A System Dynamics of Indonesia Low Carbon Energy Resilience Model

Andi Muhammad Sadli[1]
[1]Ph. D. Student in Enviromental Science Program, University of Indonesia
andimuhammad@gmail.com

Presented for the
Asia-Pacific System Dynamics Conference of the System Dynamics Society
Tokyo, Japan, February 22-24, 2014

ABSTRACT

Energy plays an important role shaping civilization as a major input from various sectors of life. For Indonesia, the management and utilization of energy will determine the likely existence as a nation forward in the future.

This research used a quantitative methodology which is the chosen method is system dynamic simulation. The system dynamic model is the shape and energy utilization in Indonesia in order to achieve a degree of energy security with complex variables covering economic, social and environmental as well. The model simulation investigates the implications the use of fuel to the economy and how to find a model of low-carbon energy sustainability in the energy mix policy in Indonesia.

The model explores the relationship between population, fuel consumption, fuel production, fuel import, and emissions resulting from the use of fuel. This model will be used as the basis for the simulation scenario of *Business As Usual* (Base case) so that the visible trend of each variable and how interventions should be done. The interventions that are chosen namely structural intervention where included gas and geothermal as the additional energy resources. Then, Hypothesis that would be tested in this research is the reduction of CO2 emission and fossil fuel import as the feedback of energy mix policy.

The result shows that mix energy policy is able to reduce the CO2 emission at least 9% in average along the simulation period. In other hand the import of fossil fuel import can be reduced averagely up to 27%. Therefore, the mix energy policy is strongly feasible to be implemented and developed in the future.

KEYWORDS
System dynamics, low carbon, energy resilience, simulation model, mix energy

1. INTRODUCTION

Indonesia is a developing country with a population of 4^{th} in the world reached 240 million. With the economic growth of 6-7% and a population growth rate of 1-2% per year in need of natural resources is not a bit better in terms of production and consumption of everyday household (Central Bureau of Statistics, 2012).

One of the natural resources became the primary input from various sectors and households are energy. Each of the activities carried out by the resident requires energy such as: production, transportation, consumption, and others. Indonesia still depends on the fossil fuels, particularly oil. Various business activities through the combustion process largely oil-fired. Most of the vehicles in Indonesia are also very dependent on oil supplies. Thus it causes the economy and population of Indonesia is very influenced by the petroleum sector.

Fuel oil (BBM) which is produced from petroleum refineries are non-renewable energy formed by hundreds of millions years so it has very restricted reserves. Indonesia's proven reserves of oil currently resides 3.7% or 0.3 billion barrels of proven world reserves, relatively less than the endowment of energy such as coal, gas, CBM (Coal Bed Methane), geothermal, hydro, biofuels (Biofuels) and so on (Partowidagdo; 2009).

Petroleum is still used as the primary energy requirement fulfillment because it is supported by the infrastructure compared to other energy: factory machinery, motor vehicle engine, gas stations, distribution pipes, and others. Petroleum is also relatively cheaper than renewable energy.

The propensity of oil production in Indonesia, both exploration through EOR (enhanced oil recovery) as well as the utilization of the existing oil wells tend to decline and was not able to meet the quota demand and fuel consumption. As a result, since 2008, the Government has been importing oil to fulfill the sufficient needs of domestic fuel consumption. Indonesia produced 357 million barrels of oil, exporting crude oil by 146 million barrels, crude oil imports by 93 million barrels of fuel oil (BBM) amounted to 153 million barrels in 2008 (EMR 2009) and consumes 457 barrels. There is a deficit of 100 million barrels per year.

The policies of affordable energy in the past time that caused the public to be difficult to accept the increase in fuel prices by the Government. At this time, the government provides fuel subsidies to cover the difference between the world price of oil by purchasing power. Indonesia is still suffering problems related to the high subsidies of fuel oil (BBM) yearly until incriminating the financial State up to 2013.

Low fuel prices also do not provide the incentives of the development of other energy that is more environmentally friendly. The energy sector contributes significantly to the emissions produced by Indonesia with the exponential growth. Besides the government subsidy, the one that causes the very low fuel prices, because of the environmental costs are not accounted for by oil producers. The environmental costs are expenses suffered by society as consequences of environmental damage incurred from oil production activities.

2. PROBLEM & RESEARCH STATEMENT

Based on the background of the above problems, the research problem can be formulated as follows: *First*, trend of oil production in Indonesia tends to decrease as a result of the limited proven reserves, meanwhile fuel oil demand is increasing due to economic growth and high population in Indonesia. *Second*, the use of fossil fuels as the primary energy producing emissions of energy sector so that exponential growth can cause damage and disruption to the environment.

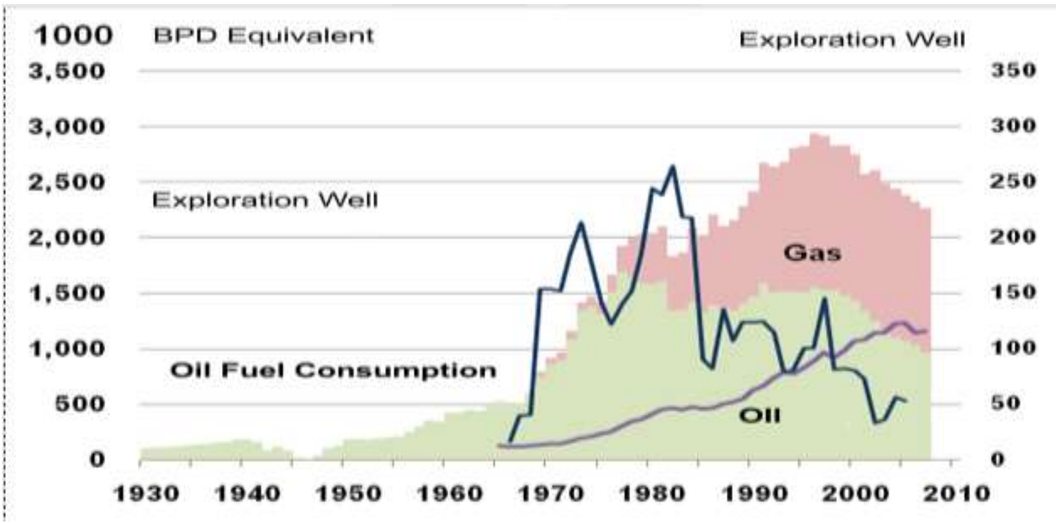
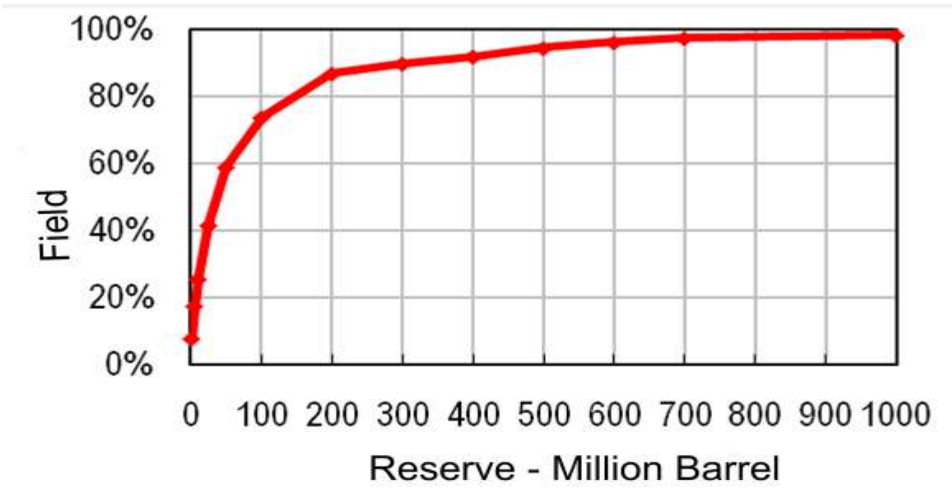


Figure 1. Comparison Between Oil Fuel Consumption and Oil & Gas Supply (Ministry of Energy & Mineral Resources of Republic of Indonesia, 2011)

Limited Oil reserve drives Indonesia to import oil to fulfill the national demand, the rate of import will much higher as the oil reserve declines over the years. From the graph below we can observe the oil reserve distribution.



Figures 2. Oil Reserve and Distribution (Ministry of Energy & Mineral Resources of Republic of Indonesia, 2011)

3. CONCEPTUAL MODEL

Loop formed of two variables is positive (reinforcing). Meanwhile, the increased mortality will reduce the number of people so that it will be negative relationship. Increasing the number of people tend to increase the number of deaths. Loop resulting from population and mortality variable is negative (balancing).

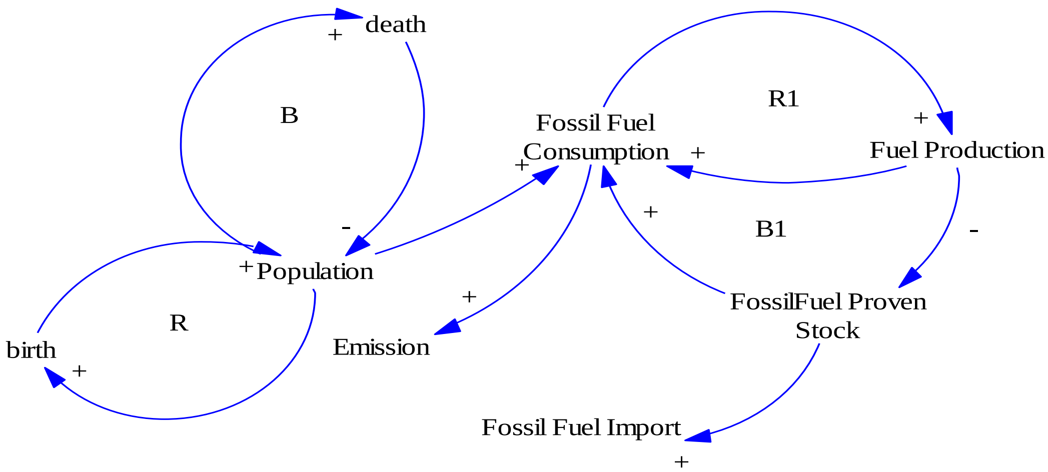


Figure 3. Causal loop diagram (Base Case Model)

Figure 1 shows the causal loop diagram of the model initial scenario (Base Case Model). Variable population is affected by two other variables, namely birth and death. Birth increases will cause the increment population. In contrast, the population increase will also lead to increased birth.

A large number of the population will drive an increase in fuel consumption. Fuel consumption affects the amount emitted by the fuel sector, the higher consumption, the greater the emissions produced. This increases fuel consumption which will be followed by an increase in oil production to fulfill the demand. Conversely, an increase in oil production is also likely to increase the fuel consumption as a result of increased availability of fuel in the public. Loop generated by variable fuel production and fuel consumption is positive (reinforcing).

Increased oil production would reduce the amount of proven oil reserves at fixed amounts, the discrepancy of energy need and fuel production is fulfilled by imported fuel, the more the production decrease the more import of fuel increase . Meanwhile, a large proven reserves tend to increase the amount of fuel consumption. Loop generated by these variables is negative (balancing).

4. SPECIFICATION OF THE MODEL

Then the causal loop diagrams is modeled into a flow chart (Stock Flow Diagram). Population is a stock where the cumulative amount each year, with the inflow of birth and outflow of death. The birth and death of each fraction is affected by the fraction of births and deaths. The population of Indonesia in 2007 was 230 million with the unit. Meanwhile, the number of births is defined as the fraction of births multiplied by the number of residents. The number of deaths is also defined as the fraction of deaths made by the population. The number of births and the number of deaths has units / year.

The fuel stock is a stock that is affected by the inflow of fuel production (derived from petroleum stock of proven reserves) and fuel consumption as a unit outflow with barrels and barrels per year for consumption and production. Fuel production is influenced by the rate of extraction and fuel consumption is affected by the number of population and per capita fuel consumption is an average fuel consumption of the Indonesian population. The fuel consumption affects the emissions produced by the fuel sector is also affected by technological variables, namely the level of emissions produced by current technologies used to burn every 1 barrel of oil.

5. RESULT & DISCUSSION

Based on the assumption of data in appendix 1. and the beginning of the generated simulation scenarios as follows:

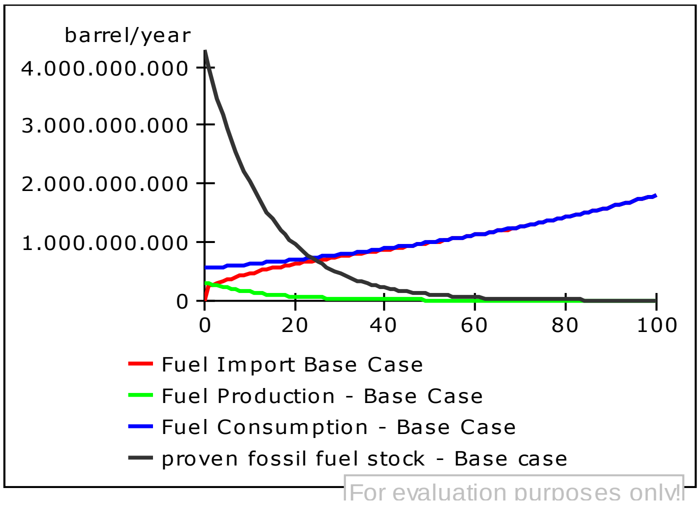


Figure 4. Proven stock petroleum, fuel stock and fuel consumption

In the figure 2 above, it can be seen that the proven fossil fuel stock gradually declines since the consumption exponentially grows. Since the energy need is not able to be fulfilled by the production, import is the only one option to cover the the discrepancy. The behavior of import and production can be seen above.

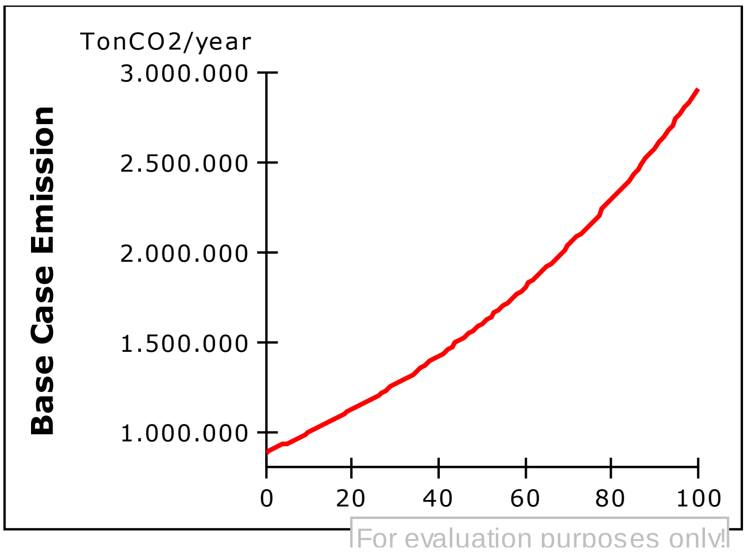


Figure 5. Emission of CO2 of the Base Model

From figure 3 above, we can see that CO2 emission increases due to the increasing of fossil fuel consumption correspond to the rising of energy needed by the exponentially growth population.

6. FUTURE SCENARIO 1 (INTERVENTION)

Optimistic scenario (forward) is done by a structural intervention by including variables and Gas energy mix, as shown in *Causal loop diagram* below:

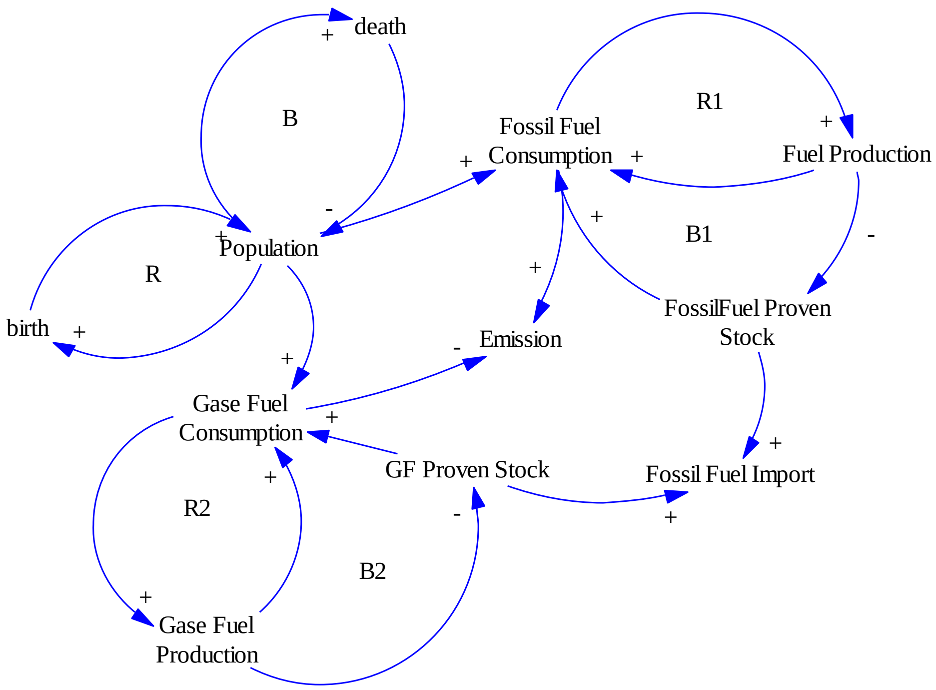


Figure 6. CLD First Scenarios

This scenario based on the following assumptions :

- Energy consumption fulfilled by the mix of gase and fossil fuel, where the present proven stock of gase in Indonesia is about 6534 TFC.
- Production rate of the gase annually is 0,00192505 rounded to 0,002
- Energy Consumption Discrepancy is fulfilled by import of fossil fuel.
- Technological coefficiency of the gase stated 0,001 TonCO2/barrel

7. FUTURE SCENARIO 2

Optimistic scenario 2 (forward) is done by a structural intervention by including variables and Gas, Geothermal, and Fossil Fuel energy mix, as shown in *Causal loop diagram* below:

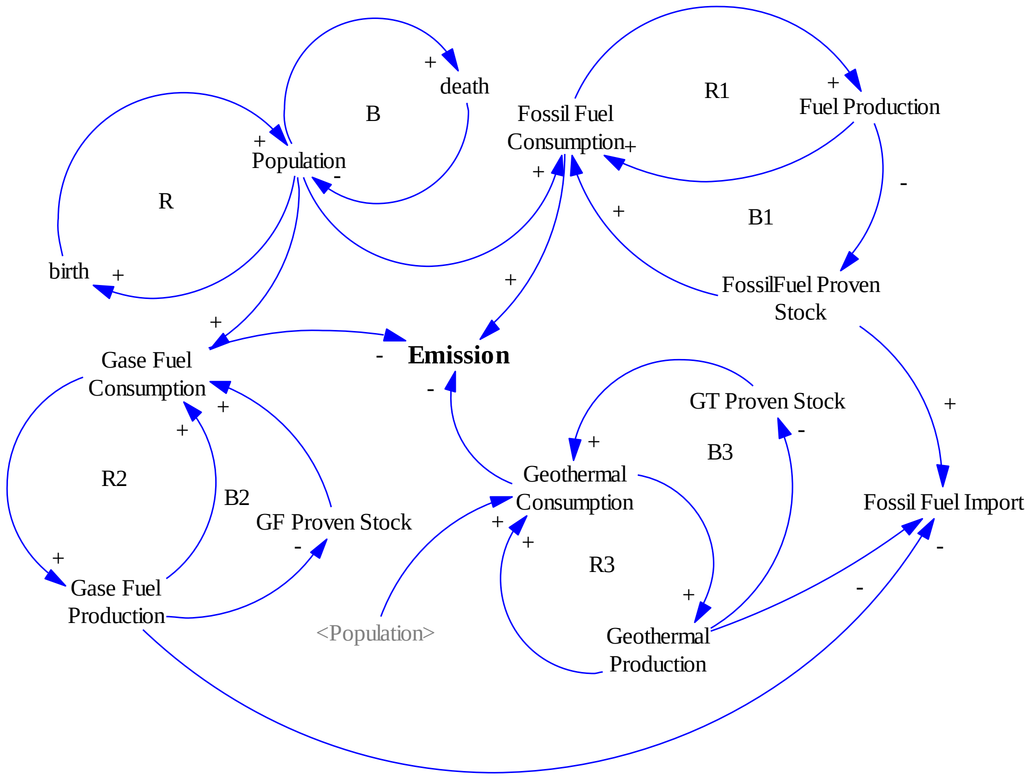


Figure 7. CLD Second Scenario

This second scenario deploys the following assumptions :

- Energy consumption fulfilled by the mix of gase, geothermal, and fossil fuel, where the present proven resource of geothermal in Indonesia is about 2.288 Mwe .
- Production rate of the geothermal annually is 0,04
- Energy Consumption Discrepancy is also fulfilled by import of fossil fuel.
- Technological coefficiency of the geothermal stated 0,00 TonCO2/barrel

8. SCENARIOS RESULT

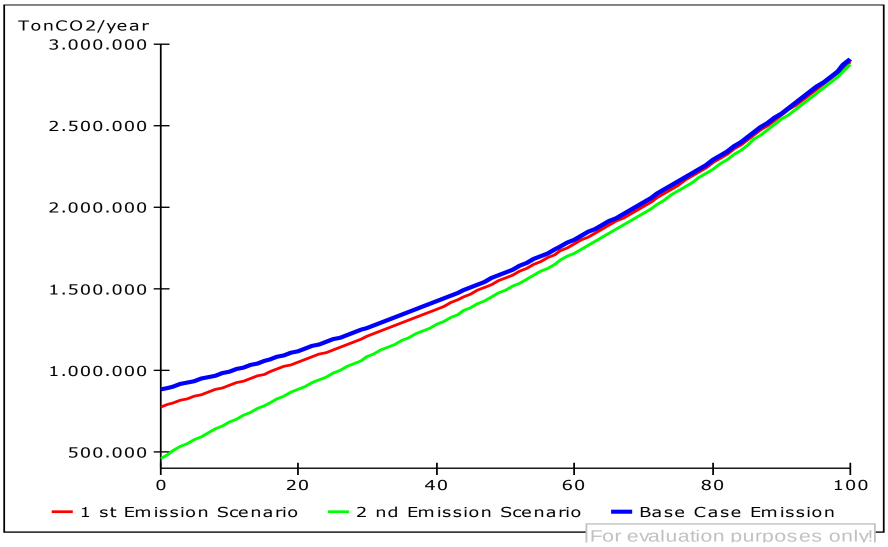


Figure 8. Emission Comparison Between Base Case and Scenario

Whole of scenarios show the similarity in behavior , but it can be seen that each scenario contributes significant leverage in the number of emission substraction. Which the presentage of the substraction from the base case model to the second model is 3% and 9% when it is compared to the base model.

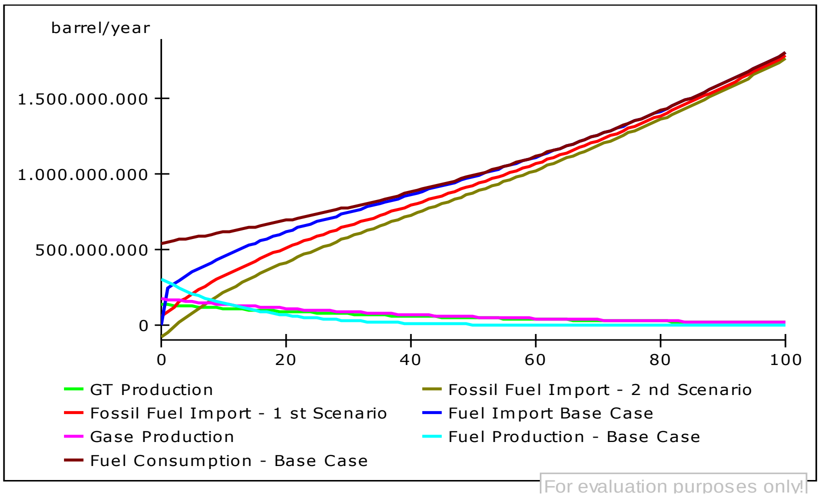


Figure 9. Import –Production- Consumption Between Scenarios

9. CONCLUSION

Based on the initial scenario (base case), the model simulations indicate that the CO2 emission along simulation period which is defined to 100 years about 1,736,166 TonCO2/year in average. After the structural intervention is conducted in the first scenario the CO2 emission decrease to 1,689,734 TonCO2/year or 2,6%. Meanwhile in the second structural intervention, the emission decrease to 1,575,284 TonCO2/year or 9% compared to the base case. This behavior can be seen in the graph of Figure 6.

The other positive result of the mix energy scenario that can be generated is succesfully decreasing the import of fuel due to the production is not enough to fulfill the energy need which can be observed obviously from the graph. When it is counted to presentage the decrease of fuel import up to 27%.

This research should be enhanced to a further modeling which include the variable of intensity, elasticity, and considering all available energy resources in Indonesia in order to get a more comprehensively and integratively energy mix policy.

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APPENDIX 1: PROVEN OIL STOCK TABLE (1990-2011)

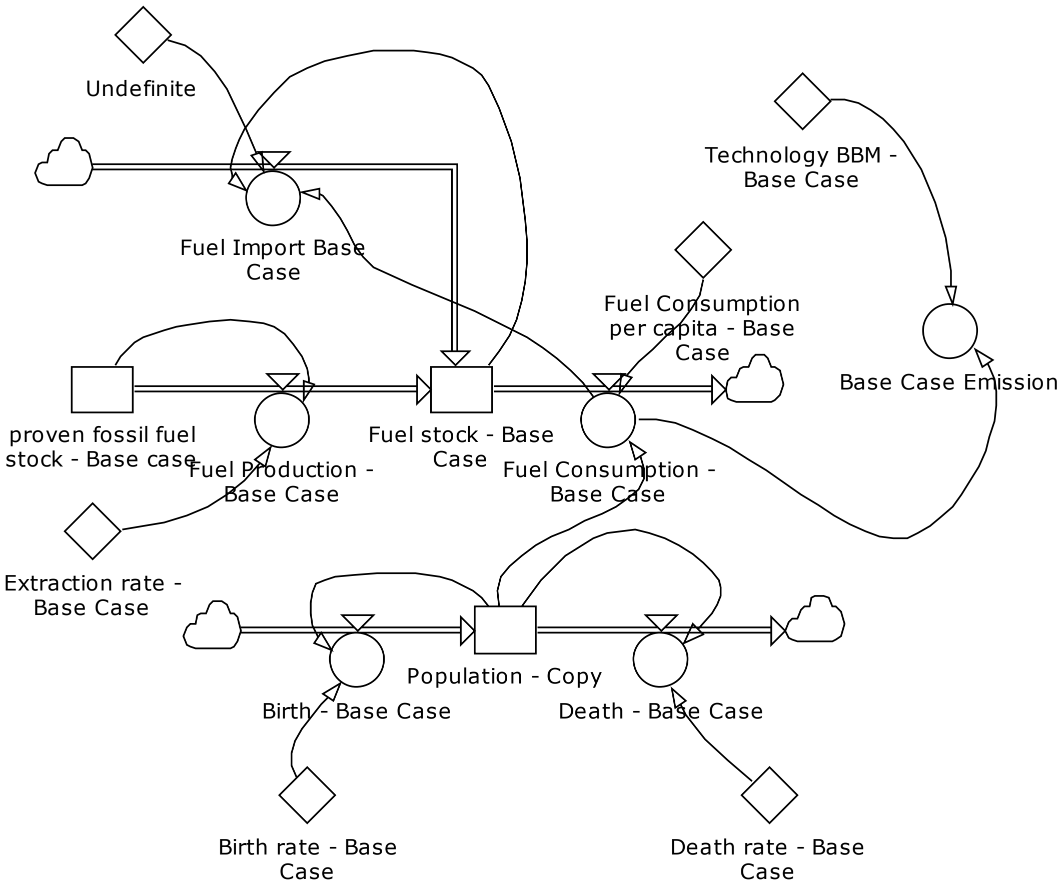
Year	(billion barrel)		
	Proven	**Potential**	**Total**
1990	5.10	5.80	10.90
1991	6.10	5.00	11.10
1992	5.80	5.50	11.30
1993	5.60	4.80	10.40
1994	5.20	4.30	9.50
1995	4.98	4.12	9.10
1996	4.73	4.25	8.98
1997	4.87	4.22	9.09
1998	5.10	4.59	9.69
1999	5.20	4.62	9.82
2000	5.12	4.49	9.61
2001	5.10	4.65	9.75
2002	4.72	5.03	9.75
2003	4.70	4.10	8.80
2004	4.30	4.31	8.61
2005	4.19	4.44	8.63
2006	4.37	4.56	8.93
2007	3.99	4.41	8.40
2008	3.75	4.47	8.22
2009	4.30	3.70	8.00
2010	4.23	3.53	7.76
2011	4.04	3.69	7.73

APPENDIX 2: OIL PRODUCTION TABLE (Thousand Barrel)

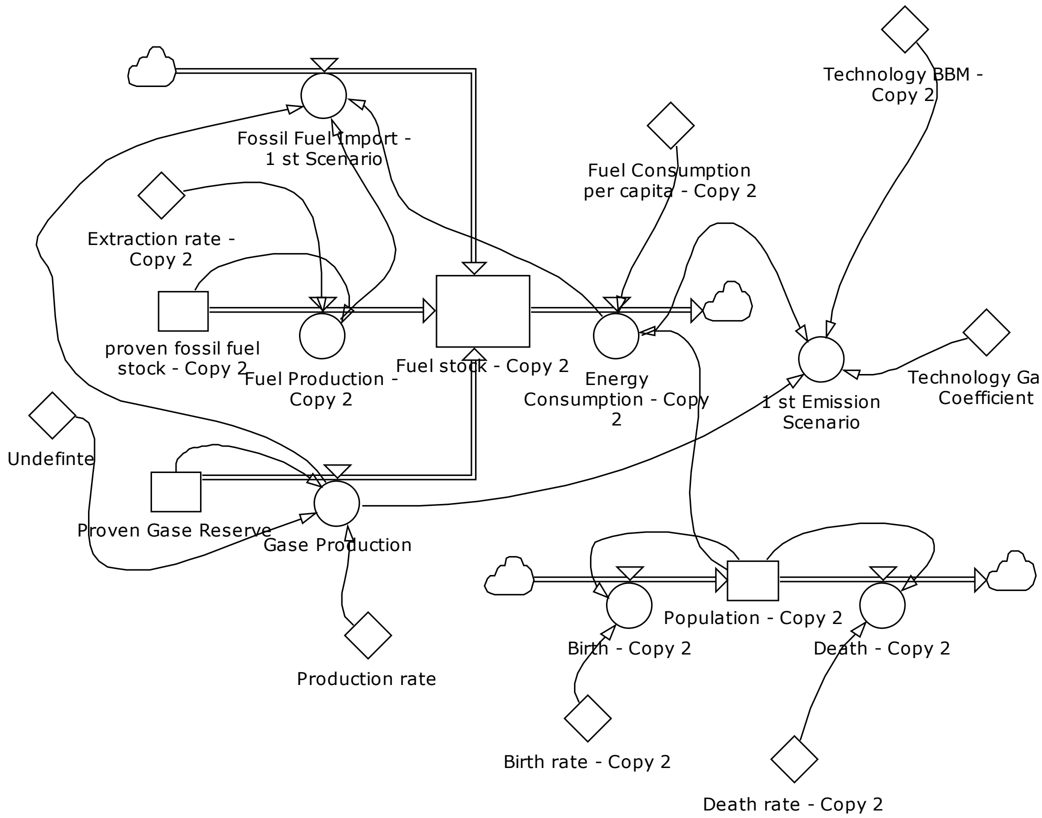
Year	Oil	Condensate*	Total
2004	353.945	46.541	400.486
2005	341.203	46.450	387.653
2006	322.350	44.699	367.049
2007	305.137	43.211	348.348
2008	312.484	45.016	357.500
2009	301.663	44.650	346.313
2010	300.872	43.965	344.837
2011	289.899	39.350	329.249
2012	143.654	19.979	163.633

Source: Statistic of Indonesia Energy (2004), Center of Energy Information and Mineral Resources, Jakarta.

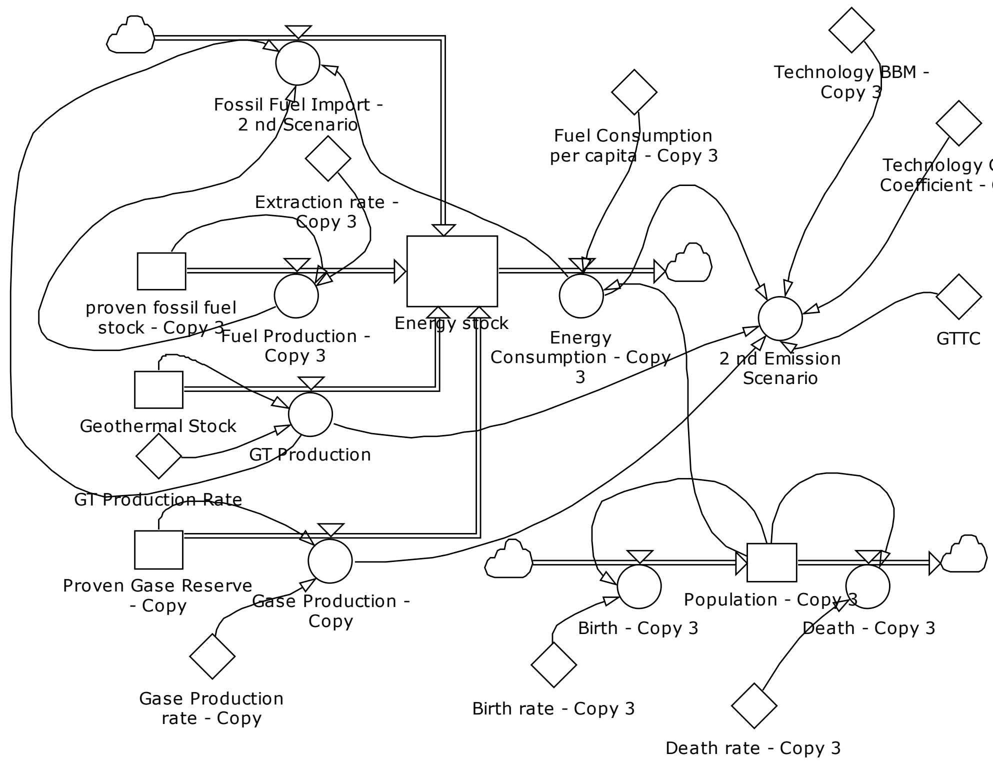
APPENDIX 3 STOCK FLOW DIAGRAM BASE CASE



APPENDIX 4 STOCK FLOW DIAGRAM 1st SCENARIO



APPENDIX 4 STOCK FLOW DIAGRAM 2nd SCENARIO



APPENDIX 5 EMISSION COMPARISON

(TonCO2/year)			
year	1 st Emission Scenario	2 nd Emission Scenario	Base Case Emission
0	773.613,54	460.714,00	881.314,00
20	1.049.845,55	882.012,56	1.118.770,28
40	1.376.095,90	1.281.609,09	1.420.205,43
60	1.774.628,94	1.718.933,13	1.802.857,58
80	2.270.543,97	2.236.383,53	2.288.609,36
100	2.893.678,11	2.872.053,83	2.905.239,36

APPENDIX 6 FUEL IMPORT

year	Fuel Import - 1 st Scenario (barrel/	Fuel Import - 2 nd Scenario (barrel/	Fuel Import Base Case (barrel/year)
0	61.241.864,00	-222.200.000,00	0,00
20	512.432.912,17	390.518.364,98	620.034.803,05
40	794.218.988,63	741.614.476,31	865.320.483,59
60	1.070.013.987,82	1.047.000.263,62	1.116.019.135,33
80	1.391.096.516,00	1.380.687.334,73	1.420.651.039,51
100	1.785.367.591,91	1.780.355.222,72	1.804.306.804,87