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Energy Security of Indonesia: System Dynamic Modelling and Policy Simulation

Yudha Prambudia, Yasuko Todo, Masaru Nakano
Graduate School of System Design and Management
Keio University
4-1-1 Hiyoshi, Kohoku-ku, Yokohama, Japan
prambudia.yudha@a6.keio.jp, yasuko_todo@a3.keio.jp, nakano@sdm.keio.jp

Abstract

Indonesia is one of emerging Asian economies with rapid economic development. Along side the economic growth, Indonesia's energy demand is rapidly increasing as well. Indonesia's primary energy consumption has doubled in four years from 2003 to 2007. It is very important for Indonesia to secure its energy supply at an adequate level to maintain its economy growth. Recently the oil import has significant importance in the dynamics of Indonesia's energy security. International oil price is affecting the capability to supply oil for the economy. This paper try to investigate policies related to energy, economy and technology system affecting Indonesia's energy security using system dynamics modeling and simulation approach. Simulation result shows that achieving high energy security may be contradictive with economic development.

Introduction

Indonesia is among the emerging Asian economies with rapid economic development. With year-on-year GDP growth of 4.2% of 2009, Indonesia outperformed other Southeast Asia economies (ADB, 2009). Along side the economic growth, Indonesia's energy needs is rapidly increasing as well. With total primary energy consumption growth average of 4.12 MTOE/year, Indonesia's primary energy consumption has doubled to 132.5 MTOE/year in 2007 compare to year 2003 consumption (APERC, 2009). One important event which marked Indonesia's energy needs concern was the withdrawn of Indonesia's membership from OPEC in 2008 due to its change from net exporter to net importer country (BP, 2008). It is very important for Indonesia to secure its energy supply at an adequate level to maintain its economy growth.

The term energy security in this study is based on the notion that energy security is a sufficient and uninterrupted supply of energy, this notion can be categorized as 'availability' (Sovacool and Brown, 2009). Therefore, the model takes into account the ratio between supply and demand to measure the energy security in term of availability. Other indicators of energy security which may be used for these categories of energy security can be found in Kryut et.al, 2009 and Scheepers et.al., 2007.

In addition, to address the changing of Indonesia's OPEC status, energy import dependency with specific interest to oil is analyzed as well. There are several ways to indicate import dependency (for example, Alhajji and Williams, 2003), however, since the interest is more on the supply side, for this study import dependency is measured by the amount of import of energy compared to total energy supply of the country.

Model Assumption and Data

Assumption. Following are main assumptions of the model:

1. Substitutions of energy uses are assumed to be represented in the data, as oil consumption decreases and gas and coal consumption are increasing.
2. Primary Energy in the model consists of four fuel type namely; Oil, Gas, Coal and Other Energy

Data. The main data for the model is the energy data, other data such as economic data and technology data are appropriately selected to follow the available energy data. There are several sources for energy data; however, for the reason of consistency, data for each energy sub-systems are come from ADB Energy Statistics in Asia and the Pacific (ADB, 2009). The data provided from this source is between the years of 1990 to 2006. Biomass data, however, is estimated due to unavailability of biomass data before year 2004.

Model Structure and Methodology

Model Structure. The model consists of three parts namely; Energy system, Economic system, Technology system. Figure 1 below represent the conceptual model structure.

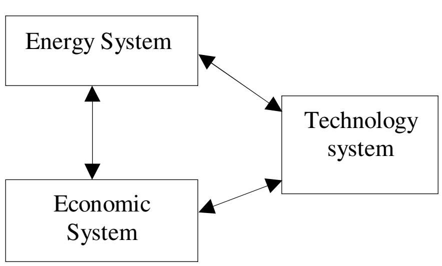

Figure 1. Conceptual Model Structure

In response to Indonesia's OPEC status change and given the fact that the data does not shows any import of gas, coal and other type of energy in Indonesia's energy system, the oil part of the model is presented in a more elaborated way.

There are three main category of loops characterized the model and four parameters available for policy simulation. In the following sections, the loops and the methodology underlying the key assumptions within the loop will be presented.

Energy-Economy Loop. This is the main loops that connect to other parts of the model. Key assumption applied in this loop is that the amount of energy consumed is depending on energy availability in term of ratio of supply over demand. Ratio value of 1 or above means that energy is sufficient and consumption will perform as usual. If the ratio value declines to below 1, it means energy is insufficient and the energy consumption will be reduced parallel to the ratio. The loop is represented in Figure 2.

Following the idea that developing countries economic development is driven by energy consumption (Lee, 2005; Lee and Chang, 2008), the model assumes that energy consumption will influence the GDP. For this assumption, regression technique was performed on GDP data and Total Energy Consumption. Since GDP data behavior shows fluctuation in response to Asian economy crises in 1998-1999, the data is divided into two periods. The regression produced two functions as follow; for period of 1990 to 1998,

$$\text{Ln (GDP)} = 1.3626\ \text{Ln(Total Energy Consumption)} + 6.5039 \quad (1)$$

$R2 = 0.9481$, $RSS = 0.0136$,

and for period of 1999 to 2003,

$$\text{Ln (GDP)} = 2.5462\ \text{Ln(Total Energy Consumption)} + 0.4425 \quad (2)$$

$R2 = 0.8819$, $RSS = 0.02498$

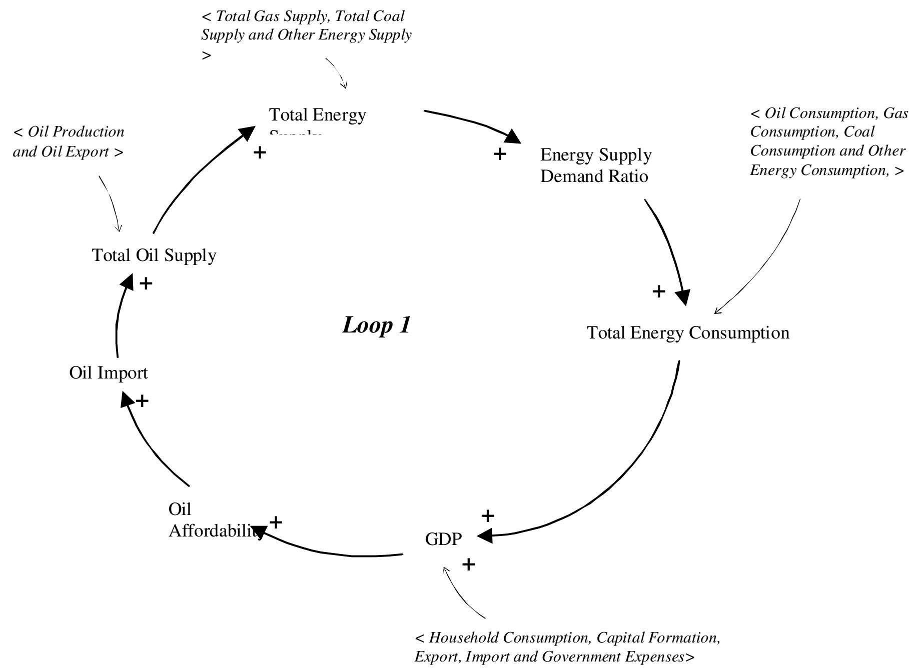

Figure. 2 Energy– Economy System Loop

In turn, the economic development will influence the energy system. Based on Lardic and Mignon (2006), the model assumes that increase of energy price will retard the economy by slowing down energy imports if the nations GDP can not afford it. Affordability variable is introduced in the model to address the assumption. The idea of affordability is that the capability to import energy is depend on the relationship between prices of energy and level of GDP. It will be explain in the next section.

The total energy supply is a summation of total supply of oil, gas, coal and other energy. Since oil is the main interest, the total supply of gas, coal and other energy types are not elaborated in further detail in figure 2. The same condition applies for total energy consumption and members of economy sub-system that constitute GDP. These sub-systems are depicted in the figures as bracketed variables with small arrows.

Oil Import Loop. Based on Lardic and Mignon (2006), that high energy prices will retard the economy, the model assume it will happen through the decrease of energy import, thus decrease in energy supply. It is represented in the model by Loop 2, depicted in the figure 3. This loop illustrates the influence of affordability towards the fulfillment of oil supply needs. The amount of oil import required is depending on the desired oil supply demand ratio level. Thus,

Oil Import Required = (Desired Oil S/D - Oil S/D) x Total Oil Demand (3)

Oil Import Affordability = (Allocation for Oil Import x GDP) / (International Oil Price x Oil Import Required) (4)

Oil Import = Oil Import Required x Oil Affordability (5)

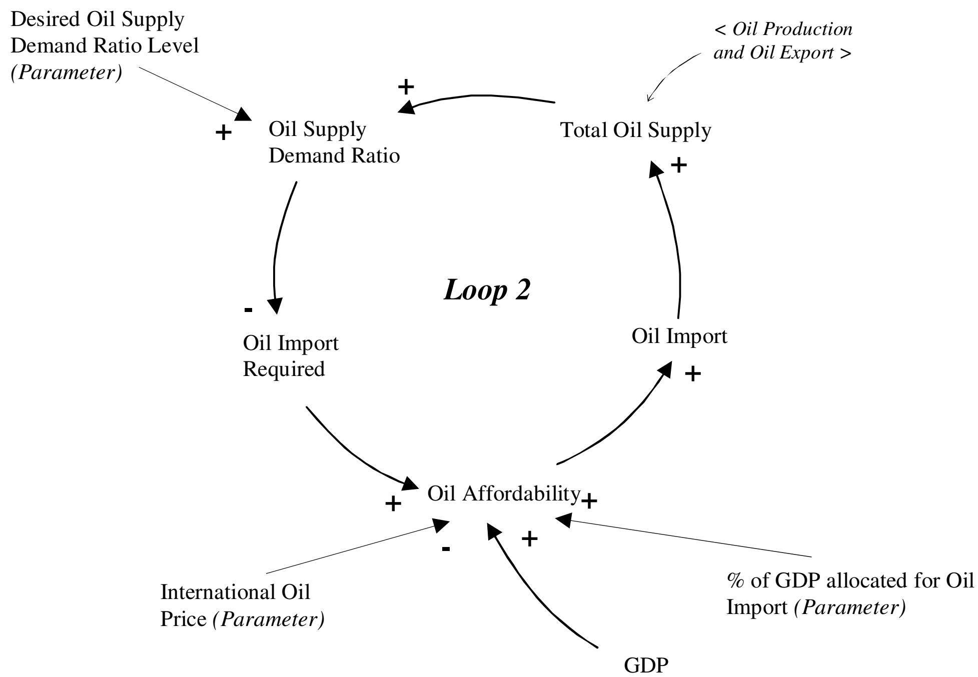

Figure 3. Oil Import Loop

The oil affordability is determined by the share of GDP allocated to buy certain amount of oil required to balance the energy supply demand ratio to a desirable level at the certain international price of oil.

Technology Influence Loop. Depicted In figure 4, loop 3 and Loop 4 represent relationship between Technology Advance and GDP. Technology Advance indicator (UNIDO, 2005) is adopted to determine the level of Technology Advance of the country. The efficiency increase is assumed to progress concurrently with the advance of technology which then influences energy consumption.

The technology advance is also affecting the GDP via productivity. It is assumed that productivity is increasing along with technology advance. In order to calculate the influence of technology advance to productivity, regression is performed to productivity data from Asian Productivity Organization (APO, 2009) and the technology advance indicator. The regression produced;

Productivity= 1.1094 Ln(Technology Advance) + 2.8632 (6)
R2 =0.7033 RSS = 0.1207

In order to calculate productivity influence over GDP, a multiplier is introduced. The multiplier is produced by regression technique using productivity as independent variable and GDP growth as dependent variable. It is expressed as follow,

GDPM=1.01163.e0.270717xTechnology Advance (7)

GDP = GDPI x GDPM (8)
Where, GDPI is the initial value of GDP and GDPM is the GDP Multiplier.

Parameter

The influence of economy and oil price over energy security can be simulated by applying three available parameters namely the International Oil Price, Desired Supply

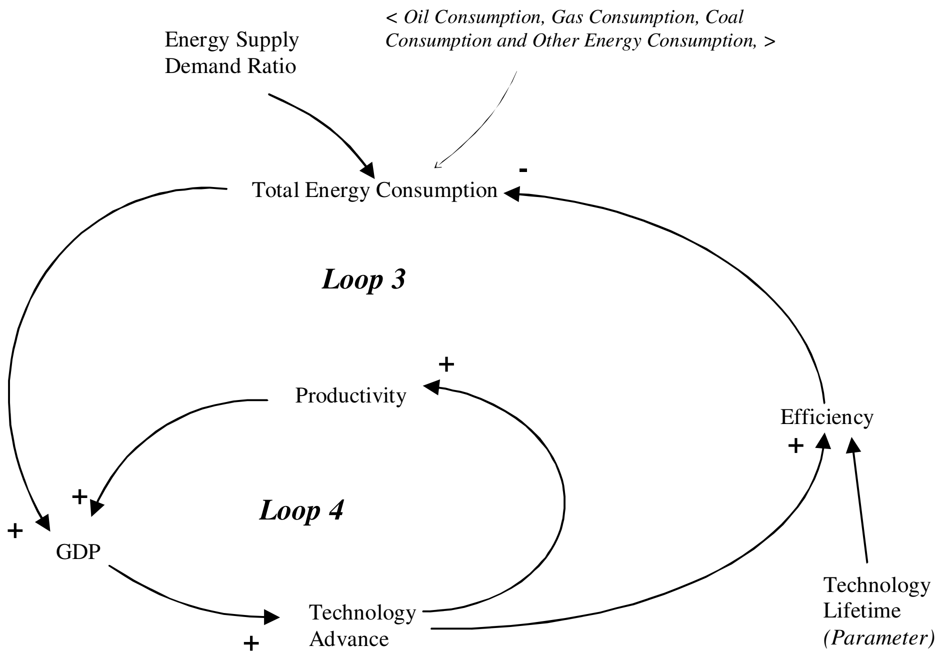

Figure 4. Technology Influenced Loop

Demand Ratio and Percentage of GDP Allocated for Oil Import.

International Oil Price can be arranged to follow certain increasing or declining trend or at certain level of price. The default value for this parameter is set to the increasing trend price of the corresponding period of the data available. Desired Oil Supply Demand Ratio Level is the amount of oil necessary to fulfill consumption need. This parameter can also be used to set the amount of oil inventory as protection from disruption (i.e sudden decrease of supply). Percentage of GDP Allocated for Oil Import is functioning as a constraint to the amount of oil that can be imported to the country at a certain oil price. The role of Technology Life Time parameter is explained as the following. The influence of technology over energy consumption is represented by efficiency. Efficiency level is depending on the replacement of older technology by newer technology that is assumed to bring more advance technology. The period of replacement is assumed as the life time of the older technology. The longer the life time of old technology then the slower the increase of efficiency.

Scenario

Two scenarios are simulated for this paper to explore the energy security of Indonesia from 2007 up to 2020. The first scenario is the Business As Usual (BAU), in this scenario the Desired Oil Supply Demand Ratio parameter is set to follow the trend curve assuming that there will not be any change in energy supply-demand policy. Oil import burden on GDP is not limited assuming that GDP will always accommodate oil import needs, therefore the Percentage of GDP Allocated for Oil Import parameter is set to 100%. The Technology Life Time is set to 50 years assuming that newer technologies are adopted by Indonesia at current rate. In both scenarios, this parameter values is based on expert estimation on lifetime of industrial machinery and vehicle in Indonesia.

The alternative scenario (ALT) is a scenario that developed from a combination of parameters value assumed to be the most probable scenario given the parameter provided and a review of recent Indonesia's policy composed from Atje and Hapsari, 2008; The Central Bank of Republic of Indonesia, 2006; APERC, 2009. In this alternative scenario, the Desired Oil Supply Demand Ratio is set to the 1.25 assuming that Indonesia will follow EU standard to have a reserve of oil for 90 days from normal oil demand (EU Commision, 2006). Percentage of GDP Allocated for Oil Import is maintained at 1.6% level assuming that high increase of oil price can only be absorb up to this level without disrupting the oil import. The level is the average of oil import spending share in Indonesia's GDP calculated from 1990-2006 data. The technology life time is set to 10 years assuming that more advance technologies are adopted by Indonesia at high rate.

In both scenario, the Oil Price is assumed to continue its increasing trend and the value is estimated by calculating the trend curve from oil price data of 1990 to 2006.

Simulation Result

The simulation goal is to examine possible policies that may affect the development of Indonesia's energy security over the period of 2007 to 2020. This is done by comparing the simulation result of BAU scenario and ALT scenario.

Energy Supply Demand Ratio. The simulation result of BAU showed a significant increase of energy security, in term of Total Energy Supply Demand Ratio as depicted in figure 5 .

It is mainly influenced by the import sector, and since the only type of energy source imported is oil, its influence over Energy Supply Demand ratio is very high. The Desired Oil Supply Demand ratio in BAU is following its increasing curve; this allows Energy Import Required to increase simultaneously if there is not any decrease in demand side. Thus Total Energy Supply is also increasing because the GDP is always able to fulfill the Oil Import Required. A policy that targets the desired energy supply demand ratio is important to keep the energy in balance and not oversupply.

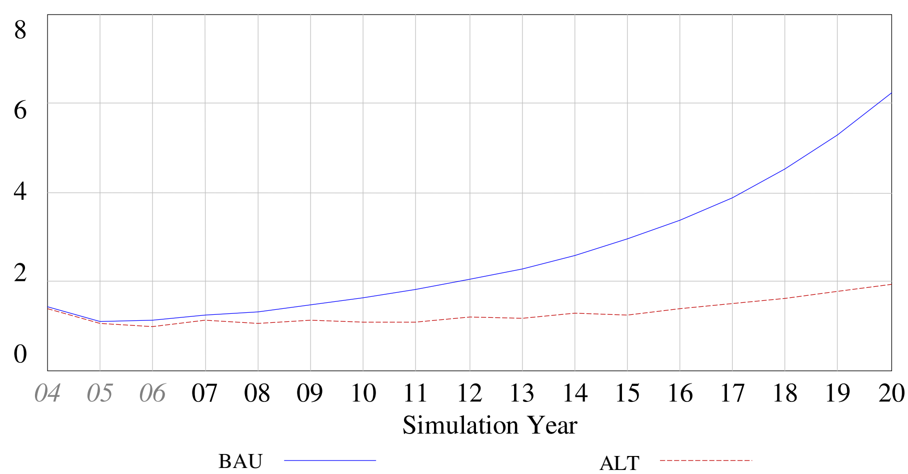

Figure. 5 Energy Supply Demand Ratio

In ALT scenario, the growth of supply demand ratio is only slightly increased, this is due to the policy of maintaining the Desired Oil Supply Demand ratio at 1.25. It prevents the oversupply of oil, even as the Energy Consumption is decrease due to higher energy efficiency. As depicted in Technology Influenced loops, the energy consumption is affected by efficiency. Policy measures that support faster technology advance are likely to be a significant demand-side factor in improving energy security. The simulation result of energy consumption is in the figure 6.

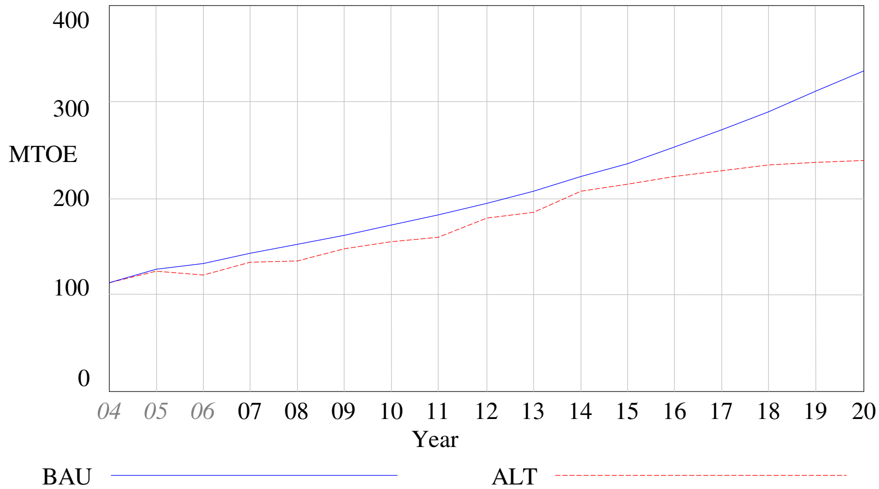

Figure 6. Energy Consumption

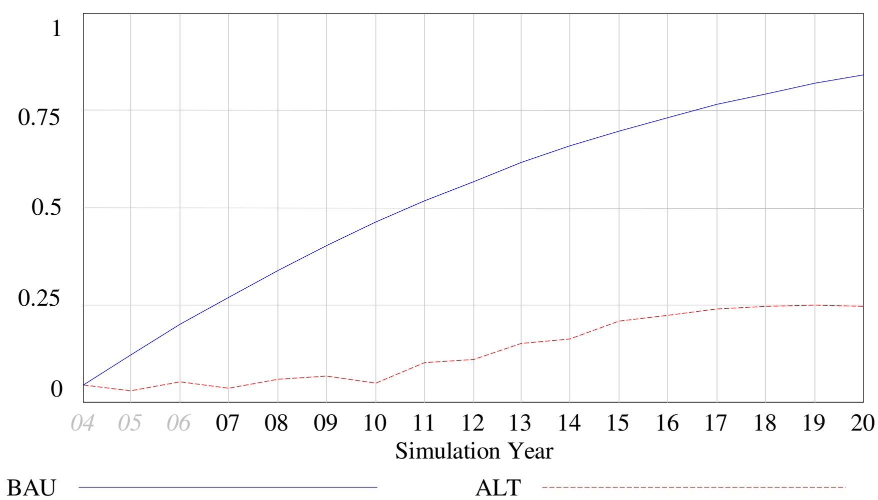

Figure 7. Energy Import Share in Total Energy Supply

Oil Import. The policy to reach the oil supply demand ratio at 1.25 in ALT scenario has a balancing effect on the overall Oil Import as when the Oil Import is sufficient to fulfill the ratio, then there will not be any import. This policy, combined with the effort to limit oil import by constraining the percentage of GDP to oil import at 1.6% has resulted a lower amount of Oil Import, thus lower amount of Total Energy Import

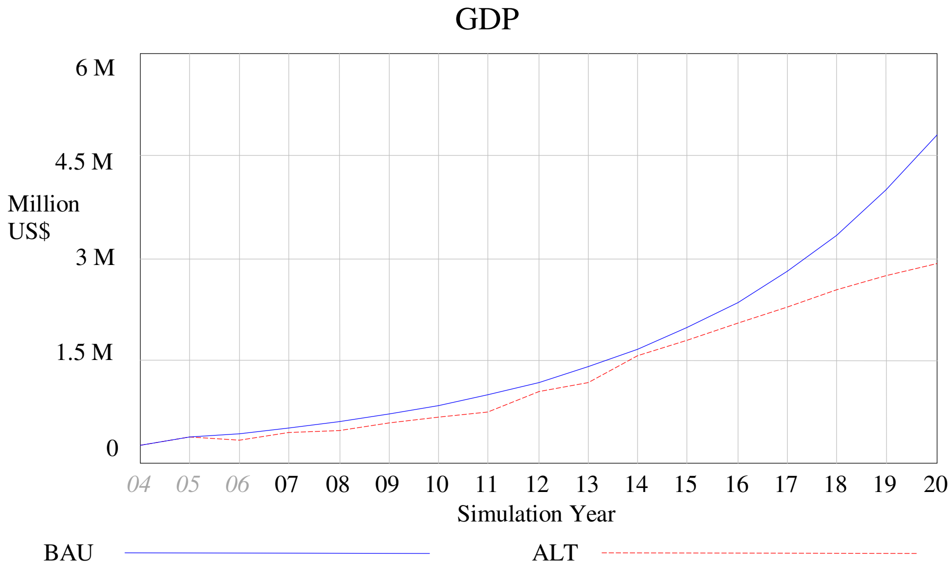

Figure 8. Gross Domestic Produc (GDP)

compared to BAU Scenario. Figure 7 shows the Energy Import share in Total Energy Supply.

Economic Development. The result of ALT scenario produces a lower GDP growth than that of BAU. The result shows resemblance of GDP curve to Total Energy Consumption, as showed by figure 8. This is due to two factors, the limitation of Oil Import at 1.6% of GDP that limit the Total Energy Supply and the increase of Energy Efficiency by Technology Advance, both eventually restrain Total Energy Consumption.

Conclusion

A modelling and simulation of future Indonesia's energy security in term of availability has been presented. The simulation result of BAU scenario shows that Indonesia will be able to achieve a very high level of energy security in term of availability. However, this is followed by a high growth of energy import resulting high energy import dependence, therefore in another sense, it suggests a low level energy security.

The ALT scenario result shows lower energy security than the BAU, however, this is mainly due to the goal of the policy in ALT scenario to maintain 1.25 energy supply demand ratio. The GDP growth in this scenario is also lower this is mainly due to the lower energy consumption which is the result of goal to limit 1.6% of GDP spend for oil import. More over, energy consumption is also influenced by the expected increase of energy efficiency by faster technology advance. Therefore, the level of energy security in ALT scenario can be concluded as sufficient, at the expense of lower economic growth.

From the simulation, it can be inferred that achievement in one aspect of energy security may be contradictive to another aspect. In this regard, inclusion of more aspects in evaluating the policy may result in broader understanding of energy security, thus more useful result for decision makers.

The availability aspects of energy security considered in this paper provide only limited insight in understanding Indonesia's energy security. Further development of the model to include different aspects of energy security (i.e, environmental acceptability) is needed.

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Biography

Yudha Prambudia is a doctoral student at Business Engineering Laboratory, Graduate School of System Design and Management, Keio University, Japan. He acquired his master degree from University of Twente, The Netherlands, and bachelor degree from National Institute of Technology, Indonesia. His research interest are energy planning, urban and regional planning, and supply chain and logistics management.

Yasuko Todo is a master student at Business Engineering Laboratory, Graduate School of System Design and Management, Keio University, Japan. Her research interest is energy security.

Prof. Masaru Nakano Ph.D, is the leader of Business Engineering Laboratory, Graduate School of System Design and Management, Keio University, Japan. He has extensive academic and professional research experience in manufacturing and automotive industries.