

## Valuating Indonesian upstream oil management scenario through system dynamics modelling

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**Abstract.** Under the existing regulation in Constitution Number 22 Year 2001 (UU No 22 Tahun 2001), Production Sharing Contract (PSC) continues to be the scenario in conducting oil and gas upstream mining activities as the previous regulation (UU No. 8 Tahun 1971). Because of the high costs and risks in upstream mining activities, the contractors are dominated by foreign companies, meanwhile National Oil Company (NOC) doesn't act much. The domination of foreign contractor companies also warned Indonesia in several issues addressing to energy independence and energy security. Therefore, to achieve the goals of energy which is independence and security, there need to be a revision in upstream oil activities regulating scenario. The scenarios will be comparing the current scenario, which is PSC, with the "full concession" scenario for National Oil Company (NOC) in managing oil upstream mining activities. Both scenario will be modelled using System Dynamics methodology and assessed furthermore using financial valuation method of income approach. Under the 2 scenarios, the author will compare which scenario is better for upstream oil management in reaching the goals mentioned before and more profitable in financial aspect. From the simulation, it is gathered that concession scenario offers better option than PSC in reaching energy independence and energy security.

### 1. Introduction

The domination of oil, coal, and gas happened in Asia – Pacific region, including Indonesia, which still mainly rely on those resources. Oil dominates the usage of energy in Indonesia for around 32%, followed by coal for 23% and natural gas for 13% in 2014. Industrial sectors dominated the energy usage for 48%, followed by transportation sectors for 35%, household sectors for 11%, commercial sectors 4% and other sectors 2%.

All the energy needs are projected to be rising for the years ahead due to the growth of Indonesian Gross Domestic Product (GDP) which is composed by the energy user sectors. With the basic scenario that there will be 6% increase in GDP per year since 2014, energy needs will increase for 5.8 times in 2050. The needs of oil will increase up to 40.7% in 2050 due to the high usage especially in transportation sector. Meanwhile, the needs of natural gas will only increase up to 13.8% in 2050. The certain increase in energy needs, especially oil and gas, unfortunately not followed by Indonesia's ability in fully supplying both oil and gas. Indonesia has been facing the supply deficit.

Since 2008, Indonesia could only produce oil and gas for 977 thousand oil barrels/day and continues to decline until 786 thousand oil barrels/day in 2015 [1]. Indonesia's oil production declined for 3.9% annually since 2009. To fulfil the oil demand, Indonesia had to import both oil both in crude and refined



forms, from several countries. In 2013, Indonesia imported 355.61 million barrels of crude oil, 237.41 million barrels refined oil, and 41.11 million barrels of gas. Indonesia, which became the 30th country with great oil reserves, even imported oil from South Korea and Taiwan which became the 94th country with great oil reserves [2]. With the increase in oil and gas demand, as the consequences, the amount of oil and gas import also increases from 122 million barrels in 2014 to 1.235 million barrels in 2050 [1]. Indonesia has turned to the net importer of oil and gas since 2004, even Indonesia used to be the net exporter of oil and became one of OPEC (Organization of Petroleum Exporter Countries) members.

The decrease in oil production caused by various factors. The upstream oil and gas mining activities is still concentrated on revitalizing the mature oil fields. Mature oil fields have no longer produce oil economically, even there's optimization effort on those fields using the water injection or Enhanced Oil Recovery (EOR). The most contributing factor is the lack of exploration activities of new oil and gas reserve in Indonesia. The new fact that 60% Indonesia's potential oil reserves located in Indonesian offshore deep-water and requires an advanced technology with high investment costs also caused the low rate of oil exploration and furthermore other upstream mining activities.

Since 1971, the upstream oil and gas mining activities are regulated by Constitution Number 8 Year 1971 (UU No 8 Tahun 1971) using Production Sharing Contract (PSC) scheme. Indonesian government act as the owner of all oil fields in Indonesia. National Oil Company (NOC) own the oil fields but doesn't do the upstream mining activities. The upstream mining activities are done by the contractors who signed the contract (Kontrak Kerja Sama/KKS) with SKK Migas as the regulator of oil and gas mining activities in Indonesia. Under the KKS, the ownership of oil fields held by Indonesian government from the beginning until the end of upstream mining activities. The production could only occur when the oil fields are proven economically-produced by the government. After production, there will be result sharing between the contractor and the government with specified percentage as stated in KKS. The KKS contractor must provide the whole initial investment costs for upstream mining activities but there is cost recovery scheme that will reimburse the "costs of oil" after the fields produce economically. When the fields can't produce economically, or even the exploration fails, the risks of loss will be owned by the contractors. Under the existing regulation in Constitution Number 22 Year 2001 (UU No 22 Tahun 2001), PSC continues to be the scheme in conducting oil and gas upstream mining activities. Because of the high costs and risks in upstream mining activities, the contractors are dominated by foreign companies, meanwhile NOC doesn't act much. The domination of foreign contractor companies also warned Indonesia in several issues addressing to energy independence, energy security, and energy equality.

Therefore, to achieve the goals of energy which is independence and security, there need to be a revision in upstream oil activities regulating scheme. The scenarios will be comparing the current scheme, which is PSC, with the "full concession" scenario for state-owned oil company in managing oil upstream mining activities. Both scenario will be modelled using System Dynamics methodology and assessed furthermore using financial valuation method of income approach.

Using the System Dynamics methodology and financial valuation, the author will compare which scenario is better for oil and gas management in reaching the goals mentioned before and more profitable in financial aspect. The chosen scenario will furthermore be the recommendation for the regulator in oil and gas management in Indonesia.

## **2. Theoretical Framework**

This chapter contains the basic theory and method utilized in solving the formulated problems. The literature review consists of oil and gas management overview, oil and gas industry, system dynamics modelling, and financial analysis.

### **2.1. Oil and Gas Management**

Oil and gas management in Indonesia have existed for more than 130 years, started since the first discovery of oil in North Sumatra in 1885 during Dutch colonialism era that makes the management of oil and gas industry done by Dutch companies. Since then Indonesia has been running various

management model to accommodate oil and gas production and consumption for all Indonesian people. The history of oil and gas management is divided into 3 eras those are colonialism era, post-Independence era, and modern industrial era.

After the independence of Indonesia August 17, 1945 the government release several constitutions about oil and gas. The first constitution “UU No. 40 Tahun 1960” about oil and gas mining, was not only the previous concession system but also holding the sovereignty of oil and gas resources but also stating that the oil, gas and mineral located in Indonesian legal mining area are national wealth managed by country and oil and gas mining only undertaken by country and only conducted by national company. In order to support the constitution, the government established three national companies named Permina, Pertamina, and Permigas. Besides doing oil and gas mining activity, those companies also supervise the foreign oil companies’ operation. As the adjustment to new regulation became tough, Pan – American Oil made a deal with the government in 1962 with the terms and condition more compatible with UU No. 40 Tahun 1960. This accord furthermore became the model for the three foreign oil companies in doing operational changes in Indonesia. Caltex, Stanvac, and Shell signed the accord in September 1963, named “Kontrak Karya”, and became the new oil and gas management concept in Indonesia. As the foreign companies no longer holding the status as concession holder, the management is still held by them. In the implementation of this contract, there’s almost no significant changes as the government role only limited to supervision and the foreign companies still doing operation as the previous system (concession). After G30S/PKI occurred in Indonesia in 1965, new regime ruled in Indonesia and led by Soeharto, changing the previous regime that was ruled by Soekarno. Permina then ruled by Dr. Ibnu Sutowo who criticized Kontrak Karya, pushing the new system where both government and contractor taking role in oil and gas management. The big foreign companies once again couldn’t accept this new change and unready to release the management right as the terms and condition in PSC. This condition attracted smaller foreign oil company, Independence Indonesian American Oil Company (IIAPCO), to operate back in Indonesia in 1966. After 2 months negotiation, IIAPCO signed Production Sharing Contract (PSC) with Permina, and became the first PSC agreement in the history world oil and gas industry. Japan Petroleum Exploration Company (Japex), Refining Associates Ltd. Canada (REFICAN), Kyushu Oil Development Company Ltd., and Asamera Oil Indonesia Ltd. moreover following IIAPCO’s footprint in signing PSC contract.

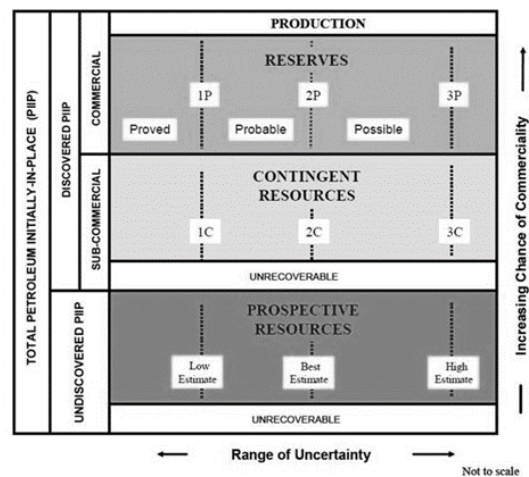
Behind the great achievement of PSC, the legality of PSC was still questioned due to the absence of regulation stating about PSC, since UU No. 44 Tahun 1960 only recognizing Kontrak Karya. Meanwhile, the other regulation, UU No. 1 Tahun 1967 about foreign investment (Penanaman Modal Asing/PMA), only regulating foreign investment about mining sector except oil and gas. Then in 1971, the government released UU No. 8 Tahun 1971 about Pertamina which become the legal foundation of PSC. PSC was stated in article 12 verse 1 and verse 2. The PSC development is divided into 3 phases as shown in table 1.

**Table 1.** Comparison between PSC Generations in Indonesia

	PSC First Gen	PSC Second Gen	PSC Third Gen
<b>First Tranche Petroleum</b>	None	None	20%
<b>Cost Recovery Ceiling</b>	40%	100% (no ceiling)	80% (due to FTP)
<b>Investment Credit</b>		20%	17% to 20%
<b>DMO</b>	DMO was defined as 25% of equity oil at 0.2\$/barrel	25% of equity oil, full price for the first 60 months and 0.2 \$/barrel there after	25% of equity oil, full price for the first 60 months and 10% of export price there after
<b>Equity to be Split Government : Contractor</b>	65%:35%	85%:15%	85%:15%
<b>Oil : Gas</b>	NA	70%:30% or 65%:35%	70%:30% or 65%:35%

## 2.2 Indonesia's Oil and Gas Reserves

Oil and gas industrial activities have produced various vocabularies related to reserves. Collaboration of several oil and gas institutions in the world (SPE, AAGP, WPC, SPEE, and SEG) releases oil and gas resource management system called Petroleum Resources Management System (PRMS) with the latest edition released in November, 2011. PRMS is the integrated system for basic classification and categorization of petroleum reserves and resources. PRMS divided each project to 3 main classes called Reserves (satisfied commerciality), Contingent Resources (satisfied sub-commerciality), and Prospective Resources (undiscovered). The illustration of PRMS is provided in figure 1. To fulfill the commerciality terms, the amount of project reserves can be estimated. Based on this classification, reserves are classified into 3 kinds, those are proved (1P), probable (2P), and possible or potential (3P). Where the uncertainty ranges from low estimation (1C), best estimation (2C), and highest estimation (3C).



**Figure 1.** Reserve and Resource Classification Framework in PRMS 2011

Indonesian potential oil reserves have been decreasing slightly each year from 2010 to 2015. While the proven oil reserves declined gradually since 2010 to 2015. This phenomenon caused the almost stable total oil reserves from 2010 to 2015. For several years coming, the demand of oil and gas are projected to increase. The demand of oil will increase 3 times compared to 2014 (BPPT, 2016). Meanwhile, oil production is projected to decrease continuously until 52 million barrels in 2050. Despite the rising demand of oil, the oil production showed conversely performance. Oil production has never exceeded oil consumption since 2010, which was only 1003 thousand barrels/day. Oil production continued to decrease until it reached 852 thousand barrels/day in 2014 with the decrease rate of 5% per year (BPPT, 2016). Production raised slightly to 876 thousand barrels/day in 2015, yet it still couldn't fulfil the oil demand in 2015. As the consequence of declining production and demand of oil and gas, the government allowed importing oil and gas. Amount of oil import is projected to increase to 933 million barrels in 2050 (basic scenario) and 1,235 million barrels (high scenario).

## 2.3 System Dynamics Modelling

System dynamics has been known as the systemic thinking discipline in system science. This methodology was firstly introduced by Jay Forrester from Massachusetts Institute of Technology (MIT) in 1963 and has been improved continuously. System dynamics was used limitedly as industrial problem-solving tool in its early emergence. In its development, system dynamics has been used for analyzing and solving social, economic, managerial, political, and environmental issues which is complex, dynamic (fast-changing), and uncertain.

There are 3 common perspectives in analyzing system, those are black box system (input-output analysis and econometrics), grey box system (operation research), and white box system (soft-system methodology, viable system, hyper-game, and system dynamics). System dynamic offers comprehensive and integrated thinking which can simplify complexity without losing the essential object and also suitable in analyzing mechanisms, pattern, and system tendency based on analysis of system's complex, dynamic, and uncertain structure and behaviour. Studying system comprehensively doesn't mean that there's no boundary between the system and environment. Non-significantly influential variables will be the boundary in system analysis and causing the closed system.

A system which has causal loops can't be analyzed partially and this causes system dynamics better than partial analysis in analyzing system that has causal loops. Causal loop diagram illustrates the causal relationships between elements using inter-related arrows so it creates causal loop where the beginning of arrow means the cause and the end of arrow means the effect. Causal loop diagram is constructed with many elements involved in it. Therefore, before simulating the system, causal loop diagram is often used as the conceptual mapping of the system to simplify complexity. Causal loop diagram must be made as real as it could be to illustrate the nature of the studied system.

To understand the behavior of system, this research conducts using a model instead of doing trial-and-error research. Model is the representation of system in the real world by emphasizing the main elements of the system. Building a model could be cheaper and time-saving rather than doing trial-and-error study in the real system. Model can be made in conceptual form and simulation form. Conceptual model is a non-software specific description of the simulation model that is to be developed, describing the objectives, inputs, outputs, content, assumptions and simplifications of the model. Meanwhile, simulation model can be made through system dynamics software, such as Vensim, Powersim, and Stella © (iSee System). Stella © (iSee System) could build the simulation model visually using computer and could see the behavior of system quickly. Simulation conducted through procedures as follows: (1) Defining objective, scope and requirements (2) Collect and analyze system data (3) Build the model (4) Validate the Model (5) Conduct experiment (6) Result Model verification is the process to determine whether the simulation model correctly reflects the conceptual model. Testing is conducted to verify whether the simulation results absolutely predictable outcomes based on test data. Simulation models often generate slightly different result depending on configuration and input data. Verification is the process of debugging the model, seeking for the bug-free model.

Meanwhile model validation is the process of establishing confidence in the soundness and usefulness of a model [4]. Verification and validation must be conducted simultaneously throughout the model development process [4]. Several testing methods are required for validating the simulation model, including the usage of statistical testing techniques. Some of the testing methods by Forrester and Senge (1980) are Structure-Verification Testing, Parameter-Verification Testing, Boundary-Adequacy Testing, Sensitivity Testing, and Extreme Conditions Testing.

## 2.4 Financial Valuation

From the financial aspect, value means the sum of economic benefits expected in the future by the owner, where each benefit is discounted to the present value with the adequate discount rate [5]. Value of a company (Market Value of Invested Capital/MVIC) is the capital market value which is the sum of liability value and equity value where equity value comes from the value of equity plus the market added value. American Society of Appraisers divided valuation to 3 approaches, those are market approach, asset-based approach, and income approach. Income approach is used in this research.

Income approach is conducted based on anticipation principle where business interest defined as the sum of economic benefits generated by that business interest in the future. Company value is estimated by quantifying income flow generated by investments and converted to present value by opportunity cost of capital. Income approach is divided into Discounted Cash Flow (DCF) method and Capitalization method.

**2.4.1 Discounted Cash Flow Method.** Discounted cash flow uses projection of all economic benefits in the future such as free cash flows or other income variable and discounting each benefit to present value



with a particular discount rate that reflects the cost of investment capital. DCF method uses time value of money theory. DCF method also based on principles that the value of investment determined by its ability in generating future cash flows, a new investment is valuable if that investment could give bigger return than the costs incurred for that investment, and the value of assets is present value of expected cash flows from that asset investment in the future. The basic formula used in DCF is shown below:

$$PV = \sum_{i=1}^n \frac{E_i}{(1+k)^i} \quad (1)$$

where PV = present value  
 $E_i$  = economic income expected in period-i  
 k = discount rate  
 i = period in the future where the economic income will be received

Economic benefit meaning can be various depending on the valuation object and purpose of valuation. Generally, economic benefits are dividends, net profit, Earnings Before Interests and Taxes (EBIT), Earnings Before Interests Taxes Depreciation and Amortization (EBITDA), Net Income After Tax (NIAT), and net cash flow to equity. Net cash flow to equity's formula is shown below.

$$NCF_e = NIAT + NCC - CAPEX - NCWC + NCLTD \quad (2)$$

Where NIAT = Net Income After Tax  
 NCC = Non-Cash Charges (Depreciation, Amortization, and Retained Tax)  
 CAPEX = Capital Expenditures  
 NCWC = Changes in Net Working Capital  
 NCLTD = Net Changes in Long-Term Debt

Discount rate defined as the return percentage to convert the amount of money that is expected in the future to present value. Discount rate can be in the form of Minimum Attractive Rate of Return (MARR) or Weighted Average Cost of Capital (WACC).

**2.4.2 Direct Capitalization Method.** In direct capitalization method, capitalization rate is more comprehensive method where the capitalization rate only changes one single income flow to present value.

### 3. Research Methodology

This chapter contains the methodology that is used in conducting the research in form of flowchart and also the explanation of methodology flowchart.

#### 3.1. Data Collection and Processing Phase

Data collection is done paralelly with literature study. All data which is related to the research, such as oil and gas reserves, oil and gas consumption, and also oil and gas production are collected for supporting the research. In this phase, dynamic hypothesis is conducted to conceptually modelling the system using Causal Loop Diagram to map the problem and understanding the relation between stakeholders. Furthermore, the alternative scenarios for oil and gas management in Indonesia must be determined as comparison for the system improvement.

#### 3.2. System Modelling Phase

The Causal Loop Diagram (CLD) that has been made in previous phase can't be simulated directly to produce the result. CLD elements must be transformed into stock, rate, and converter to convert the CLD into Stock and Flow Diagram. STELLA is one of the system dynamics modelling software. Stock and Flow Diagram furthermore needs to be simulated to gain the result.

### *3.3. Model Testing*

Simulation model must be credible in order to represent the real system correctly. Every model used in simulation must be verified and validated to test the credibility of the model. Verification is the process to check whether the operational logic of the model compatible with the logic in flow diagram. Meanwhile validation is the process to determine whether the model is the accurate representation of the real world. Validation is done through 5 methods, those are model structure testing, boundary sufficiency testing, model parameter testing, mean comparison testing, and extreme condition testing.

### *3.4. Scenario Development and Financial Valuation*

After verifying and validating the simulation model, as the improvement of the system, the better resulted scenario must be developed. Scenario will be developed through financial valuation that will assess the value of each scenario in achieving the goals of energy independence, energy security, and energy equity.

## **4. Simulation Design & Output Analysis**

This chapter contains the simulation results for both before concession scenario and after concession scenario.

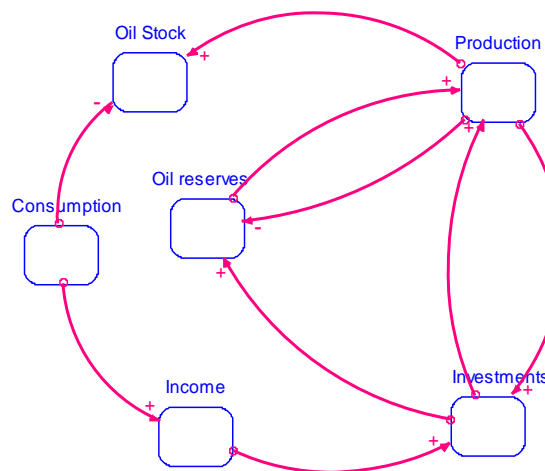
### *4.1 Dynamic Hypothesis*

To understand the dynamics of the system, the historical data that related to the system are collected. This final project set time horizon for 20 years, which consists of 10 years historical data (since 2005 – 2015) and 10 years future projection (started from 2015 – 2025). The data then led to theory development, called dynamic hypothesis, to account for the problematic behavior of the system. Dynamic hypothesis consists of variable identification of the system and conceptual modelling using Causal-Loop Diagram to show the inter correlation of the system elements.

*4.1.1 Variable Identification.* All variables that are related to oil management system must be identified to understand the function and relation of each variable in affecting the work of the system. Oil management system, in this case, will be divided into 5 sub models to understand the role of the variables in the system. The sub models are Production, Consumption, Oil Market, Investments, and Income.

*4.1.2 Causal-Loop Diagram.* Causal-Loop Diagram is a tool for conceptual modelling used to illustrate the causal relationships between elements using inter-related arrows so it creates causal loop where the beginning of arrow means the cause and the end of arrow means the effect. Causal-loop diagram used in this research is provided in appendix A.

*4.2 Stock and Flow Diagram (Main Model).* Main model is used as a basic guidance in developing the Stock and Flow Diagram. The relation between the entities can be shown in the figure 2.



**Figure 2.** Main Model of Indonesian Oil Management

Production of oil will add the amount of oil stock available in the market. The more production will add more oil stock available, shown in positive relation of both entities. However, due to consumption, this activity will reduce the amount of oil stock. The more consumption occurs, the less oil stock available in the market. Then, when consumption occurs, the consumers will spend funding to consume oil. Consumption activity will generate income for oil producer (in this term NOC) and moreover for the government (due to the ownership of NOC by government, the income of NOC will be shared to government too). The more income that NOC and government have, the more investment in oil upstream mining activity will occur. When there are more investments, there will be more oil upstream mining activity such as exploration that will reveal new oil reserves both onshore and offshore. The more oil reserves available may increase oil production activity. More investments also led to more production activity due to the availability of fund to produce oil. Finally, the bigger oil production will result in bigger oil stock available for the market.

#### 4.3 Verification and Validation

In the software, verification can be done by 2 processes, those are units checking and verify/repair model menu. Units checking is conducted to know whether all units used in the model are consistent or not. Units consistency is a crucial thing in simulation model, otherwise the simulation will not be able to run. After units checking, verification can be done through verify/repair model menu in the software to see whether there are any errors in the model and to see whether the total count of all entities in the model. From the verification process, there is no error found in the model. Therefore, it can be concluded that the model is already verified or it has reflected the real system.

Model validation is the process of establishing confidence in the soundness and usefulness of a model [4]. Validation aims to know whether the simulation result is appropriate with the modelled process. Model can be considered as good when its simulation result has relatively small mistakes.

Structure assessment testing is done through interview with the system owner which is NOC. All variables in each sub model has been assessed and considered to be valid qualitatively. From the parameter testing, according to the simulation output of sub model oil market, as the production rate declines (due to the decline of oil production), the amount of oil stock also declines as the consumption rate that consumes oil increases exponentially. The oil stock then fulfilled by crude oil import activity, therefore the amount could fulfil the demand. It is proven that the variables in the model are consistent with the logic of the variables.



#### 4.4 Scenario Development

The difference between before concession and after concession scenario lies in the amount of potential oil reserves. In sub model production, amount of potential oil reserves is determined by the addition of new potential oil reserves explored from exploration activity. Potential oil found will determine the amount of proven oil and furthermore the oil production. In the 2<sup>nd</sup> scenario, there's an addition of new potential oil reserves that will be added when concession scenario is applied.

#### 4.5 Simulation Result

The highlighted result of the simulation is summarized in the table below.

**Table 2.** Simulation Result of Existing Scenario and Concession Scenario

	Existing Scenario	Concession Scenario	Difference (Concession vs. Existing)
Potential Oil Found (barrels)	2.956.019.832,53	2.956.019.832,53	0%
Proven Oil (barrels)	614.022.158,89	19.646.632.184,62	3100%
Oil Stock (barrels)	61.629.763,42	1.671.463.169,02	2612%
Gross Income (USD)	2.894.996.887,11	92.629.642.736,88	3100%
Retained Earnings (USD)	45.109.669.504,23	226.913.830.076,09	403%
NPV (USD)	578.888.611.428,69	843.904.408.816,51	46%

After the simulation of both scenario, it can be interpreted that the concession scenario offers better option for upstream oil management in Indonesia because it resulted in the distinctive difference to achieve the goal of energy independence and energy security. Concession scenario will also strengthen the value of NOC to help NOC in doing upstream oil mining activity such as investment for finding new oil reserves.

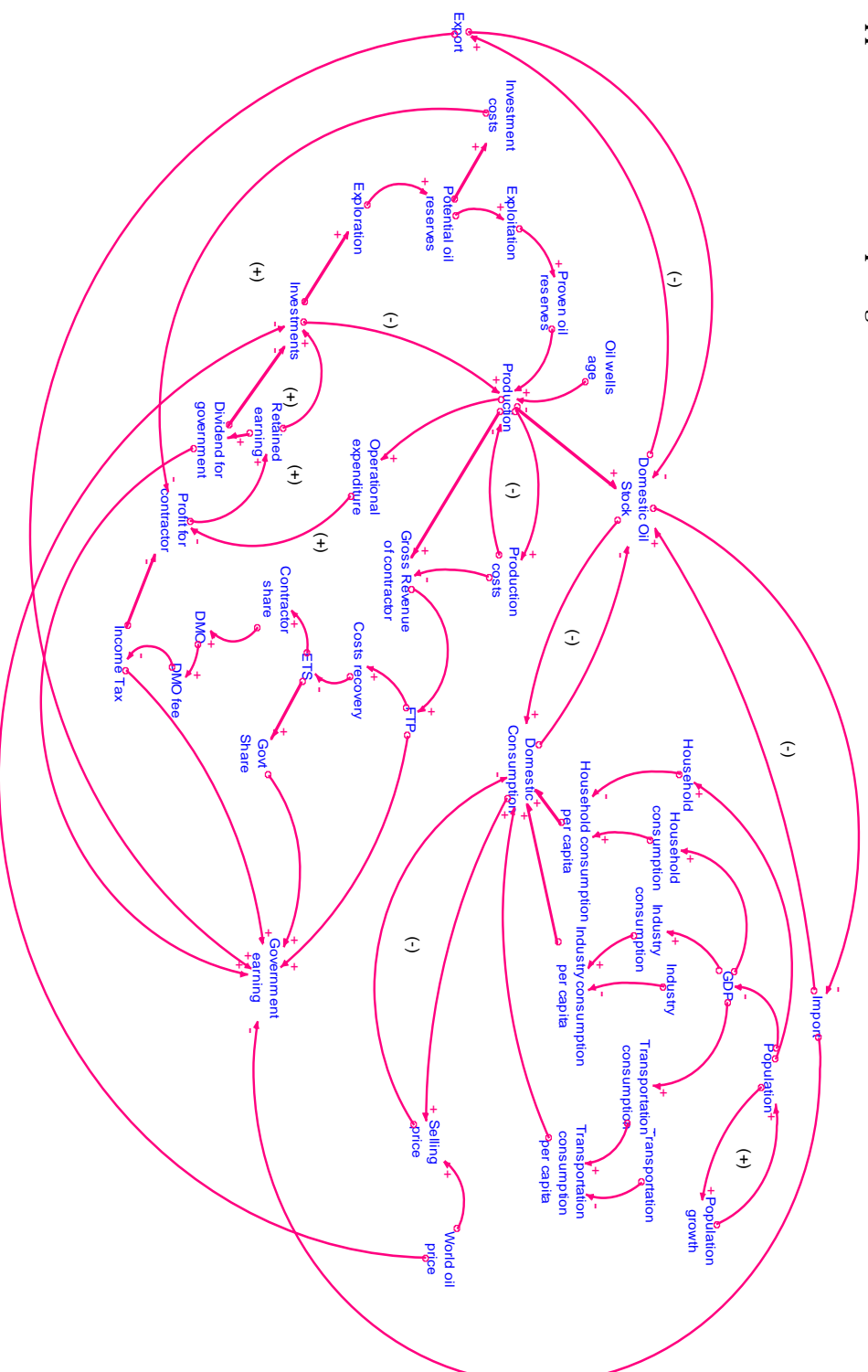
#### 5. Conclusion

The conclusions of this research are as follows:

1. Concession scenario offers the better result than the existing scenario. Addressing to energy independence goal, when NOC is given the concession, NOC could earn more proven oil due to the acquisition of oil wells. The amount of proven oil handled by NOC could up to 19.646.632.184,62 barrels, much higher than the existing scenario which is 614.022.158,89 barrels. There will be more oil wells managed by NOC, such as through the takeover of Mahakam Block, ONWJ Block, Sanga – Sanga Block (under discussion), and East Kalimantan Block (under discussion). When NOC is given more priority to manage oil fields, the more reserves and stock that NOC will handle and the more independent NOC is.
2. The acquisition of oil field will also help NOC in securing the amount of oil available in the market (oil stock). Before the concession scenario occurs, the amount of oil stock is 61.629.763,42 barrels. After implementing concession, the amount of oil stock will turn into 1.671.463.169,02 barrels. The higher amount of oil fields managed by NOC will lead to higher amount of production that will result in the higher amount of oil stock. Besides that, with concession scenario, NOC could minimize the amount of oil import because of its ability in fulfilling the demand. Therefore, the goal of energy security in fulfilling domestic oil demand can be accomplished.
3. Under the valuation method, the existing scenario has the value of US\$ 578.888.611.428,6. Concession scenario offers the higher value which is US\$ 775.492.486.128,98. With 34% difference of value amount between two scenarios, concession scenario offers higher value for NOC (where NOC represents the government). The higher value adds the power of NOC's capital and will add the ability of NOC in doing upstream oil mining operation both domestic and overseas and also the possibility of developing the non-conventional oil.

## Appendices

### Appendix A Causal Loop Diagram



## 6. References

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