Evaluating the Supply, Efficiency and Environmental Aspects of ASEAN Energy Security: Indonesia

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Abstract

Energy security is an increasingly important subject for regions around the world, including in ASEAN. The expanding production network and uneven energy resource endowment placed energy security as an important issue in this context. Indonesia is among ASEAN countries with rapid economic development. With the large population supporting its domestic market and high GDP growth, Indonesia's economic development is confidently growing. Alongside economic growth, Indonesia's energy consumption is continuously growing as well. On the other hand, Indonesia's supply of energy is facing some issues. Oil production has been declining, while alternatives to oil, such as gas and coal are apprehended by export contracts. In addition, coal brought significant environmental concern. As part of ASEAN, Indonesia's efforts to improve energy security must consider its condition as well as its regional commitment toward energy security. This study presents an evaluation of future energy security of Indonesia considering its national perspective and ASEAN's Cebu declaration perspective. Energy security is evaluated by measuring indicators from supply, efficiency and environmental using policy simulation. It is found that Indonesia's policies are contributing largely to its future energy security in the supply aspect, but conflicting with efficiency and environmental aspects.

Keywords: Energy security, self sufficiency, energy efficiency, CO2 emission.

1. Introduction

The staggering energy demand growth of Association of South East Asian Nations (ASEAN) countries due to rapid economic development has placed energy security as a central issue. The fact that energy resources are distributed unevenly in this context is even put more weight on the importance of the issue. In a larger context, ASEAN plays a major role in the expanding production/distribution network within East Asia region (Ozeki, 2008), therefore energy security becomes a major concern in considering production/distribution counterparts. The Cebu declaration on East Asia energy security (ASEAN, 2007) exemplifies the importance of energy security in East Asia region including the ASEAN.

Indonesia is among ASEAN countries with rapid economic growth. With the large population supporting its domestic market and high GDP growth, Indonesia's economic development is confidently growing. Alongside economic growth, Indonesia's energy demand is continuously growing as well. On the other hand, Indonesia's supply of energy is facing some issues. Oil production has been declining, while alternatives to oil, such as gas and coal are apprehended by export contracts. In addition, coal brought significant environmental concern which is highly regarded in the regional context.

This study evaluates energy security level of Indonesia with regards to its energy, socio, economic and technological development. The main focus is on Indonesia's energy development policy. A system dynamic model is developed to simulate Indonesia's energy security level progression into the future. Evaluation is conducted by analyzing energy security from the supply, efficiency and environmental aspect in terms of self sufficiency, energy efficiency and emission mitigation.

The rest of the paper is organized as follows; section two describes the profile of Indonesia. Section three explained the model and scenario used to examine energy security in this study. Section four present the results and its analyses. Section five concludes with some salient points from the study.

2. Indonesia Country Profile

2.1 Socio-economic

Since 1998's economic crisis, Indonesia economy has been growing confidently. With the year-on-year GDP growth of 6.1% in 2009-2010 (BPS, 2011), the government is confident that future economic development will be thriving. The GDP per capita is at 3.263 USD (2000 at PPP) (APEC, 2011). The population growth of Indonesia has been modest for the last decade (BAPENNAS-BPS, 2005); however, a considerable increase in population growth is expected. Latest census result in 2010 shows 1.49% annual growth which is 14% higher than previously predicted (BPS, 2011). Indonesia's technology achievement in 2001 and 2002 is at the lower part of technology adopter category and ranked at 60^{th} (UNDP, 2001; Nasir, Ali, & Shahdin, 2011).

2.2 Energy

Indonesia's energy demand is increasing following the growth of economic development. The average energy consumption growth has been increasing from 9.2% in 2000-2005 to 12.1% in 2005-2008 (BPPT, 2010). Oil is the dominant energy source for Indonesia, however, its role is decreasing while coal and gas consumption is increasing. The increasing growth in coal utilization is noticeably important due to concerns over environmental impact such as CO2 emission. Indonesia's CO2 emission has been worsening in the last decade. The average annual CO2 emission from 1999 to 2004 is 11.2 mton-CO2/year while from 2005 to 2009 is 21.1 mton-CO2/year (EIA, 2011).

2.3 Environment

Indonesia is traditionally an energy exporter country, however, oil production has been declining within the last decade (BPPT, 2010). This eventually compels Indonesia to leave OPEC in 2008 as it became a net oil importer country. On the other hand, coal production is increasing significantly in recent years, but most of it is exported. At the same time, gas production has been steadily increasing over the years. However, long-term contracts hinder gas domestic supply to increase (BPPT, 2010).

3. Methodology

A model is developed for the policy scenario simulation for energy security evaluation. The model is based on the works of (Prambudia, Todo, & Nakano, 2010) as a starting point. For this study, the model then has been modified and improved to allow wider policy scenario to be included.

Two types of scenario are developed for the simulation. First, Business-as-Usual (BAU) scenario is developed and simulated to examine the outcome of continuation of existing energy development policies to energy security level. Second, Alternative Development Scenarios (ADS) is developed and simulated. The alternative scenarios introduce various energy development policies to the model. Analysis is done by comparing the results of these two types of scenario.

3.1 Model

Energy security is characterized by interrelated relationships between various aspects, i.e. energy, socio-economy and environment aspects. From a system point of view, the interplay between the aspects can be represented by a complex system. For this study, system dynamics (Sterman, 2000) is employed to capture interplays between aspects of energy security by modeling the interrelated relationship as a complex system. The model is broadly segregated into three sectors namely; energy, socio-economy and environment.

From aggregated point of view the model mechanism is characterized by feedback loops between the sectors. The conceptual framework of the model is presented in figure 1.

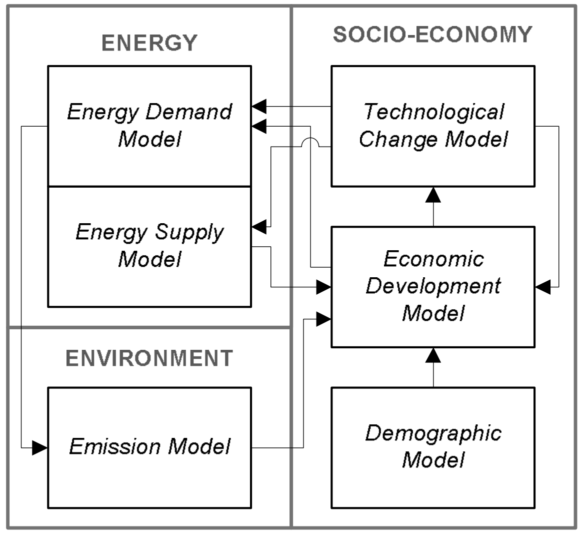

Figure 1 Model Overview

3.1.1 Structure

3.1.1.1 Energy Sector

The Energy sector is central for the model. This sector is composed of Energy supply and Energy demand model. Each type of energy source considered in this study (oil, gas, coal, hydro, geo-thermal, biomass, waste, wind and solar) is represented in the model using these two model framework. In the case where a certain part of the framework is not applicable (i.e. energy trade sub- model for geothermal), it will then be deactivated.

Energy supply model consists of energy trade and energy production sub-model. The energy trade sub-model allows the influence of energy import and export dynamics to energy supply to be considered. Energy production sub-model is influencing energy supply by its energy production taking into account energy production performance and the dynamics of energy reserve level. The Energy demand model consists of five energy consumption sectors namely; Household, Industry, Transport, Commercial and Other, assembled within the energy consumption sub-model.

3.1.1.2 Socio-Economy Sector

This sector composed of Demographic, Economic development and Technological change models. In the Demographic model, the variable determining the number of population is exogenous. It is calculated using non-linear equation derived from country's historical population data. Economic development is indicated by Gross Domestic Product (GDP). GDP is calculated as a summation of all economic value added (VA) from VA sub-model according to International Standard Industrial Classification (ISIC) of all economic activities (UN, 2011a). The VA sub-model is influenced by technology advance index. GDP per capita is calculated as a division of GDP by Population. Technological change is estimated by adopting Technological advance index of UNIDO (2005).

3.1.1.3 Environment Sector

The Environment sector consists of Emission model which is composed by CO2 emission and CO2 tax sub-model. CO2 emission sub-model basically calculates the level of CO2 inventory by considering CO2 emission from fossil energy consumption and natural CO2 sink. CO2 tax sub-model calculates the effect of CO2 tax to economic growth.

3.1.2 Feedback Loop

3.1.2.1 Energy Supply -Economic Development -Technological Change loop

The Energy sector is influencing Socio-Economy sector through Energy supply. Increase of energy supply does not necessarily mean increase of GDP, but it decreases the chance of disruption by energy shortage therefore allows the GDP to grow. In addition, surplus of energy production contributes to GDP growth of exporter countries. The GDP influences positively the advancement of technology thus increase of GDP may accelerate Technological change. In turn, technology advance influences energy supply positively. The level of technology influences positively to Energy supply, i.e. it will make cleaner and renewable energy supply more viable. This loop is a reinforcing feedback loop.

3.1.2.2 Energy Demand -Emission - Economic Development - Technological Change loop

The Energy sector is influencing Environment sector by Energy consumption. The CO2 emission is influenced positively by Energy consumption. Increase of Energy consumption will cause CO2 emission from energy use to increase as well. Subsequently, CO2 emission is assumed to have negative impact to economic growth, thus may reduce GDP. The GDP influences positively the advancement of technology thus increase of GDP may accelerate Technology advance. In turn, the technology advance is influencing Energy consumption negatively as technology advance is assumed to bring more efficiency to energy consumption. Finally, Energy consumption is influencing positively the CO2 emission. Decrease of energy consumption will decrease CO2 emission. This loop is a balancing feedback loop.

3.1.2.3 Energy Demand – Emission - Economic Development loop

The Energy demand sector is influencing positively CO2 emission through Energy consumption. Subsequently, CO2 emission is assumed to have negative impact to economic growth, thus may reduce GDP. In turn however, GPD is influencing positively to energy consumption, thus increase of GDP will result in increase of Energy consumption. This loop is a balancing feedback loop.

3.1.2.4 Technological Change - Economic Development loop

Technological change is assumed to be influenced positively by GDP. The increase of GDP will result in faster technology advancement. In turn, Technology advance is influencing positively the GDP, thus faster technology advancement will hasten economic growth. This is a reinforcing feedback loop.

3.1.3 Energy Security Indicators

In analyzing energy security level, both Indonesia's and regional perspective of energy security are considered. In order to determine the indicators of energy security, the study is referring to government's energy policy targets. Furthermore, the Cebu declaration is taken as a reference to represent ASEAN perspective.

Availability of energy has been considered as the central dimension of energy security (Kruyt, van Vuuren, & Groenenberg, 2009). It is also true for Indonesia. In the presidential decree no.5/2006 on national energy policy, the government put emphasis on the supply side of Indonesia's energy system to improve this aspect of energy security. Along with it efficiency in energy use is regarded as an important measure to improve energy availability. Environmental concern is also mentioned in the decree as an aspect to consider in improving energy availability. Aligned with Indonesia's energy policy, the Cebu declaration expressed that improvement of efficiency and environmental performance of fossil fuel are the main objectives in improving energy security. Furthermore, it considers green house gas emission as an important issue to address (ASEAN, 2007). In the light of these, self-sufficiency, economic-energy-efficiency and CO2-emission-mititgation indicators are selected to respectively represent energy security level from supply, efficiency and environmental aspects.

In this study, self sufficiency is defined as the share of indigenous energy production in total supply of energy. It can be expressed as follows;

$$SS = \frac{IEP}{TPES} \quad (1)$$

Where, SS is self sufficiency, IEP is Indigenous energy production, and $TPES$ is Total primary energy supply. The indicator shows the capacity of the country to fulfill its energy demand on its own resource. The range of SS value is from 0 to 1. The higher the SS value is the better.

Efficiency is indicated by energy intensity. It is defined as the amount of energy consumed to produce one unit of GDP. The indicator can be expressed as follow;

$$EI = \frac{TPEC}{GDP} \quad (2)$$

Where, EI is energy intensity, $TPEC$ is total primary energy consumption, GDP is gross domestic product. This indicator shows the energy efficiency of the country in producing economic wealth. The lower the value of energy intensity, the higher is energy efficiency, thus it is the better.

Environmental aspect is indicated by CO2 emission intensity. This indicator is defined as the amount of energy consumed for every unit of CO2 produced. This indicator shows the environmental performance of the country's energy system. The indicator can be expressed as follow;

$$EM_{CO2} = \frac{em_{co2}}{TPEC} \quad (3)$$

Where, EM_{CO2} is the CO2 emission intensity level, em_{CO2} is CO2 emission from energy use, $TPEC$ is total primary energy consumption. The higher the emission mitigation is the better.

3.1.4 Data

Energy data are mainly come from APERC energy data base (IEEJ, 2011). In the case of data unavailability, data is estimated. Some energy data are combined with national energy data to improve accuracy. GDP data in term of economic value added according to ISIC at constant prices (1990) in US dollar is collected from United Nation Statistical Division (UN, 2011a). The population data is from UN Population Division (UN, 2011b). CO2 emission data from Energy Information Administration of U.S. government (EIA, 2011) is used.

3.2 Scenario

Two scenarios are considered in this study; Business As Usual (BAU) scenario and Alternative Development Scenario (ADS).

3.2.1 Business as Usual Scenario

In BAU scenario, it is assumed that development pathway is a result of continuation of policies which were implemented before 2009 (based on the most recent available data). It is also assumed in this scenario that there will be no policy intervention within the simulation period. On the other hand, the ADS scenario takes into account policies introduced within and after 2009.

3.2.2 Alternative Development Scenario

Peraturan Presiden (President's Decree) no 5/2006 regarding National Energy Policy is further expressed in the Blueprint Pengelolaan Energi Nasional (blueprint of national energy management) 2006-2025 (KESDM, 2006) and other ministerial regulations (KESDM, 2010; KESDM, 2011). Guided by the documents, following policies are adopted for ADS, as summarized in Table I.

Table. I Summary of Alternative Development Scenario

Sector/Country	Indonesia
Oil	No new development on oil
Coal	A minimum of 25% of coal production is directed to domestic supply. Coal consumption growth increases gradually 5% per year.
Gas	New contract of long-term gas export is banned. Surplus of gas production is directed to domestic market.
Nuclear	No nuclear plan is implemented.
Geothermal	Geothermal capacity increases 20% by 2020 and 40% by 2030.
Solar	No new development on solar energy
Wind	No new development on wind energy
Hydro	Micro-hydro capacity is assumed to increase at 5% per year
Biomass	Biomass utilization is assumed to increase gradually 5% per year
Efficiency by Technology advancement	Energy efficiency in household and commercial sectors increase 30% by 2030.
Carbon Tax	Gradually increasing CO2 tax of Rp.80.000 to Rp.280.000 is implemented from 2009 to 2030.

- Domestic energy supply priorities; Coal and gas production will be relocated to fulfill domestic energy demand. Ministrial regulations controlling coal and gas export has recently been announced in 2011. The regulation stated that the government will determine annually a minimum percentage of coal to be allocated for domestic market. The regulation also introduces restrictions to new gas export contracts. In this scenario, it is assumed that a minimum of 25% of coal production is reserved for domestic demand. Following this development, it is assumed that coal consumption will grow at rate of 5% per year. Gas export, starting from 2011 is assumed to be constant at 40.15MTOE/year as no new long term contracts will be signed. There are no development regarding oil, thus the scenario assumed that oil development will follow historical data. However, it is assumed that substitution between oil and other energy is present. The development of other energy sources contributes negatively to oil consumption.

- Introduction to renewables energy: Rencana induk pengembangan energi baru dan terbarukan (new and renewable energy development masterplan) or RIPEBAT (KESDM, 2010) for non-fossil energy production technology and market development has recently been revised. Particularly, the government focuses more on development of biomass, geothermal and micro-hydro energy market. In this scenario, biomass utilization is assumed to increase gradually 5%, micro-hydro capacity is assumed to increase at 5% per year and geothermal capacity will increase 20% in 2020 and 40% by 2030.

- Energy efficiency and conservation: Rencana Induk Konservasi Energy Nasional (national energy conservation master plan) or RIKEN is introduced in 2005 (KESDM, 2010). Currently RIKEN is implemented mainly by establishing energy performance standards and labeling schemes. In this scenario, it is assumed that RIKEN will allow more efficient technology to be adopted faster and make ways to realize higher efficiency goals. Thus, higher efficiency up to 30% will be gained by 2030 in energy consumption of the commercial and household sector as standards and labeling on buildings and appliances are assumed to be fully effective.

- Nuclear power; There have been many discussions and forums on nuclear power development plan in Indonesia. The government has been planning nuclear since 1956 (BATAN, 2010), however, the plan has never been very successful. It is mainly due to strong public oppositions which have been traditionally resisting the plan. The recent Fukushima crisis also made the resistance even stronger. Therefore, this scenario assumed that nuclear capacity will not be available during the simulation period for Indonesia.

- Carbon Tax: The Ministry of Finance proposed a plan for full carbon tax implementation in 2020 (MoF, 2009). According to (Yusuf & Resosudarmo, 2007) carbon tax implementation may inflict little damage to Indonesia's GDP due to its distributional effect. A carbon tax rate of Rp280.000/ton-CO2 may decrease Indonesia's GDP as much as -0.04%. It is assumed in this study that the rate is implemented gradually from Rp.80.000/ton-CO2 to Rp.280.000/ton-CO2 starting from 2010. The summary of the ADS scenario is presented in table I

4. Result and Analysis

The following sections present the results and analysis of simulations in terms of supply, efficiency and environmental aspects. The green line represents the BAU scenario while the blue line represents ADS. Lines from 1980 to 2008 represent historical data while lines from 2009 until 2025 are simulated results.

4.1 Self Sufficiency

The BAU scenario simulation result on Indonesia energy self sufficiency shows 11.5% decrease from 0.93 in 2008 to 0.82 in 2025. The ADS scenario simulation results only show slight decrease of self-sufficiency with slightly increasing trend during 2016 to 2021. The self-sufficiency level difference between BAU and ADS at 2025 is 11.5%. The result is presented in figure 2.

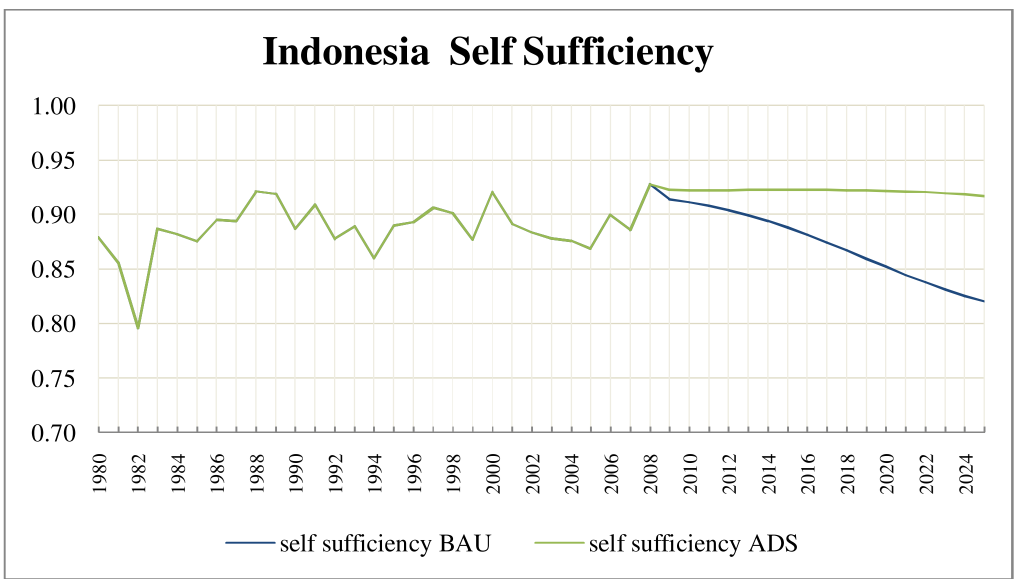

Figure 2. Indonesia's Energy Self-Sufficiency

4.2 Energy Intensity

The BAU scenario simulation results on energy intensity show 20.6% decrease from 620 TOE/Mil.USD in 2008 to 492 TOE/Mil.USD in 2025. The ADS scenario simulation results show 16.7% decrease of energy intensity by resulting 520 TOE/Mil.USD in 2025. The BAU scenario produces 3.9% lower energy intensity level than ADS. The result is presented in figure 3

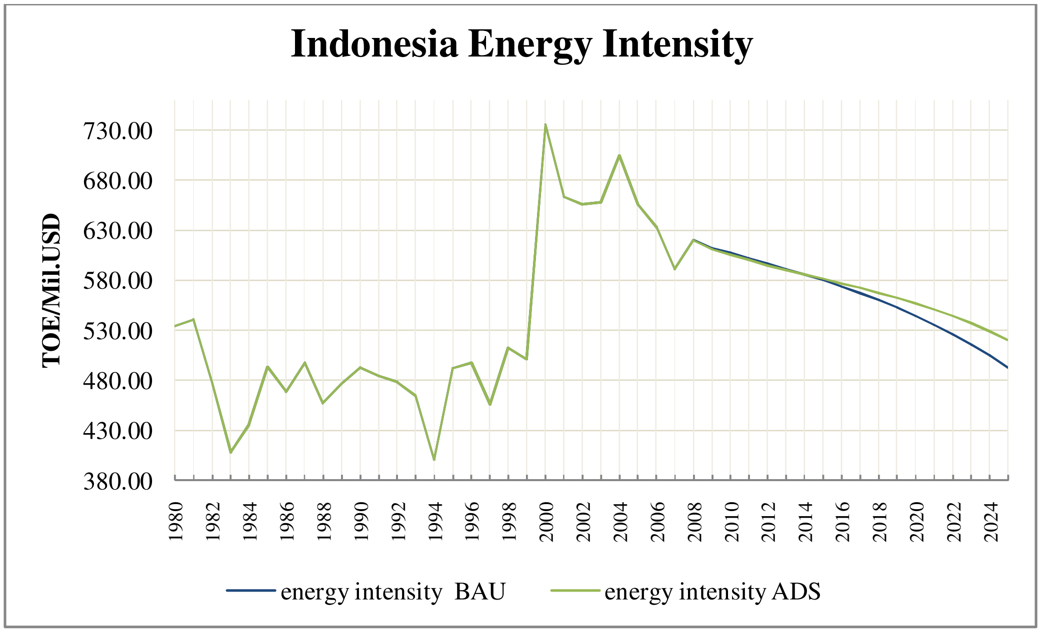

Figure 3. Indonesia's Energy Intensity

4.3 CO2 Emission Intensity

The BAU scenario simulation results on Indonesia CO2 emission intensity show 23% increase from 2.4 Ton-CO2/TOE in 2008 to 2.9 Ton-CO2/TOE in 2025. The ADS scenario simulation results show higher increase of 32% from 2.4 Ton-CO2/TOE in 2008 and 3.1Ton-CO2/TOE in 2025. The CO2 emission intensity level of ADS is 7.1% higher than BAU. Figure 4 shows Indonesia's CO2 emission intensity performance.

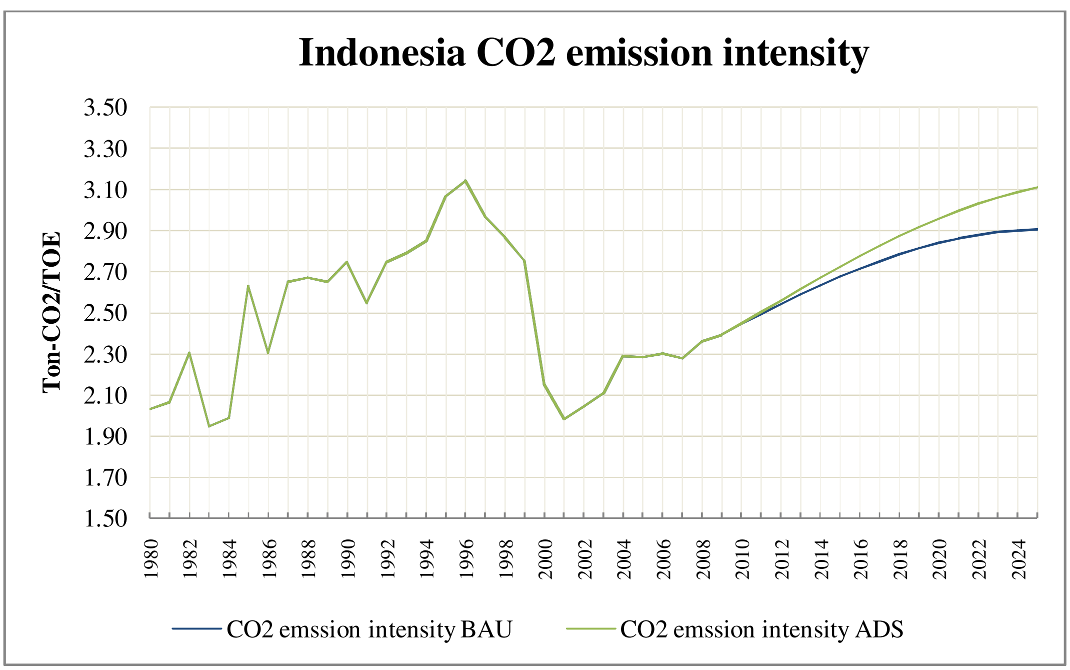

Figure 4. Indonesia's CO2 emission intensity

5. Discussions and Conclusion

An energy security evaluation of Indonesia has been presented. The evaluation is conducted by modeling and simulating Indonesia's energy security level using system dynamics from 2009 to 2025. The analysis covers supply, efficiency and environmental aspects of energy security.

Based on the analysis, Indonesia's future energy security can be described as follow; (1) Supply aspect: Indonesia's self-sufficiency will be maintained at high level if polices in ADS are implemented successfully. (2) Efficiency aspect: In general, Indonesia's energy intensity is improving. However, new policies in ADS do not contribute to future energy intensity improvement. In fact, the result of ADS simulation suggests that energy intensity level is worsening if the new policies are implemented. (3) Environmental aspect: Indonesia's CO2 emission intensity is worsening in both scenarios. Policies in ADS are contributing to higher CO2 emission intensity than BAU.

This study does not simulate the policies in isolation, therefore each policy contribution on energy security indicators cannot be identified. However, the structure of the model and the equation of indicators provide some hints on what factors may be responsible for the change, as described in the following; (1) In the ADS, self-sufficiency is maintained at stable level. This is likely due to higher portion of indigenous energy production directed towards domestic supply. Over the simulation period, the growth of indigenous energy supply is on par with energy demand growth. (2) Energy intensity is improving better without new policies introduced. This is likely due to higher GDP growth in BAU scenario compared to ADS. The reason may be found in the decrease of energy export as fossil energy is directed toward domestic supply. (3) CO2 emission intensity in ADS is higher due to higher availability of fossil energy, which is contributed by indigenous energy production directed towards domestic energy supply. In the light of this, it is likely that the policy to directed indigenous energy production to domestic supply has a significant role. Further studies should seek the role of each policy by conducting isolated policy simulation to find leverage points, in particular, futher investigation on the role of domestic energy supply policy will be very useful.

In conclusion, it is found that Indonesia's new policies related to energy development are contributing largely to the supply aspect improvement but conflicting with efficiency aspect improvement, and contributing to the worsening of environmental aspect. In particular, the new policy of domestic energy supply seems to have significant overall impact to the aspects analyzed. The worsening environmental aspect can be seen as indicator of Indonesia's commitment level toward ASEAN pledge on energy security and may have political impact to Indonesia's role as a member country.

6. Acknowledgement

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