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A System Dynamic Model for Indonesia Upstream Oil and Gas Industry Greenhouse Gas Emissions Reduction Effort

AstriPradiptaningtyas* and YosSunitiyoso

School of Business and Management, InstitutTeknologi Bandung, Indonesia

*E-mail address:*astri.pradiptaningtyas@sbm-itb.ac.id

Abstract - **Oil and gas industry is still expected to be the source of energy in Indonesia despite its contribution to greenhouse gas emissions. There are several factors that might affect oil and gas industry effort to reduce emissions. Literature review and interview with key stakeholders were conducted to find out the contributing factors and how these factors affect greenhouse gas emission reduction effort. The system dynamics model then was developed based on those factors to measure it impact to the effort and industry profitability.Carbon tax & carbon market mechanism, availability of incentives, availability of advance technology and the industry profitability were considered in the study as contributing factors. The system dynamic modeling result shows that the implementation of carbon tax mechanism will give significant impact to profitability, while the implementation of advance technology will reduce the profitability but will significantly reduce emission. The model shows that continuous development of fossil fuel based energy will lead to high emissions and high investment risk in relation with increasingly binding emissions reduction agreement. Government support in providing Paris agreement – aligned emissions requirement that will drive the effort to reduce emissions in upstream oil and gas industry will still be the turning point**

Keywords - **Causal loop diagram, Greenhouse gas emissions, Stock and flow diagram, System dynamics, Upstream oil and gas industry**

I. INTRODUCTION

1.1 Background

The Indonesia oil and gas industry, despite being labeled as sunset industry, still contribute to 7.38% of the Indonesia state revenue in 2019. However, it has decreased by 50% from the contribution in 2009. Based on modeling in National Energy General Plan (RencanaUmumEnergi Nasional/RUEN)[1], it is estimated that in 2025 around 1.76 million BOPD of fuel oil is needed and in 2050 around 3.72 million BOPD of fuel oil is needed. The RUEN is developed with consideration to the technology maturity and the resources availability in Indonesia. The oil and gas industry still expected to be the source of energy in Indonesia. In 2018, Oil and Gas still has 59.1% contribution in Indonesia energy mix, it is expected to be decrease to 44% in 2050.

The lower contribution of oil and gas industry in the state revenue is partly due to the many challenges that is faced by upstream industry in the recent years. The fall in oil prices in 2014 have cause slowdown in the oil & gas exploration and production hence, less investment in Indonesia has occurred. Although the investment in the last 2 years has increase consistently, the total exploitation investment in 2019 of USD 12,003 Million is still below the total exploitation investment happened in 2014 of USD 19,235 Million [2]

A greenhouse gas is a gas that absorbs and emits infrared radiation.Due to their chemical properties, the greenhouse gas can remain in atmosphere for long period ranging from a decade to many millennia.In 2018, use of petroleum fuel and natural gas is estimated to contribute to approximately 50% of GHG emissions. However, it is to be noted that most of it come from the use of petroleum fuel in transportation sectors. In the industry sector oil and gas contribute to more than 50% of the GHG emissions.Globally the oil and gas contributed to 4.1GtCO2e of emissions, or 10% of all anthropogenic greenhouse gas, two-thirds of it from upstream [3].Routine flaring and venting contribute to 40% of carbon intensity of hydrocarbon production [4], Fugitive emissions & intermittent flaring & venting account for 34% of oil production emissions & 41% of gas production emissions [5].

The journey to climate change agreement started more than 30 years ago with the establishment of Intergovernmental Panel on Climate Change (IPCC) in 1988 and development of report that highlight the increasing greenhouse gases concentration in the atmospheric due to human activities and call for a global treaty. The panel then initiates the Rio Earth Summit in 1992 to sign the United Nations Framework Convention on Climate Change (UNFCCC). However, in there is no legally binding target that were agreed in the summit hence the UNCFCC is mostly ineffective. The UNFCC committed signatory governments to reduce their levels of GGHG emissions but binding emissions targets were not agreed to until 1997 in Kyoto [6], the Kyoto Protocol that document the agreement among 34 countries on emissions reduction target within specified target were reached. In 2016, the COP21 were held in Paris and reach an agreement to combat climate change and unleash actions and investment towards a low-carbon, resilient and sustainable future. The 196 parties involved agree on the common target to limit the global warming to well below

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2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels by implementing the climate change plan that would be submitted as nationally determined contributions (NDC) in 2020 to document the actions that each countries would implement to reduce their greenhouse gas emissions.

The ITB Center for Research on Energy Policy has defined the four (4) pillars of Indonesia GHG emissions reduction:

- Energy efficiency measures would decrease energy intensity of GDP
- Renewable energy will reduce fossil fuel combustions and reduce emission
- Decarbonization of electricity will reduce fossil fuel combustions and reduce emission (as long as the power generation is also decarbonized)
- Fuel switching to low carbon emitting fuels would decrease GHG emission in households

The fuel switching and utilization of renewable energy will be the most effective way to reduce the emission, however, considering the big portion of fossil fuel and the require energy volume for Indonesia, the journey to full renewable is still far. In the meantime, the current energy source need to find way to have less emission so that the Indonesia can fulfill its require energy, increase development in the industry but does not sacrifice the environment in the process. In oil and gas industry sectors especially in the upstream industry, the focus is in the energy efficiency. There are several options that is available for upstream oil and gas industry, namely optimizing operations, balanced portfolio and sustainable design [3]

2.2Research Objectives

The study will use system dynamics to analyze the situation and simulate the condition of GHG emissions reduction effort of the Indonesia upstream oil and gas industry. The result will identify the key factors that influence the issue. The system dynamic will be developed using Vensim software.

2.3 Research Limitation

This research aims to present the impact of key variable changes in Indonesia upstream oil and gas industry GHG emissions reduction effort by only considering the change in key variables applies for the effort. As the modeling basis is historical trending of representative parameter of each variable, hence there is a model limitation if there is any anomaly or major changes in the trending. Furthermore, several variable is excluded from this research i.e. employment constraint, reserve development constraint, population growth, electricity market dynamics and advancement of electric vehicle technology.

II. PESTEL ANALYSIS

2.1 PESTEL Analysis

PESTEL analysis is a framework to evaluate the external factors that might affect the analyzed object. The external factor that is considered in the analysis are political, economic, socio-cultural, technology, environmental and legal factors. The following are the PESTEL analysis for GHG reduction effort in Indonesia upstream oil and gas industry

- Political

The portion of oil and gas industry in the state revenue makes it become one of the politicized issue in Indonesia. Historically, oil and gas industry has been the main revenue maker in Indonesia thus control over it is one of the big issue in the political sector. The national energy security has become the regular issue to be discussed. It is viewed as a way to stabilized the country. When the energy demand of the nation can be satisfied then the nations become stable both economically and politically.

- Economic

In 2014 the oil industry experience rapid decrease in oil price and it never went back to the previous level after that. It has been predicted that the low oil and gas price is expected to continue for the next few years due to the abundant supply of both oil and gas by discovery of giant reserve and non-conventional oil reserves. Recently the pandemic situation has decreased the oil price to the lower level due to the mobilization restriction and halt in industrial sectors. It strengthens the view that oil and gas economic is very prone to the social condition. The volatility of oil price makes it hard for investor to commit to a big investment in new exploration block. The cost to conduct exploration and development for oil and gas industry is very high thus some of the investors choose to allocate their investment in other sectors.

In the emissions reduction sector itself, some of the technologies such as carbon capture and storage is still in the early development phase hence it still require investment for research and development. Moreover due to lack of established regulation for carbon market and lack of incentives, the emissions reduction project is often considered as uneconomical and cannot comply with the company project hurdle. In additions to those factors, there is some pressure for existing energy company to also invest in renewable energy. However, the investment decision itself is not as simple as the public perception as there are many factor involve in the decision including the financial calculation, the readiness of technology advancement itself and also the knowledge base that is need to be acquired by existing energy company. Specific for National Oil Company, investment decision mandate or direct intervention in term of upstream downstream integration that might be beneficial to emissions reduction, i.e. integration with fertilizer industry to manage the H2S byproduct

- Socio Cultural

Indonesia has very big area and very large population, it result in high energy demand for the whole archipelago.

Generally the average Indonesia population has lower income compare to other Asian country. Hence the needs of affordable energy is very high. According to World Economic Forum, Indonesia's global competitiveness index in 2019 is ranked 50th out of 141 countries studied. The study mentioned that Indonesia's macroeconomic stability is at number 54th while the infrastructure availability is ranked 72nd. In term of workers skills, Indonesia is ranked 65th, while for innovation capability Indonesia I ranked 74th [7]. However it is to be noted that Indonesia is ranked 7th in term of market size, justifying the very large energy demand.

The view among Indonesia population is still that the nations has very big oil and gas production, hence the people should easily get affordable energy. However, it is to be noted that Indonesia oil and gas production is only 0.82% and 1.69% of global oil and gas production respectively [8]. The acceptance rate of new technology in Indonesia is relatively low, hence the resistance that the CCS technology has received in Europe might become an issue as well in Indonesia.

In general, the Indonesia people accept the upstream oil and gas production activity that take place in nearby of their area as long as the corporate conduct close communication, employ local people and provide CSR for the community.

- Technological

The technology implemented to create emissions reduction is still in their learning curve. The process efficiency is actually not a new thing, however they have their limitation that might affect to the maximum reduction it might give. The carbon capture and storage, while can have up to 90% emission reduction rate, is still relatively new and require high research and development cost, moreover the impact to environment and its safety have not been proven and resulted in many resistance on the implementation. However, from technology point of view, oil and gas industry has many benefits for CO2 capture. The highly concentrated CO2 and the high pressure of emission from oil and gas make it easier to implement the technology. The upstream oil and gas industry will has the benefit of first mover, moreover as the CO2 itself can be utilize in EOR, this is the only industry where Carbon capture can be a value added process.

The shift to renewable energy itself, if the company decide to implement balance portfolio in their business, still in the development phase thus require high capital, combine with the local content requirement in Indonesia might face big challenge to implement. However, in the future, where technological and legal barrier has been passed, renewable energy will be considered cheaper and it can be more profitable compare to the oil and gas industry that need to have additional investment as compliance to more stringent emissions requirement.

- Ecological / Environmental

Through ratification of the Paris Agreement in Law No. 16 Year 2016, Indonesia has committed to achieve the target in maintaining global temperature increase below 2degC in 2050. Based on the agreement, Indonesia is committed to reduce its greenhouse gas (GHG) emissions by 29% by its own efforts and 41% through international cooperation. Oil and Gas industry is one of the GHG emitters that need to reduce the emissions in order to support the national goal. Generally the public view disfavor oil and gas company in term of emissions and there is assumption that most of the emissions come from the oil and gas industry thus result in high pressure for the oil and gas industry to be involved in the emissions reduction effort. It is to be noted, that based on global data, oil and gas industry is the source of 10% of anthropogenic emissions, two-thirds of it comes from upstream side. The current perception in Indonesia that upstream oil and gas industry become major contribution to emissions is mostly due to more stringent reporting requirement for oil and gas industry that make the data visible for public.

In other location such as Europe Union, carbon emission trading or carbon market has been existed. Carbon emission trading or carbon market refers to the market in which carbon credits, in other words carbon certificates, are obtained and sold within defined standards for the prevention or reduction of GHGs. This market punishes businesses that emit more than the limit, while rewarding those who emit less [9]. This is a mechanism that might boost the implementation of emissions reduction effort, however, for the market to exist, supporting regulation must be issued to allow the oil and gas company to participate in the market. Other option to increase the emissions reduction is by implementation of Carbon Tax that was implemented in Australia, by implementation of carbon tax emitters have to pay taxes based on their produced emissions. For the case of Indonesia, the implementation of carbon emissions trading and carbon tax should also consider state budgeting and subsidy for end-user energy such as electricity or fuel. Tax has direct impact to consumer, as theoretically the implementation of tax should increase the energy price, while in Indonesia the end user energy price is regulated and subsidy mechanism is applied hence if the price is not adjusted the state budget will be reduced.

- Legal

Legal factors include the laws, mandates, regulations and court decision that have direct impact to the issue. In some cases, the revision or issuance of a regulation have major impact to the industry. In the GHG Emissions Reduction Effort, the related regulations is not only come from the Ministry of Environment, Regulations from Ministry of Energy and Mineral Resources, Ministry of Finance and for offshore facility Ministry of Maritime also has some impact to the effort. The following are several regulations that impacted the GHG emissions reduction effort:

- Presidential Regulation No. 22 of 2017 [1] concerning National Energy General Plan RencanaUmumEnergi Nasional. This regulations governs the requirement of oil and gas reduced portion in the energy mix.

- Ministry of Energy and Mineral Resources Regulation No. 8 of 2017 [10] Gross Split Production Sharing Contract and No. 12 of 2020 [11] concerning Production Sharing Contract. In cost recovery scheme oil and gas company cannot have any income other than from E&P activity, hence income for carbon trading is prohibited. For gross split scheme, there is permission for CO2 to be sold, however it is not specified whether the CO2 can be sold as product or by-product only or as waste/emission. In addition, with lack of regulation that govern specific emission reduction target, emission reduction effort is still viewed as a "beyond compliance" effort, hence it cannot be view as recoverable cost.
- Presidential Regulation No 61 of 2011 [12] concerning Action Plan for Greenhouse Gas Emission Reduction - RencanaAksi Nasional PenurunanEmisi Gas RumahKaca. This regulation becomes the basis of emissions reduction effort that is conducted by several industry sectors.
- Ministry of Energy and Mineral Resources Regulation No. 14 of 2012 [13] concerning Energy Management and Government Regulation No 70 of 2009 concerning Energy Conservation [14].
- Presidential Regulation No 71 of 2011 [15]concerning National Greenhouse Gas Invetarization - PenyelenggaraanInventarisasi Gas RumahKacaNasional and Ministry of Environmental Regulation No 12 Year 2012 [16] concerning Calculation Guideline for Oil and Gas Activity Emissions - Pedomanperhitungan Beban EmisiKegiatanIndustriMinyak dan Gas Bumi. These regulations become the basis of Ministry of Environmental and Forestry role as the data custodian of GHG Emission Inventory, the emission reduction method is up to other technical ministry such as Ministry of Energy and Mineral Resources or Ministry of Industry. This regulation still permit several calculation method as input data, there shall be an update to this regulation if in the future the emission inventory will become basis of more stringent regulations such as related to carbon emissions cap and trading.

In the contrary to those regulations, currently there is no regulation that governs the permit for CCS/CCUS. Without clear permit, it will become another barrier for upstream oil and gas company to implement it. With the current global energy trend, media attention and public awareness of emissions reduction and also emissions reduction target by international oil company, Indonesia will have to catch up with this trend and issue regulation to support it. In worst case condition, if Indonesia regulations cannot support emission reduction effort or facilitate carbon trading, there will be reluctance from international oil company to invest in Indonesia and develop Indonesia oil reserve especially field that have high CO2 content.

2.2 Existing Studies

The summary of existing system dynamic models related to energy and GHG emission reduction is provided below:

1. The system dynamics scenarios developed by De Castro [17] cover the aspects of the conventional oil peak, the relations with the economy, the implications on the rest of energies and the subsequent emissions of greenhouse gases.

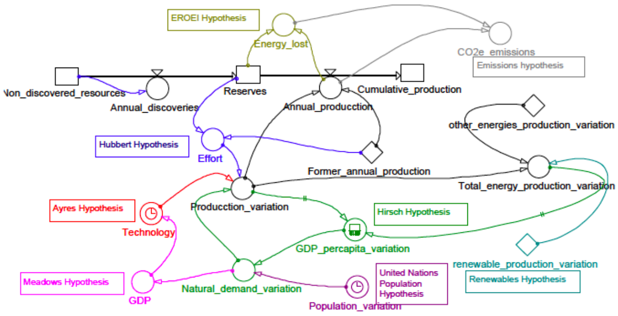

Fig. 1. General model for the net conventional oil production with all the hypothesis [17]

2. The model developed by Chi [18], separate causal loop diagram of exploration sector, production-consumption sector and demand projection – substitution sectors

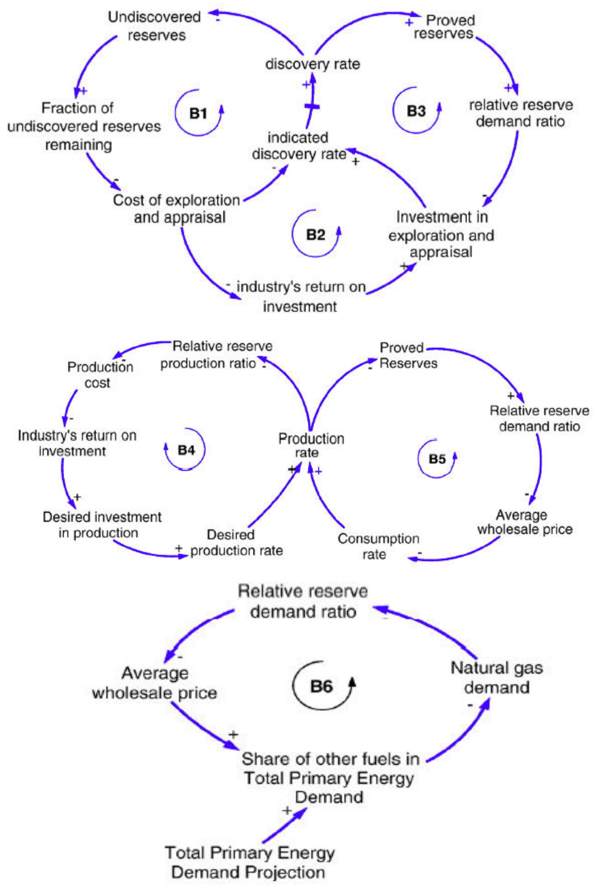

Fig. 2. Causal Loop/Flow Diagram of exploration, production & consumption, demand projection & substitution sector [18]

3. The model developed by Eker[19], shows a simplified CLD for natural production that cover reserve development, production rate, demand, investment and profitability

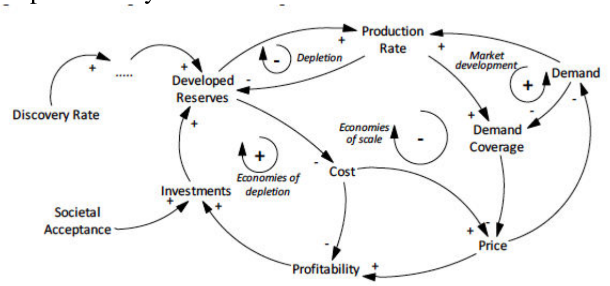

Fig. 3. Simplified Causal Loop Diagram of the Natural Gas Production [19]

4. The model developed by Davies [20] cover energy system in general including separating the production/supply model and supply/demand model

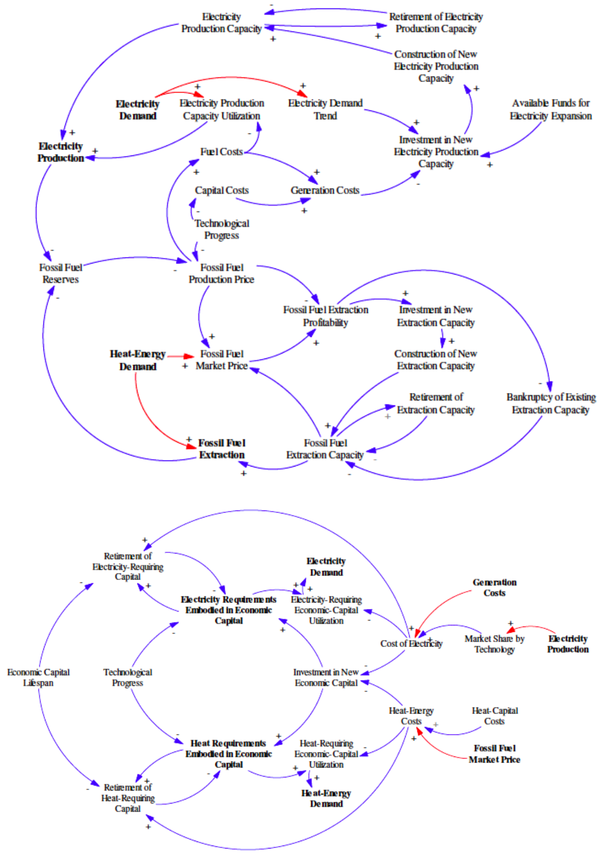

Fig. 4. Causal Loop Diagram of energy/production supply and energy supply-demand connections[20]

5. The model developed by Laimon [21] consist of integrated and comprehensive CLD that cover the energy demand model, energy production capacity, energy security and Net CO2 Emissions aspect

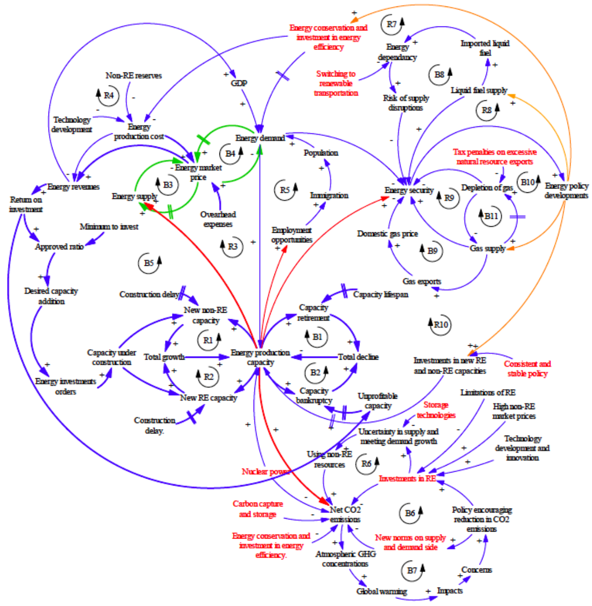

Fig. 5. Causal Loop Diagram of Australia Energy System[21]

6. The model by Sani [22,23] specifically developed for Indonesia policy environment by inclusion of fossil fuel vs renewable energy and government policy.

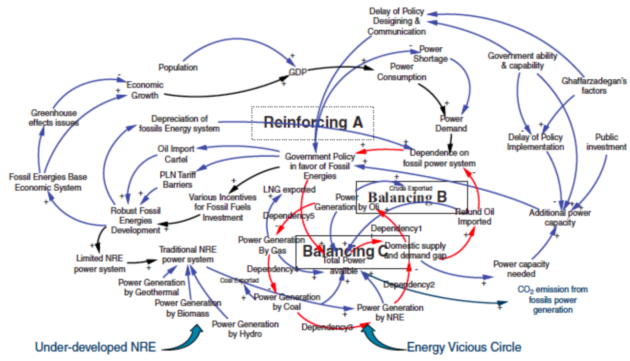

Figure 5: Causal loop diagram for energy portfolio management in indonesia today

Fig. 6. Causal Loop Diagram for Energy Portfolio Management in Indonesia[22,23]

III. METHODOLOGY

System dynamics can be use to model a complex system where the variable interact in dynamic conditions. There are five (5) steps in the modeling process [24]

1. Problem articulation (Boundary Selection)

Problem articulation can define the clear purpose of the model so that the model building process can be conducted by knowing what to cut out and what to emphasize in the model. In the problem articulation, the model objective, boundary and scope is to be identified.

2. Formulation of Dynamic Hypothesis

Based on the identified problem, the developer can create a dynamic hypothesis or a working theory that can be change based on the condition of the dynamic system or

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the system's underlying feedback and stock and flow structure

3. Formulation of Simulation model
Based on the defined model boundary and dynamic hypothesis, formulation of a fully specified formal model can be conducted. The model is completed with equations, parameters and initial conditions. In the formulation, over time modelers can adjust the model in order to resolve ambiguity and test initial hypothesis.

4. Testing
The next step is testing that consist of comparing the behavior of the simulation model to the behavior of actual system. In addition the model must be checked for dimensional consistency and extreme conditions. All of tests are critical to discover error and improve system understanding.

5. Policy Design and Evaluation
The initial model then can be simulated to model the intervention or policy applied, thus the impact of the policy can be known. Several sensitivity cases can be model to assess the wide range of alternative scenarios. In the end the optimum policy can be taken based on the potential impact that is simulated in the system.

IV. ANALYSIS

4.1 Causal Loop Diagram

Causal Loop Diagram is useful tool to visualize system's feedback structure. Causal diagram consist of variables connected by arrows denoting the causal influences among the variables [24]. The positive (+) or negative (-) polarity is assigned to the causal link to indicate the dependency of a variable to changes of other variable. A loop identifier indicates the polarity of important feedback loop, there are two kind of feedback loop, reinforcing (positive) and balancing (negative).

Reinforcing or positive loop is indicated by even number of negative link. In this loop, changes in one of the variables will propagate around the loop and the feedback effect reinforces the original change. While for balancing or negative loop, the opposite will happen, changes in one variable will return to an opposite variable deviation to the initial changes.

The causal loop diagram for this research is adapted based on the previous studies conducted by De Castro [17], Chi [18],Eker[19], Davies [20], Laimon et. al [21] and Sani, et.al [22,23] with several modification to adjust with the current condition in Indonesia and based on interview with stakeholders. The causal loop diagram for Indonesia upstream oil and gas industry greenhouse gas emission reduction effort is provided in Figure below.

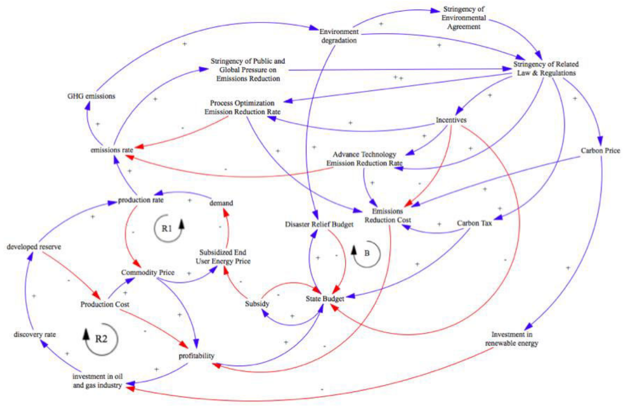

Fig. 7. Causal Loop Diagram

4.2 Stock and Flow Diagram

While causal loop diagram is design the visualize interdependencies and feedback process, it lack of ability to capture the stock and flow structure of the systems and their underlying physical structure [24]. In the stock and flow diagram, stocks are represented by rectangles with inflow and outflow represented by pipes with arrow going in and out respectively. Stocks are accumulation or integration of the inflow and outflow. The mathematical model of a stock and flow is represented by the following integral equation:

$$Stock(t) = \int_{t_0}^{t} [Inflow(s) - Ouflow(s)]ds + Stock(t_0) \quad (1)$$

The equation of stocks diagram from Indonesia upstream oil and gas industry greenhouse gas emission reduction effort are as follows:

a. Developed Reserve

$$Developed\ Reserve(t) = \int_{t_0}^{t} [Discovery\ Rate(s) - Production\ Rate(s)]ds + Developed\ Reserve(t_0) \quad (2)$$

b. State Budget

$$State\ Budget(t) = \int_{t_0}^{t} [State\ Revenue(s) - Expenditure(s)]ds + State\ Budget(t_0) \quad (3)$$

The following figure shows the stock and flow diagram for upstream oil and gas industry greenhouse gas reduction effort in Indonesia. For modeling simplification purpose, several variables that is related to scenarios will be simplify or merged into one variable to reflect the scenario.

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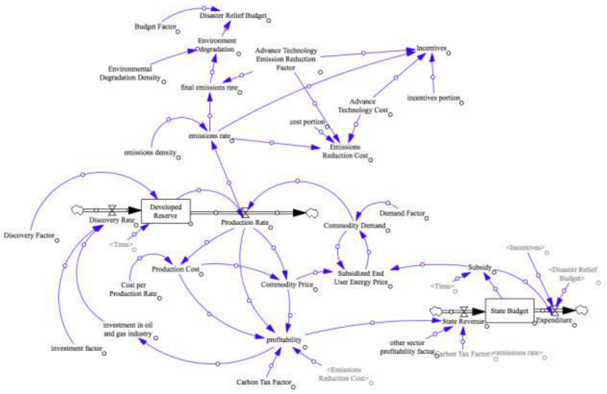

Fig. 8. Stock and Flow Diagram

4.3 Mathematical Model for SFD

To runs the system modeling in Vensim, the equations need to be developed for each variables. The correlation between each variable can be derived from quantitative analysis of available data. The summary of those variables is provided below:

TABLE I
Variable Correlation Rate

No	Y	X	Correlation	Factor (Y/X) Rate if needed
1	Developed Reserve	Discovery Rate	Positive	7
2	Production Rate	Developed Reserve Commodity demand	Positive	212
3	Commodity Demand	Subsidized Price	Positive	1.25E-05
4	Commodity Price	Production Rate Production Cost	Positive	8200
5	Subsidized End User Energy Price	Commodity Price Subsidy Commodity demand	Negative	1
6	Discovery Rate	Investment in oil and gas industry	Positive	2.50E-08
7	Investment in oil and gas industry	Profitability Investment in renewable energy	Negative	0.5
8	Production Cost	Production rate	Negative	6200
9	Profitability	Production cost Production rate Commodity price Emissions reduction cost	Negative	0.00065
10	Emissions rate	Production rate	Positive	1.60E-04
11	Environmental Degradation Factor	Emission rate	Negative	36
12	Disaster Relief Budget	Environmental Degradation	Negative	13
13	State Revenue	Profitability	Positive	4.40E-03
14	State expenditure	Subsidy Disaster relief budget	Negative	12
15	Emissions Reduction Cost	Emissions rate	Positive	80000
16	Subsidy	State Budget	Positive	0.07

4.4 Scenarios Development

4.4.1 Major Discovery

Even though the portion of oil and gas in energy mix is decreased, the total energy demand will increase thus the production rate from oil and gas need to grow to fulfill the target energy mix. However, with the current developed reserve and discovery rate, it will be very difficult to achieve the target energy demand without relying on supply from abroad. For this study, it will be assumed that there will be major discovery to cover the demand. Three scenarios are made to model the major discovery in order to achieve the target as follows:

- Scenario 1: Major discovery increase the production by 50% in 2025
- Scenario 2: Major discovery increase the production by 75% in 2025
- Scenario 3: Major discovery increase the production by 100% in 2025

It is to be noted that the modeling for the scenario here onwards use the year 2025 as the turning point. The year 2025 is also being the reference year for scenario basis of major energy company set their emissions target by the year 2025. Furthermore, The Law No 17 Year 2005 concerning 2005-2025 Long Term Development Plan (RPJP) that is used as the legal basis of the National Action Plan for Greenhouse Gas Emissions Reduction (RAN-GRK), used the year 2025 as their end of range. Hence, it is assume that the changes considered in the scenarios will happen on 2025 at the end of the long-term plan

4.4.2 Advance Emission Reduction Technology

Implementation of advance emission reduction technology such as CCS/CCUS in the form of CO2 reinjection both for storage and for enhanced oil recovery is one of the major emission reduction method. However, this technology is currently still under development and not widely use. To see the impact of advance emission reduction technology implementation that assumed to be happen in 2025, the following scenarios are made:

- Scenario 4: Implementation of advance emission

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reduction technology in 2025 successfully reduce emission by 50%

- Scenario 5: Implementation of advance emission reduction technology in 2025 successfully reduce emission by 75%
- Scenario 6: Implementation of advance emission reduction technology in 2025 successfully reduce emission by 90%

4.4.3 Incentives

Incentives is required to cover the emission reduction cost without being burden to company profitability. To see the impact of incentives to cover the emission reduction cost, the following scenarios are made:

- Scenario 7: in 2025 30% of emission reduction cost covered by incentives
- Scenario 8: in 2025 50% of emission reduction cost covered by incentives
- Scenario 9: in 2025 70% of emission reduction cost covered by incentives

4.4.4 Carbon Tax & Carbon Market

Other mechanism that might be applied as an effort to reduce the GHG emission is to apply carbon tax and carbon market mechanism. Implementation of carbon tax & carbon market will decrease the oil and gas company profit. To find out the effect of carbon tax & carbon market implementation, the following scenarios are made:

- Scenario 10: Implementation of Carbon Tax in 2025 that decrease company profitability by 5%
- Scenario 11: Implementation of Carbon Tax in 2025 that decrease company profitability by 10%
- Scenario 12: Implementation of Carbon Tax in 2025 that decrease company profitability by 20%

4.5 Scenario Configuration

Based on the factors described as scenarios above, there will be 12 scenarios modeled. It is to be noted that to model the incentives and carbon tax-market scenarios, implementation of advance technology that might increase the emission reduction cost should be included in the scenario, hence scenario 4 will be use as basis of incentives and carbon tax-market scenarios. The following table summarizes the scenarios.

TABLE II

Scenario Configuration

No.	Major Discovery	Advance Technology	Incentives	Carbon Tax & Carbon Market
1	S1			
2	S2			
3	S3			
4		S4		
5		S5		
6		S6		
7		S4	S7	
8		S4	S8	
9		S4	S9	
10				S10
11				S11
12				S12

4.6 Model Validation

To validate the developed stock and flow model in Vensim, unit and model check is conducted. Model checks is conducted to ensure that all formula in the model is correct while the unit checks it conducted to ensure that the unit used in the model are compatible with each other. The model has gone through the model and unit check in Vensim.

4.7 Model Verification

Model Verification is conducted to ensure that the model can reflect the actual condition. Model verification is conducted by comparing the simulation result with the historical data for several key parameters (i.e. Developed Reserve, Production Rate, Profitability). The model is considered as valid when the result has similarity with no significant deviation [25].

Comparison has been made for developed reserve, production rate and profitability where normalized root mean squared error is 9%, 24% and 40% respectively. The difference in profitability trend happen due to model high dependency to production rate that make it more insensitive to other input variable for profitability, furthermore, there is model limitation as the causal relation factor is defined based on the 2020 projection ofthe causal relation.

4.8 Scenarios Simulation Results

There are twelve (12) simulations that was carried out for the model:

- three (3) scenarios for major discovery
- three (3) scenarios for implementation of advance emission reduction technology
- three (3) scenarios for government incentives
- three (3) scenarios for implementation of carbon tax and carbon market

The results of those simulations are as follows.

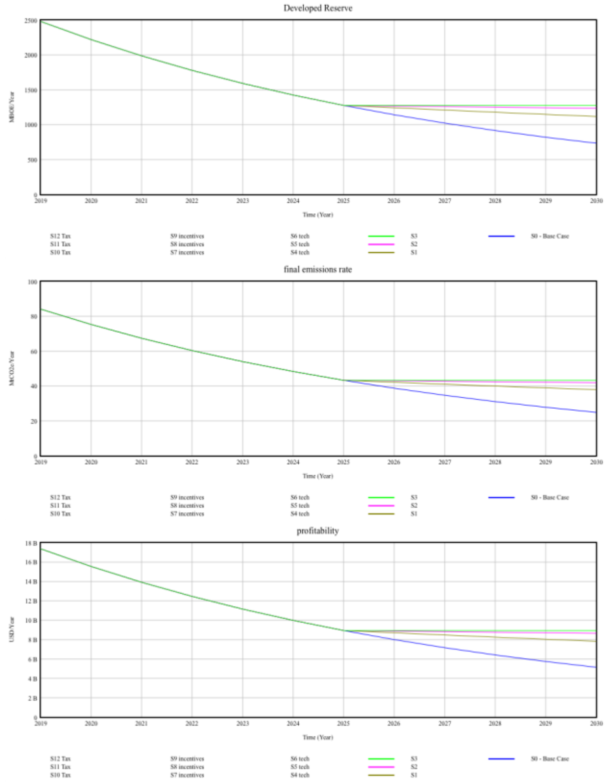

Fig. 9. Major Discovery Scenario Results

Figure above shows the simulation result of major discovery scenario. Based on the graph, it can be seen that major discovery that is reflected in the developed reserve parameter will give higher profitability for the company, however, in the other hand, it has the side effects of higher emissions rate that is not preferable from environmental stand point.It is to be noted that prior to 2025 where the scenario of major discovery start, the trend of emissions is declining similar to the production, this is due to oil and gas reservoir natural decline.

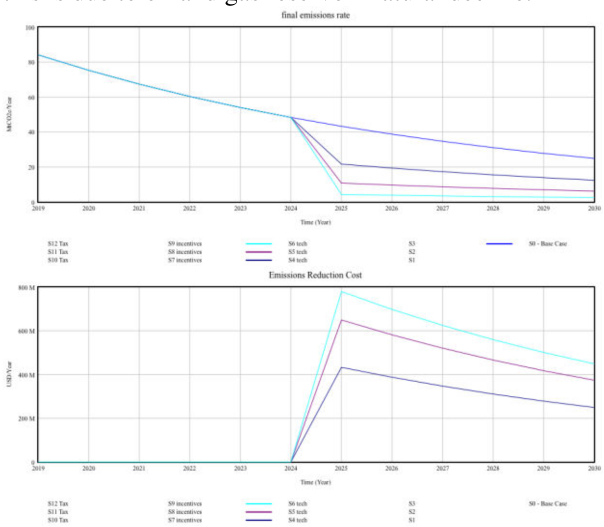

Fig. 10. Advance Emission Reduction Technology Scenario Results

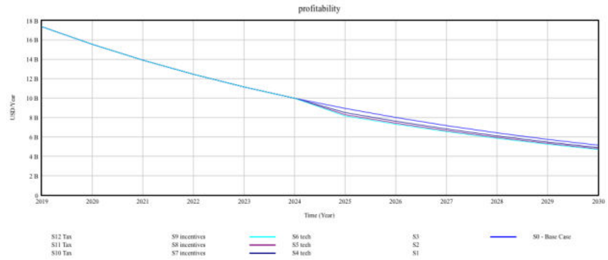

Fig. 10. (cont.) Advance Emission Reduction Technology Scenario Results

The simulation result for implementation of advance emission reduction technology is shown in figure above. Based on the simulation result, it can be seen that the emission reduction achieved through implementation of advance technology such as carbon capture and storage might increase the cost that then will decrease the profitability. However, based on the assumption of USD 20 USD cost per tonnes of CO2 [26] the cost will only give maximum 8.72% decrease of profitability based on scenario 6 of 90% emissions reduction.

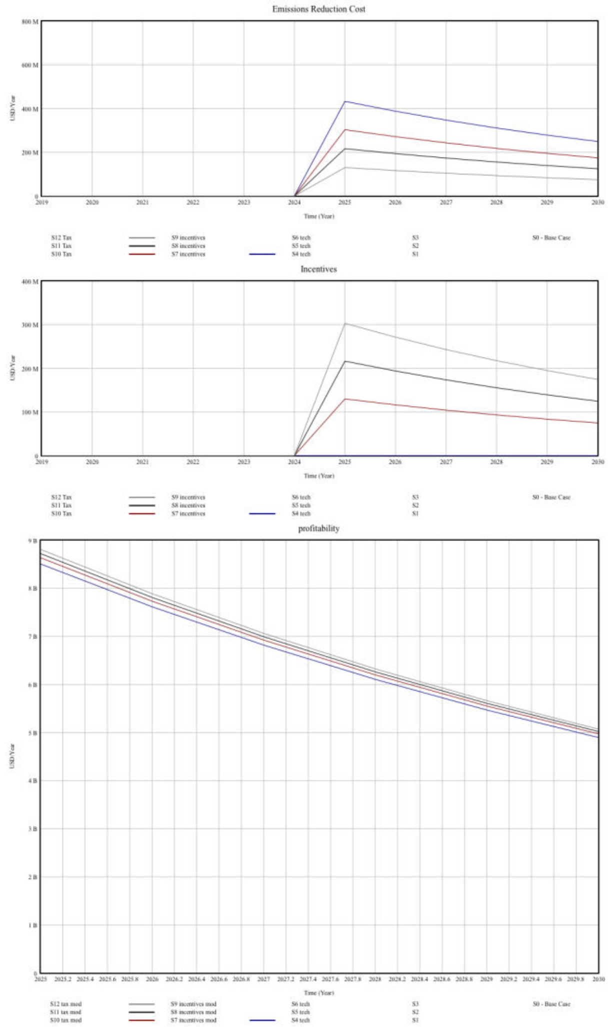

Fig. 11. Government Incentives Scenario Results

It can be seen from the figure that the bigger the incentives portion, the lower the emission reduction cost that is burdened to the industry, hence the decrease of profitability will be even lower

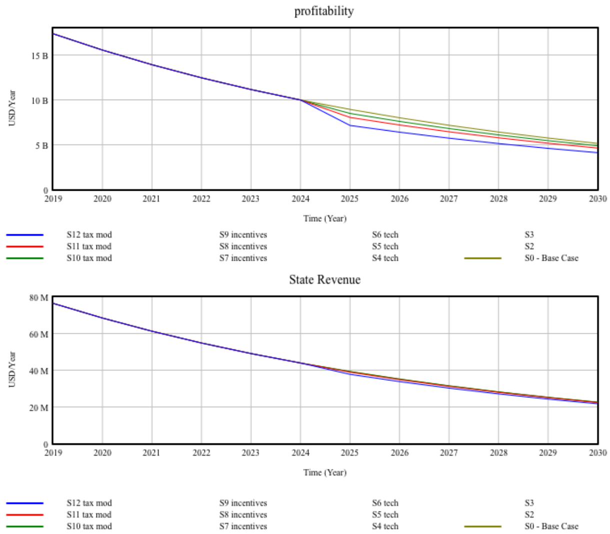

Fig. 12. Carbon Tax & Carbon Market Scenario Results

Figure above shows the simulation result of implementation of carbon tax and carbon market mechanism in 2025. The simulation shows that implementation of carbon tax and carbon market mechanism will only slightly compensate loss of profitability in the revenue. It can be seen from the graph that carbon tax mechanism can reduce the profitability of oil and gas company, even though the state will get additional state revenue in return, the additional revenue from carbon tax cannot fully compensate the loss of profitability in oil and gas sector that will decrease the oil and gas development rate and eventually decrease the production rate.

V. CONCLUSION

The Greenhouse gas emission reduction effort in Indonesia upstream oil and gas industry is currently still in the initial phase. Most of the oil and gas company has started their effort to reduce emissions and has self-commitment to it. The government has started to build a system to ensure better reporting that is aligned with recent study that highlight the important of public emissions data availability [4] however there is lack of available incentives and supporting regulations that can optimize the effort.

There are several factor that affect greenhouse gas emission reduction effort in Indonesia upstream oil and gas industry, based on literature study and interview with several key stake holders the factors are global trend and availability of binding environmental agreement that drive implementation of carbon tax & carbon market mechanism, availability of incentives, availability of advance technology for emissions reduction and the oil and gas industry profitability itself.

Based on the system dynamics modeling simulation, it is known that major discovery to cover energy demand will increase the emissions rate but in the other hand will also increase the profitability. The factors that will influence the industry profitability is implementation of carbon tax scheme and implementation of advance emission reduction technology, both factor will reduce the profitability. Implementation of advance emission reduction technology can reduce the emission rate significantly. While the availability of incentives can compensate the loss of profitability due to implementation of advance emission reduction technology.

Similar to the study related to Australia energy sector [21] the model shows that continuous development of fossil fuel based energy will lead to high emissions and unsustainable fossil fuel extraction, this will also have high risk related to the Paris agreement that require sharp decline in fossil fuel utilization. It is also aligned with the previous study [4] that highlight the risk of fossil fuel investment under increasingly binding emissions reduction agreement. This model also echoing the finding made by similar study where innovative technologies implementation becomes one of the important factor in the strategy to reduce GHG impacts.

It can be concluded that the support of government in providing Paris agreement – aligned emissions requirement that will drive the effort to reduce emissions in upstream oil and gas industry will still be the turning point as the effort will reduce the profitability without giving them any increase of production or revenue. However, further study is required to provide clearer incentives mechanism and its impact to the effort.

The following recommendation was raised for both policy maker and oil and gas company management:

- Government need to respond to the global trend of GHG emissions reduction by providing supportive policy and regulations that will increase the emissions reduction effort from the industry such as incentives provision, however, further study is required on the incentives impact and detail incentives mechanism.
- Policy development should be coordinated among related ministry such as Ministry of Energy and Mineral Resources, Ministry of Maritime and Ministry of Finance. This is to ensure that all related regulations could create supporting ecosystem to achieve Indonesia commitment to Paris Agreement as documented in the NDC.
- Oil and Gas Company need to as proportional as possible continue to reduce their GHG emissions while keep updating their knowledge in the emissions reduction technology so that in the future more advance and more effective technology can be quickly updated in Indonesia

upstream oil and gas industry.

REFERENCES

[1] PeraturanPresidenNomor 22 Tahun 2017 tentangRencanaUmumEnergi Nasional. 13 Maret 2017. Lembaran Negara Republik Indonesia Tahun 2017 Nomor 43. Jakarta
[2] SKKMigas (2020). Annual Report 2019. Retrieved January 15, 2021 from https://www.skkmigas.go.id/publikasi/annual-report
[3] McKinsey (2019) Toward a net-zero future: Decarbonizing upstream oil and gas operations. Retrieved Jan 31, 2021 from https://www.mckinsey.com/industries/oil-and-gas/our-insights/toward-a-net-zero-future-decarbonizing-upstream-oil-and-gas-operations
[4] Masnadi, M.S., El-Houjeiri, H.M., Schunack, D., & Li, Y. (2018) Global Carbon Intensity of Crude Oil Production. Science 361(6405):851-853
[5] International Energy Agency (IEA) (2020) World Energy Outlook 2020. Retrieved January 15, 2021 from https://www.iea.org/reports/world-energy-outlook-2020
[6] Schreuder (2009) The Coprorate Greenhouse : Climate Change Policy in a Globalizing World. Zed Books Ltd. New York.
[7] Schwab, K. (2019) The Global Competitiveness Report 2019. World Economic Forum. Switzerland. Retrieved on February 15, 2021 from http://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2019.pdf
[8] BP (2020) Statistical Review of World Energy Retrieved January 15, 2021 from https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf
[9] Ulucak et al. (2019) The Process of Sustainability: From Past to Present. Environmental Kuznets Curve (EKC) 37-53
[10] Peraturan Menteri Energi dan SumberDaya Mineral No 8 Tahun 2017 TentangKontrakBagi Hasil Gross Split
[11] Peraturan Menteri Energi dan SumberDaya Mineral No 12 Tahun 2020 PerubahanketigaatasPeraturan Menteri Energi dan SumberDaya Mineral nomor 8 Tahun 2017 TentangKontrakBagi Hasil Gross Split
[12] PeraturanPresidenNomor 61 Tahun 2011 RencanaAksi Nasional PenurunanEmisi Gas RumahKaca
[13] Peraturan Menteri Energi dan SumberDaya Mineral No 14 Tahun 2012 tentangManajemenEnergi
[14] PeraturanPemerintahNomor 70 Tahun 2009 tentangKonservasiEnergi.
[15] PeraturanPresidenNomor 71 Tahun 2011 tentangPenyelenggaraanInventarisasi Gas Rumahkaca Nasional.
[16] Peraturan Menteri LingkunganNomor 12 Tahun 2012 tentangPedomanPerhitungan Beban EmisiKegiatanIndustriMinyak dan Gas Bumi.
[17] De Castro, C., Miguel, L. J., &Mediavilla, M. (2008). World energy-economy scenarios with system dynamics modeling . Unpublished manuscript.
[18] Chi, K. C, Nuttak, W. J., & Reiner, D. M. (2008). Dynamics of the UK natural gas industry: System dynamics modeling and long-term energy policy analysis. Technological Forecasting and Social Change , 76 (3), 339-357. https://doi.org/10.1016/j.techfore.2008.06.002
[19] Eker, S. & Van Daalen, E. (2015) A Supply-Demand Model for the Dutch Gas Sector. Technical Report.
[20] Davies, E. G. R., & Simonovic, S. P. (2009). Energy sector for the integrated system dynamics model for analyzing behaviour of the social-economic-climatic model . London, Ontario, Canada: The University of Western Ontario Department of Civil and Environmental Engineering
[21] Laimon, M., Mai, T., Goh, S., &Yusaf, T.F. (2019) Energy Sector Development: System Dynamics Analysis. Applied Sciences 10(1):134
[22] Sani, K., Siallagan, M., Putro, U.S., &Mangkusubroto, K. (2017) Policy Development for the Energy Mix in Indonesia Using System Dynamics. Global J. Bus. Soc. Sci. Review 5 (3) 137 – 158
[23] Sani, K., Siallagan, M., Putro, U.S., &Mangkusubroto, K. (2018) Indonesia energy mix modeling using system dynamics. International Journal of Sustainable Energy Planning and Management Vol. 18 2018 29–52. http://dx.doi.org/10.5278/ijsepm.2018.18.3
[24] Sterman, J. (2000). Business Dynamics: Systems Thinking and Modeling for a Complex World. Boston: Irwin/McGraw-Hill.
[25] Rahmawati R., (2020) A System Dynamic Models for Analyzing Company Revenue of PT Susu Segar Indonesia.
[26] Irlam, L., (2017) Global Cost of Carbon Capture and Storage. Retrieved March 20, 2021 from https://www.globalccsinstitute.com/resources/publications-reports-research/global-costs-of-carbon-capture-and-storage/