Market Analysis of Natural Gas Supply and Demand in East Java Province to Enable a Sustainable Scenario Using System Dynamics Simulation

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Abstract. In the last 5 years, Indonesia has seen an increasing amount of infrastructure development, from toll road, airports, and power plants. This will continue for a number of years. As the economic and population growth, energy needs in Indonesia are also increasing every year. Indonesia has abundant natural gas reserves at 142.71 trillion standard cubic feet (TSCF) and the largest reserves in Southeast Asia. Indonesia is also Southeast Asia’s biggest gas supplier, with exports accounting for roughly 45% of its production. Natural gas is an affordable energy source and very accessible. At the current rate of consumption and assuming no new discoveries, existing reserves would last around 50 years. In this study, there are two scopes of research, first determining the supply and demand of natural gas in Java Island, and then market analysis. A market study on gas supply and demand is done on various industries, from power plants, factories, and households needs. From the market study, the condition will be analyzed, whether the gas supply meets the demand or not. Then, from the current condition, an improved and sustainable model of gas distribution system will be proposed. The result of the simulation is that there will be a deficit of supply every year except for 2023. The maximum daily deficit is 230.1 MMSCFD in the year 2022. Additional supply of 200 MMSCFD is required in year 2022. The viable option would be building a LNG Receiving Terminal with a capacity of 150-200 MMSCFD in Pasuruan area or to use the LNG Teluk Lamong facility.

1. Introduction
Indonesia has abundant natural gas reserves at 142.71 trillion standard cubic feet (TSCF) and the largest reserves in Southeast Asia. Indonesia is also Southeast Asia’s biggest gas supplier, with exports accounting for roughly 45% of its production. The largest undeveloped gas reserves are located in the offshore East Natuna Block, which holds approximately 49.6 TSCF, there are also many high potential areas like West Papua and Maluku. At the current rate of consumption and assuming no new discoveries, existing reserves would last around 50 years.

In contrast to the 2000s, the current supply of natural gas for domestic market is greater than for export. Natural gas export is expected to continue to decline until the end of 2035 so that all natural gas production can be used for domestic demand. However, natural gas production will not be able to meet national gas demand in the future. To overcome the shortage in gas supply, it is necessary to consider non-conventional gas and import gas in form of LNG.
Natural gas is relatively low-carbon (as compared to coal) and is generally medium-cost. Gas is therefore likely to remain a favoured fuel for at least the next decade especially given Indonesia’s extensive gas reserves. While the electricity generated from natural gas in 2027 is expected to increase by over 80% from 2018 (in TWh) the share of gas in the energy mix in 2027 is expected to be only 20.6% representing a decrease from 24.8% of the energy mix in 2017. An oversupply of global and Asian (including Indonesian) Liquefied Natural Gas (“LNG”) is likely to stimulate further consumption although the LNG market is expected to tighten over the next few years. Certainty over the upstream oil and gas investment climate and improved physical infrastructure (including pipelines and Floating Storage Regasification Units (“FSRUs”)) as well as pricing for gas-for-power arrangements (currently under review again) are crucial to enabling a strong long-term role for gas in the Indonesian power generation mix. (PWC Power Guide in Indonesia 2018).

Energy demand and manufacturing activities are growing every day, with the government targeting an economic growth. The activities are creating investment opportunities in Indonesia’s oil and gas sector. While in the past most oil and gas would be exported, strong economic growth and rapidly rising household spending mean the sector will focus more on self-consumption. A modernized, efficient and reliable energy supply system is needed to advance the economic development. Despite the availability of coal in Indonesia, the government’s plan to rely more on cleaner burning gas and less on coal to fire new power plants is set to create stronger and stronger demand for gas.

With the growing energy demand, there is an absence of information on the integrated supply and demand. The gas distribution system already is hard pressed to maintain stable supplies in areas with high load densities, including Jakarta, Bandung, and Surabaya.

In order to overcome this condition and to fulfil the needs of gas in Java Island, it is considered necessary to improve the efficiency of natural gas distribution. To provide with an accurate recommendation, the historical data and forecasts will be analysed. The method that will be used is system dynamic simulation.

2. Method
In the study there are 2 scopes of discussion, the first is demand and supply analysis, in order to model the current situation. After the conceptual model is created and the existing condition is assessed, a system dynamic simulation will be done. System dynamic simulation is used to analyse the current and future supply fulfilment capability. Then, scenario will be made to fulfil the demand.

2.1. Description
Model is a result of interpretation of a real system consists of logic combination and mathematics that takes into account. Those factors are influenced by the problem beforehand. The model itself must be done carefully and in detail, in order for the simulation model that obtained to be very similar with the real one. In order to create a good model, the criteria are easy to understand, having clear objectives, conation clear problem solving, and easy to be controlled and manipulated by model users.

Modelling is the process of producing a model that is a representation of the structure and system that works. Verification and validation also needed to be done to find out that the model has no different with the real system. Verification is the process of checking the data, ensuring the model is suitable with the logic of the flow chart. Verification needed to check the translation of conceptual models into programming languages correctly [9]. On the other hand, validation is the determination process of whether the model that has been made is in accordance with the real system being modelled [9]. Simulation will be used to improve the performance of dynamic and complex system like the natural gas supply chain. The simulation will help imitate the supply and demand behaviour and provide predictions of the demand coverage. Various scenarios will be made in order to analyse the baseline for improvement and recommendation.

System is a collection of several components or elements that operate simultaneously in order to achieve a goal. Similar to agent-based modelling, system dynamics is a simulation technique that links “components” of the model via pre-defined functions. System dynamics models include a “growth
function” of their variables that allows for a “dynamic” modelling of processes over time. It also assumes that the system is functioning continuously as defined by the input data, which implies that possible disequilibria in the system are maintained. This is a major difference to the neo-classical paradigm (the framework for this thesis) where the existence and convergence to an equilibrium state is a central concept. Another drawback from an industrial economics point of view is that system dynamics can not represent imperfect markets as we find them in the natural gas sector today and the studies using this approach generally predefine a perfectly competitive market.

System dynamics has traditionally been used for the analysis of management processes. As a tool for energy systems analysis, system dynamics has been used for more than 30 years. The system dynamics approach is suitable for modelling complex environments, such as ecosystems and human activities, on a multi-dimensional scope with time-dependent variables. The system dynamics modelling helps more clearly demonstrate the interactions of the environment and socio-economic variables, and also helps to identify the key factors that significantly alter a dynamic system.

As a review of the research on the dynamic model of the natural gas industry, the present paper develops a system dynamics model to analyse the factors influencing upstream behaviour.

The established natural gas system dynamics model can clearly reveal all kinds of production process aspects of gas company exploration and development, and the relationship between production process input factors and output factors. The system dynamics model is a combination of qualitative and quantitative methods; the most prominent feature of this method is its ability to handle non-linear, high-level, multiple feedback, complex time-varying system problems. Indonesia’s upstream gas
companies often have insufficient data. In this situation, the system dynamics (SD) model can be used to carry out the calculation and research.

2.2. Literature Review

Several system dynamics models that investigate natural gas or petroleum resources exploration and production have been described in the literature [21], [22], [23], [24], and [25], which originate form an early model of [26]. The model developed in this study is similar to these models, in terms of the relation between the exploration and production activities and the corresponding investments, and the factors that affect investments such as price and demand. However, this model is different from those in terms of three main aspects: Firstly, a more detailed lifecycle structure of natural gas fields is implemented in this model, as will be explained further below, in order to test policies specific to Indonesia and to different steps of extraction process. Secondly, this model includes the profitability of natural gas production and its effects on investment, due to the recent development of economic growth in East Java Province. Lastly, having the general purpose of focusing on uncertainties to generate a large number of future scenarios, this model includes several parametric and structural uncertainties, i.e. the model formulations representing different assumptions that could be made for the same phenomenon.

The technical subsystem of natural gas production is modelled based on the field lifecycle which is composed of exploration, appraisal, development, and production phases [27]. The oil and gas resource base is divided into four types, which are Prospective Resources, Contingent Resources, Undeveloped Reserves, and Developed Reserve. Some research also divided the resources into two categories, as discovered and undiscovered resources. The supply is divided into several categories because the delay from discovery to production that can strongly affect the producible volume, and the actions that should be taken at different stages to keep the volume high.

2.3. Data Collection

The data needed in this study:

1. Literature Study
   Literature study is an information research on related data, methods, and problems that are raised in the research, through internet, journals, papers, and books
2. Simulation
   Several scenarios will be developed based on the current condition and then the system dynamics simulation will be done. The purpose of this process is to develop a scenario with better performance. The distribution system will be represented using various tools: model boundary diagram, causal loop diagram, and system dynamics
   East Java is now a producer of oil and gas. As many as 30 percent of 800 thousand Barrel of Day (BOD) of national production, donated of oil and gas field production from East Java. While for gas, also very important. East Java is able to contribute 10 to 12 percent of the total gas supply in the country. Currently, in the working area of SKK Migas Java Bali Nusa Tenggara (Jabanusa), there are 32 cooperating contractors (KKKS) operating companies. And, 16 KKKS companies already in production.
   The data collection will be conducted by performing an identification action in the current gas distribution of East Java Province. The process of this data collection is done by secondary data collection. The main data is obtained from the following sources:
   a. Natural gas production rate, well reserves, prospective resources from Neraca Gas Bumi Indonesia 2018-2027 published by Ministry of Energy and Mineral Resources Indonesia.
   b. Infrastructure of natural gas pipe, pipe capacity and utilisation from Rencana Induk Jaringan Transmisi dan Distribusi Gas umi Nasional tahun 2012-2025 based on Keputusan Menteri Energi dan Sumber Daya Mineral Nomor 2700 K/11/MEM/2012
   c. Natural gas demand for household, electricity generation, and industrial and demand forecast from Neraca Gas Bumi Indonesia 2018-2027 published by Ministry of Energy and Mineral
d. Natural gas for electricity demand and future projection from Rencana Usaha Penyediaan Tenaga Listrik PT PLN (Persero) 2019-2028.

3. Results and Discussion

After the required data has been obtained, the next step is to make a model of the natural gas existing system conditions by using the variables indicated by the causal loop diagram. These variables must be determined first because it is required to formulate the diagram. Then the causal loop diagram will be the guideline for making a base model. The base model is a model that already represented the existing system. To find out if the Base model is in accordance with the real system, verification and validation need to be done. The conceptual model of supply and demand in East Java Province can be seen in Figure 2.

![Figure 2: Hierarchy Structure](image)

The price variable is also used in the demand sub-model since consumer demand changes as the price changes. The demand volumes determined in this sub-model are used in the market sub-model for price-setting in return, to indicate the effect of the supply/demand balance. Between the supply and demand sub-models, the demand volumes determined in the later are major factors used in the supply sub-model to determine production rates or import volumes. From the supply sub-model to the demand sub-model, the link is the societal acceptance of natural gas production and the fulfilment ratio, which determines the demand flow between natural gas via consumer preference.

This system dynamics model concentrates on the total or average values of system variables at a high aggregation level. For instance, the production rate of natural gas does not represent the production from a single natural gas field based on a single natural gas field based on a decision of a single producer, but the total production rate from all such field based on a decision of a single producers, assumed to be a homogenous group. With this homogeneity assumption, this model include the actions and decisions of several actor groups in addition to the system components mentioned above, as the drivers of change in the system.

The Figure 2 depicted the main causal relations and loops governing the natural gas production mechanism in the model. In this diagram, an arrow denotes a causal link between two variables, and the sign next to it signifies the polarity of that causal link. If a change in the first variables changes the second variable in the same direction, then the polarity is positive, otherwise, it is negative. The depletion loop is the main loop in the field lifecycle, implying that increased production rate depletes the volume of the developed reserves, which reduces further production. Regarding the investment of
producers to stimulate production and new discoveries. The Economies of Depletion is a reinforcing loop, which means that depletion due to increasing Production rate increases the unit cost, leading to a price increase which makes the investments in production more attractive. The Economies of Scale loop, however, is a balancing loop which describes the increased production reducing price, which further reduces the investments, and hence the production rate. Lastly, the Market Development loop summarizes the supply-demand relation in the market, where high production decreases the price, and hence increases the demand, which further increases the production.

3.1. Result
The simulation is done each day for 15 years, and the table show the summary per year. Fulfilment ratio is the value of supply divided by demand. The Average Daily Total Supply is the total of field production. It can be seen that the supply decreased each year, except for year 2023, because there will be additional supply from several fields; PHE WMO, Husky-CNOOC, Jambaran Tiung Biru, and increase of capacity in LNG Teluk Lamong, from 30 MMSCFD to 180 MMSCFD. The Average Daily Total Demand is the total natural gas consumption in industrial, electricity, and household gas usage.

![Figure 3. Stock and Demand Diagram](image)

The Average Daily Total Demand (MMSCFD) increased over the year. The value is the total of natural gas from household demand, electricity demand, and industrial demand. The demand increased steadily based on the projected population and economic growth.

| Year | Fulfilment Ratio | Average Daily Total Supply (MMSCFD) | Average Daily Total Demand (MMSCFD) | Average Daily Deficit (MMSCFD) |
|------|----------------|-----------------------------------|-----------------------------------|-------------------------------|
| 2018 | 0.95           | 579.99                            | 610.52                            | -30.53                        |
| 2019 | 0.85           | 523.33                            | 619.27                            | -95.94                        |
| 2020 | 0.85           | 523.33                            | 619.27                            | -95.94                        |
| 2021 | 0.73           | 458.97                            | 628.19                            | -169.22                       |
| 2022 | 0.64           | 407.17                            | 637.28                            | -230.11                       |
| 2023 | 1.36           | 878.72                            | 646.55                            | 232.17                        |
| 2024 | 1.22           | 802.26                            | 656                               | 146.26                        |
| 2025 | 1.16           | 772.03                            | 665.63                            | 106.4                         |
| 2026 | 1.06           | 719.29                            | 675.44                            | 43.85                         |
| 2027 | 0.99           | 678.62                            | 685.45                            | -6.83                         |
| 2028 | 0.99           | 686.89                            | 695.65                            | -8.76                         |
| 2029 | 0.94           | 660.65                            | 706.05                            | -45.4                         |
| 2030 | 0.89           | 638.88                            | 716.66                            | -77.78                        |
| 2031 | 0.85           | 620.57                            | 727.46                            | -106.89                       |
| 2032 | 0.82           | 604.98                            | 738.48                            | -133.5                        |
The Average Daily Total Supply (MMSCFD) shows the total of natural gas produced and supplied in East Java Province. In 2018, the supply came from Kangean Energy Indonesia Ltd., PHE WMO, Husky CNOOC, Ophir – Santos Sampang Pty., Ophir – Santos Madura Offshore Pty., and Pertamina EP Poleng. With the current condition, with no new field discoveries, the supply will decrease. In 2023, there will be an increase of supply because three new sources of supply will operate, LNG Teluk Lamong will increase their capacity from 30 MMSCFD to 180 MMSCFD, Husky CNOOC, and Pertamina EP Cepu’s Jambaran Tiung Biru, with capacity of 170 MMSCFD.

Figure 4. Natural Gas Demand and Supply Comparison

Figure 4 show that there are shortage in the gas supply from the year 2020. To fulfil the demand, there are several alternatives to choose, such as increasing the capacity of LNG Terminal Teluk Lamong, and increase exploration of gas sources in East Java Region.

3.2. Mapping

After the base model is valid and verified, the next step is to create a simulation scenario. Before a scenario is made, first we need to make a geographical distribution of the supply and demand in East Java, the supply and demand mainly came from two area; Gresik and Pasuruan.

Figure 5. Natural Gas Supply and Demand Distribution in East Java
Figure 6 shows that there are two heavily populated areas for gas supply and demand. In Gresik, the supply came from PHE WMO, Pangkah Indonesia Saka Limited, Husky-CNOOC Madura Limited, and LNG Terminal Teluk Lamong with a total of 293.96 MMSCFD. The demand came from PT Petrokimia Gresik, industrial area, and PLTGU Jawa 3, which will soon operate in 2021. The total demand in Gresik area is 333 MMSCFD.

In Pasuruan, the supply came from Kangean Energy Indonesia, from four of their operating fields, which are Terang, Sirasaun, and Batur Field. The total supply is 201.77 MMSCFD. The current demand are from PLTGU Grati and industrial estates. The total current demand is calculated at 110 MMSCFD.

Figure 7. Natural Gas Supply and Demand Distribution in East Java in 2032
In 2032, the supply and the demand geographical location is more or less the same, with the addition of Kawasan Industri Tuban. In Gresik, the supply came from PHE WMO, Pangkah Indonesia Saka Limited, Husky-CNOOC Madura Limited, and LNG Terminal Teluk Lamong with a total of 320.55 MMSCFD. The demand came from PT Petrokimia Gresik, industrial area, and PLTGU Jawa 3, which will soon operate on 2021. The total of demand in Gresik area is 370 MMSCFD.

In Pasuruan, the supply came from Kangean Energy Indonesia, from four of their operating fields, which are Terang, Sirasaun, and Batur Field and from PHE, in Jambaran Tiung Biru Field. The total supply is 150 MMSCFD. The current demand are from PLTGU Grati and industrial estates. The total current demand is calculated at 225 MMSCFD.

4. Conclusion
Based on the research and analysis natural gas supply and demand in East Java Province, there are some conclusion that the author would summarize:

1. The current supply and demand condition is inadequate. There will be deficit of supply every year except for 2023. The maximum daily deficit is 230.1 MMSCFCD in the year 2022.
2. Additional supply of 200 MMSCFCD is required in year 2022. The viable option would be building a LNG Receiving Terminal with a capacity of 150-200 MMSCFCD in Pasuruan area or to use the LNG Teluk Lamong facility because the distribution pipeline of East Java is well developed and connected. The supply would come from BP Tangguh Train 3 that is currently in development and will operate in 2021.

Based on the research and analysis natural gas supply and demand in East Java Province, there are some recommendation that the author would suggest; Geographical distribution of industrial demand should be made in detail, because the study only use estimation based on the size of the industry estate., More demand and supply scenario should be made, because a project, for example the development of a field or the construction of a power plant can be delayed or finish before the due date., A technical, economical or HSE aspect of building a new natural gas infrastructure can be included in further study.

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