Integrated Assessment Model for Indonesian Energy Forecast

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Abstract

Indonesia is an Organization Petroleum Exporting Countries member and holds large energy reserves, especially gas, coal resources, indeed, has a lot of oil reserves. The energy sector in Indonesia has been a dominant factor in the whole economic development of Indonesia. Oil and gas exports contributed significantly to securing foreign exchange revenue of the country. This research investigates Indonesian energy forecast as impact of international climate policy to reduce emissions during the century. To project Indonesian energy development, we need an integrated assessment model which examining the whole of energy in the world. That model should convince these criteria: Firstly, the model has to have a reasonably detailed energy sector. Secondly, the model has to cover the whole world, but include Indonesia as a separate region. Thirdly, the model must be calibrated to real data. MERGE (a **M**odel for **E**valuating the **R**egional and **G**lobal **E**ffects of greenhouse gas reduction policies) is an intertemporal 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. The only problem is that MERGE includes Indonesia in its ROW (Rest of the World) region.

An integrated assessment model consisting of energy model, economic model, climate model and climate change impact model was developed and used to perform a long-term simulation study for Indonesia. We have extended version of MERGE to forecast changes in the energy system out from the year 2000 until 2100.

In this paper, we provide an overview of MERGE; the model is appropriated with energy and economic statistics for the year 2000. The original MERGE model has 9 regions. We therefore developed a new version of MERGE that separates out Indonesia to form the tenth. The new version of MERGE developed since we included coal as tradable goods such as oil, gas and some other sources of energy. To analyze the impact of international climate policy on Indonesian energy development, we analysed some scenarios.

We start the analysis by examining how carbon emissions might grow in absence of policy intervention. The baseline scenario analysis shows supply electric and non-electric energy as indicated to energy production of Indonesia. We will also present energy demand for domestic sector and export quantities. With international climate policy will influence energy consumption while developed countries will use the energy with the low emissions, such as gas.

Keywords: MERGE; Integrated assessment model; Energy production; Economics performance

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1. Introduction

Indonesia's economic growth increased modestly in 2002 despite the continuing global economic crisis. Gross domestic product (GDP) grew at a rate of 3.7% in 2002, rise from 3.1% in 2001. In 2003, GDP growth is forecast higher than 2002.

Indonesia has significant gas and coal resources, indeed, has a lot of oil reserves. Indonesian gas reserves at 170.3 trillion standard cubic feet (TCSF), are equal to three times Indonesia's oil reserves. Coal has identified 38.8 billion metric tons of coal deposits and oil reserves at 9.6 billion barrels. In energy sector, Indonesia dominated by oil with it production 5 exajoules in 2000, later gas and coal production are 2.6 exajoules and 1.6 exajoules, respectively.

The primary energy supply is dominated by oil products, coal and gas. In the last 10 years, the share of oil production has been declining; but there was significant increase in the role of natural gas and coal in the energy supply. On the next decade, Indonesian energy development would be influenced by international climate policy as a way of limited of emission. To project Indonesian energy development as impact of international climate policy to reduce emissions as target on Kyoto Protocol, we used an integrated assessment model which examining the whole of energy in the world. We analysed these conditions using MERGE (Model for Evaluating the Regional and Global Effects of greenhouse gas reduction policies) and arrange a recently developed mitigation scenario.

This paper investigates the energy development in absence of emission reduction and also the implications of emission reduction in the Annex B countries on the energy sector of Indonesia.

2. Overview of the MERGE model

In this section, we provide a brief overview of MERGE (a model for evaluating regional and global effects of greenhouse gas reductions), see Manne, Mendelsohn, and Richels 1995. MERGE is an intertemporal general equilibrium model of the global economy, which incorporates perfect foresight. Although we will focus on global results, the underlying model is based on a world divided into nine geopolitical regions: 1) the USA, 2) OECDE (Western Europe), 3) Japan, 4) CANZ (Canada, Australia and New Zealand), 5) EEFSU (Eastern Europe and the Former Soviet Union), 6) China, 7) India, 8) MOPEC (Mexico and OPEC) and, 9) ROW (the rest of the world), please see Manne and Richels 2001.

MERGE provides a bottom-up perspective of the energy supply system and a top-down perspective on the reminder of the economic. MERGE developed by Alan S Manne from Stanford University and Richard Richels from the Electric Power Research Institute, US. 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, (4) the climate change impact (damage) model. See Figure 1.

The economic model is used to assess the economy-wide cost of alternative emission constraints at the regional and global level (cf. Hourcade *et al.*, 1996). The economy is modeled through nested constant elasticity production functions. The production function determine how aggregate economic output depends upon the inputs of capital, labor, 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 maximizes the discounted utility of consumption subject to an intertemporal budget constraint. A region's wealth includes not only capital, labor, and exhaustible resources, but also its negotiated international share in emission rights, 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 resources. The model has also international trading of gas, and energy-intensive goods.

The energy model distinguishes between electric and non-electric energy. There are 10 alternative sources of electricity 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 electricity generation. There are four alternative sources of non-electric energy in the model (oil, gas, coal, renewables) plus a backstop technology, which is available in unlimited quantities, does not emit greenhouse gases, but is fairly expensive. Please see Table 1 and Table 2.

The climate sub-model is limited to the three most important anthropogenic greenhouse gases: 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 model includes net emissions from land use and forestry. Greenhouse gas concentrations influence the global mean temperature. In this paper, we only consider emission reduction of carbon dioxide.

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 using prices and observed demand and supply functions. Non-market effects have no observable prices and so they must be valued using alternative revealed preference or attitudinal methods (e.g., Pearce *et al.*, 1996). Climate change impacts play no substantial role in the analyses of this paper.

3. MERGE model for Indonesian energy forecast

The original MERGE model has 9 regions. We separated out Indonesia from rest of the world to form the tenth (Susandi 2002). There is no conceptual change, but required changes in databases and scenarios. MERGE is calibrated to the year 2000. Future periods are modeled in 10-year intervals. Hence, the Kyoto Protocol's first commitment period (2008-2012) is represented as 2010. The first commitment period of Kyoto Protocol is represented as 2010 in the model.

The model has also international trading of gas, oil and energy intensive goods. Now, we have developed the new version of MERGE since it included coal as a tradable good. The significant modification on new MERGE is the changing of supply of coal in MACRO and ETA sub models. The supply for coal with includes demands for coal and allowance for net exports. This also includes an allowance for fuel consumption in the electric power sector (Susandi, 2003).

To analyze the impact the international climate policy on energy development, we developed two scenarios, specified in Table 3. In the first scenario (reference scenario), there is no emission reduction policy. In the other scenario, we assume that all Annex B countries adopt the Kyoto Protocol with reduces their emission by 5 percent per decade in the years after 2010. We assume that Indonesia accepts a target in 2050. After 2050, Indonesia's emission falls by 5 percent per decade. This paper is concentrated to the implications of reliable scenario for Indonesia. (Note that some different scenarios can be developed).

4. Indonesian energy forecast

4.1 Reference scenario

In the energy sector, Indonesia currently dominated by oil, gas and some coal. Oil shares to 57% of total primary energy of Indonesia, gas contributes 23%, coal allot 18%, and 2% from carbon-free energy technology such as hydroelectric, geothermal and other renewables energy, as shown in Figure 2. Share of gas is to increase substantially by the middle of the century and then fall gradually. Oil production is contributes almost constant during the first of half of the century before falling gradually till the end of century. Coal production increases slightly to 2010 and then almost the same amount contributor in energy share to 2100. Carbon-free energy technologies begin inroad in 2020 into the energy market of Indonesia, but these are still relative more expensive than fossil fuel energy.

Carbon-free energy technologies extend rapidly after the middle of century, while oil production decline sharply till the end of century. Oil consumption is decrease to 2020, but picked up slightly to the middle the end of century. Gas consumptions would be dominated in Indonesia energy market till end of century, even there are mix energy after 2060 with carbon-free energy technology. Please see Figure 3. Coal price is lower since energy with lower emissions distributed in energy market.

4.2 Emission reduction for all countries.

If all countries has emissions target as specified above, Indonesia will produce more gas in energy sector to meet export demand, but oil export decrease while oil consumption increases to 2060. Gas would contribute to enhance of foreign exchange revenue of Indonesia. Share of coal decreases slightly during the century and fall sharply after 2080. In domestic sector, coal is lower used in energy sector as switch of by gas. Carbon-free energy technology increases sharply to share in Indonesian energy market, as away of Indonesia committed to their emission target. In this scenario, carbon emission of Indonesia will lower after date of commitment.

5. Conclusion

We have chosen the MERGE model to predict Indonesia energy development. MERGE model has complete detailed energy sector and calibrated to the real data. We expanded the MERGE model, involving Indonesia as a different region. We developed also a new version of MERGE since we include coal as tradable good together with other source of energy. Some various scenarios can develop in this model based on some objectives.

This study has describes the structure of MERGE model and interaction within sub-model. Adjust of this model can do with the real data, to simulate the economic-energy-climate-damage for further assessment. In energy sector, Indonesia dominated by oil but consumption rise lower than gas consumption. Carbon-free energy technology will grew up significantly while oil and gas decrease till the end of century, coal still using cause the lower price.

If Indonesia has emission target, share of gas dominated in the energy sector of Indonesia, do simultaneously export demand as energy with low emission. Coal is not much in energy market. Carbon-free energy technology share more and more in Indonesia energy sector.

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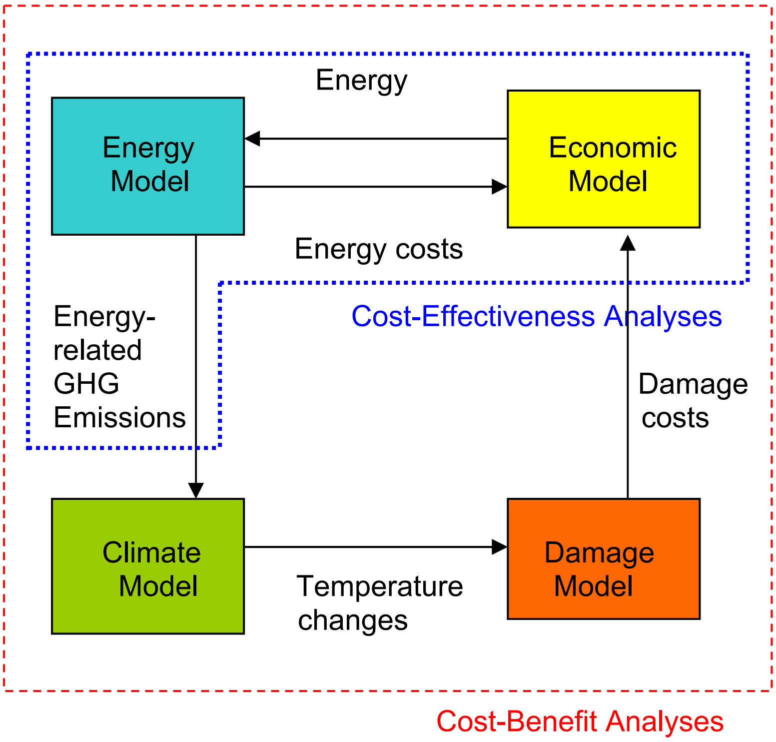

Figure 1. MERGE: an Integrated Assessment Model

Table 1. Electricity generation technologies Available to Indonesia

Technology	Identification	Earliest possible introduction date	Carbon emission coefficients (Billion tons per TKWH)
Hydro	Hydroelectric, geothermal and other renewables	Existing	0.0000
Nuclear	Remaining initial nuclear	2010	0.0000
Gas-r	Remaining initial gas fired	Existing	0.1443
Oil-r	Remaining initial oil fired	Existing	0.2094
Coal-r	Remaining initial coal fired	Existing	0.2533
Gas-n	Advanced combined cycle	2010	0.0935
Gas-a	Fuel cells with captured and sequestration gas fuel	2030	0.0000
Coal-n	Pulverized coal without CO2 recovery	2010	0.1955
Coal-a	Fuel cells with capture and sequestration coal fuel	2030	0.0068
IGCC	Integrated gasification and combined cycle with capture and sequestration coal fuel	2030	0.0240
ADV-HC	High cost advanced carbon-free technologies	2020	0.0000
ADV-LC	Low cost advanced carbon-free technologies	2060	0.0000

Source : MERGE4.3

Table 2. Non-electric energy supplies

Technology	Identification	Carbon emission coefficients (tons of carbon per GJ)
CLDU	Coal – direct uses	0.0241
Oil	Oil	0.0199
Gas	Gas	0.0137
RNEW	Renewables energy	0.0000
NEB	Non-electric backstop	0.0000

Source : MERGE4.3

Table 3. The scenarios

Scenario	Emission reduction	Start date	Emissions trade
Reference (Ref)	No		No
Kyoto all countries with trade (KAT)	Annex B countries	2010	All participating countries
	USA, China, India and MOPEC.	2030	
	Indonesia	2050	
	ROW	2070	

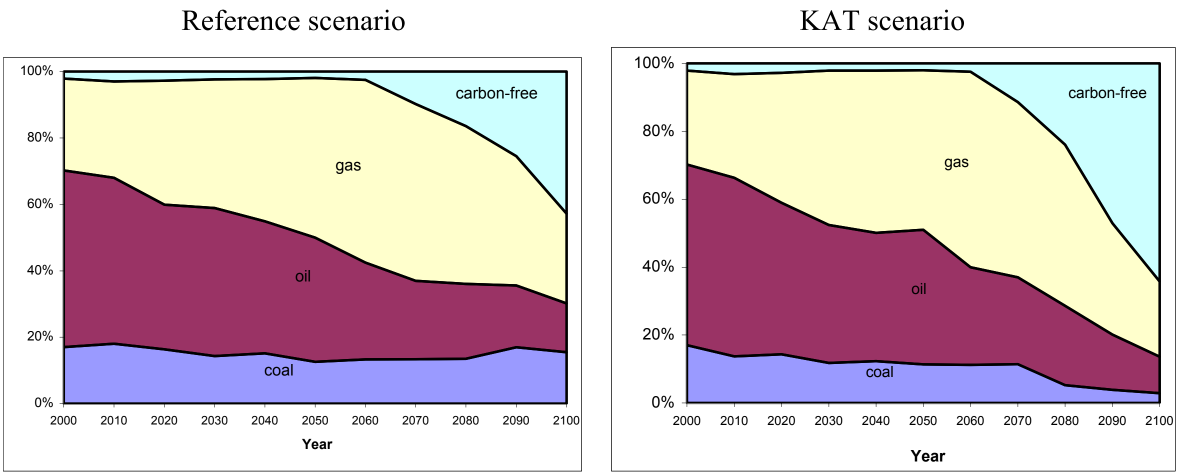

Figure 2. Total primary energy on Indonesia (%) – fuel shares

Reference scenario KAT scenario

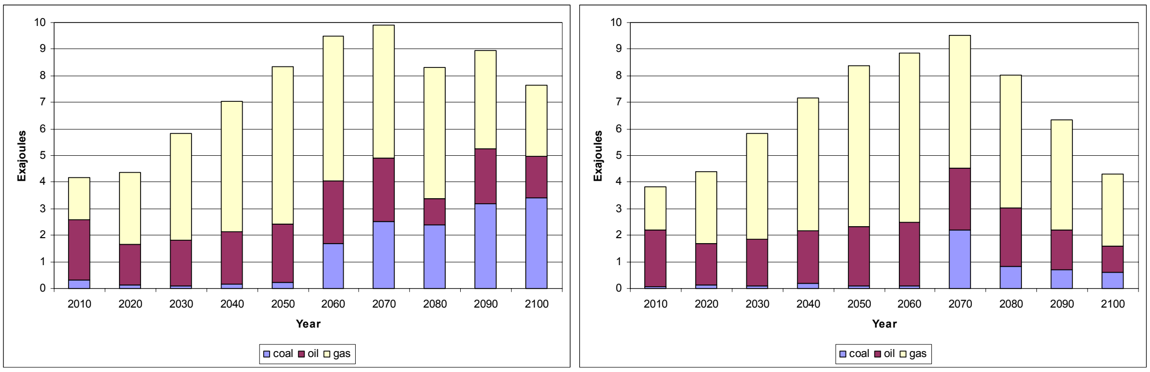

Figure 3. Energy consumption on Indonesia

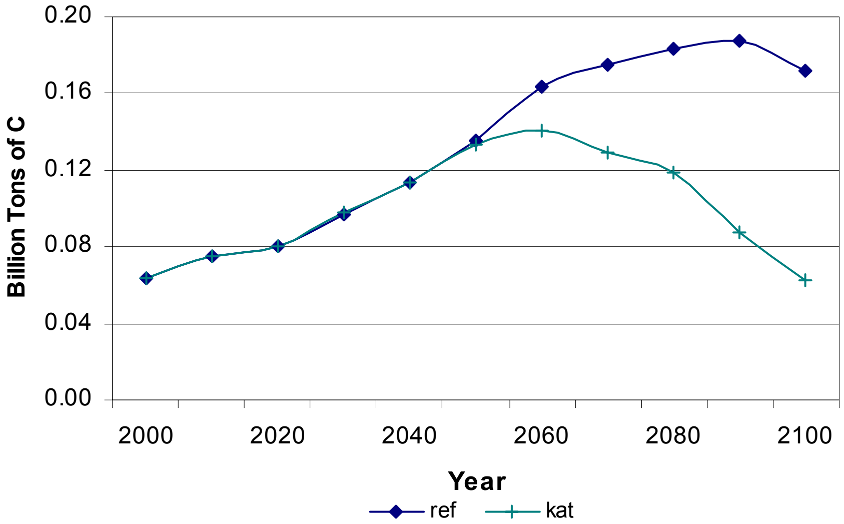

Figure 4. Total carbon emission of Indonesia