticipate future emission reduction targets (relative to a future base year), the country would have the incentive to increase the emissions in the medium term. This would not only soften its emission reduction target, but also provide cheap emission reduction permits for sale in the international market.

Overall, it appears that the effects of GHG emission reduction on Indonesia are fairly small, particularly as compared to the level of uncertainty in long-term projections of economic development. It may even accept an emission reduction target without incurring large costs. However, on the other hand, as Indonesia is likely to be vulnerable to climate change, it should actively support international climate policy.

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Chapter 3

Impact of international emission reduction on energy and forestry sector of Indonesia

Abstract

We have extended the simulation model MERGE – Model for Evaluating the Regional and Global Effects of Greenhouse Gas Reduction Policies - to develop a set of energy projections for a reference and various mitigation scenarios to the year 2100. We included coal together with oil, gas and some others sources of energy as a tradable good. In Indonesia, oil imports will increase while coal exports will decrease. If the OECD countries reduce their emissions, oil price would fall, Indonesia would import more oil but less gas and its per capita income would fall slightly. With international trade in emission permits, Indonesian energy development is similar to the earlier scenario, but Indonesia would gain some income. If all countries reduce their emissions, Indonesia would export more coal and would substitute coal by gas and carbon free technologies in energy consumption. If Indonesian commits to emissions reduction, per capita income would slightly fall.

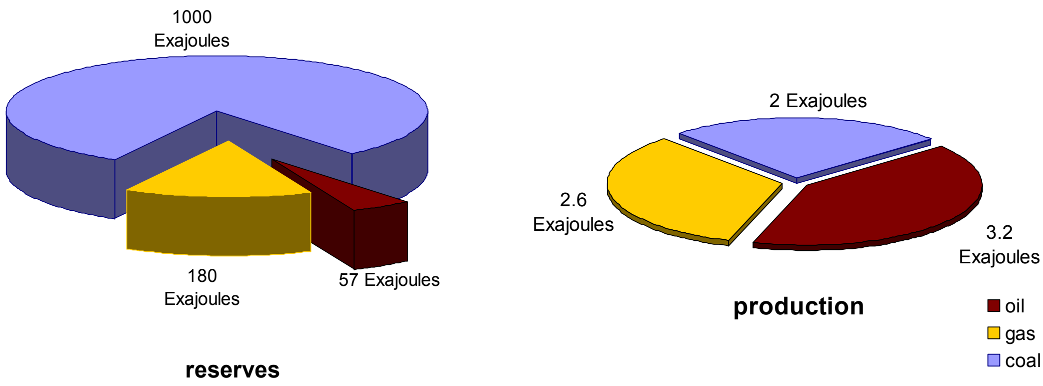
Population and economic growth are the driving forces of deforestation. In the reference scenario, deforestation increase by 60% in 2020 relative to today, indicating that Indonesia has large potential to mitigate emissions in the forestry sector. International climate policy would slightly increase the deforestation rate, mainly because of more rapid economic growth. Indonesia would gain from the sale of emission permits from reduced deforestation.

3.1 Introduction

Indonesia holds a special position in international climate policy. On the one hand, it exports oil and coal, a business it could lose under stringent emission reduction. On the other hand, Indonesia has gas reserves as well, the demand for which would grow. Furthermore, Indonesia could use the money of the Clean Development Mechanism to slow deforestation and avoid carbon dioxide emissions. This paper seeks to shed light on the implications of international climate policy on Indonesia, and particularly its energy and forestry sectors.

Indonesia has significant reserves of oil, gas, and coal. The Government of Indonesia estimates its gas reserves at 170 trillion standard cubic feet (TCSF) or around 180 exajoules, of which 95 TCSF are proven and 75 TCSF are probable (EUSAI, 2001), as seen in Figure 3.1a. Gas reserves are three times larger than oil reserves. Coal deposits are estimated at 39 billion metric tonnes, or around 1,000 exajoules, of which 12 billion metric tonnes are classified as measured and 27 billion metric tonnes as indicated. Indonesia's crude oil reserves amount to 9.6 billion barrels or around 57 exajoules, with proven reserves of 5 billion barrels. Oil production, at 3.2 exajoules per year in 2000, dominates the energy sector of Indonesia; this leaves Indonesia with 17 years of production. Gas production was around 2.6 exajoules per year in 2000, so that gas can be supplied for another 69 years at current production rates. Coal production was 2 exajoules per year, as shown in Figure 3.1b, so that reserves would last another 500 years. Recently, Indonesia produced 1.15 million barrels oil per day, decreasing by 5 percent per year since 1998. Gas and coal production increased significantly; the export of coal increased to 1.5 exajoules per year in 2000.

The energy sector in Indonesia has been a dominant factor in the overall economic development of Indonesia. The oil and gas exports contribute significantly to securing foreign exchange revenue of the country. As the country is still striving to develop its industrial sector, foreign exchange revenue is an



Source: EUSAI (2001)

Figure 3.1a Fossil fuel reserves and production of oil, coal, and gas in 2000

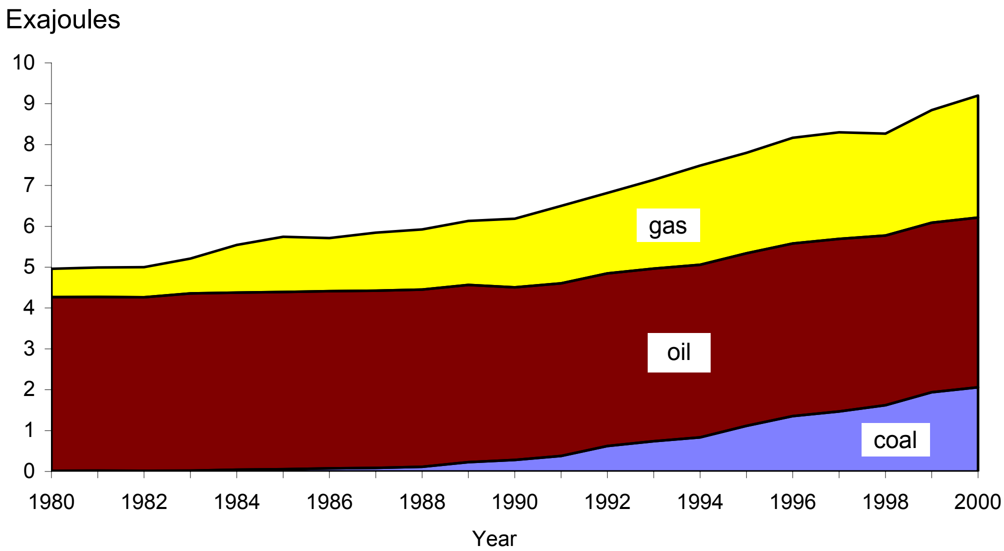
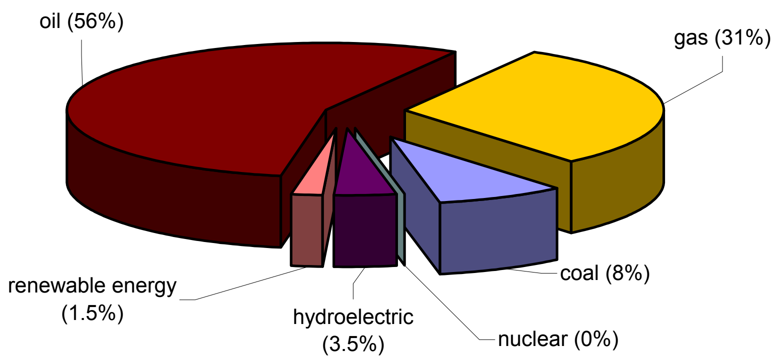


Figure 3.1b Energy production of Indonesia

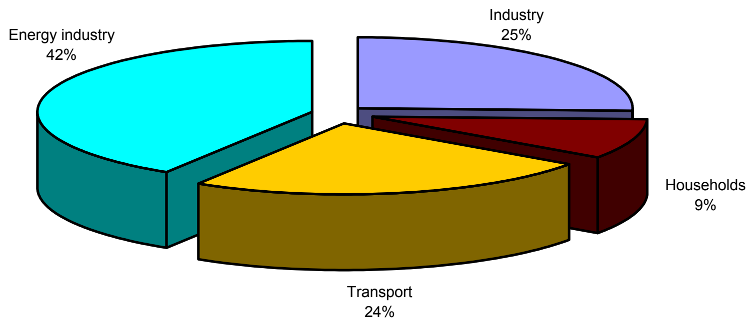
important ingredient to the acquisition of technology from foreign sources. In the domestic sector, oil has dominated for the past 30 years and is likely to continue to dominate in the immediate future. In recent years, however, the share of oil in domestic consumption is slightly declining due to significant increase in the role of gas, which now takes a second position in the energy mix.

Indonesia consumed 3.9 quadrillion British thermal unit (Btu) of energy, 95 percent of energy consumption is currently supplied by fossil fuel (DGEED, 2000).



Source: IEA, International Energy Agency (2000)

Figure 3.2 Energy consumption of commercial energy sources (oil, gas, coal, hydro + nuclear)



Source: SME-ROI (1996b)

Figure 3.3 Sources of emissions from the energy sector in Indonesia, year 2000

Oil is the dominant fuel (see Figure 3.2) accounting for 56% of 2000 total energy consumption in Indonesia, followed by natural gas and coal (31% and 8%, respectively). In 2000, total CO_2 emissions from energy demand sectors amount to 228 million metric tonnes of carbon dioxide, of which 42% are from the energy-industry sector (including power plants), 25% from industry, 24% from transport, and 9% from households; see Figure 3.3. The growth rate of CO_2 emissions from the energy industry at 7% per year, is the highest; all sources average to 3.3% per year.

In addition to the carbon emissions from fossil fuels, the forest sector also has high emissions, mostly as a result of deforestation. In Indonesia's National Communication under UNFCCC (SME-ROI, 1999a), it was found that, in 1994, Indonesia's net emissions from land use change and forestry sector reached 156 million metric tonnes of net carbon dioxide emissions. Activities that contribute to increase of deforestation are agricultural expansion, shifting cultivation, transmigration, illegal logging and forest fires. According to several studies, the rate of deforestation in Indonesia has increased, although estimates differ among these studies (Boer, 2001). In the early 1990s, the rate of deforestation reached a level of 1.3 million ha per year (FAO and MoF 1990). Based on 1997 satellite imagery, the ministry of Forestry and Estate Crops estimated that nationwide annual deforestation rate is more than 1.5 million ha. For 1998 – 2002, Sari *et al.* (2001) estimated the rate of deforestation in Indonesia at about 2–2.4 million ha per year.

In this paper, we study the impact of international climate policy on the energy sector of Indonesia and study the interaction between the forest sector and energy policy. Emission reduction policy elsewhere would increase the demand for Indonesian gas, and decrease the demand for its coal. We analyze the implications of emission reduction in Annex B countries, without and with emission trade, on the energy sector and the causes of deforestation. Finally, we analyze the direct effect of international climate policy on deforestation in Indonesia, for instance through potential projects under the UNFCCC Clean Development Mechanism.

This paper expands the work of Susandi and Tol (2002) in three ways. Firstly, we make coal an internationally tradable good. In the original model, coal is not traded internationally. This may not matter on a global scale, but it does matter to Indonesia. Secondly, we updated the fossil fuel reserves. Thirdly, we add avoided deforestation as a way to reduce carbon dioxide emissions, and allow for trade of such permits.

The remainder of this paper is organized in the following way. Section 2 presents a brief overview of the MERGE model, and specifies the changes we made to the model. Section 3 presents and discusses the model results for reference and mitigation scenarios. Section 4 describes the forest land use change and the interactions between the new forest sub-model and the rest of MERGE; Section 4 also assesses slowing deforestation. Section 5 contains conclusions.

3.2 MERGE – with coal as tradable good

In this analysis, we use version 4.3 of the MERGE model, originally developed by Alan S Manne from Stanford University and Richard G. Richels from the Electric Power Research Institute. MERGE (Model for Evaluating the Regional and Global Effects of greenhouse gas reduction policies) is an inter-temporal general equilibrium model, which combines a bottom-up representation of the energy supply sector with a top-down perspective on the remainder of the economy. See Manne and Richels (1992) and Manne *et al.* (1995) for a detailed description. MERGE consists of four major parts: (1) the economic model, (2) the energy model, (3) the climate model and (4) the climate change impact model. The model is calibrated with energy and economic data to the year 2000. The economy is modelled through nested constant elasticity production functions. The model also has international trading of gas, oil and energy intensive goods. We extended MERGE to include coal as a tradable good.

In the original version of the model (MERGE 4.3), supply and demand for coal are equated at the regional level. We allow for international trade in coal. The production costs of coal is assumed to be 2-3 US$/GJ, compared to 3-5 US$/GJ and 2-4 US$/GJ for oil and gas, respectively. Interregional transport costs are proportional to net exports; we assume that unit cost of coal export is 0.67 x10^{-3} US$/GJ; the unit transport cost of coal is higher than the transport cost of oil but lower than the unit transport cost of gas. Production, consumption, and export of coal are calibrated to observations for the year 2000.

The energy model distinguishes between electric and non-electric energy. There are 10 alternative sources of electric generation (hydro; remaining initial nuclear; gas fired; oil fired; coal fired; gas advanced combined cycles; gas fuel; coal fuel; coal pulverized; integrated gasification and combined cycle with capture and sequestration), plus two “backstop” technologies: high and low-cost advanced carbon-free electric generation. There are four alternative sources of non-electric energy in the model (oil, gas, coal, and renewables) plus a backstop technology.

The climate sub-model is confined to the three most important anthropogenic greenhouse gas: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The emissions of each gas are divided into two categories: energy related and non-energy related emissions. The climate damages of the model is divided into market and non-market damages, which enter in the regional and overall welfare development.

To analyze the impact of international climate policy on energy production and net exports of Indonesia, we developed four scenarios, specified in Table 3.1. We assume that all Annex B countries (with the exception of the USA) adopt the Kyoto Protocol and reduce their emissions by 5 percent per decade in the years after 2010. Indonesia is assumed to accept a target in 2050. After 2050, Indonesia’s emission falls by 5 percent per decade.

3.3 Results of MERGE

3.3.1 Reference scenario

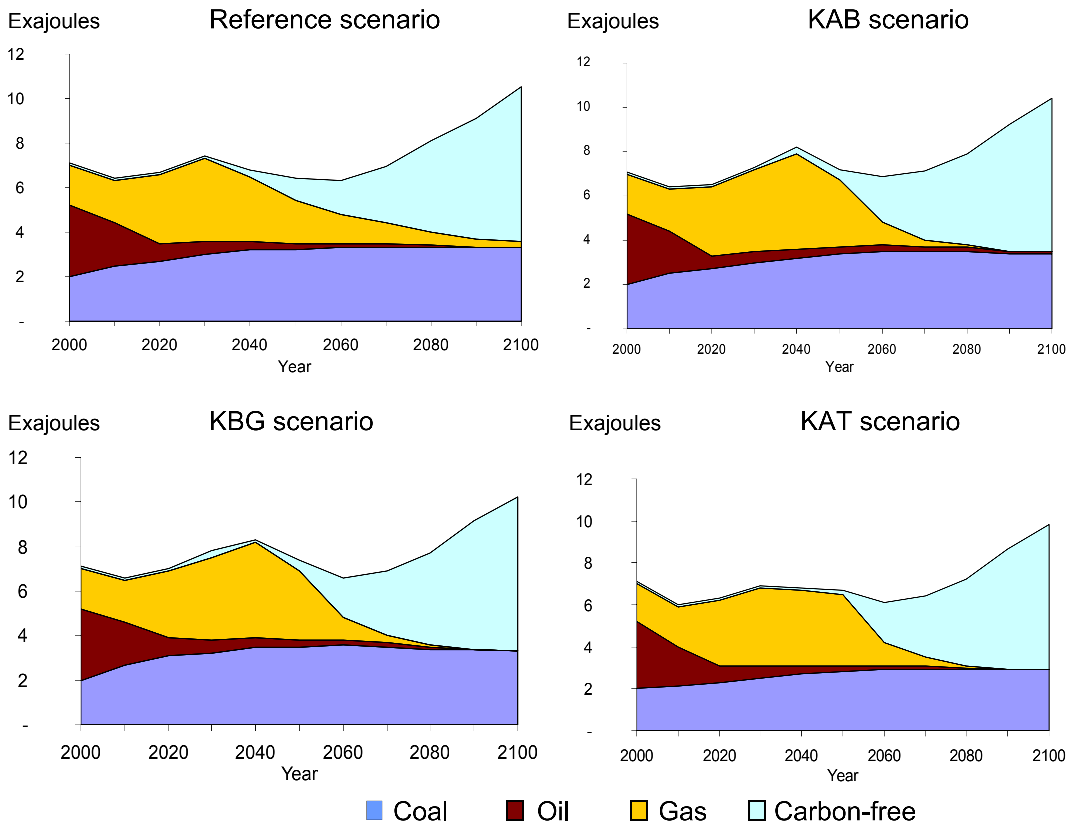
In 2000, Indonesia’s population was about 212 million and is projected to grow to 389 millions in 2100. The growth rate of the population was 1.6 percent in the period of 1990 – 2000. Indonesia's economic growth increased modestly in 2002 due to the continuing global economic slowdown. In 2000, per capita gross domestic product (GDP) was some US$ 722 at market exchange rate. GDP grew at a rate of 3.7% in 2002, and 3.1% in 2001. In the MERGE model, growth continues, reaching a per capita GDP level of US$ 19.8 thousand[1] in 2100.

Between 1990 and 1994, emissions of carbon dioxide, methane and nitrous oxide from households, transport and industry grew at a rate of 1.8 percent per year; these sectors are responsible for 35–60 percent of total Indonesian emissions from fossil fuel combustion. In 1999, the energy industry contributed a further 29 percent of total carbon dioxide emissions from fuel combustion (SME-ROI, 1999b). Without emission reduction policies, carbon dioxide emissions grow from 64 million tonnes in 2000 to 172 million tonnes in 2100.

Table 3.1 Different scenarios of the impact of the international climate policy on Indonesia

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

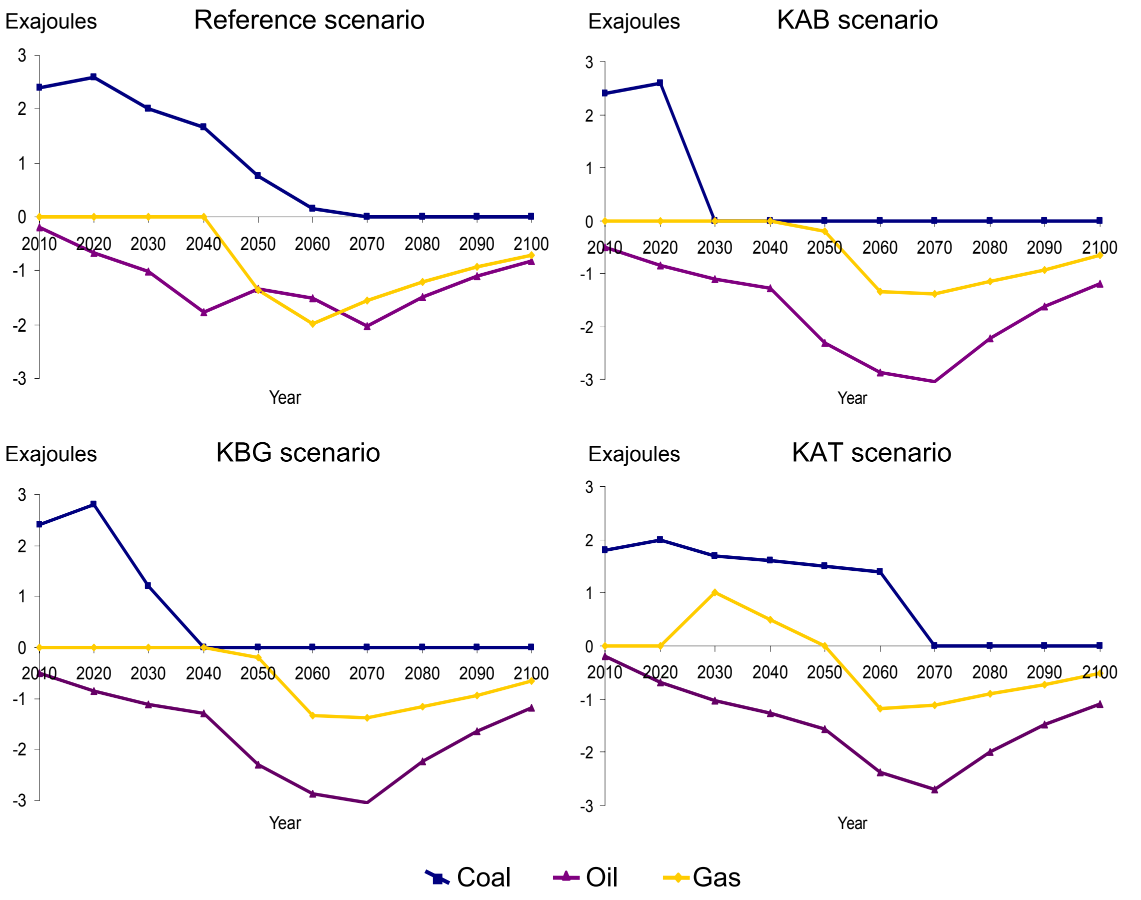
[1] Without international trade in coal, per capita GDP reaches US$ 19.5 thousand in 2100, or 1.6% less than with trade.



KAB – Kyoto Annex B scenario; KBG – Kyoto Annex B with Global trade scenario;
KAT – Kyoto All countries with Trade scenario

Figure 3.4 Primary energy production of Indonesia

In energy production, Indonesia ranked 17th among world oil producers in 2000, with approximately 1.9 percent of the world's production. Current trends suggest that oil production will fall (EUSAI 2001). In our model, oil production falls rapidly until 2020, and gradually thereafter (Figure 3.4, Reference scenario). Gas production is projected to increase substantially during the first half of the century, but falls after that. Coal production grows gradually to cover the shortfalls in domestic and foreign energy demand. Coal will be the dominant fuel after 2040 in Indonesian energy production as the others sources of fuels get more and more depleted. Carbon-free technologies are the dominant energy source at the end of the century. To fulfil its oil demands, Indonesia imports oil. Oil imports increase to 2040, then fall slightly, and reach a new peak in 2070



KAB – Kyoto Annex B scenario; KBG – Kyoto Annex B with Trade scenario;
KAT – Kyoto All countries with Trade scenario

Figure 3.5 Net exports of Indonesia

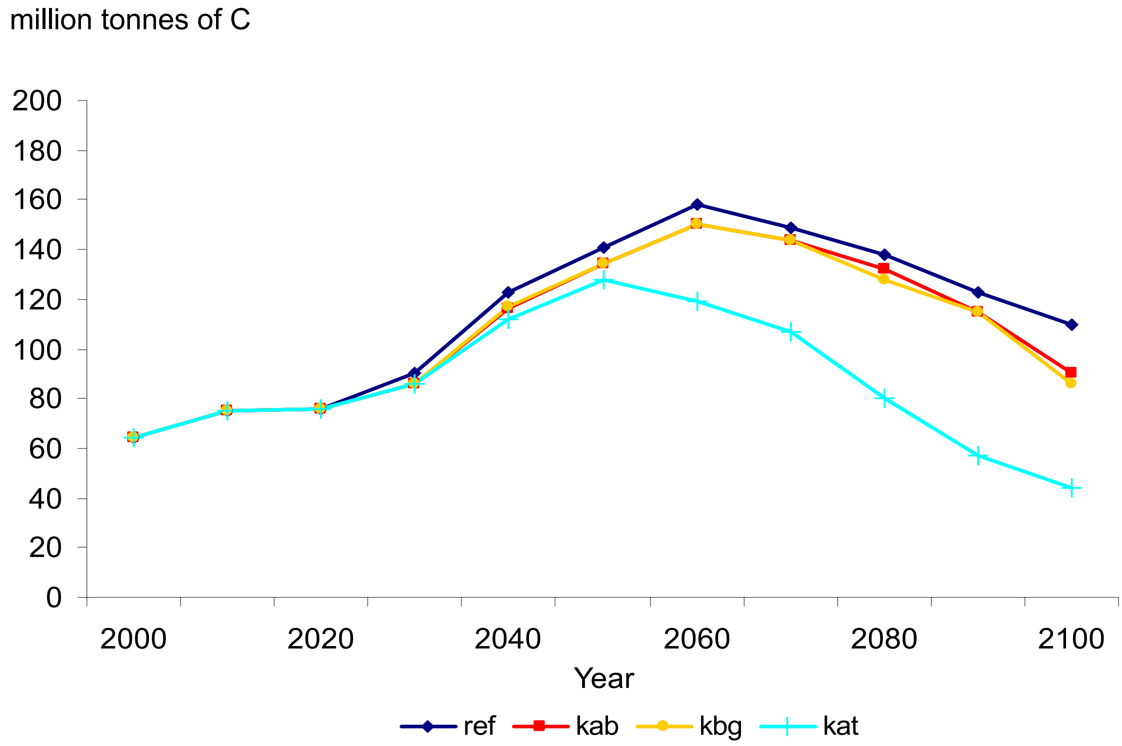
(Figure 3.5, Reference scenario). Indonesia will be a net importer of gas after 2040; gas imports increase substantially to 2060, and then decrease to the end of century. Coal is the only energy export of Indonesia, increasing a little to 2020 – a continuation of recent years – and then falling gradually till 2070.

3.3.2 Mitigation Scenarios

In this section, we explore greenhouse gas emission reduction in the OECD and elsewhere and its effects on Indonesia. If the OECD countries were to reduce their emissions as specified above, the price of gas on the world market would rise while the oil price would fall. Indonesia responds to this in the first half of the 21st century by importing less gas while increasing the production of gas to meet domestic demand; at the same time, oil imports are increased (Figure 3.5). This extends the life time of oil production, as shown in Figure 3.4. Coal production is slightly higher than in the reference scenario in the second half of century. Although coal exports fall after 2020, this is offset by a domestic increase in coal use. Indonesian energy consumption is almost the same as in the reference scenario, except in the final decade of this century. Indonesian GDP per capita drops by 0.14% from reference in 2020, primarily because of reduced coal exports, but per capita GDP more than catches up later, primarily because of decreased gas imports (Figure 3.7). Emission control in the OECD affects Indonesian emissions only slightly (Figure 3.6); carbon leakage, at least to Indonesia, is minimal.

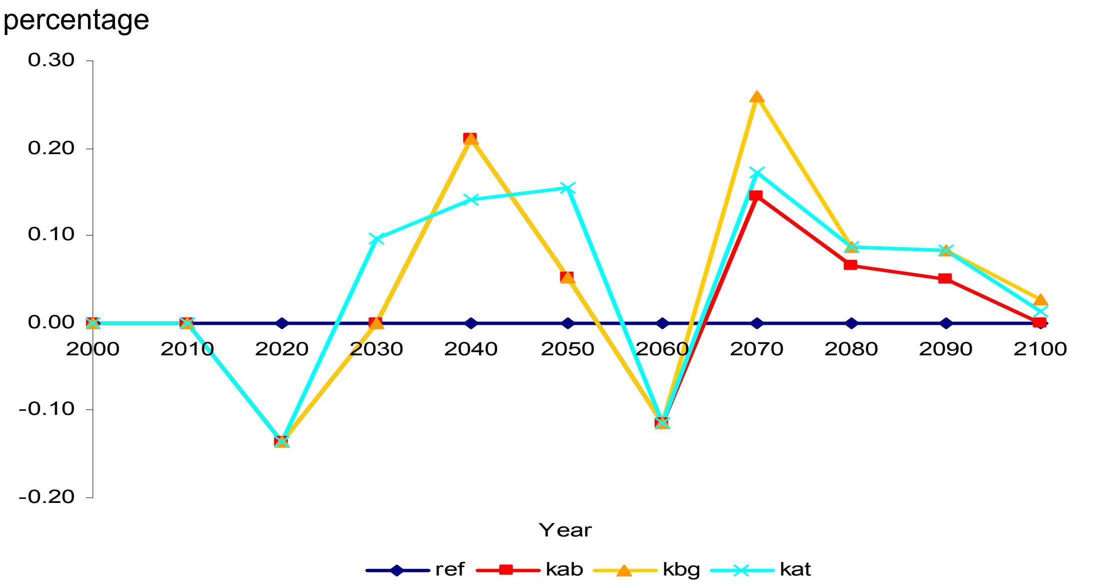
With international trade in emission permits, results are essentially the same as in the previous scenario, but slightly less pronounced as total emission reduction costs in the OECD are lower.

In the last scenario, not only the OECD countries but also all other countries commit to limiting their emissions. Under this scenario, Indonesian fossil-fuel, particularly gas, production would be brought forward in time (Figure 3.4). Gas would dominate domestic energy use during the first half of the century. Furthermore carbon-free technology would be increasingly adopted as the growth in domestic energy consumption exceeds the rate of emission reduction. Oil production is approximately the same as in the reference scenario. Coal production increases slightly to the end of century, but is lower than in the other scenarios. However, Indonesian coal exports are stable till 2070 as the suppressed coal price offsets the carbon penalty. The pattern of oil imports is approximately the same as in the previous two scenarios, but with lower quantities. Indonesia exports gas in the first decades, and then becomes a net importers. The total quantity of gas imports is slightly lower than in the reference scenario.



REF – Reference scenario; KAB – Kyoto Annex B scenario; KBG – Kyoto Annex B with Trade scenario; KAT – Kyoto All countries with Trade scenario

Figure 3.6 Total carbon emissions of Indonesia



REF – Reference scenario; KAB – Kyoto Annex B scenario; KBG – Kyoto Annex B with Trade scenario; KAT – Kyoto All countries with Trade scenario

Figure 3.7 GDP losses for mitigation scenarios relative to the Reference scenario

GDP per capita increases after 2030 and slightly declines relative to the reference after 2050, the date that Indonesia accepts its emission target; it falls by less than 0.2% (Figure 3.7). Carbon dioxide emissions from energy consumption would reach 129 million tonnes of carbon by 2050 and would then fall to 44 million tonnes in 2100 (Figure 3.6), reflecting the switch from coal to gas to carbon-free fuel in power generation.

3.4 Forest land-use change

Indonesia has the second largest tropical forest after Brazil, that is, about 144 million ha or about 10% of global area (Trisasongko, 2002). Forest products are significant in the Indonesian economy. The forestry sector is the second highest contributor to foreign exchange after the oil and gas sector (BPS, 2000). However, the large timber trade is poorly regulated and eventually leads to climate changes as well as species extinction and disruption of the water cycle. The forest sector is the second largest contributor to Indonesia's carbon emissions. Emissions resulting from changes in land use fluctuated strongly due to changes in the rate of forest harvesting, but the Indonesian forest area decreases substantially from year to year. The World Bank (2000) estimates that the rate of deforestation now stands at 2 million ha per year, as also reported by Sari *et al.* (2001). The causes of forest degradation and loss are complex and vary widely from place to place. Major causes of forest degradation are expansion of agriculture, transmigration, development of infrastructure, shifting cultivation, illegal logging and forest fire (Boer, 2001).

Anticipating continued deforestation, the Indonesian government has regulated that the area of conservation, protection and production forests have to be maintained, while only so-called conversion forests can be converted into other uses, such as industrial timber plantation, non-forest tree plantations, transmigration programs, etc. However, a reduction of one hectare conversion forest into non-forest land has to be compensated by the conversion of two hectares non-forest land into forest land (ALGAS, 1997b). With this regulation, in the long run total area of forest land would be expected to increase.

Existing policies to mitigate carbon emissions in Indonesia include forest plantation and timber estate, afforestation, reforestation, enhanced natural regeneration, forest protection, bioelectricity, reduced impact logging. The potential of each option to avoid emissions or sequester carbon vary considerably, ranging from 37 to 218 Mg C per ha (Boer, 2001). Reforestation activities have the highest potential and plantation the lowest (Boer, 2001).

3.4.1 Interaction between direct and indirect causes of deforestation

Causes of tropical deforestation have been classified into direct and indirect. Direct causes can be grouped into two classes: pressure from forest products for consumption and exports, and pressure from alternative land uses, particularly agriculture. Indirect causes of deforestation relate to population, gross domestic product, external debt and government policies. The rate of deforestation is expressed as a function of the direct causes, each of these expressed as a function of the indirect causes. Kant and Redantz's (1997) model assume that deforestation is caused by roundwood consumption, export of forest products, conversion to crop land, and conversion to pasture land.

We modified the econometric model of tropical deforestation by Kant and Redantz (1997) for Indonesia. ALGAS (1996) reports deforestation from crop land conversion (including transmigration and infrastructure development) at 838,000 ha per year during 1982 – 1990. We extrapolate this to increase to 938,560 ha per year in 2000, assuming 1.2% annual increase during 1990 – 2000 (FWI/GFW, 2002). Boer *et al.* (1998) identify agriculture development as the main cause of deforestation in Indonesia. Roundwood consumption and forest-product export are the next main causes of deforestation in Indonesia. Deforestation rate due to roundwood consumption was 377,000 ha per year during 1982 – 1990 (ALGAS, 1996). A report by the Ministry of Forestry in July 2000 indicates that, in a survey of nearly 47 million ha of forest land for export, about 30 percent had been degraded during the previous 20 years, or around 705,000 ha per year. The main destination countries for Indonesian forest-product export are Japan, United States, China and the Europe Union (Kartodihardjo, 1999). It is estimated that forest loss due to illegal logging was minor (Dick 1991; FAO and MoF 1990; Angelsen and Resosudarmo 1999).

Pasture land or natural grassland develops as a result of shifting cultivation and degradation of forest (Deptan ROI, 1988) and is maintained by grazing and (uncontrolled) burning (forest fire). The average area of grassland burnt was 6,120 ha per year (ALGAS, 1996). The total area of grassland in Indonesia is about 10.2 million ha. Large areas of natural grassland are found in Sumatera, Kalimantan, Sulawesi, Nusa Tenggara and Irian Jaya (Ivory and Siregar, 1984). We substituted conversion to pasture land as a direct cause of deforestation with forest fire, which occurs mostly every year in Indonesia. Forest fires have caused considerable damage to economy and environment. The causes of fires are largely due to changes in land use, such as shifting cultivation and crop land conversion (START, 2000). Most fires are in agricultural lands rather than in forest lands (KMNLH and UNDP, 1998). Based on the forest fire data from 1982-1990, the average area affected by forest fire was about 100,000 ha per year (Bappenas, 1992). In the El-Niño years of 1991, 1994 and 1997, the forest area burnt amounted to 119,000, 162,000, and 265,000 ha, respectively (Dirjen PHPA, 1997). In 1998, the largest known forest fire ever in the world burnt 514,000 ha (Dirjen PHPA, 1999). DGFPNC (2003) reports that the extent of forest fire was 44,090, 3,016, 14,330, and 35,497 ha for the years of 1999, 2000, 2001, and 2002, respectively. Based on these data from 1991-2000, the average area affected by forest fire was about 184,518 ha per year.

Understanding the linkages between the direct causes and the indirect ones is also important. The interactions between direct and indirect causes are shown in Figure 3.8. We used the population and GDP growth as indirect causes of deforestation. We calculated the elasticity (e) of deforestation (D) with respect to the population (P), $e = (\delta D / D)/(\delta P / P)$, and GDP growth ($Y$), $e = (\delta D / D)/(\delta Y / Y)$ for Indonesia, based on deforestation data between 1990 and 2000, as suggested by Kant and Redantz (1997); see Table 3.2.

Formally, deforestation follows

$$D_t = D_t^{roundwood} + D_t^{export} + D_t^{cropland} + D_t^{fire} \tag{3.1}$$

with

$$D_t^{roundwood} = \left(\frac{P_t}{P_{t-1}}\right)^{0.06509} D_{t-1}^{roundwood} \tag{3.2}$$

$$D_t^{export} = \left(\frac{\dot{Y}_t^W}{\dot{Y}_{t-1}^W}\right)^{0.00668} D_{t-1}^{export} \tag{3.3}$$

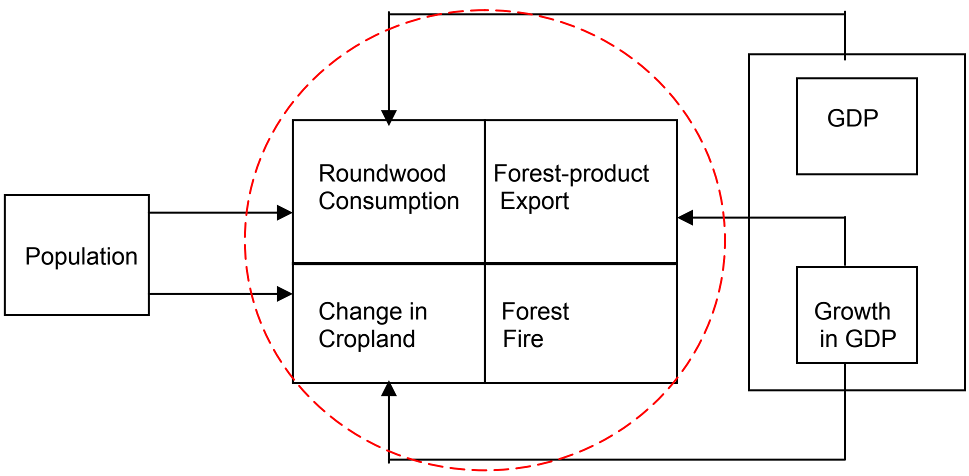
$$D_t^{cropland} = \left(\frac{\dot{Y}_t}{\dot{Y}_{t-1}}\right)^{0.06171} D_{t-1}^{cropland} \tag{3.4}$$

$$D_t^{fire} = f(t) D_{t-1}^{fire} \tag{3.5}$$

where

D_t	is total deforestation in year t
$D_t^{roundwood}$	is deforestation of roundwood consumption in year t
D_t^{export}	is deforestation of forest-products export in year t
$D_t^{cropland}$	is deforestation of cropland in year t
D_t^{fire}	is deforestation of forest fire in year t
P_t	is the total population of Indonesia in year t
$\dot{Y}_t^W$	is the GDP growth of the rest of the world in year t
$\dot{Y}_t$	is the GDP growth of Indonesia in year t

The specification of the above Equations (3.2)-(3.4) follows Kant and Redantz (1997). Splitting GDP into population and GDP per capita does not improve the description of the data. We assume that D_t^{fire} falls gradually over time by 5% per decade in the years after 2000, based on the average forest fire in last decade, because of an increasing effort in forest fire prevention.



Note: Modified from Kant and Redantz' model

Figure 3.8 Interaction between deforestation, population and economic growth

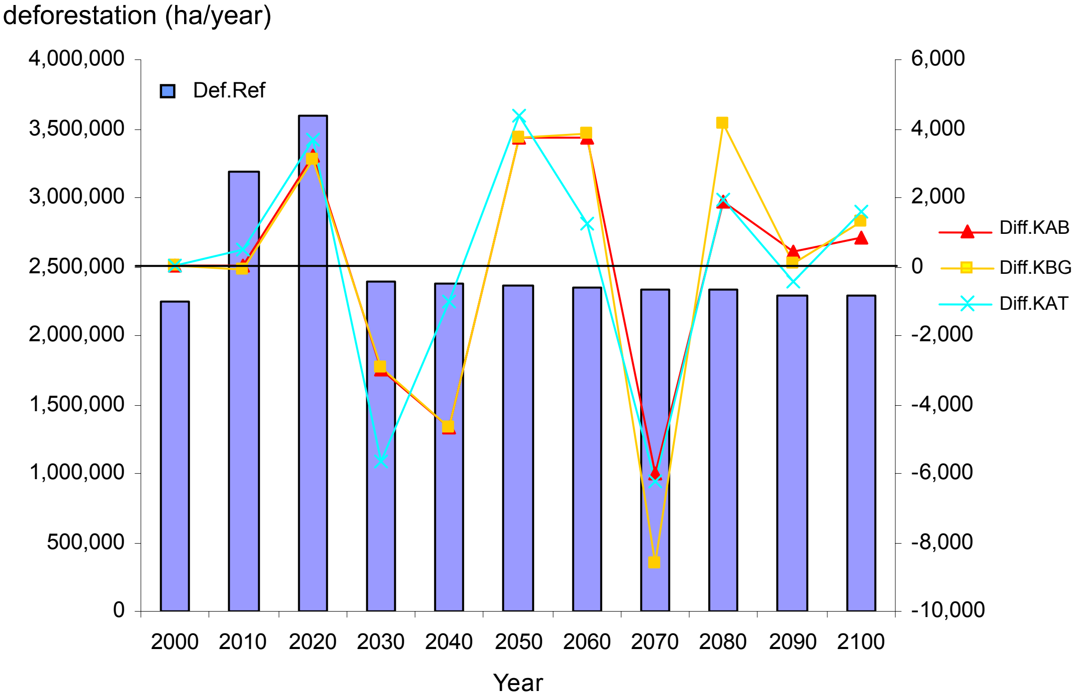
Table 3.2 Elasticities of deforestation for Indonesia

Variable	*Elasticity*		
	RWCONS	*FOPREXP*	*CHCROPL*
Population	0.06509	-	-
GDP growth	-	0.00668	0.06171

RWCONS: Annual roundwood consumption
FOPREXP: Forest-product exports
CHCROPL: Annual change in cropland

3.4.2 The effects of fossil fuel emission reduction on deforestation

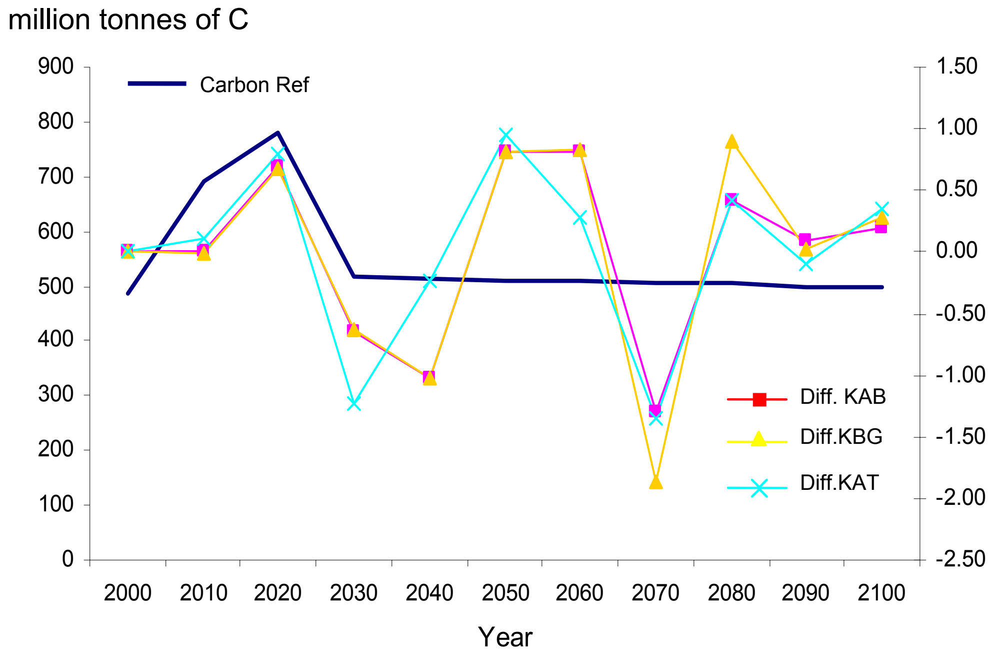
The results are given in Figure 3.9. In the reference scenario, population and economic growth lead first to increasing deforestation, rising from 2.3 million ha per year in 2000 to 3.6 million ha per year in 2020, then falls to 2.4 million



Def. Ref = Deforestation Reference scenario;
Diff. KAB = Difference (Reference – Kyoto Annex B scenario)
Diff. KBG = Difference (Reference – Kyoto Annex B with Global trade scenario)
Diff. KAT = Difference (Reference - KAT – Kyoto All countries with Trade scenario)

Figure 3.9 The effects of fossil fuel reduction on deforestation

ha per year in 2030, and decreasing gradually to 2.3 million ha per year in 2100 (Figure 3.9). Cropland is the main contributor to the rate of deforestation, increasing by a factor of 2.4 between 2000 and 2020, corresponding to about 2.2 million ha per year of deforestation in 2020; this falls to 1.0 million ha per year in 2030, later decreasing gradually to 0.9 million ha per year in 2100. Forest-product export is the second contributor to deforestation, with some 705,000 ha per year in 2000, rising to 723,000 ha per year in 2010, falling to 700,000 ha per year in 2030, and fluctuating until the end of century, reaching



Carbon Ref = Carbon emission Reference scenario;
Diff. KAB = Difference (Reference – Kyoto Annex B scenario)
Diff. KBG = Difference (Reference – Kyoto Annex B with Global trade scenario)
Diff. KAT = Difference (Reference - KAT – Kyoto All countries with Trade scenario)

Figure 3.10 Carbon emission from land use change and forestry

702,000 ha per year in 2100. Deforestation of roundwood consumption increases substantially from 422,000 ha per year in 2000 to 627,000 ha per year in 2100. Deforestation due to forest fires falls from 185,000 ha per year in 2000 to 110,000 ha per year in 2100.

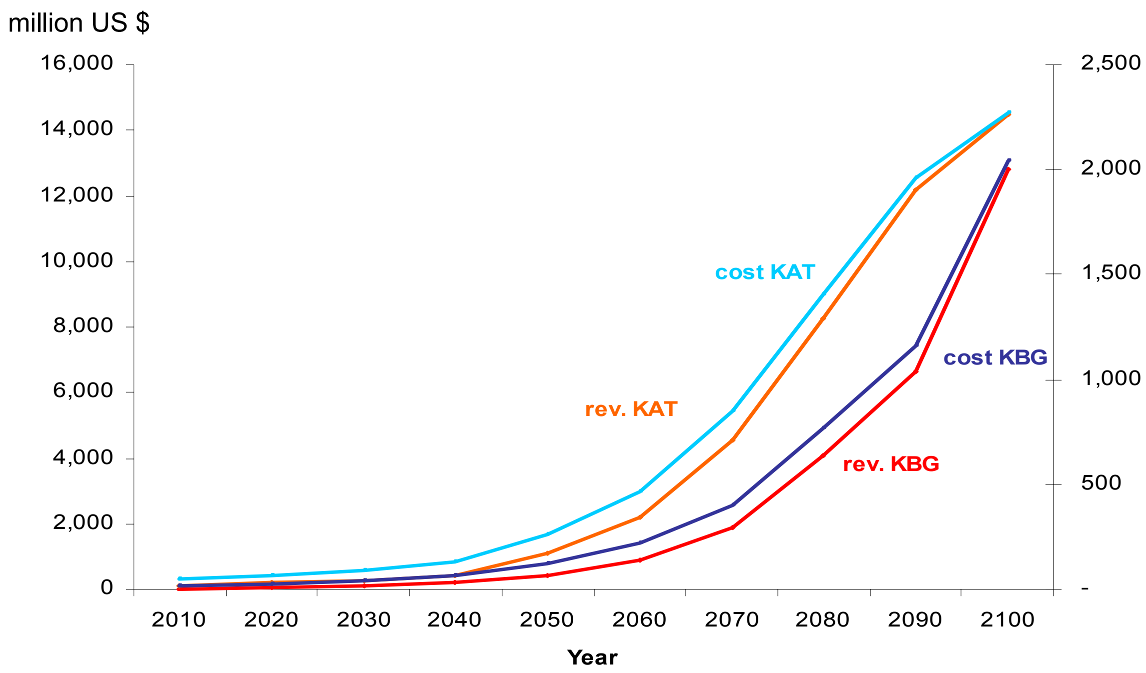
If the OECD countries reduce their emission as in the KAB scenario described above (Table 3.1), the rate of deforestation changes. The rate of deforestation is slightly below the reference deforestation, but slightly above the reference deforestation in the KBG and KAT scenarios (Figure 3.9). Figure 3.10 shows the corresponding emissions of carbon dioxide.

3.4.3 The economic gain of slowing deforestation

Changes in the use and management of forests can make a meaningful contribution to emission reduction (IPCC, 2001). Mitigating carbon emissions in the forestry sector can be divided into three categories: slowing deforestation, reforesting degraded lands, and adoption of sustainable agriculture practice (Niles *et al.*, 2001). Government policy can help by slowing deforestation. The best mitigation options in this sector seem to be sustainable forest management, afforestation, reforestation and agroforestry. Although developing countries have no specific emission targets under current climate policy agreements, there are many opportunities for mitigating carbon emission by sustainable land management in developing countries (IPCC, 2000a, b); these options could be harnessed through the Clean Development Mechanism or, later, an international system of tradable carbon permits.

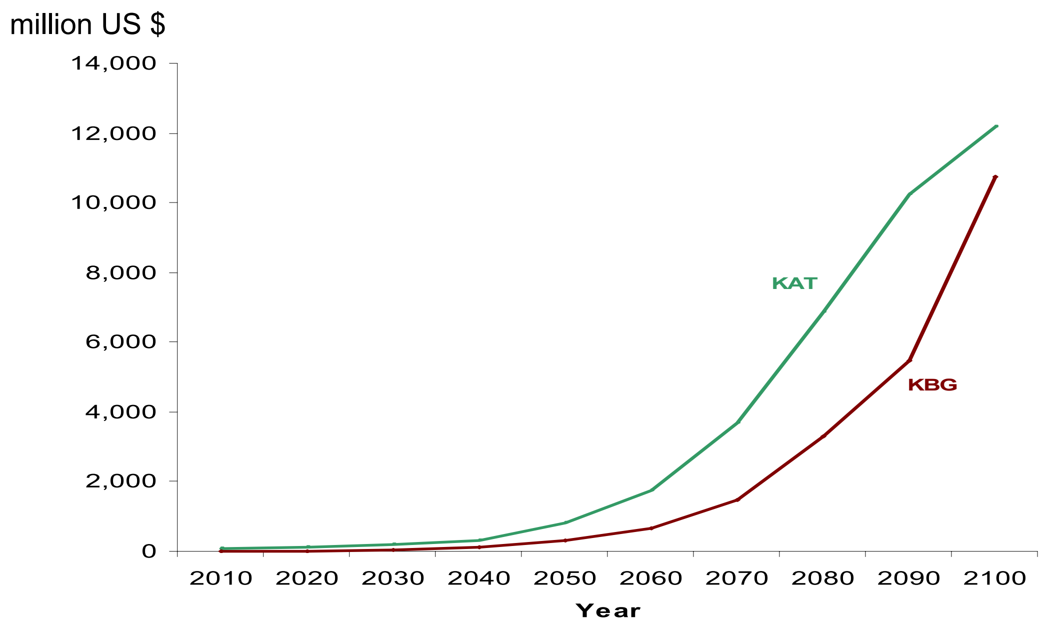
We estimate the cost of slowing deforestation from Indonesian forest based on the optimal rate of slowing deforestation. The optimal rate is achieved at the point where the marginal costs of slowing deforestation equal the shadow price of carbon. We use the marginal cost of slowing deforestation as reported in ALGAS (1997c). We use the shadow price of carbon in the KBG and KAT emission reduction scenarios. From these, we derive the costs, revenues and profits of slowing deforestation to reduce net carbon emissions in Indonesia.

The cost of slowing deforestation in Indonesia increases exponentially from US$ 12.3 million in 2010 to US$ 2.0 billion in 2100 (Figure 3.11 on the right-hand axis) if the OECD countries reduce their emission and all countries participate in global trade as in the KBG scenario. Indonesia would have large profits since revenues would be much greater than the costs of slowing deforestation. The profits increase exponentially from US$ 1.7 million in 2010 to US$ 10.7 billion in 2100 (Figure 3.12). If all countries commit to limiting their emission as in the KAT scenario, the cost of slowing deforestation is higher than in the previous scenario; that is, US$ 49.3 million in 2010 rising to US$ 2.3 billion in 2100.



KBG – Kyoto Annex B with Global trade scenario;
KAT – Kyoto All countries with Trade scenario

Figure 3.11 The revenues and costs of slowing deforestation



KBG – Kyoto Annex B with Global trade scenario;
KAT – Kyoto All countries with Trade scenario

Figure 3.12 The Profits of slowing deforestation

Nonetheless, the price of carbon is higher, so that Indonesia would receive higher profits, that is, US$ 75.5 million in 2010 rising to US$ 12.2 billion in 2100. These profits would amount to 0.14% of the GDP of Indonesia in 2100 in the KBG scenario, and to 0.16% in the KAT scenario.

3.5 Conclusions

In this paper, we extend the MERGE model to analyse the impact of international emission reduction on the energy and forestry sectors of Indonesia. In contrast to the standard version of MERGE, coal is internationally traded in the same manner as oil, gas and other sources of energy. The impact of international emission reduction on the energy sector indicates that Indonesia would produce more gas earlier than in the reference scenario. Oil imports would increase gradually to 2040, and increase substantially to 2070 because the oil price is falling as a result of reduced demand in the OECD countries. With international emissions permits trade, oil imports are essentially the same as in the last scenario. Coal production increases gradually to the year 2100 in all scenarios, but would be slightly lower if all countries, including Indonesia, have emission reduction targets.

We further extend MERGE to include a forest model, in order to assess the impact of international climate policy on the rate of deforestation in Indonesia. If international climate policy is implemented, the total rate of deforestation would be slightly higher than in the reference scenario. However, slowing deforestation would be a profitable option for Indonesia if it can sell the resulting emission permits.

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Chapter 4

Air Pollution, Health, and Greenhouse Gas Emissions Reduction in Indonesia

Abstract

The objective of this study is to assess Indonesia's air quality and its interaction with international climate change policy. This comprises an assessment of Indonesia's air pollution levels and their impact on health and well-being. Estimates are given of concentrations of two of the major pollutants: sulfur dioxide (SO_2) and nitrogen dioxide (NO_2). Emissions are estimated for Indonesia, based on energy consumption, using the MERGE simulation model. The projection of air pollution levels for the year 2000 to the year 2100 are based on four IPCC reference scenarios A1B, A2, B1 and B2 (differing with respect to population growth, socio-economic development, and technological progress) which were augmented by applying three different mitigation scenarios based on various extensions of the Kyoto protocol.

If the OECD countries reduce their emissions, Indonesian oil consumption increases, and emissions of SO_2 and NO_2 are higher than in the reference scenarios. Health problems increase substantially, peaking in the middle of century in the A1B and B1 scenarios, and rising further to the end of century in the A2 and B2 scenarios. Health-problem costs will accordingly be highest

during the middle of the century in the A1B and B1 scenarios and toward the end of century in the A2 and B2 scenarios. With international trade in emission permits, emissions of SO_2 and NO_2 in Indonesia is higher than in the reference scenario, since more domestic oil and coal is used, creating larger health problems. The percentage of the population affected by health problems increases by 28% relative to the reference scenario. If all countries reduce their emission, including Indonesia, the total concentrations of SO_2 and NO_2 are lower than in the previous scenarios. The resulting health costs are reduced by 26% of GDP relative to the reference scenario over the 100 year simulation period.

4.1 Introduction

Indonesia is the world's fourth most populated country with a population of 215 million in 2003. More than 60% of the population lives on Java, covering only 7% of the land area of Indonesia. Gross Domestic Product (GDP) has grown around 5-6% per year during the last decade, driven by government deregulation and market oriented policies. Manufacturing and the modern service sector are making up an increasing proportion of GDP. The share of oil in GDP fell from 11.6% in 1990 to 9.6% in 1995 (MOEROI, 1999). However, air pollution caused by fossil fuel combustion remains high in Indonesia.

Soedomo *et al.* (1991) published the first air pollution maps for Indonesia, estimating the 1989 isopleths for NO_2 and SO_2, carbon monoxide (CO), and total suspended particulate (TSP) for Jakarta, Bandung, and Surabaya. In a joint BPPT-FZJ report (1993) this was extended to the entire island of Java. Shah and Nagpal (1997) studied air pollution (reduction) in the metropolitan area of Jakarta. Downing, Ramankutty and Shah (1997) report total emissions of SO_2 in Indonesia, including estimates for 2020.

Ostro (1994) estimated the health effects of air pollutants in Jakarta. Ostro found that air pollutants in Jakarta caused approximately 1,600 cases of premature mortality, 39 million cases of respiratory symptoms, and 558,000 cases of asthma attacks. Shah and Nagpal (1997) report that PM_{10} emissions (particulate matter of 10 microns in diameter or less) in Jakarta caused 4,364 excess deaths, 32 million restricted activity days, 101 million respiratory symptoms days, at a total cost of about US$ 1,638 million in 1990. Syahril *et al.* (2002) compared health problems associated with PM_{10} and NO_2 in 2015 to those in 1998. The number of health problems associated with PM_{10} for the whole of Jakarta in 2015 is estimated as approximately 2.4 times the number in 1998. For the case of NO_2, the number of health problems for the whole of Jakarta in 2015 is estimated as approximately three times the number in 1998.

In this study, we develop scenarios of total air pollution from fossil fuel consumption and its impacts for the 21st century, using an inter-temporal general equilibrium model MERGE (Model for Evaluating Regional and Global Effects of greenhouse gas reduction policies). The model is used to project energy consumption and production. We use four base scenarios from IPCC (2000), which assume that no measures are undertaken to control greenhouse gas emissions. These are further extended by applying three different mitigation scenarios, in which the Kyoto reduction measures are implemented in various versions beyond the immediate 10-year Kyoto period. The air pollution impacts are computed for all 16 scenario combinations. For this purpose, the MERGE model was extended to analyze emissions and concentrations of sulfur dioxide (SO_2) and nitrogen dioxide (NO_2), together with their impacts on human health and economic costs.

4.2 Emission scenarios in MERGE

Between 1996 and 2000, the Intergovernmental Panel on Climate Change (IPCC) developed a new set of emissions scenarios as substitutes for the IS92 scenarios. The IPCC 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. We selected four SRES scenarios (A1B, A2, B1 and B2). The set of scenarios includes anthropogenic emissions of all greenhouse gas (GHG), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOCs). In this study, we focus on SO_2 and NO_x emissions.

GHG emissions are primarily driven by population growth, socio-economic development, and technological progress. Three different population trajectories were chosen for SRES to reflect future demographic uncertainties

(Lutz, 1996; UN, 1998). These are exogenous inputs to MERGE. The A1 and the B1 scenarios families assumed the lowest population (7 billion) trajectory, based on Lutz' (1996) projection, which combines low fertility with low mortality and central migration rate assumptions. The B2 family scenario is the UN median population projection (UN, 1998), in which the global population increases to about 10 billion in 2100. It is characteristic of recent median global population projections, which continue historical trends as a demographic transition settling at a constant global population. The high population growth of 15 billion by 2100 used in the A2 family scenario (Lutz, 1996) is characterized by heterogeneous fertility patterns that remain above replacement levels in many regions, but nonetheless decline compared to current growth levels.

The gross world product ranges across the scenarios from US$ 250 trillion to US$ 550 trillion by 2100. The upper bound is the A1 scenario; the A2 and B2 scenarios form the lower bound. The B1 scenario reaches US$ 350 trillion by 2100.

We adjusted the MERGE model to the SRES scenarios as follows. We added two constraints to the optimization of MERGE, namely global population and global gross domestic product (GDP) by 2100. These quantitative targets ensure that MERGE matches SRES. Technological progress in the energy sector, the third major component of SRES, is calculated endogenously in MERGE. The Autonomous Energy Efficiency Improvement (AEEI) is proportional to the annual growth rate of per capita income in SRES. Fortunately, the calculated AEEI in MERGE at least qualitatively matches SRES. The total AEEI growth rates between 2000 and 2100 are 1.53% per year in the A1B scenario, 0.84% per year in the A2 scenario, 1.36% per year in the B1 scenario, and 0.95% per year in the B2 scenario (Table 4.1).

Table 4.1 Total growth in the IPCC base scenarios between 2000 and 2100 (resume for Indonesia)

Set	*A1B*	*A2*	*B1*	*B2*
Population growth (% per year)	0.14	0.87	0.14	0.59
GDP growth (% per year)	4.08	3.03	3.63	3.07
Per capita GDP growth (% per year)	3.93	2.15	3.48	2.46
AEEI (% per year)	1.53	0.84	1.36	0.95

Except for the Indonesia, the growth domestic product data used in this study for 2000 to 2020 are from EIA (2004), using a mean (the reference case) and high and low projections.

The SRES scenarios do not have data for Indonesia specifically. We used historical and projected population data from UN (2003). These contain population projections from 2000 to 2050, with three different variants: low, medium, and high. The GDP data for Indonesia are taken from the AIM model (Morita and Lee, 1999). We extrapolated the population and GDP data projections for the years 2000 to 2050 to 2100, using the same growth rates. Table 4.1 shows the resulting total growth between 2000 and 2100 for the SRES scenarios.

4.3 Economic and energy development of Indonesia

Indonesia's population grew from 175 million in 1988 to 207 million in 1998. The growth rate of population was 2.3% per year between 1970 and 1980; the growth rate declined to 2% per year for 1985-1988, further declining to 1.5% per

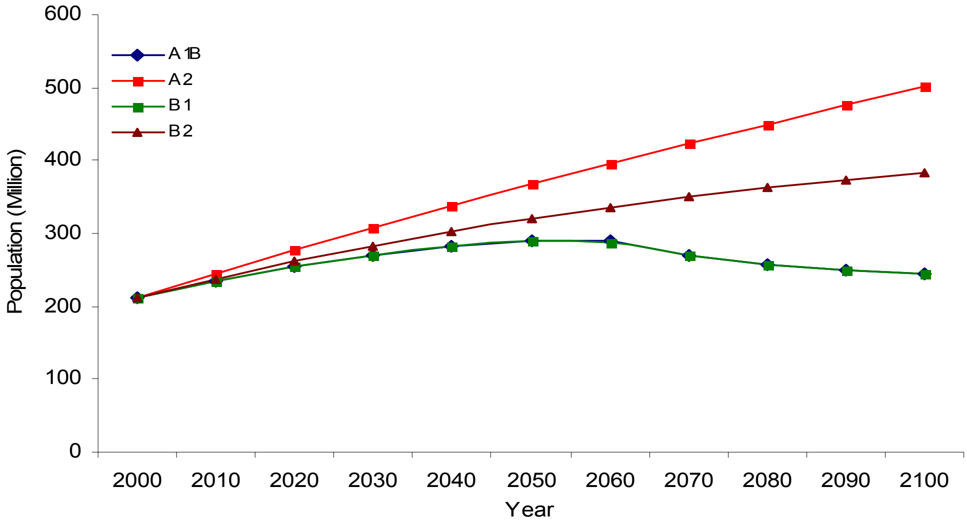


Figure 4.1 Population of Indonesia

year during the last decade (World Bank, 1997). In MERGE, Indonesian population increases from 212 million in 2000 to 244 million in 2100 in the A1B and the B1 scenarios (Figure 4.1), with annual growth rates dropping from 1.6% in 2000 to -0.2% by the end of century. These scenarios are based on a variant of the low population projection. The highest population trajectory in Indonesia will reach 502 million in 2100 (A2 scenario); the average Indonesian population growth rate over 100 years is 0.87% per year (Table 4.1). For the median population projections, in the B2 scenario, Indonesian population increases to 384 million in 2100; the average Indonesian population growth rate over 100 years is 0.59% per year (Table 4.1).

The gross domestic product (GDP) of Indonesia was about US$ 153 billion in 2000. This increases exponentially to US$ 8,199 billion in 2100 in the A1B scenario (Figure 4.2); the Indonesian economy is projected to expand at an average annual rate of 4.08% between 2000 and 2100 (Table 4.1). In the A1B scenario, per capita income of Indonesia increases from US$ 722 in 2000 to US$ 33,600 in 2100 (Figure 4.3), with an average annual growth of 3.93% between 2000 and 2100 (Table 4.1). The average Autonomous Energy Efficiency Improvement rate between 2000 and 2100 is also the highest among the SRES scenarios, at 1.53% per year (Table 4.1). The A2 scenario is distinguished by

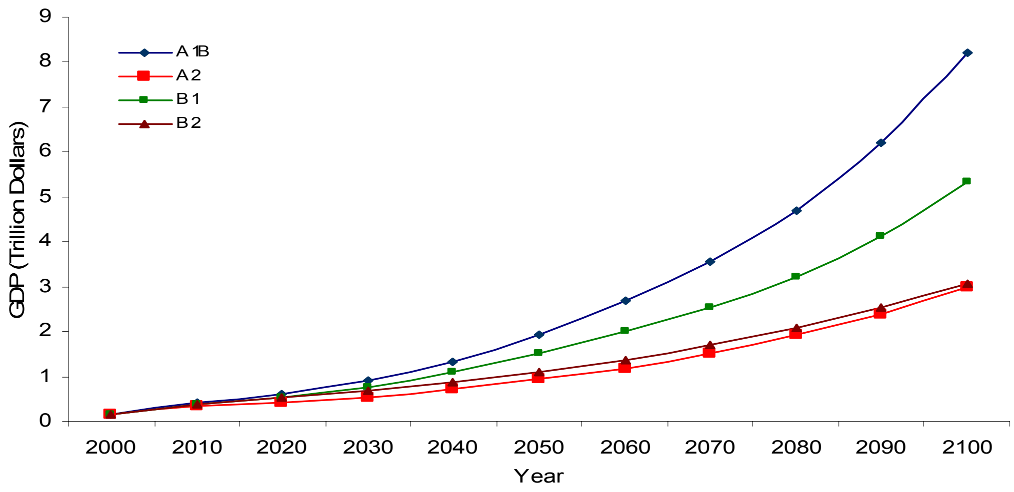


Figure 4.2 Growth domestic product (GDP) of Indonesia – Reference scenario

relatively slower productivity growth rates. The GDP average (2000-2100) growth rate is 3.03% per year (Table 4.1), combined with a slow demographic transition that underlies A2's high population growth. Per capita income in the A2 scenario is the lowest in the SRES scenarios, achieving only US$ 5,976 in 2100 (Figure 4.3). In the B1 scenario, GDP reaches US$ 5,329 billion in 2100, which corresponds to an average growth rate of 3.63% per year between 2000 and 2100 (Table 4.1). Per capita GDP in the B1 scenario is lower than in the A1B scenario, reaching US$ 21,840 in 2100, with an average growth of 3.48% per year (Table 4.1). The AEEI over the next 100 years is on average about 1.36% per year (Table 4.1). Indonesian GDP in the B2 scenario is assumed to increase at an average annual rate of 3.07% between 2000 and 2100 (Table 4.1) and is close to the median GDP growth in the A2 scenario (Figure 4.2). In the B2 scenario, per capita GDP and energy efficiency grow by 2.46% per year and 0.95% per year, respectively (Table 4.1). Per capita income in the A2 scenario reaches about US$ 8,018 by 2100, with a growth of 2.15% per year. The AEEI is only 0.84% per year (Table 4.1).

In order to analyze the impact of international climate policy on air pollution in Indonesia, we developed in addition to the reference scenario set three sets of reduction scenarios. The four sets are specified in Table 4.2. The first set is the

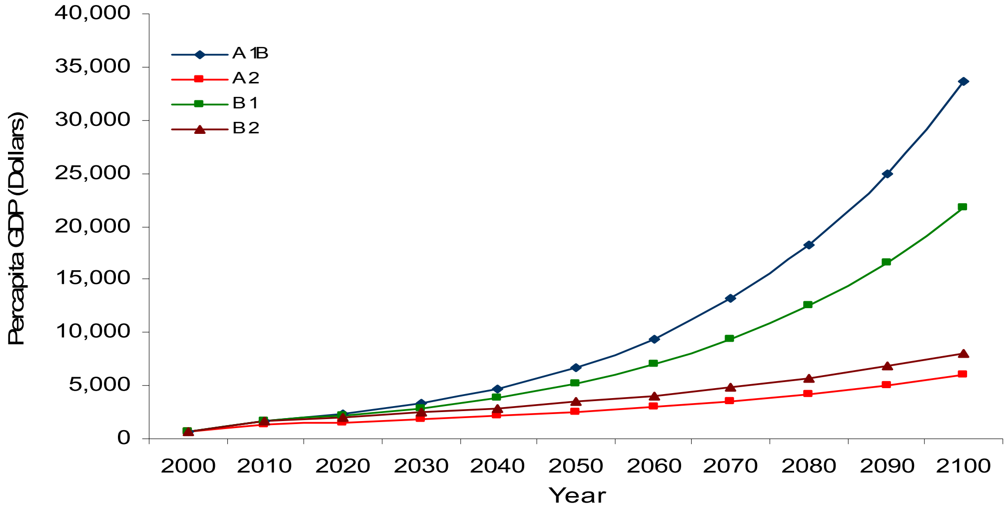


Figure 4.3 Per capita GDP of Indonesia – Reference scenario

Table 4.2 The International emissions reduction scenarios

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

reference scenario set without a GHG emission reduction policy. In the second set (Kyoto Annex B scenario), we assume that all Annex B countries (except the USA) adopt the Kyoto Protocol with a five percent emission reduction per decade in the years after 2010. In the third set, we add international trade in emission permits. In the fourth set, finally, we assume that all countries, including Indonesia, accept targets to reduce emissions. The results of these 16 scenarios are described below.

4.4 Emission in Indonesia

Total carbon emissions are shown in Figure 4.4 for the four SRES scenarios and the mitigation scenarios. In the A1B reference scenario, carbon dioxide emissions grow from 64 million tonnes of carbon in 2000 to 102 million tonnes of carbon in 2100; in the other IPCC scenarios, the emissions in 2100 are slightly lower. All carbon dioxide emissions peak around 2050. The highest emission for the reference scenarios is 320 million tonnes of carbon for the A2 scenario. The emissions for the different scenarios lie close together because the differences in AEEI largely offset the differences in population and economic growth.

If the OECD reduces their emissions as specified above without trade in emission permits, the gas price rises and Indonesia burns more coal. CO_2 emissions increase, peaking at 386 million tonnes of carbon in the B1/KAB scenario (Figure 4.4). With international trade in emission permits, total CO_2 emissions are higher still, but the pattern remains the same (Figure 4.4). If all countries reduce their emission, CO_2 emissions are lower than in the reference scenario. Under this scenario, Indonesian CO_2 emissions peak earlier than in the other scenarios (Figure 4.4).

A simple and popular method to represent emissions is as the product of an emission coefficient times the energy consumption (Changhong *et al.*, 2001). The emission coefficients of pollutants used in this study are based on different types of fuels in Indonesia, as reported by Sasmojo *et al.* (1997) in the ALGAS Report (Table 4.3). Emission coefficients are not constant over time, however.

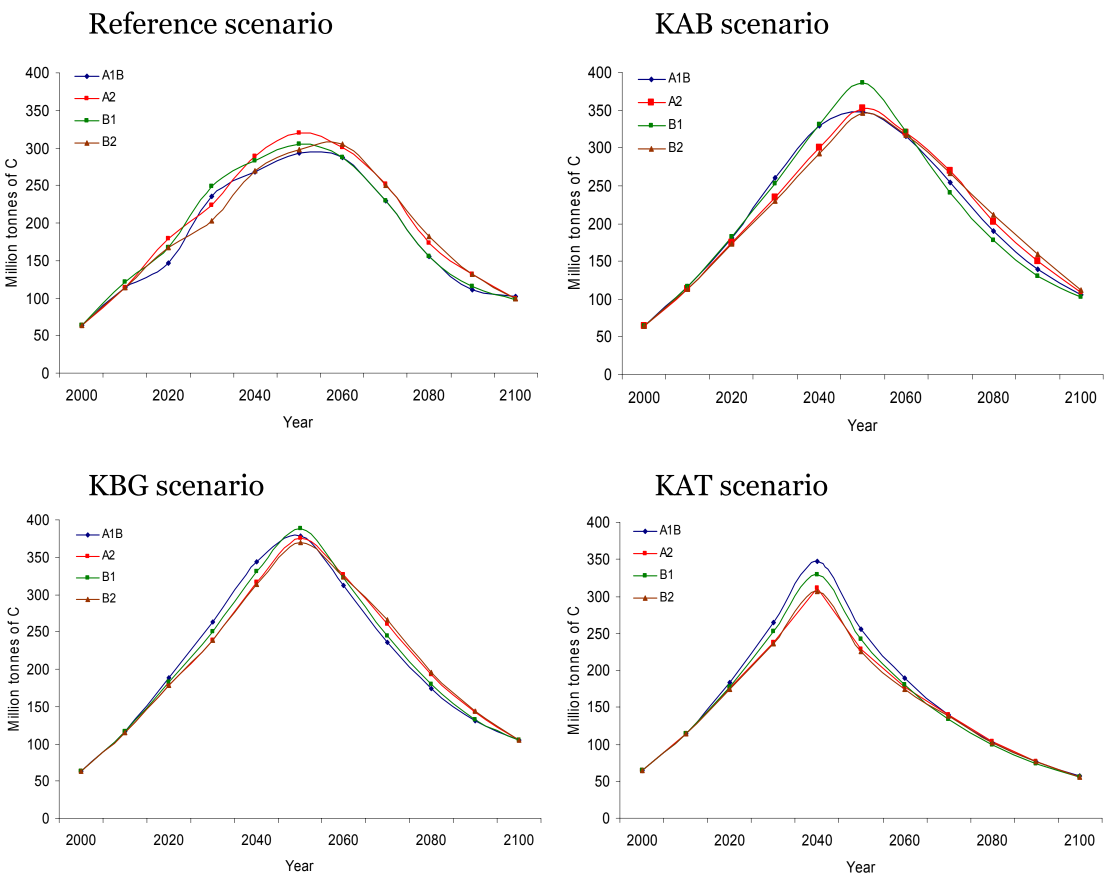


Figure 4.4 Total carbon emissions of Indonesia

We use the environmental Kuznets curve (EKC) to describe the relationship between various indicators of environmental degradation and income per capita.

Selden and Song (1994) suggest the following relationship between per capita emissions, m, and real per capita GDP, y:

$$m_t = \beta_0 + \beta_1 y_t + \beta_2 y_t^2 + \varepsilon_t \qquad (4.1)$$

where t is a time index, ε is a disturbance term with mean zero and finite variance and β_0, β_1, and β_2 are regression parameters of EKC by Selden and Song (1994), as shown in Table 4.4. The turning point is $-\beta_1 / 2\beta_2$.

Table 4.3 Emission coefficient of Indonesian pollutants

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

Source: Sasmojo *et al.*, 1997

Table 4.4 Estimation EKC results

Parameter	*Sulfur dioxide*	*Nitrogen oxides*
β_0	-148.41 (335.9)	-54.832
β_1	201.26 (73.85)	73.524 (44.46)
β_2	-9.4216 (4.070)	-1.4796 (1.800)
Turning point (US$ per capita)	10,681	12,041

Source: Selden and Song, 1994

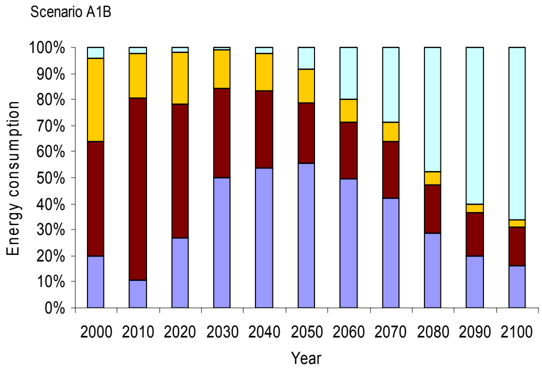
Computations of the emission predictions for sulfur dioxide (SO_2) and nitrogen oxide (NO_x) for the fossil fuel energy consumption curves computed with the MERGE model for the 16 scenarios considered in this study are shown in the following section.

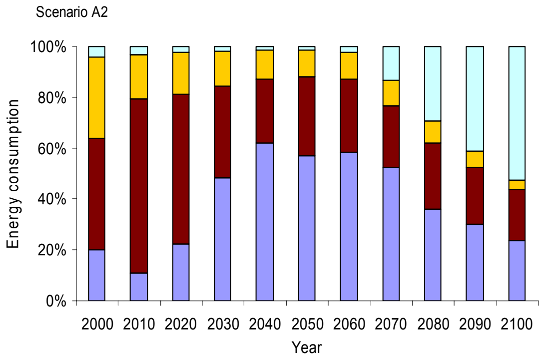
4.4.1 Sulfur dioxide

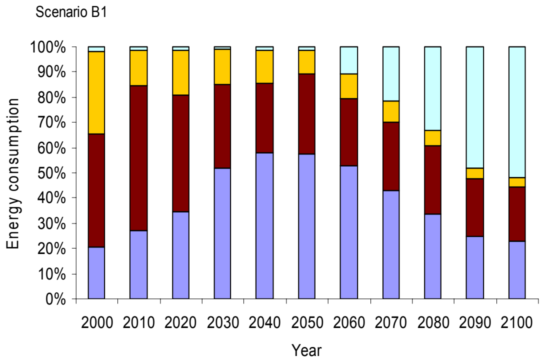
In the energy sector, emissions of sulfur dioxide (SO_2) are mainly produced by burning coal and oil. The government of Indonesia estimated the emissions at 0.8 million metric tons of SO_2 in 1995 (MOHROI, 2003). In MERGE, sulfur dioxide emissions in 2000 are 1.4 million metric tons (Figure 4.6), higher than the 1.1 million metric tons of SO_2 that Downing, Ramankutty, and Shah (1997) report. If present energy and environmental policies remain unchanged, rapid economic development in Indonesia leads to an unprecedented increase in sulfur dioxide emissions. In the A1B scenario, sulfur dioxide emissions rise to 2.8 million metric tons $_2$ in 2010, while Downing, Ramankutty, and Shah (1997) projected 1.9 million metric tons in 2010 using the RAINS-ASIA model. The emissions of SO_2 increase exponentially to a peak of 81 million metric tons around 2060, and fall thereafter. In this scenario, coal consumption increases rapidly after 2010. In the A2 scenario, SO_2 emissions increase rapidly to 2070, reaching 83 million metric tons, falls for a decade, and then start rising again. The percentage of oil use in this scenario is higher than in the A1B scenario, especially during the first half of the century. Sulfur dioxide emissions in the B1 scenario are higher than in the B2 scenario up to 2060, increasing exponentially to 76 million metric tons (Figure 4.6), and then fall to 9 million metric tons in 2100. In the B2 scenario, emissions of SO_2 increase substantially up to the middle of century, peaking at 63 million metric tons in 2060, and then decrease gradually to 53 million metric tons in 2100. In this scenario, Indonesian energy consumption is dominated by coal after 2010, while oil consumption decreases rapidly.

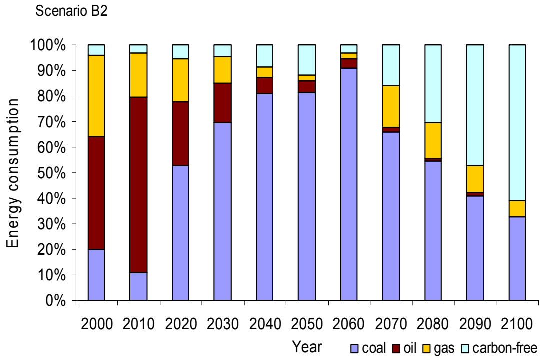
If the OECD countries reduce their emissions, emissions of SO_2 in Indonesia are higher than in the reference scenario. In the A1B/KAB and B1/KAB scenarios, emissions increase exponentially up to the middle of century, peaking at 94 million metric tons (A1B/KAB) and at 93 million metric tons (B1/KAB) in 2060.

Reference scenario

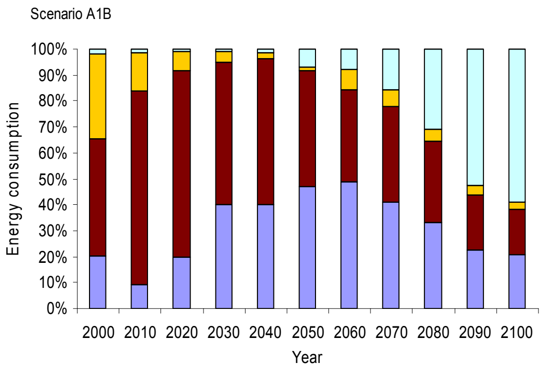


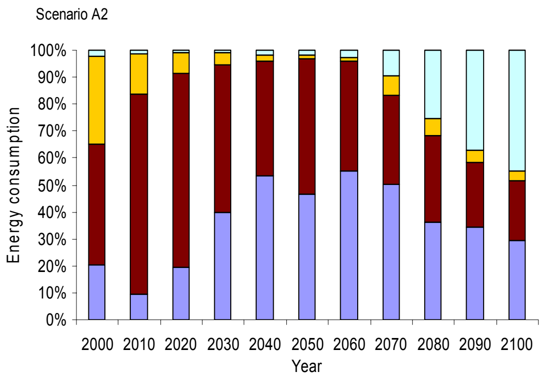


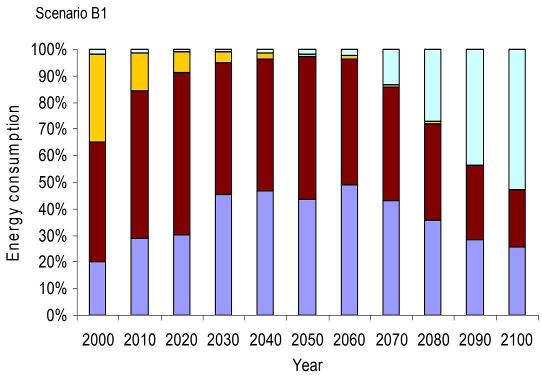


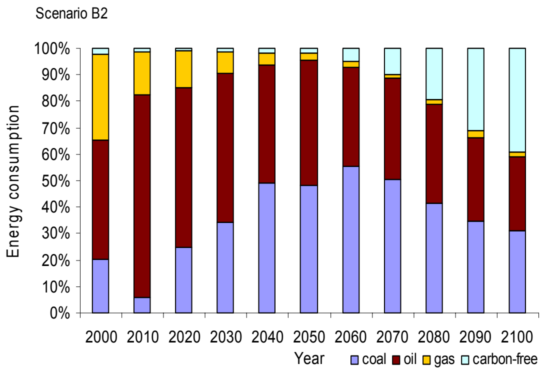


KAB scenario

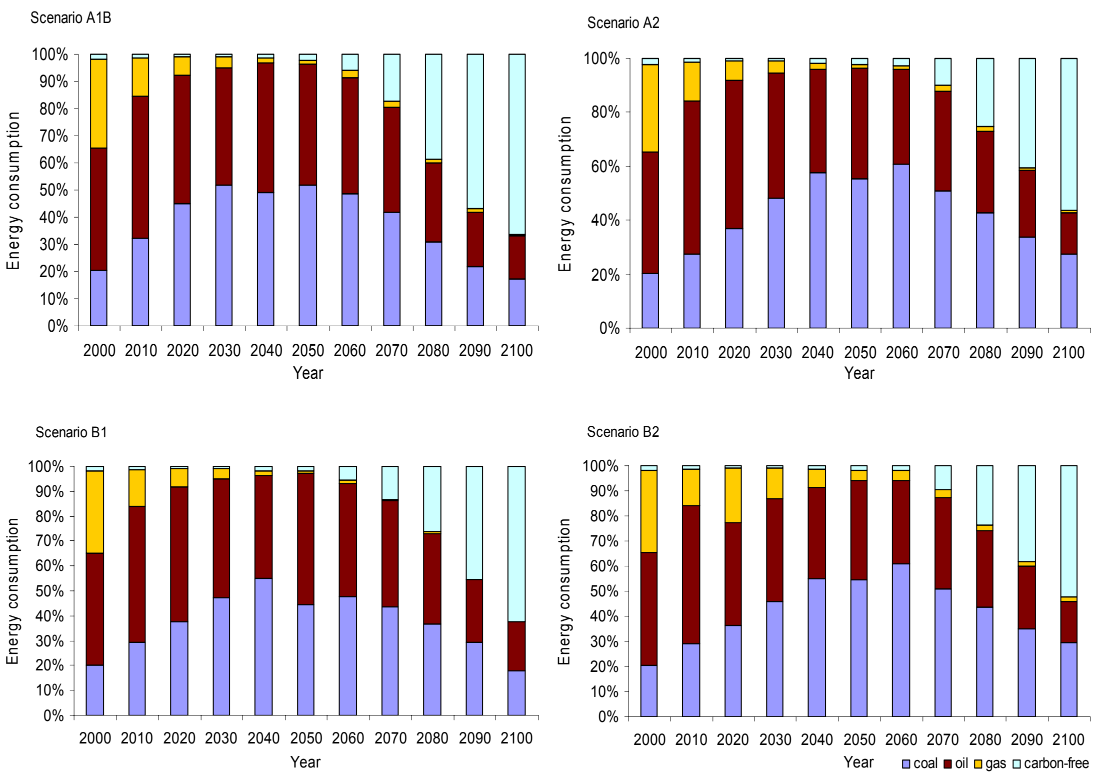








KBG scenario



KAT scenario

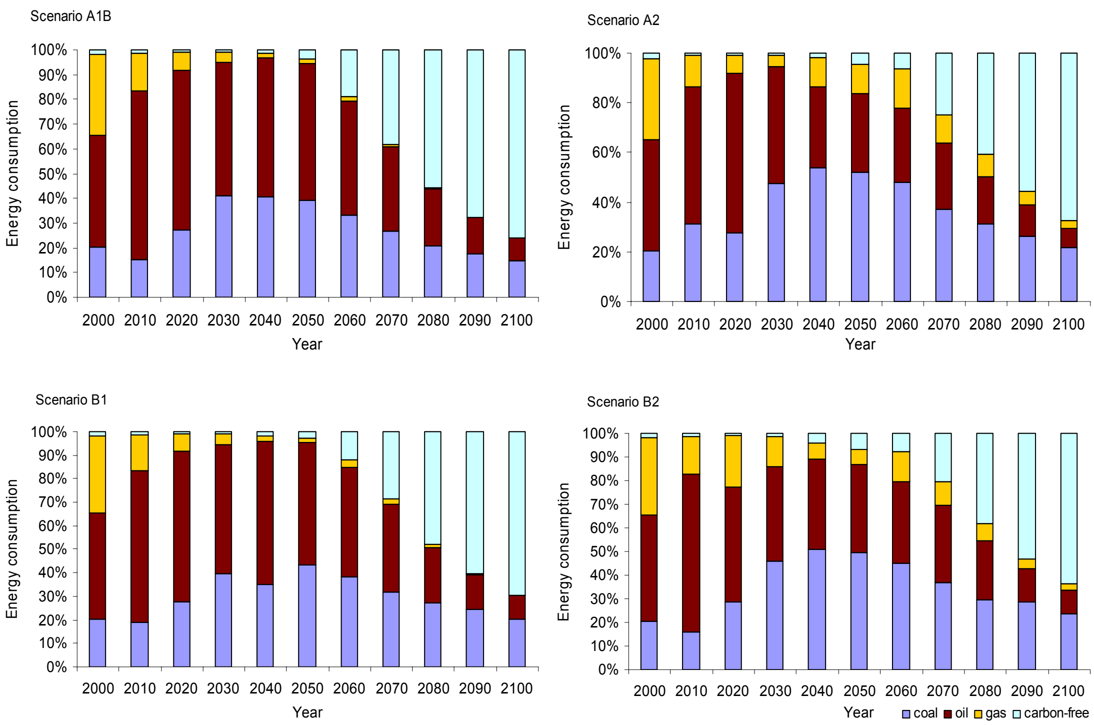


Figure 4.5 Energy consumption of Indonesia

In the B1/KAB scenario, oil is the dominate energy source from 2030 to 2070 (Figure 4.5). The emissions fall to 3.9 million metric tons by the end of century in the A1B/KAB scenario, lower than in the B1/KAB scenario with 9.2 million metric tons in 2100 (Figure 4.6). In the A2/KAB scenario, SO_2 emissions increase substantially to 94 million metric tons in 2070, then decrease to 77 million metric tons in the next decade and increase again to 84 million metric tons by the end of century. In the B2/KAB scenario, emissions increase to 74 million metric tons of SO_2 in 2070, decreasing slightly to 59 million metric tons of SO_2 by the end of century.

With international emission-permits trade (KBG scenarios), the total emissions of SO_2 are still higher than in the reference scenarios (Figure 4.6). In the A1B/KBG scenario, more oil is imported to meet domestic demand. Emissions of SO_2 increase rapidly to 99 million metric tons in 2050, then fall to the end of century. In the A2/KBG scenario, SO_2 emissions increase to 95 million metric tons in 2070, then decrease slightly to 2090. Emissions in the B1/KBG scenario increase rapidly to 95 million metric tons in 2060, falling to 8 million metric tons in 2100. Emissions of SO_2 are lowest in the B2/KBG scenario.

If all countries accept emission reduction targets in the future (KAT scenarios), sulfur dioxide emissions increase substantially up to 2040 in the A2/KAT and B2/KAT scenarios, rising to 42 million metric and 40 million metric tons, respectively. These values are 9% and 24.5% higher in 2040 than in the A2 and B2 reference scenarios, respectively. Later, emissions in the A2/KAT and B2/KAT scenarios increase more slowly, stabilizing towards the end of century. In the A1B/KAT scenario, emissions of SO_2 rise to 62 million metric tons in 2040, corresponding to a decrease of 29.6% compared to the peak of emissions in the A1B of reference scenario, and then fall to the end of century. Emissions of SO_2 in the B1/KAT scenario increase to 56 million metric tons in the middle of century, 26.6% lower than the highest emissions in the B1 reference scenario, then fall to 8 million metric tons in 2100. In summary, greenhouse gas

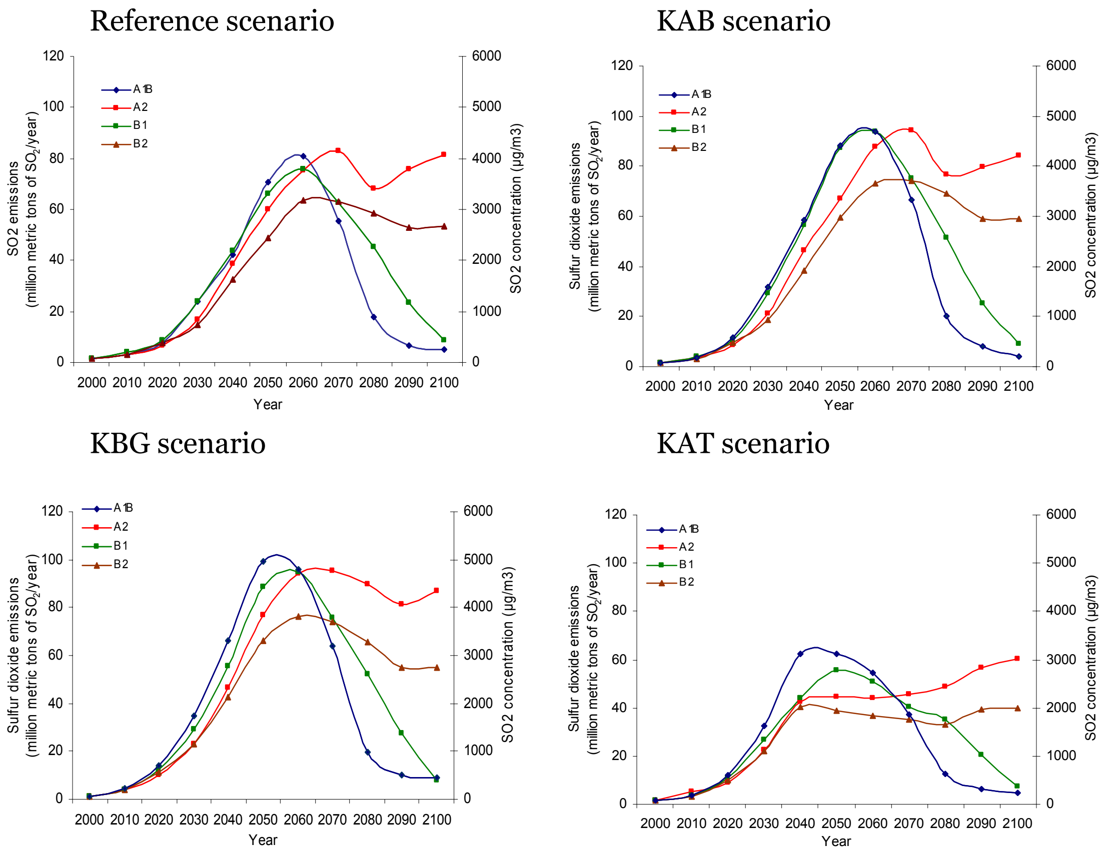


Figure 4.6 Sulfur dioxide emissions and ambient concentration of Indonesia

emissions reduction changes the fossil fuel consumption levels and patterns, leading to a decrease in air pollution, particularly in later years. This effect is generally more important than other factors such as changes in the per capita income of Indonesia.

4.4.2 Nitrogen oxide

Indonesia's gross domestic product (GDP) grew even faster than its population during the last two decades. However, because environmental controls were not rigorously enforced, Indonesia experienced significant environmental degradation during this period (EIA, 2004). In the reference scenarios, GDP growth increases more rapidly towards the end of the century, especially in the A1B scenario (figure 4.2). Nitrogen oxide (NO_x) emissions generally increase until the middle of the century in all reference scenarios, and can then either stabilize or decrease again, depending on Indonesian energy use of coal and oil, the main source of NO_x emissions (figure 4.7).

In 1995, Indonesia's emissions of NO_x were about 1.4 million metric tons of NO_x (MOHROI, 2003). In the A1B scenario, NO_x emissions increase substantially from 2.4 million metric tons in 2000 to 5 million metric tons in 2010 (higher than the 3 million metric tons projected by Van Aardenne *et al.,* 1999), increasing further to 108 million metric tons in 2060, and then fall to 7 million metric tons in 2100 (Figure 4.7). In the A2 scenario, emissions of NO_x rise to 125 million metric tons in 2070, fall for a decade and rise again to 133 million metric tons at the end of century. Emissions of NO_x in the B1 scenario peak at 85 million metric tons in 2060, and fall to 26 million metric tons in 2100. In the B2 scenario, emissions rise to 88 million metric tons in 2070, falling gradually thereafter.

If the OECD countries reduce their emissions (KAB scenarios), emissions of NO_x are higher than in the reference scenarios (Figure 4.7) as a result of increasing oil imports (Figure 4.5). In the A1B/KAB scenario, emissions of NO_x peak at 132 million metric tons in 2060, whereas in the B1/KAB scenario emissions are slightly higher at 138 million metric tons at this time. In the A2/KAB and B2/KAB scenarios, emissions of NO_x rise to 146 million metric tons and 105 million metric tons, respectively in 2070.

With international trade in emission permits (KGB scenarios), oil and coal prices fall. Indonesia increases its oil imports, resulting in increasing emissions of NO_x for all scenarios during the first half of the century. Emissions of NO_x in the A1B/KBG scenario peak at 126.9 million metric tons in the middle of century, the highest level of all scenarios. The emissions of NO_x in the B1/KBG scenario peak in 2060 at 137 million metric tons. In the A2/KBG and B2/KBG scenarios, emissions of NO_x peak in 2070 at 143 million metric tons, and 103

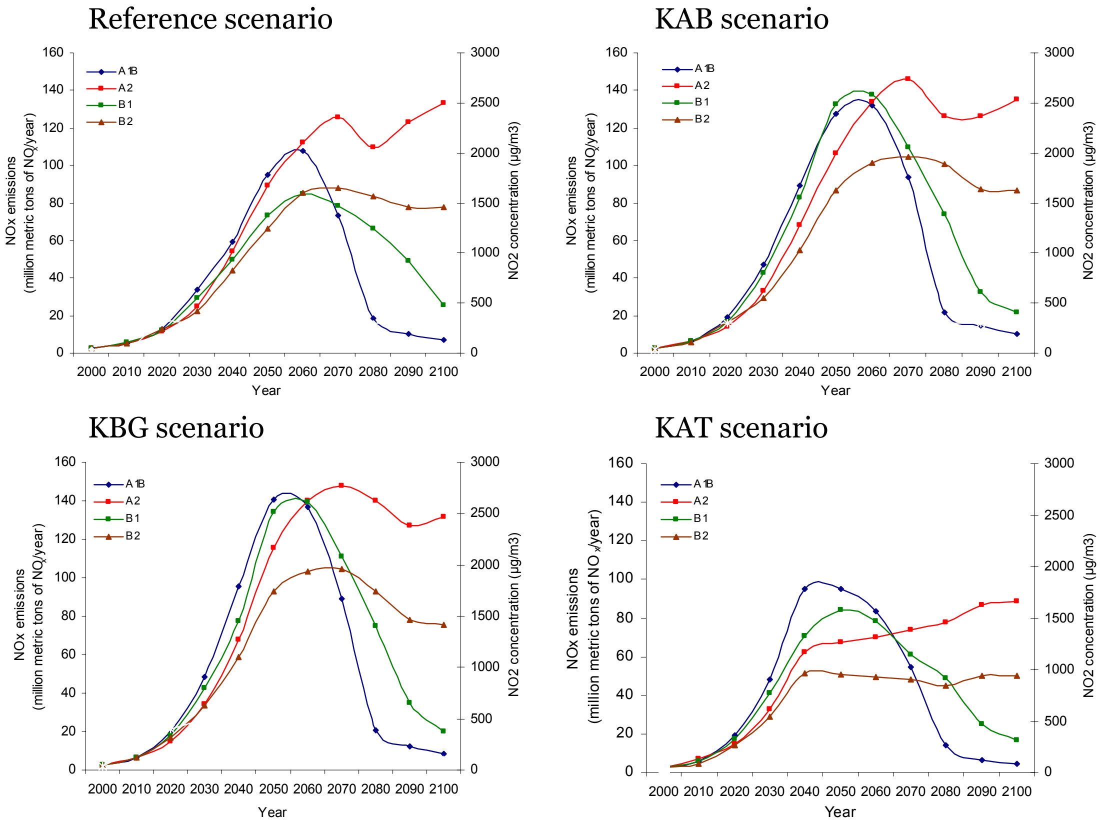


Figure 4.7 Nitrogen oxide emissions and NO_2 ambient concentration of Indonesia

million metric tons, respectively. After 2070, emissions decrease more gradually to the end of century.

If all countries reduce their emissions (KAT scenarios), emissions of NO_x in the A1B/KAT scenario still increase significantly up to 2040, although the peak is 11.7% lower than the peak at 2060 in the A1B reference scenario. Emissions then fall again, relatively fast up to 2080, and more slowly for the rest of the century. In the B1/KAT scenario, emissions increase gradually to 84.3 million metric tons by 2050, which is slightly higher than the peak at 2060 in the B1 reference scenario, and then fall gradually to the end of century. In the A2/KAT and B2/KAT scenarios, emissions increase gradually to 2040, then increase more slowly in the A2/KAT scenario while decreasing in the B2/KAT scenario to 2100. At the end of century, emissions of NO_x in the A2/KAT and B2/KAT scenarios are lower by 51% and 36%, respectively, than in the corresponding reference scenarios A2 and B2. Starting in 2060, fossil fuel is rapidly replaced by alternative energies with low emissions in these scenarios (Figure 4.5), which has a strong impact on NO_x emissions.

4.5 Air pollution concentration and impact on health

Indonesia is an archipelago between the Indian Ocean and the Pacific Ocean, consisting of 17,508 islands that cover 1,904,500 km^2 of land. The average thickness of the lower atmosphere (the troposphere) over the equator is 16 km (Campbell, 1986; Lamb, 1982). The troposphere contains most of the gaseous mass of the atmosphere, as well as nearly all of the water vapor and aerosols (Barry and Chorley, 1992). We assume that the thickness of the Indonesian atmosphere averages 14 km rather than 16 km, to capture the effect of Indonesia as an archipelago rather than the open ocean. From the energy consumption of Indonesia we calculated yearly averages of the concentrations of air pollutant with respect to the volume of the Indonesian atmosphere. We neglect meteorological and chemistry aspects which influence these concentrations. Our estimates of the concentration trends of air pollutant are therefore the same as the emission trends of air pollutant, except for the units. The units for the ambient concentrations of sulfur dioxide and nitrogen dioxide are indicated on the right-hand axis of the corresponding emission figures 4.6 and 4.7.

The evaluation of health outcomes is a critical component in determining the social cost of air pollution, as it allows the application of cost-benefit analysis in setting priorities for policy. In the following we derive quantitative estimates of the health effects (benefit/damage) of air pollution in Indonesia for our set of emission scenarios. Within the framework of risk assessment, the health effects can be described in term of the dose response to air pollution. A dose-response function is a formula to calculate the percentage of people that will contract a certain health problem when exposed to an air pollutant concentration above a certain threshold level.

There are methods for the quantification of social costs of air pollution and the application of these costs to appraise the potential benefits of alternative strategies of air pollution control. We apply these methods to derive quantitative estimates of the benefits of reducing ambient concentrations of two pollutants: sulfur dioxide and nitrogen dioxide. We use the general dose-response functions of Ostro (1994), since functions derived for Indonesia are not yet available. In our model, we used the ambient level of air pollutant based on World Health Organization (WHO) air quality guidelines. The standards are presented in Table 4.5, together with the national ambient air quality standards (AAQS) in Indonesia, based on the Government Decree of Republic of Indonesia No. 41 (1999), and the AAQS standards of the United States Environmental Protection Agency (US-EPA).

The estimated health impact can be represented in the form

$$dH_i = b_i * P_i * dA \qquad (4.2)$$

where:

dH_i	is the change in the number of people that contract health effect *i* or number of cases for health problem *i*
b_i	is the slope of the dose-response function
P_i	is the population at risk of health effect *i*
dA	is the change in the ambient level of a given air pollutant above the WHO air quality guidelines

The slope of the dose-response function indicates the additional health problem caused by a unit increase of given air pollutant above the WHO guidelines. We consider in this study specifically the impact of ambient levels of SO_2 and NO_2 for the period 2000 to 2100. The relevant dose-response functions are presented below.

Table 4.5 Ambient air quality standards for annual averaged (micrograms/m^3 of air)

Pollutant	*Indonesia*	*EPA*	*WHO*
Total Suspended Particles (TSP)	90	n.a.	n.a.
Lead (Pb)	1.0	n.a.	0.5
Nitrogen Dioxide (NO_2)	100	100	40
Sulfur Dioxide (SO_2)	60	80	50
Ozone (O_3)	100	n.a.	n.a.

Note: n.a. signifies standards with averaging time other than annual average

4.5.1. The case of sulfur dioxide

Dose-response functions for ambient levels of SO_2 are available in the epidemiological literature for premature mortality, lower respiratory illnesses among children (*LRI*) and chest discomfort among adults (*CDA*) (eqs. (4.3)-4.5), see Ostro, 1994, for details on the background studies).

Premature mortality:

$$NP(t) = \begin{cases} 0.048 * \left[\dfrac{SO_2(t) - SO_2st}{SO_2st} \right] * P(t) * CM(t) & \text{for} \quad SO_2(t) > SO_2st \\ 0 & \text{for} \quad SO_2(t) \le SO_2st \end{cases} \tag{4.3}$$

where:

NP(t)	is the number of premature mortality in year *t*
$SO_2(t)$	is the annual average ambient level of SO_2 (μg/m^3) in year *t*
SO_2st	is the standard for allowable SO_2 annual average concentration
P(t)	is the population in year *t*
CM(t)	is the crude mortality rate for Indonesia in year *t*

The crude mortality rate (i.e mortality for all causes of death for the entire population) in Indonesia were 10.9 per 1000 people in 1980, 7.9 per 1000 in 1990 and 7.5 per 1000 in 2000, corresponding to a decrease of about 31% over these two decades (MOHROI, 2001). Lutz (1996) estimated that the crude mortality rate of Indonesia will decline to around 7.0 per 1000 people by the year 2020, at a rate of -3% per decade. We further assume that the crude mortality rate of Indonesia in 2100 will be close to the average of the crude mortality rate of countries with 2002 incomes close to the projected Indonesian income in 2100. The crude mortality rate in 2100 is set at 9.3 per 1000 people in the A1B scenario, at 7.6 per 1000 people in the A2 scenario, and at 12.5 and 8.4 per 1000 people in the B1 and B2 scenarios, respectively. The crude mortality rates are interpolated linearly for the years between 2020 and 2100.

Thus, between 2020 and 2100, the crude mortality rate of Indonesia increase gradually by 3.5% per decade in the A1B reference scenario, more slowly by 0.9% per decade in the A2 scenario, very rapidly by 7.4% per decade in the B1 scenario and moderately at 2.2% per decade in the B2 scenario.

Below, we give the dose-response relationships for selected diseases as a function of the concentrations of SO_2 and NO_2.

Lower respiratory illnesses among children (LRI):

$$NLRI(t) = \begin{cases} 0.00018 * \left[\dfrac{SO_2(t) - SO_2st}{SO_2st} \right] * PrC(t) * P(t) & \text{for} \quad SO_2(t) > SO_2st \\ 0 & \text{for} \quad SO_2(t) \leq SO_2st \end{cases} \tag{4.4}$$

where:

NLRI(t)	is the number of *LRI* in year *t*
PrC(t)	is the proportion of children in year *t*

For the year 2000, the proportion of children under 14 years in Indonesia was 35.7% (Syahril *et al.*, 2002). We use the projected number of children in Southeast Asia up to 2050 from Westley (2002) and then extrapolated the number to 2100 on the basis of the 2000-2050 growth rates.

Chest discomfort among adults (CDA):

$$NCDA(t)=\begin{cases} 0.010*\left[\dfrac{SO_2(t)-SO_2st}{SO_2st}\right]*PrA(t)*P(t) & for \quad SO_2(t)>SO_2st \\ 0 & for \quad SO_2(t)\le SO_2st \end{cases} \tag{4.5}$$

where:

NCDA(t) is the number of *CDA* in year *t*

PrA(t)[2] is the proportion of adults in year *t*

In the A1B scenario, air pollutants in Indonesia caused 614 cases of premature mortality in 2000 or 0.0002% of the population (Figure 4.8a), 6 thousand cases of respiratory illnesses among children or 0.0072% of the under-age population (Figure 4.8b), and 55 thousand cases of chest discomfort among adults or 0.04% of the adult population (Figure 4.8c). These are associated with an SO_2 concentration of 70 µg/m^3 (Figure 4.6, right-hand axis), which exceeds the WHO and Indonesian AAQS (Table 4.5). In the A1B and B1 reference scenarios, concentrations of SO_2 increase strongly to 2060, and then fall to the end of the century, while in the A2 and B2 scenarios, concentrations of SO_2 also increase to 2070, but then remain fairly constant until the end of the century, (see discussion of the emissions, Figure 4.6, left-hand axis)

In the A1B scenario, the number of premature mortality cases increases to 0.031% of the population in 2060, falling to 0.002% by the end of century (Figure 4.8a). In the A2 scenario, the number of premature mortality case increases to 123 thousand cases, or 0.029% of the population, in 2070 and

[2] The proportion of Indonesian adults in year *t* [PrA(t)] is 100% - PrC(t)

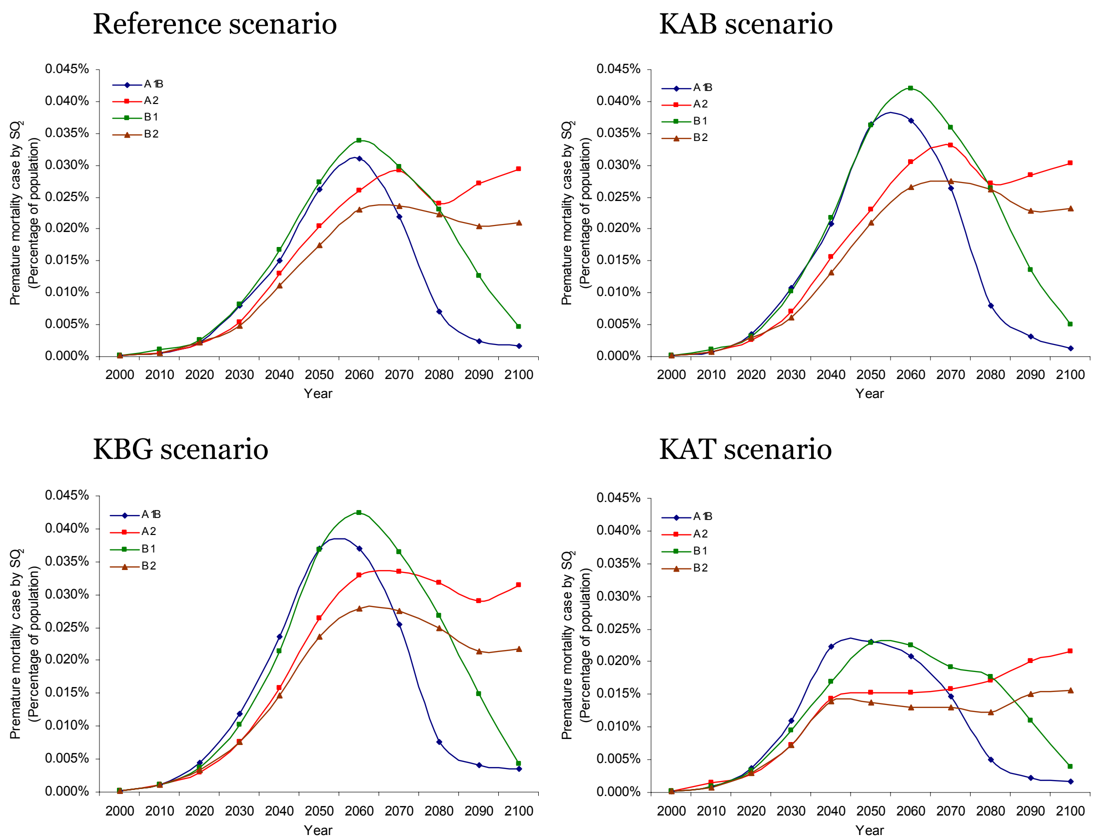


Figure 4.8a Estimated premature mortality cases associated with SO_2 in Indonesia

fluctuates around this value thereafter. The percentage of premature mortality cases peaks at 0.034% of the population (the highest of the four reference scenarios) in 2060 in the B1 scenario and at 0.024% in 2070 in the B2 scenario, the mortality rates then decreasing towards the end of the century in both scenarios.

If OECD countries reduce their emission (KAB scenarios), the peaks of SO_2 concentration are higher than in the reference scenarios (Figure 4.6, right-hand axis). In the A2/KAB scenario, the highest number of premature mortalities is 0.033% of the population in 2070, while in the A1B/KAB and B1/KAB scenarios, the peaks are in 2060 at 0.037% and 0.042% (the highest overall value), respectively. In the B2/KAB scenario, premature mortality peaks at 0.028% of the population in 2070, decreasing to 0.023% at the end of century (Figure 4.8a).

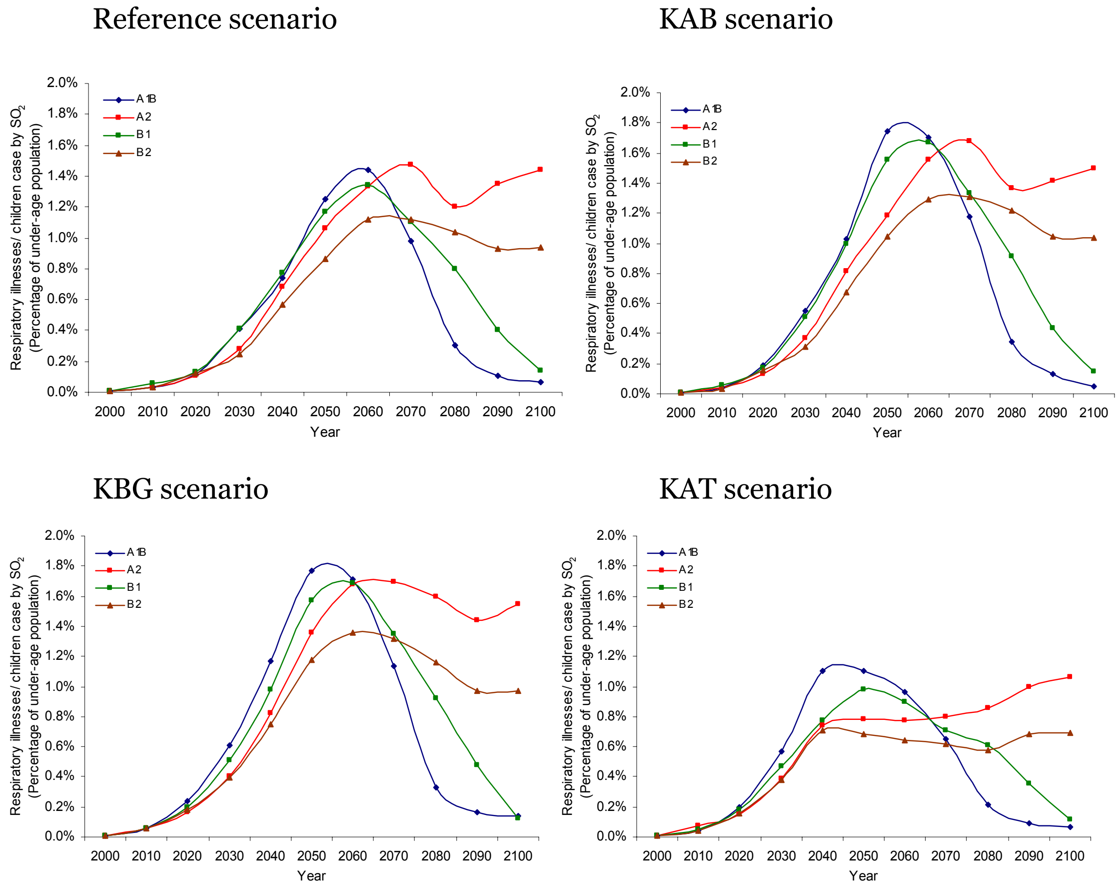


Figure 4.8b Estimated respiratory illnesses among children (*LRI*) cases associated with SO_2 in Indonesia

With international trade in emission permits (KBG scenarios), SO_2 concentrations are still higher than in the reference scenarios (Figure 4.6, right-hand axis). The highest SO_2 concentration in the A1B/KBG scenario is 4,795 μg/m³ in 2060 (Figure 4.6, left-hand axis), which would cause 108 thousand cases of premature mortality, or 0.037% of the population. This is approximately 31 times the 2010 death toll. The number of premature mortalities in the A2/KBG scenario increases to 0.033% of the population in 2070 and remains fairly constant thereafter (Figure 4.8a). In the B1/KBG scenario, the number of premature mortality rises rapidly to 0.042% of the population (the highest population percentage) in 2060, and then falls again. The number of cases in the B2/KBG scenario is projected to peak at 0.028% of the population in 2060, decreasing to 0.022% of the population in 2100.

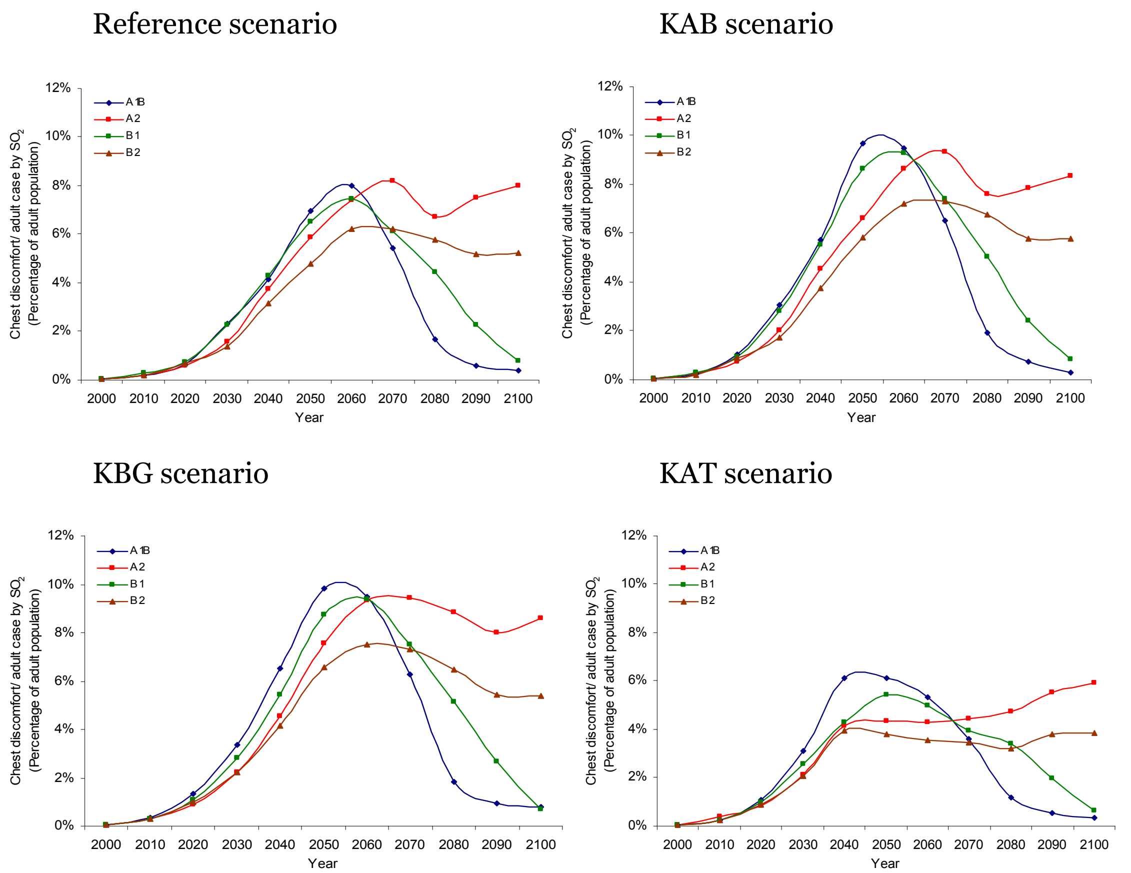


Figure 4.8c Estimated chest discomfort among adults (*CDA*) cases associated with SO_2 in Indonesia

If all countries, including Indonesia, reduce their emissions (KAT scenarios), the number of premature mortalities is significantly reduced. In the A1B/KAT and B1/KAT scenarios premature mortalities peak at 0.023% of the population in the middle of the century, while in the A2/KAT and B2/KAT scenarios the mortality values increase gradually to around 0.022% and 0.016% of the population at the end of century, respectively.

The projections for respiratory illnesses among children (*LRI*) and the chest discomfort among adults (*CDA*) are identical, except for a change in units, to the curves already discussed for premature mortality (cf. eqs. (4.3)-(4.5)). They need therefore not be discussed in detail. In general, the premature mortality due to SO_2 emissions is clearly the most significant factor economically, but the other two impacts, as well as other health effects, are also non-neglible and need to be considered in assessing the overall health impact of SO_2 emissions.

4.5.2. The case of nitrogen dioxide

Nitrogen dioxide (NO_2) and nitric oxide (NO) are often referred to collectively as nitrogen oxide, or NO_x (WHO, 1972). To estimate nitrogen dioxide (NO_2) impacts on respiratory symptoms, we calculated the NO_2 concentration by applying a factor of 0.39 to the nitrogen oxide (NO_x) concentration, as suggested by Laxen and Wilson (2002). The ambient concentrations of NO_2 (Figure 4.7, right-hand axis) follow the emissions of NO_x, since these were assumed proportional to the yearly average of the concentrations of air pollutant. The dose response functions for NO_2 only for respiratory symptoms (*RSD*) among adults is given by Ostro 1994:

$$NRSD(t)=\begin{cases} 10.22*\left[\dfrac{NO_2(t)-NO_2st}{NO_2st}\right]*PrA(t)*P(t)*1877.55 & for \quad NO_2(t)>NO_2st \\ 0 & for \quad NO_2(t)\leq NO_2\,st \end{cases} \qquad (4.6)$$

see (4.4)
where:

NRSD(t)	is the number of *RSD* in year *t*
$NO_2(t)$	is the NO_2 concentration (μg/m³) in year *t*
NO_2st	is the standard allowable for NO_2
1877.55	is the conversion factor from ppm to (μg/m³)

The number of respiratory symptoms (*RSD*) among adults associated with NO_2 in Indonesia is estimated at around 263 thousand cases, or 0.001% of the adult population, in 2000 (A1B scenario, Figure 4.9). This is slightly higher than the WHO AAQS value (Table 4.5). Respiratory symptoms among adults generally increase rapidly up to the middle of the century (reaching a number of cases peak of 10% of the adult population in 2070 in the reference scenario A2, for example) and then either remain at high values, in the A2 and B2 scenarios, in

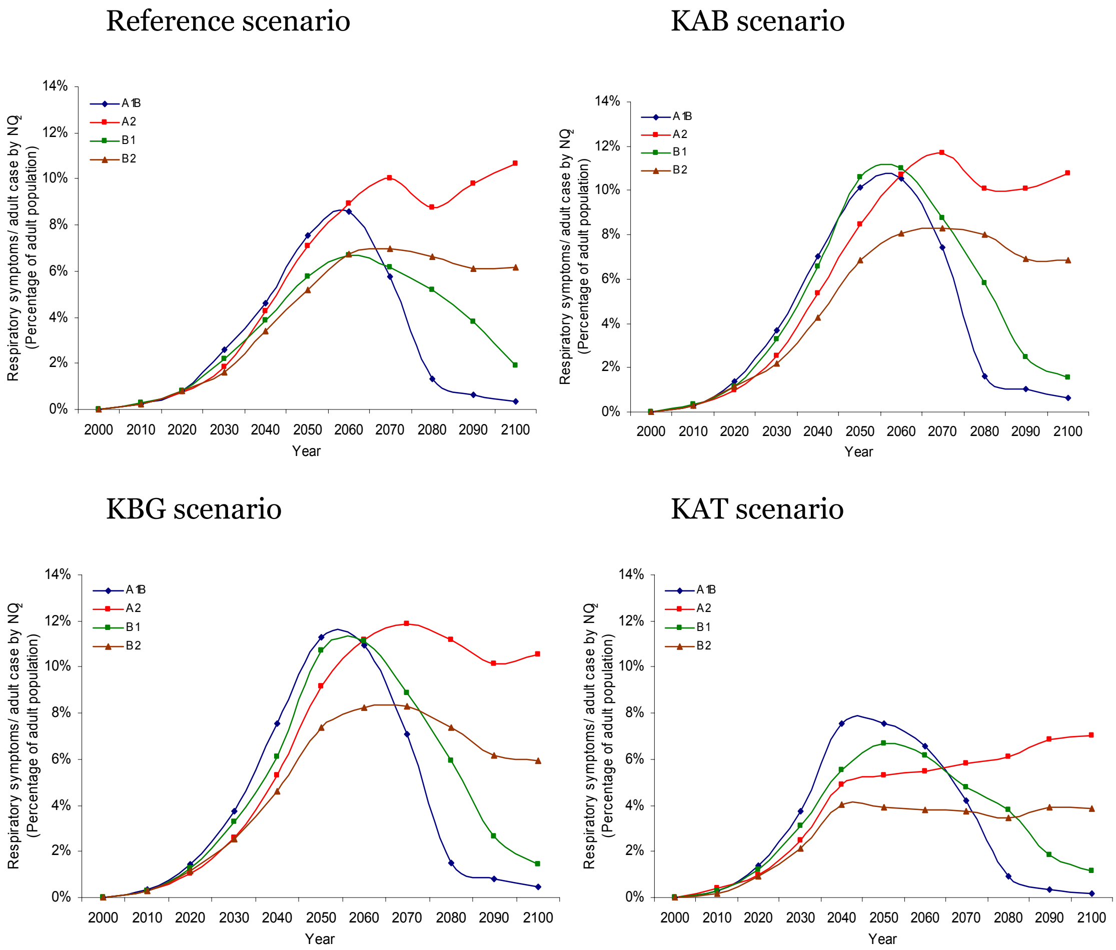


Figure 4.9 Estimated respiratory symptoms (*RSD*) among adults cases associated with NO_2 in Indonesia

which fossil fuel use remains high, or fall again in the A1B and B1 scenarios, in which fossil fuel use is reduced (Figure 4.9).

The impact of the various mitigation strategies is relatively minor except for the KAT case, in which all countries, including Indonesia, adopt stronger reduction targets. In general, the impact of NO_2 emissions is qualitatively similar to the curves shown previously for the impact of SO_2 emissions, differences arising only from the different proportions of NO_2 and SO_2 emitted in the burning of different fossil fuels.

4.6 Economic impact

A better understanding of the effects of air pollution and the resulting costs to society will enable decision makers to better evaluate the effectiveness of measures for reducing emissions and improving air quality. The economic impact of air pollution is determined by the economic value (i.e. the costs) of the health problems associated with air pollution. The economic value of health can be calculated using the general formula:

$$TC_i = V_i * dH_i \tag{4.7}$$

where:

TC_i	is the total economic value of health problem *i*
V_i	is the value of health problem *i* per unit case
dH_i	is the change in the number of cases for health problem *i*

In addition to the costs of an individual health problem, costs are also calculated for the two net variables premature mortality and morbidity:

Mortality costs

The value of a premature mortality case resulting from pollution, also know as the value of statistical life (*VSL*), is set in this study as 200 times the per capita income (Tol, 2002). For the year 2000, the *VSL* in Indonesia is US$ 144,000.

Morbidity costs

Morbidity costs include the costs of the health problems considered in this study that do not directly result in premature death, namely low respiratory illness (*LRI*), chest discomfort among adults (*CDA*) and respiratory symptoms (*RSD*).

The value of a low respiratory illness (*LRI)* case is calculated as the average costs of medical treatment per *LRI* case, given by the costs of a medical doctor and the medicine needed to the treat the case. We use the same procedure for chest discomfort among adults *(CDA)* and respiratory symptoms (*RSD).*

The average per capita costs of medical treatment of public hospital, private hospital and individual medical doctor practices for *LRI, CDA,* and *RSD* cases in the year 2000 were 11,900 Indonesia Rupiah (IDR) or 1.35 US Dollar (USD)[3] (Syahril *et al.*, 2002). We assume that the average costs of medical treatment for morbidity cases increase linearly for the years after 2000, extrapolated from these data from 1990-2000.

Figure 4.10a shows the estimated cost of premature mortality associated with SO_2 concentrations. The cost of premature mortality was US$ 88 million in 2000 (0.06% of GDP) in the A1B reference scenario without emissions reduction. The curves for the costs generally follow the emission curves for the different reference scenarios, but are modified by the increases in GDP, which vary with the different cases. Thus, the cost increases exponentially to 6.23% of GDP in 2060 for scenario A1B, after which it decreases rapidly to the year 2080 and more slowly to 0.34% of GDP in 2100. In the A2 scenario, the cost of premature mortality is to 5.86% of GDP in 2100, slightly higher than the earlier peak in 2070. Increasing cases of premature mortality are associated with over-proportional increasing costs in the B1 scenario, as individual income is high in this scenario. The highest cost of premature mortality is US$ 151 billion (5.97% of GDP) in 2070 in the B1 scenario, whereas the highest cost compared to GDP is 6.75% of GDP in 2060. In the following years, the cost declines again. The cost of premature mortality in the B2 scenario increases to a peak in 2060, and remains high afterwards, reaching 4.21% of GDP in the end of century.

[3] The USD-IDR conversion in 2000, USD 1 = IDR 8,800

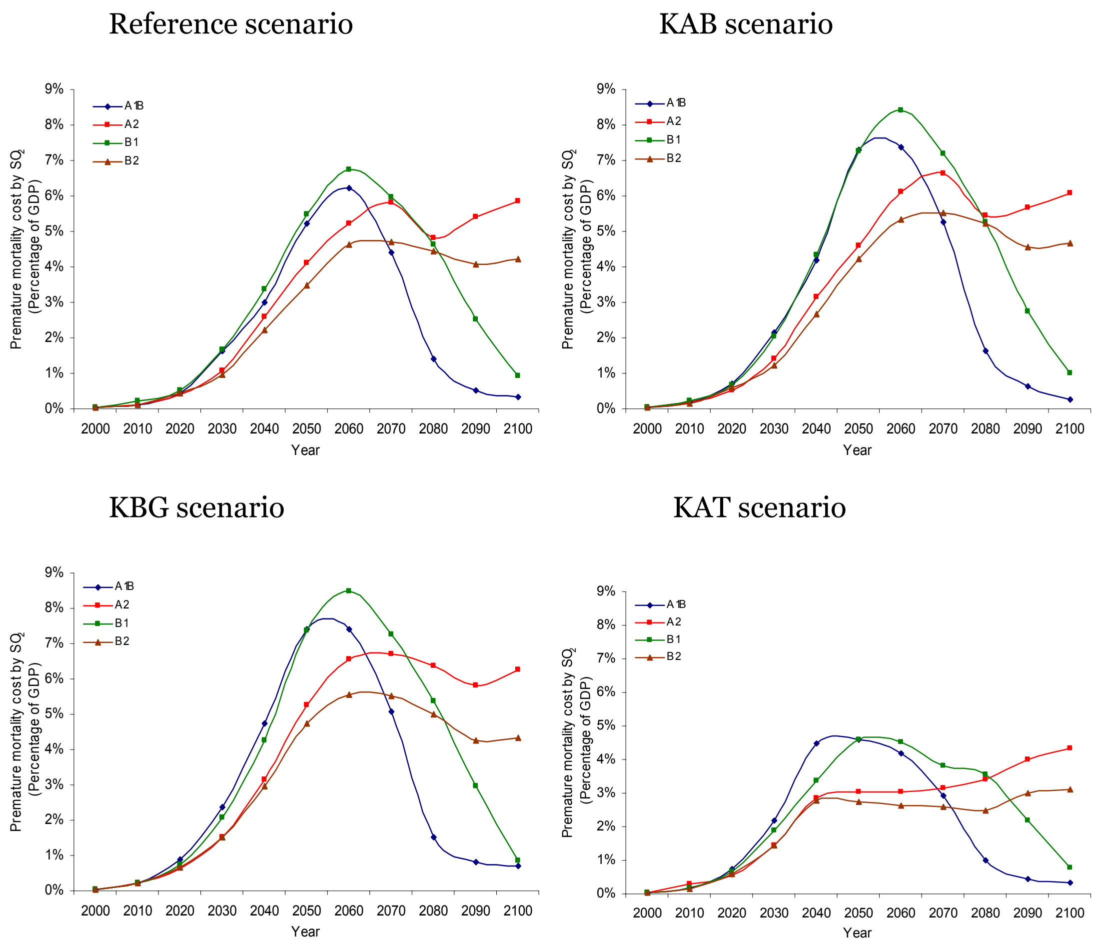


Figure 4.10a Estimated economic costs of premature mortality associated with SO_2 in Indonesia

If OECD countries reduce their emissions (KAB scenarios), the evolution of the cost of premature mortality is essentially the same as in the reference scenario, except that the cost values are higher because GDP is higher.

With international emission trade (KBG scenarios), the cost of premature mortality is still higher than in the reference scenarios, again for the same reasons.

In the last case, in which all countries reduce their emissions (KAT scenarios), the relative costs of premature mortality are lower than in all other scenarios, since the total number of premature mortalities lower (cf. Figure 4.10a and

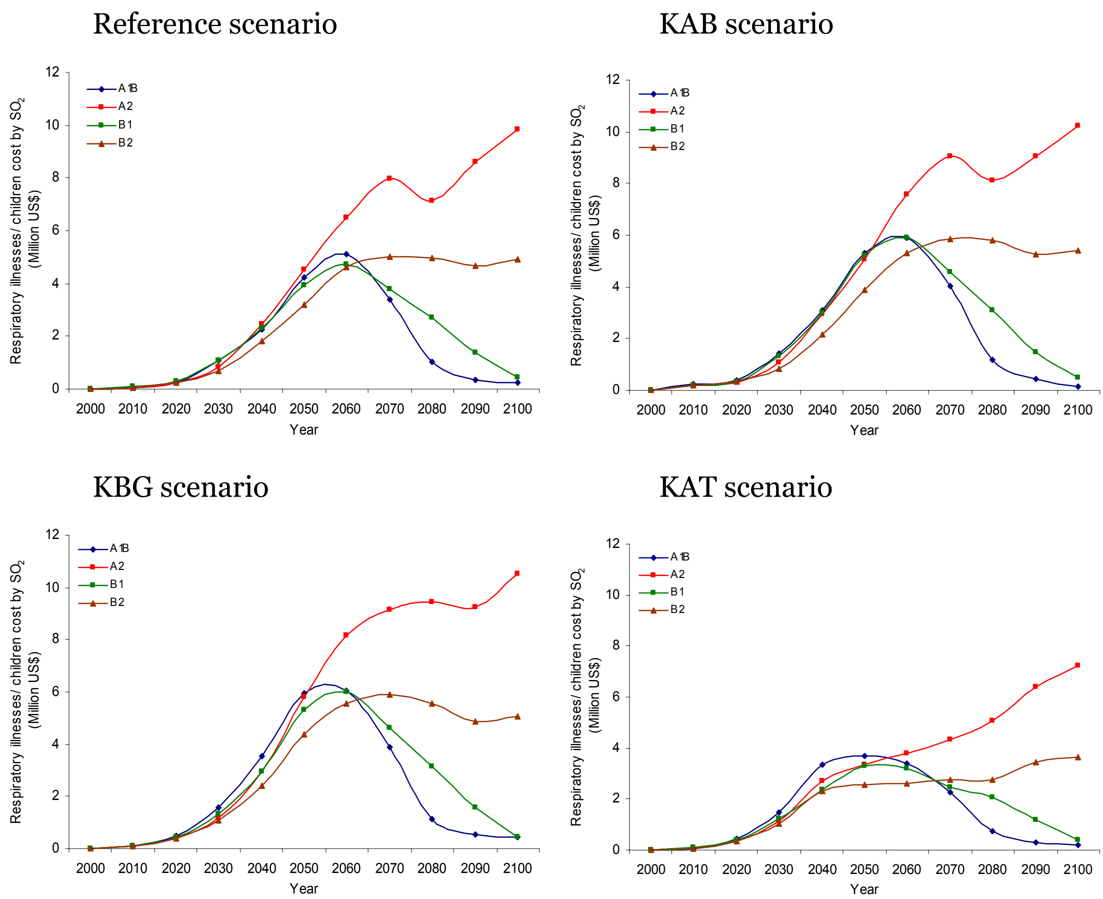
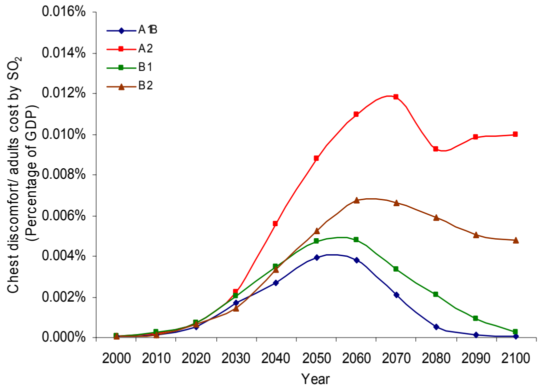


Figure 4.10b Estimated economic costs of respiratory illnesses among children (*LRI*) associated with SO_2 in Indonesia

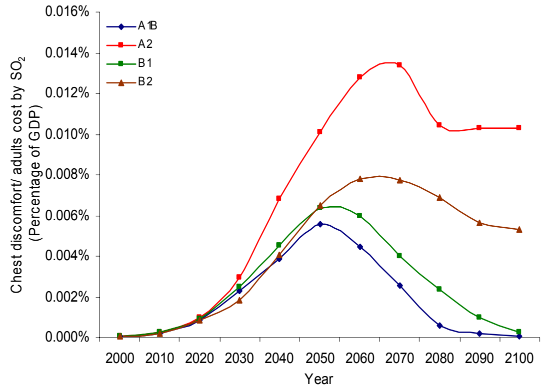
Figure 4.8a). This effect dominates over the normalization of the premature mortality rates by changing GDP levels.

The estimated economic cost of both health problems associated with SO_2, respiratory illnesses among children (*LRI*) and chest discomfort among adults (*CDA*), are shown in Figure 4.10b and Figure 4.10c. The cost of respiratory illnesses among children is about US$ 7.4 thousand in 2000 without emissions reduction. In the A1B scenario, economic cost of respiratory illnesses among children increases exponentially to US$ 5.1 million in 2060, later falling to US$ 229 thousand in 2100 (Figure 4.10b). In the A2 scenario, this cost rises to US$ 9.8 million in 2100. In the B2 scenario the cost is rise to US$ 5 million.

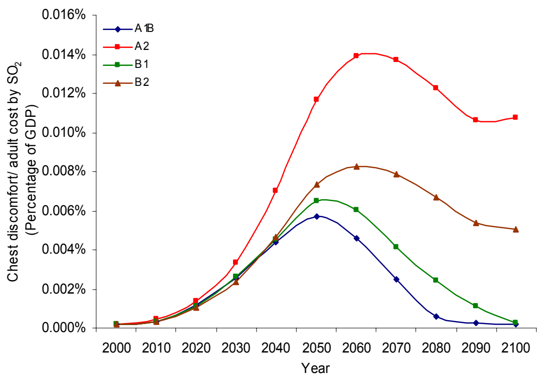
Reference scenario



KAB scenario



KBG scenario



KAT scenario

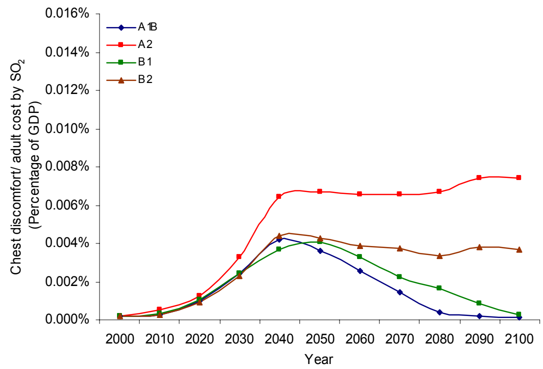


Figure 4.10c Estimated economic costs of chest discomfort among adults (*CDA*) associated with SO_2 in Indonesia

In the B1 scenario, the cost will fall to the end of century, after peaking to US$ 4.7 million in 2060 (Figure 4.10b).

If OECD countries reduce their emissions with and without international emission trade, the development of the cost of respiratory illnesses among children (*LRI*) is essentially the same as in the reference scenario, except that the cost values are higher because GDP is higher. Whereas, in the last scenario of MERGE, the costs of respiratory illnesses among children are lower than in all other scenarios of MERGE.

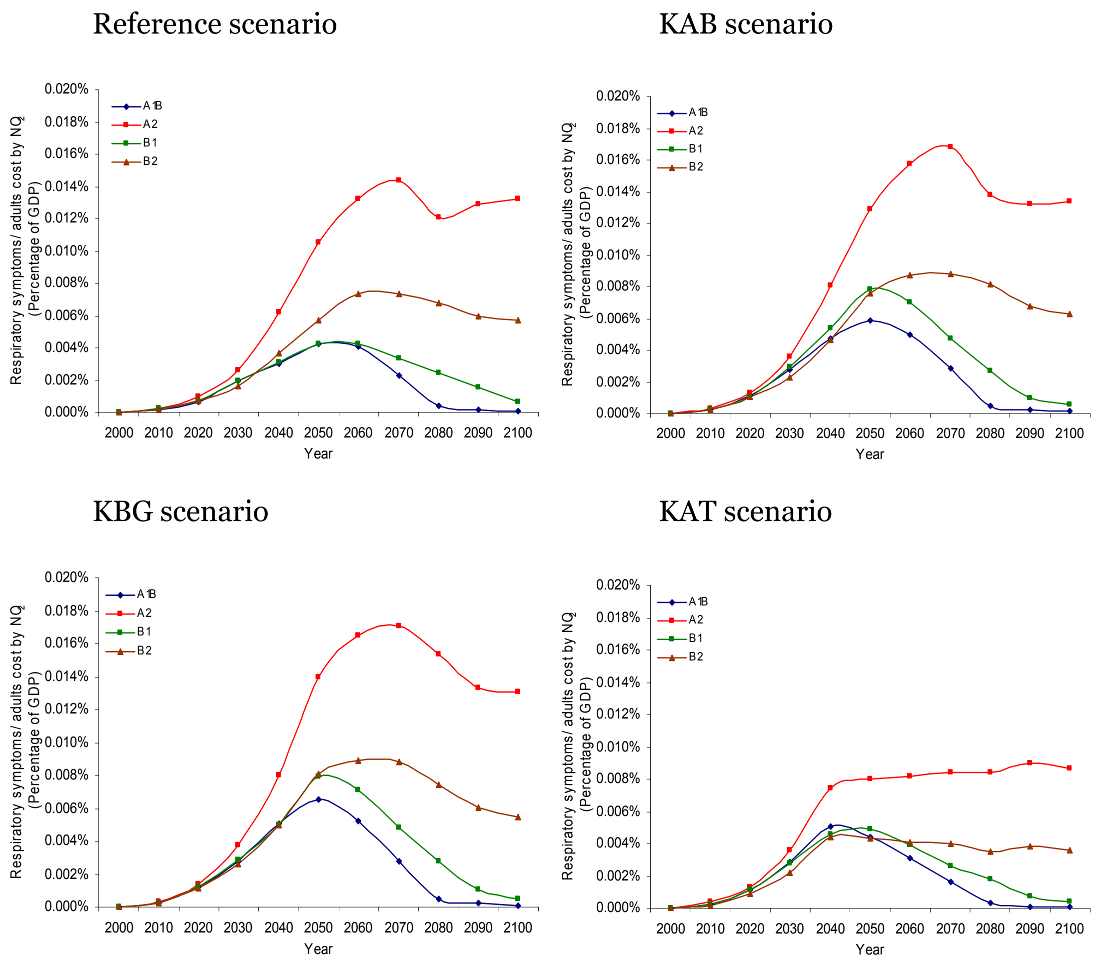


Figure 4.11 Estimated economic costs of respiratory symptoms (*RSD*) among adults associated with NO_2 in Indonesia

The projection for cost of chest discomfort among adults (*CDA*) is essentially identical with cost of respiratory illnesses among children, except for a change in units. In addition to, the cost of chest discomfort among adults increases to the end of century in the B2 scenario, while the cost of respiratory illnesses among children slightly decreases to the end of century, after peaks during the middle of century.

The cost of respiratory symptoms (*RSD*) among adults associated with NO_2 shows in Figure 4.11. In 2000, the cost of respiratory symptoms among adults is to US$ 355 thousand. In the reference scenario, in the A1B scenario, the percentage of cost increases gradually to 0.0043% of GDP in 2050 and falls thereafter. In the A2 scenario, the cost is rising to 0.0132% of GDP in 2100. In the other scenario, the cost of respiratory symptoms among adults increases to 0.0043% of GDP by 2060 in the B1 scenario and falls gradually thereafter, whereas, in the B2 scenario, the percentage of cost increases gradually to 0.0074% of GDP by 2070, slightly decreases thereafter.

In the second and third scenarios, the cost of respiratory symptoms (*RSD*) among adults is essentially the same as in the reference scenario, except that the cost values are slightly higher because GDP is higher also. In the last scenario, the cost will be lower than in the reference scenario.

Bruce *et al.* (1996) estimated the average co-benefits vary widely, from about US$ 2 per tonne of carbon abated to over US$ 500/tC. We estimate the co-benefit from reducing CO_2 emissions for export based on the difference in total health costs between the second scenario (KAB scenario) and the third scenario (KBG scenario) divide by the emission permits that Indonesia exports. The value of co-benefits will around US$ 14 – 21/tC in the year 2010. This is low compared to Barker's (1993) estimates of about US$ 40/tC. The price of carbon is about US$ 2.2 – 9.9/tC in the year 2010.

4.7 Conclusions

We have investigated in this paper the impact of predictions of air quality in Indonesia on the health and economy. Our results represent a preliminary effort to integrate a model of health effects from fossil fuel use in an integrated assessment model. We plan to use more sophisticated air quality modeling techniques in future work. The purpose is investigated how policies designed to reduce emissions of greenhouse gas might simultaneously affect also emissions of air pollutants and ultimately human health.

In this paper we have concentrated on two air pollutants, sulfur dioxide (SO_2) and nitrogen dioxide (NO_2). The analysis of the health effects of other pollutants, such as particulate matter and lead, are left for future work.

Current trends in energy production and consumption in Indonesia indicate that air pollutant concentrations in the reference scenarios will increase rapidly up to the middle of the century, but can be expected to fall in the second half of the century. In the mitigation scenarios limited to OECD countries (KAB scenarios), Indonesia increases consumption of imported oil and decreases gas consumption compared to the reference scenario. Consequently, health problems associated with SO_2 and NO_2 are higher than in the reference scenarios. In the third set of scenarios including also trade in emissions permits (KBG scenarios), the health problems associated with SO_2 and NO_2 also remain higher than in the reference scenarios, as fossil fuel imports and coal use remain high. Health problems in Indonesia are reduced only in the last set of scenarios (KAT scenarios), in which all countries including Indonesia reduce their emission in the future.

The estimated economic costs of health problem associated with SO_2 and NO_2 are also higher in absolute terms in the second and third scenarios because GDP is higher. In the last scenario, the reduction of emissions in Indonesia dominates over the increase in GDP, and the absolute costs are also lower than in the other scenarios.

Our scenario projections indicate that SO_2 and NO_2 pollution will become a serious problem, by the middle of century for all scenarios. This holds particularly for the more strongly fossil-fuel based reference scenarios A2 and B2, for which pollution levels remain high until the end of the century. The pollution levels are somewhat smaller and decline in the second half of the century for the reference scenarios A1B and B1, in which alternative energy technology is introduced. The effects of emission reduction by other countries

(KAB and KBG scenarios) have little impact on air pollution levels in Indonesia, as to be expected. A reduction of air pollution levels is achieved only if Indonesia also adopts emission reduction targets (scenarios KAT). The air pollution reduction factor is limited to about 50 percent if emission reductions are based on the extrapolated Kyoto targets.

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Chapter 5

Summary, conclusions and outlook

The goal of this thesis was to investigate the impact of international climate policy on the energy sector and the economy of Indonesia, including analyses of the interaction between energy policy and the forestry sector and the impact of pollution resulting from fossil-fuel use on health.

In order to address these problems we adopted and extended the MERGE model to project Indonesia's energy development till the year 2100. This required first the inclusion of Indonesia as an independent region, separated out from the standard Rest of the World (ROW) region of MERGE. With the extended model we were able to simulate the impact of international climate policy on the energy and economic development of Indonesia, as presented in Chapter 2. In Chapter 3, after the further inclusion of international trade in coal, in the same manner as oil, gas and other sources of energy, and the representation of the forestry sector, an important economic resource and also a significant source of CO_2 emissions, we were able to refine the projections of Chapter 2 and gain new insights into the interaction between the forestry energy sectors. The MERGE model was augmented in Chapter 4 by the inclusion of the emissions of the most important pollutants, SO_2 and NO_2, produced by burning fossil fuels and was then applied to compute the impact of the pollutants on health and health costs.

The principal conclusions of our investigation are the following:

In the absence of emission reduction measures (the reference scenarios), oil production in Indonesia drops and is replaced by gas and later coal. To fulfill its energy demand, Indonesia imports oil and gas after a few decades. Whether coal is continued to be used out or is phased out in the second half of the century by carbon-free energy generation depends on the assumed technology scenario.

If emissions are reduced in the OECD countries (the KAB scenarios), initial oil exports from Indonesia drop, while gas and to a lesser extent coal exports would increase. However, the increase in gas exports is insufficient to compensate the loss of oil income. With international emissions trade (the KBG scenarios), Indonesia would export emission permits, but the revenues would still not be sufficient to make up for the loss of fossil fuel revenues. If Indonesia accepts emission reduction targets in the future (the KAT scenarios), the Indonesian economy will grow more slowly, but the adverse affects of air pollution on health (see below) would be significantly reduced.

Our investigations of the interactions between the energy and forestry sections of the Indonesian economy suggest that the rate of deforestation would be slightly lower than in the reference scenarios without mitigation measures in the case that OECD countries reduce their emissions without emissions trading (KAB scenarios), but slightly higher if emission trading and all countries reduces their emissions are also implemented (KBG and KAT scenarios). The results of model projections of deforestation rates indicate that Indonesia has a large potential to mitigate emissions in the forestry sector. If Indonesia reduces emissions by slowing deforestation, its profits from the sale of emission permits would be greater than the losses from reduced forestry income.

The current trends in energy consumption of Indonesia clearly indicate that concentrations of air pollutants damaging to health (SO_2 and NO_2) will increase rapidly until at least the middle of the century. Emission reductions in OECD countries (Scenarios KAB and KBG) would reduce oil prices and increase the use of fossil fuels in Indonesia, leading to higher air pollutant peaks than in the reference scenario. The economic costs of the health problems associated with high SO_2 and NO_2 concentrations are considerable. The air pollution levels and health costs are reduced only in the case that Indonesia also reduces emissions (scenarios KAT). However, if the reductions are based on the extrapolated Kyoto targets (5% per decade), the air pollution reduction factors are limited to the range of maximally 50%.

Our study leaves several unanswered questions and thus points to a number of possible extensions. An obvious open question is the sensitivity of our results to the model parameters and the relation between our conclusions and the conclusions that may have resulted from the application of other models. An extensive energy model intercomparison study (Weyant *et al.*, 1996) revealed a strong sensitivity of such models to model parameters and model calibration

A general shortcoming of the MERGE model projections is that they apply in detail only for emissions from the energy sector. In order to gain a more complete picture of the total emissions of the Indonesia region, more extensive studies of the emissions from land use change are needed.

Another planned extension of the MERGE model which would be particularly relevant for Indonesia is the inclusion of the clean development mechanism (CDM) in the suite of global emissions abatement measures. Also of interest in the Indonesia context is a better understanding of the uptake, transport and storage of CO_2 in the ocean in the Indonesian archipelago, as well as an investigation of the potential of the (controversial) option of CO_2 sequestration in the ocean.

We were able in the present study to use dose-functions only for developed countries, whereas the model was applied to explore and analyze the health impacts of air pollution in a tropical country, Indonesia. We propose to apply dose-functions specifically for developing countries in future work.

Further research should also be focused more on national and sectoral levels with higher time resolution. This would provide a more reliable base for assessing policy options for medium term national and sectoral economic development.

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Glossary

A1B	Scenario group within the A1 scenario family
A2	SRES scenario family A2
AAQS	Ambient Air Quality Standards
AEEI	Autonomous Energy Efficiency Improvement
AIM	Asian Integrated Model
ALGAS	Asian Least Cost Greenhouse Gas Abatement Strategy
B1	SRES scenario family B1
B2	SRES scenario family B2
Bappenas	Badan Perencanaan Pembangunan Nasional (National Development Planning Board)
BAU	Business As Usual (scenario)
BPS	Badan Pusat Statistik (Central Bureau Statistical)
BPPT	Badan Pengkajian dan Penerapan Teknologi (Agency for the Assessment and Application of Technology)
BTU	British Thermal Unit
CDA	Chest Discomfort among Adults
CDM	Clean Development Mechanism
CHCROPL	Annual change in cropland
Datacon	Data Consult
Deptan	Departemen Pertanian (Agriculture Department)
DGEED	Directorate-General of Electricity and Energy Development
DGFPNC	Directorate General of Forest Protection and Nature Conservation

EIA	Energy Information Administration (US)
EKC	Environmental Kuznets Curve
EPA	Environmental Protection Agency (US)
EUSAI	Embassy of the United States of America in Indonesia
FAO	Food and Agriculture Organization
FOPREXP	Forest product exports
FWI	Forest Watch Indonesia
GDP	Gross Domestic Product
GFW	Global Forest Watch
GHGs	Greenhouse gases
IDR	Indonesia Rupiah
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
J	Joule
KAA	Kyoto All countries (scenario)
KAB	Kyoto Annex B countries (scenario)
KAT	Kyoto All countries with Trade (scenario)
KBG	Kyoto Annex B with Global trade (scenario)
KBT	Kyoto Annex B with Trade (scenario)
KMNLH	Kemenetrian Negara Lingkungan Hidup (Ministry of Environment)
KRA	Kyoto All countries relative to Reference (scenario)
KRT	Kyoto all countries relative to Reference scenario with Trade
LRI	Lower Respiratory Illnesses

MERGE	Model for Evaluating the Regional and Global Effects of Greenhouse Gas Reduction Policies
MOEROI	Ministry of Environment Republic of Indonesia
MOHROI	Ministry of Health Republic of Indonesia
MoF	Ministry of Forestry
MPI	Max Planck Institute for Meteorology
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of Petroleum Exporting Countries
PHPA	Perlindungan Hutan dan Pelestarian Alam (Forest Protection and Nature Conservation)
POP	Population
PropA	Proportion of Adults
PropC	proportion of Children
REF	Reference (scenario)
ROW	Rest of the World
RSD	Respiratory Symptom Day
RWCONS	Annual round wood consumption
SME-ROI	State Ministry for Environment, Republic of Indonesia
SRES	Special Report on Emission Scenarios
TCSF	Trillion Standard Cubic Feet
TSP	Total Suspended Particulate
UN	United Nations
UNDP	United Nation Development
UNFCCC	United Nations Framework Convention on Climate Change

USA	United States of America
USD	US Dollar
US-EPA	United States Environmental Protection Agency
VSL	Value of Statistical Life
WHO	World Health Organization

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Beginn einer neuen Veröffentlichungsreihe des MPIM, welche die vorherigen Reihen "Reports" und "Examensarbeiten" weiterführt:

„Berichte zur Erdsystemforschung" , „Reports on Earth System Science", ISSN 1614-1199
Sie enthält wissenschaftliche und technische Beiträge, inklusive Dissertationen.

Berichte zur Erdsystemforschung Nr.1 Juli 2004	**Simulation of Low-Frequency Climate Variability in the North Atlantic Ocean and the Arctic** Helmuth Haak
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