BACHELOR THESIS & COLLOQUIUM – ME 184841

A GAS INFRASTRUCTURE PATHWAY IN EAST JAVA USING SYSTEM DYNAMIC APPROACH

Muhammad Haekal
NRP 04211641000024

Supervisor I
Prof. Dr. Ketut Buda Artana, S.T., M.Sc.
NIP. 197109151995121001

Supervisor II
Dr. Eng. Dhimas Widhi Handani, S.T., M.Sc.
NIP. 198705272014041001

BACHELOR THESIS – ME184841

A GAS INFRASTRUCTURE PATHWAYS IN EAST JAVA USING SYSTEM DYNAMICS APPROACH

MUHAMMAD HAEKAL
04211641000024

SUPERVISOR
Prof. Dr. Ketut Buda Artana, S.T., M.Sc.
NIP. 197109151995121001
Dr. Eng. Dhimas Widhi Handani, S.T., M.Sc.
NIP. 198705272014041001

DEPARTMENT OF MARINE ENGINEERING

FACULTY OF MARINE TECHNOLOGY

SEPULUH NOPEMBER INSTITUTE OF TECHNOLOGY

SURABAYA

2020

“This page intentionally left blank”

APPROVAL SHEET

A GAS INFRASTRUCTRE PATHWAYS IN EAST JAVA USING SYSTEM DYNAMIC APPROACH

BACHELOR THESIS

Submitted to Fulfil One of the Requirements to Obtain an Engineering Degree
On
Reliability Availability Management and Safety Field of Study (RAMS)
Bachelor Program Department of Marine Engineering
Faculty of Marine Technology
Sepuluh Nopember Institute of Technology

By:
Muhammad Haekal
NRP. 04211641000024

Approved by
Supervisors,

Prof. Dr. Ketut Buda Artana, S.T., M.Sc. (   )
NIP. 197109151995121001

Dr. Eng. Dhimas Widhi Handani, S.T., M.Sc. (   )

“This page intentionally left blank”

APPROVAL SHEET

A GAS INFRASTRUCTURE PATHWAYS IN EAST JAVA USING SYSTEM DYNAMICS APPROACH

BACHELOR THESIS

Submitted to Fulfill One of the Requirements to Obtain an Engineering Degree

on

Reliability Availability Management and Safety Field of Study (RAMS)

Bachelor Program Department of Marine Engineering

Faculty of Marine Technology

Sepuluh Nopember Institute of Technology

by:

Muhammad Haekal

NRP. 04211641000024

Approved by,
Head of Marine Engineering Department

KEMENTERIAN PENDIDIKAN DAN KEBUDAYAAN INSTITUT TEKNOLOGI SEPULUH NOPEMBER FAKULTAS TEKNOLOGI KELAUTAN DEPARTEMEN TEKNIK SISTEM PERKAPALAN

Beny Cahyono, S.T., M.T., Ph. D
NIP. 197903192008011008

SURABAYA, JUNI 2020

“This page intentionally left blank”

A GAS INFRASTRUCTURE PATHWAYS IN EAST JAVA USING SYSTEM DYNAMICS APPROACH

Name	: Muhammad Haekal
Student Number	: 04211641000024
Department	: Marine Engineering
Supervisor I	: Prof. Dr. Ketut Buda Artana, S.T., M.Sc.
Supervisor II	: Dr. Eng. Dhimas Widhi Handani, S.T., M.Sc.
Field of Study	: Reliability, Availability, Management, and Safety (RAMS)

ABSTRACT

As a developing country, Indonesia has been consuming energy with 114 Million Ton Oil Equivalent (MTOE) and estimated that the demand for energy will increase up to 167,4 MTOE in 2050. It is also estimated that natural gas will play the role in fulfilling the energy demand in Indonesia. However, in utilizing the natural gas spread of the regions, Indonesia still lack of natural gas infrastructures. As natural gas infrastructures are playing a vital role on those problems, the condition of supply demand, capacity of infrastructure and the effectiveness of the route need to be adjusted and considered. In this study, system dynamics method is employed in order to forecast the supply and demand of natural gas in East Java Province. In addition, a simulation will be done to optimize and simulate the scenario model of the natural gas infrastructure at certain time-year period. With the constraint and condition given to the system dynamics, a supply-demand condition in East Java area that mainly comes from electrical power generation, industry and household is assessed. Based on developed scenarios, the model is expected to fulfil the needs of natural gas in East Java. The possibility of establishing new LNG terminal in certain location or expanding the capacity of existing facilities are also considered in this study.

Keyword: Supply Demand Analysis, Gas Infrastructure Pathways, System Dynamics.

“This page intentionally left blank”

PREFACE

First of all, a never-ending gratitude to Allah SWT for his blessing and grace, so the author can complete this thesis well and on time. Thesis under the title;

"A GAS INFRASTRUCTURE PATHWAYS IN EAST JAVA USING SYSTEM DYNAMICS APPROACH"

Submitted as one of the requirements for completing the study of engineering programs in the Department of Marine Engineering, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember Surabaya. On this occasion, the author would like to thank all those who have provided assistance and support so that this thesis can be resolved properly. In particular the author would like to thank to:

1. Parent, brother, sister, and other extended families who always provide motivation and moral support to the writer.
2. Prof. Dr. Ketut Buda Artana, ST., M.Sc. as the first supervisor who is willing to take the time to share knowledge and be available to guide the writer until this thesis is completed. Thank you also for the motivation that is always given to the writer all this time.
3. Dr. Eng. Dhimas Widhi Handani, S.T., M.Sc. as the second supervisor, thank you for the guidance and input that is always given to the author when the writer experiences obstacles in working on this thesis.
4. Ir. Dwi Priyanta, MSE. as academic advisor lecture who has helped and guided the writer while author was in the Department Marine Engineering, FTK-ITS.
5. RAMS NIGGAH 2016, Vira and Kemal who always fight and help each other during the process of this research.
6. The entire RAMS laboratory extended family, ranging from lecturers, staff, and students who always take the time to help the writer in completing this thesis.
7. All lecturers of Marine Engineering Department ITS who have provided knowledge to the author for four years of education in college.
8. All parties who have helped either directly or indirectly that the author cannot mention one by one.

The author is fully aware that the research undertaken is still far from perfect so it needs to get criticism, suggestions and corrections from readers. Finally, I hope this research can be useful for writers and readers for the advancement of Science.

Surabaya, June 2020

Author

“This page intentionally left blank”

LIST OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background

Energy has become the most crucial element for every sector in human life for the last decades. Industries (Power Plant, Construction, Other Industries), Transportation, and Household are several core sectors that consume big amount of energy. Based on International Energy Agency (IEA), up until 2030 energy demanded by the world increase to 45% or 1,6% per year. In Indonesia for instance, in 2018 the total consumption of energy (without traditional biomass) is about 114 Million Tonnes Oil Equivalent (MTOE) with 40% on transportation sector, 36% on industrial sector, 16% on household sector, 6% for commercial , and 2% for other sector according to Indonesia Outlook Energy 2019 (ESDM, 2019), while in 2030 Indonesia's Ministry of Energy forecasted that the total energy need will be around 200 MTOE. As we can conclude that the total need of world energy is increase significantly, the source of energy has been produced by many means of form. In Indonesia, the energy sources are form in oil, natural gas, coal and renewable energy sources. In 2050, Indonesia government has set a foresight that Natural Gas will be the biggest source energy (not including renewable energy) with 167,4 MTOE three times bigger than Indonesia can produce in 2018.

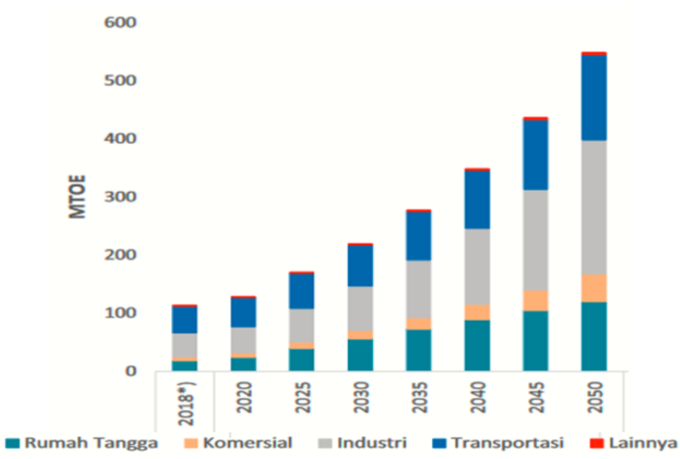


Figure 1.1 Energy demand form every sector (Source: Indonesia;s Energy Lookout 2019)

Natural Gas (NG) is a gas that came out from earth that contain methane as its main ingredient. This source of energy has been known as the cleanest, safest, and handiness. It has unique characteristics such as colorless, odorless and shapeless. The use of natural gas is quite advantageous because it has the lowest point in term of emission per released joule of energy comparing to other fossil fuel. About 20% of CO_2 dropped and 80% for NO_x. Other point that contributing NG popularity is the price of produced energy. The cost includes not the only cost of the main gas but also the cost of the technology needed as well as the cost for other things necessary such as subsequent minimization of environmental impact, ecological fees and carbon credits. Additional point that our country, Indonesia, has is the quite excessively amount of natural gas resource, 142.71 trillion standard cubic feet (TSCF) and stated as the largest reserves in Southeast Asia. As the world demand big amount of gas to fulfill the energy needed, transporting this form of energy become the world spotlight. Many form and way of transporting this energy has been developed in the last several decades, contributing the worldwide demand for NG. Directly transferred with fixed network pipeline, compressing, and liquifying are several methods in transporting this form of energy. In Indonesia, directly and liquify method is quite prevalent with this matter, with 1.2 TSCF of export from total of 2.9 TSCF of production in 2018, was transferred using t hose two methods.

LNG or Liquefied Natural Gas popularity has been increasing year by year, exclusively in terms of volume. Unlike other gaseous transferring method, LNG can give more flexibility for both exporters and importers. The facts, mixed with the relatively easy transferring and good shelf life of LNG over long distances, have leads to significant growth in the global trade of this form of energy. It has been predicted that between 2010 – 2030, the value of consumption growth will reach 39%. Now days, one-third of all trade process worldwide regarding NG is transported with LNG.

With the demand of NG in the form of LNG, the supply cannot always supply the amount needed. In Indonesia, even as government has stop the export of NG in any form gradually until 2035, it does not mean that the demand of domestic use in Indonesia will fulfilled completely. It sad to be said that despite the great amount of NG that Indonesia has, Indonesia has been forecasted that there will be no more new gas reservoir in 50 years. With 5.6% of economic growth as 2045 Indonesia's vision see and 0.7% as *Bappenas* foresight in 2045, hard-dense scenario and optimization must be well planned, especially in big with superfast growth region such as East Java.

Furthermore, the current natural gas infrastructures of East Java have been affects in the price of the gas itself. East Java has been become one of the lowest regions which successfully consume the gas consumption plan and gas price is one of the issues. The current high price in East Java cannot help this region to par up with what national government, despite in many possibilities of supply resources that East Java can have in upcoming day, thanks to the current infrastructures.

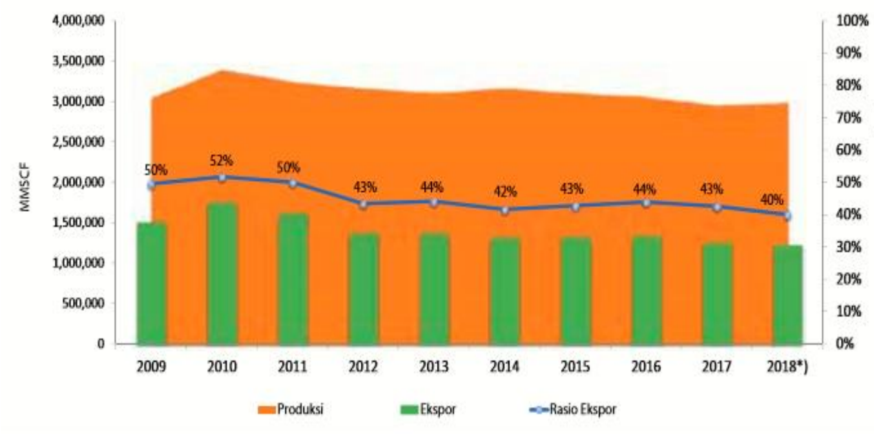


Figure 1.2 Production and Export Growth of Natural Gas (Source: HEESI, 2018)

Blessing with many good resources of gas, WMO, Saka, and many others, East Java has the absence of data and strategy in overcoming future problems regarding supply - demand unmatched, especially in infrastructure condition. To overcome the condition and meet the needs, it is necessary to have the optimum scheme on natural gas distribution. In order to have an accurate solution, any historical and forecast data will be obtained and analyzed, then the scenario will be simulated.

1.2 Problem Statement

From the description above, then we can determine the main issues that will be discussed more as mentioned below:

1. How is the performance of the upcoming gas distribution system in East Java region?
2. How to develop infrastrure scenario to serve a stable supply – demand condition?
3. How to simulate current and upcoming scheme based on supply – demand relation?

1.3 Research Objectives

Based on problems mentioned above, the goals of this research are:

1. Provide a supply and demand study of natural gas distribution and its infrastructure in Industrial sector, Household sector, and Electrical Generation in East Java.
2. Provide forecasted simulation model of supply and demand chain to minimize the risk of under-supply condition of natural gas.
3. Provide the infrastructure capacity and location.
4. Provide a gas supply and demand map for the forecasted condition in East Java.

1.4 Scope of Study/Research Limitation

This final project will be focused and organized with limitations on problem, which are:

1. Analysis will be done on gas supply in transportation sector, industrial sector, household sector, and electricity generation in about 12 years ahead.
2. Analysis of supply and demand in East Java region, including Madura Island.

1.5 Research Benefits

This final project is expected to give benefits for various parties. The benefits that can be obtained are:

1. Present a model plan regarding the supply and demand chain of energy (natural gas) in East Java, in order to avoid any unnecessary temporary solution.
2. Present suggestion for gas supply model chain along with the effort to overcome the unmatched condition by overlooking the infrastructure as the solution point of view.
3. Present a visualization of the forecasted national gas supply and demand in East Java.
4. Present a visualization of the future gas infrastructure condition in East Java.

CHAPTER 2

LITERATURE STUDY

2.1 Natural Gas

2.1.1. Natural Gas Contents

Natural Gas become the most mainstay resource of energy in the world as time flew by. Start with a mixture of gaseous hydrocarbons occurring in reservoirs of porous rock (commonly sand or sandstone) trapped downside by impervious level. Similar as petroleum, origin in the decomposition of organic matter such as animals, plants, and microorganism in sedimentary deposits. According to (N. *et al.*, 2001) As one of the cleanest, safest and most mainstay of all energy resources, Natural Gas consist of 70 – 90% methane (CH_4) and 0 – 20% ethane (C_2H_6), along with propane (C_3H_8) and butane (C_4H_{10}) with 0 – 20%, also other substance like nitrogen (N_2) with 0 – 5%, 0 – 0.2% of oxygen (O_2), 0 – 8% of carbon dioxide (CO_2), hydrogen sulfide (H_2S) with 0 – 5%, sometimes helium (He), and other higher alkanes (C_5H_{12} and above).

Based on (Pospíšil *et al.*, 2019), Indonesia, known as one of the biggest players of pure natural gas, does not grow bigger just because its quantities but also the qualities. With 2.9 Trillion Standard Cubic Feet of natural gas production in the last 2018 and expected to be more in the upcoming years, yet also serve a good quality of gas. With 90.6% of methane, 6% of ethane, 2.48% of propane and 0.82% of butane, it has been very handy in market quality matters exclusively in LNG, CNG or other energy transporting form.

As big industries, transportation, power generator, and household needed not small amount of energy, NG provide a clean solution. As (Pospíšil *et al.*, 2019) stated, CO_2 emissions from engine powered with NG dropped in around 20% and 80% for $NO_{x.}$ While the world scream on green fuel polemics, the future low-carbon power industry is supposed to renounce carbon and oil completely and move on to NG as the void replacement in the market.

Table 2.1 Chemical components of various LNGs in the world (Source: (Pospíšil *et al.*, 2019))

Terminal	Methane	Ethane	Propane	Butane	Nitrogen
Abu Dhabi	87,07	11,41	1,27	0,14	0,11
Alaska	99,8	0,1	N.A.	N.A.	N.A.
Algeria	91,4	7,87	0,44	N.A.	0,28
Australia	87,82	8,3	2,98	0,88	0,01
Brunei	89,4	6,3	2,8	1,3	N.A.
Indonesia	90,6	6	2,48	0,82	0,009
Malaysia	91,15	4,28	2,87	1,36	0,32
Oman	87,66	9,72	2,04	0,69	N.A.
Qatar	89,87	6,65	2,3	0,98	0,19
Trinidad	92,26	6,39	0,91	0,43	N.A.
Nigeria	91,6	4,6	2,4	1,3	0,1

2.1.2. Natural Gas Supply Chain

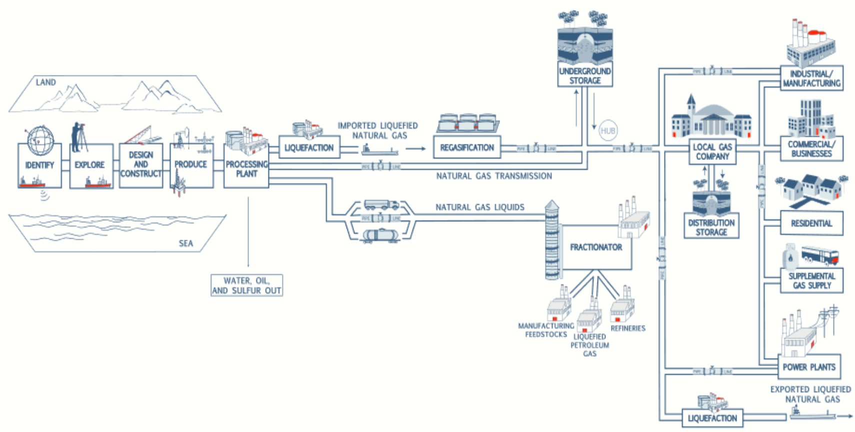


Figure 2.1 Natural Gas Supply Chain (Source: https://energyinfrastructure.org/)

Adapted from (Kusuma, 2019), the natural gas supply chain, as other fossil energy supply chain, consist of several steps of process. Exploration, exploitation, production, distribution – transportation, and consumption are the process that have to be passed before the energy can be used by any kind of user. In term of business, natural gas can be separate in 3 term that converted into 3 different type of industry sector: upstream, midstream, and downstream.

The upstream sector is the first step to be taken in the whole process of natural gas supply chain. It is referring to anything that have to do with exploration and production of natural gas. Onshore survey, offshore survey and any other geological information gathering are used to locate the exact area that contain of mineral with certain content desired is commonly called exploration. The other thing is the steps that involved in bringing natural gas/oil up to the surface, known as production. This production term technically consists of the actual drilling and pumping.

While midstream, as the second step, refers to anything that need to be done before the gas be refined and processed into usable elements needed in everyday life. It consists of answer on how the energy be transported and stored. The term of midstream includes all the infrastructure needed to store and move these resource, short and long distance, such as pipelines, pumping stations, LNG terminal, rail tank cars, transcontinental tankers and many others depend on what behavior that the gas has been treated, liquified or compressed.

The final sector which known as downstream is everything involved in turning those natural gas into finished product that we people needed and depend on every day. To turn those raw material into sell-able yet usable and consumable, many steps of process such as refining, distilling, and purifying must be done.

2.1.3. Natural Gas Reserves in Indonesia

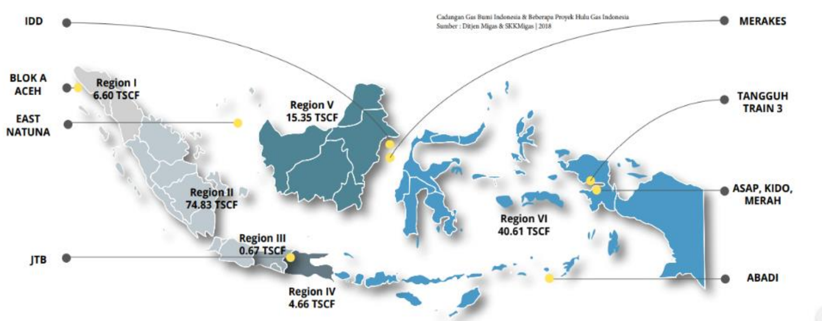


Figure 2.2 Indonesian Gas reserves region (Source: Ditjen Migas 2018)

Having a tremendous amount of gas reserves with 142.71 trillion standard cubic feet (TSCF), Indonesia still have many large gas resources that are still undeveloped such as offshore East Natuna Block which hold 49.6 TSCF. Indonesia gas resource area has been separates in several region.

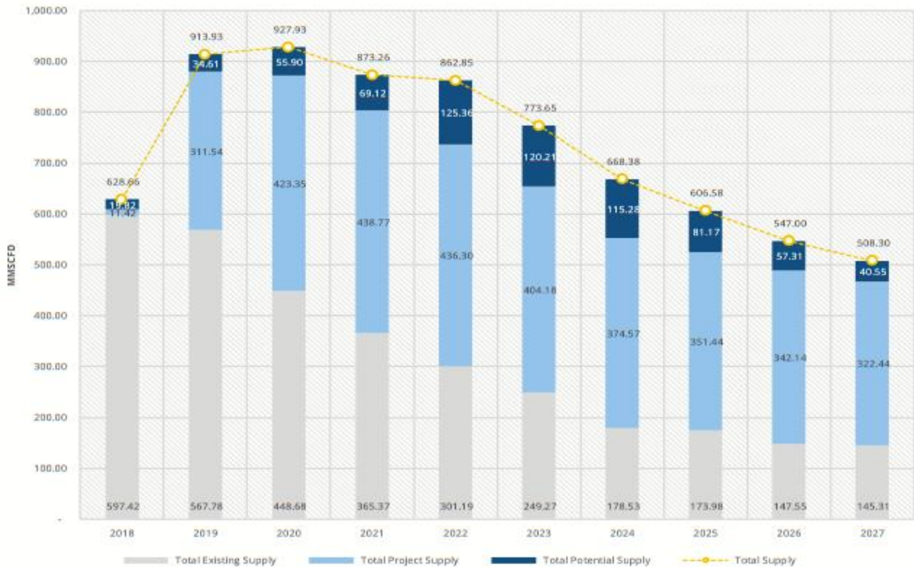


Figure 2.3 Indonesia region IV supply trend (Source: Neraca Gas Indonesia 2018)

Per January 2017, East java which known as the region iv has 4.66 TSCF of gas reserves. Both are proven reserves with 2.54 TSCF and 2.12 TSCF of possible reserves. The ownership of this region is dominated by Kangean Energy Indonesia with 1.48 TSCF followed by Husky with 0.9 TSCF and PHE WMO with 0.53 TSCF. The rest 1.75 TSCF is divided into many reserves and ownership such as Pertamina EP, Cepu, and many more

2.2 Gas Utilization

Based on (KESDM, 2018) from the total of Indonesian natural gas production in 2017, 58.59% were allocated to domestic use while 41.41% exported. The domestic use is covering the industrial sector which absorbs 23.18%, the Electricity Sector 14.09%, the Fertilizer Sector 10.64%, the Oil and Gas Lifting 2.73%, the Domestic LNG by 5.64%, the Domestic LPG by 2.17% and 0.15% for the Government Program in the form of Household pipelines and SPBG. For the export of pipeline gas by 12.04% and LNG for exports by 29.37%. Although natural gas production has decreased by 3% from 2017, the utilization of natural gas for the domestic year to year increase. An average increase of 7% from 2004 to 2017.

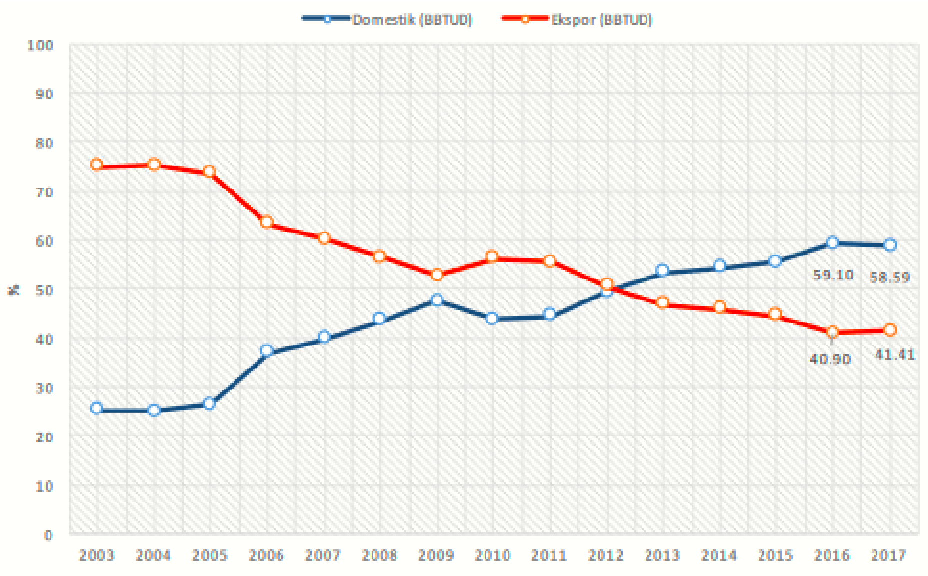


Figure 2.4 Indonesia Gas Utilization (Source: Neraca Gas Indonesia 2018)

Based on the contract and realization, region IV consume gas with 82.7% from the signed contract. It is the lowest comparing to others region. Region III by far is the one which having the biggest percentage of gas consumption with 93.2%. Region IV mostly use gas supply for industrial and electrical sector. Gas price become one of the reasons why Region IV is having a difficulty to utilize the gas consumption contract.

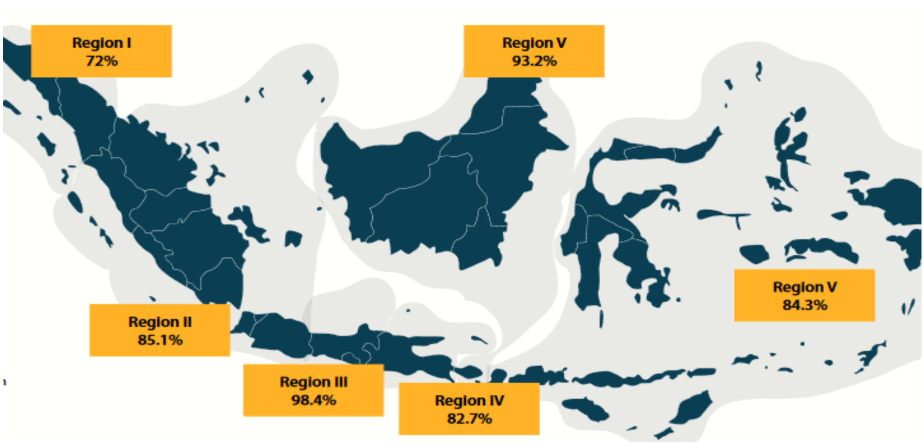


Figure 2.5 Gas consumption utilization per region (Source: Neraca Gas Indonesia 2018)

2.2.1. East Java Gas Consumption

The natural gas energy demand is mainly use for energy generator for national use and industrial use. It is also used for production in industry such as fertilizer, petrochemical, cement mill, steel mill, and other industry. It also prevails to each region. The sector of gas consumer is divided into industrial, electricity generation, and household use.

East Java or region IV has many cities that become their industrial center such as Surabaya, Sidoarjo, and Gresik. Big player such as Petrokimia Gresik become one of the biggest gas consumers in East Java Region.

1. Household

The need of the gas in term of the need of household sector in region IV is around 1.10 MMSCFD. Surabaya, Sidoarjo, and Mojokerto is the area of the gas household pipeline covered.

The household sector covered the daily needs of Region IV society. Activities that using gas in the household scope area will be supplied through the pipeline that come across the houses directly to their kitchen or other desired area.

2. Industrial Sector

From Neraca Gas Indonesia, Indonesia Region IV need 153.62 MMSCFD in 2018. That value of amount was affected by the condition of Industrial area in East Java that continuously growing. While petrokimia gresik, need 150 MMSCFD on 2018, that distributed into 2 big factories owned by petrokimia, Ammurea I and Ammurea II.

At the end of 2017 the Indonesian Government had issued 42 Wilayah Usaha, including the Wilayah Usaha of PLN, with a breakdown of 27 Wilayah Usaha already in operation and 15 Wilayah Usaha not yet operating.

3. Power Generation

At the end of 2017 the total installed capacity was 60.7 GW divided between: PLN and its subsidiaries which accounted for 41.7 GW (69%); IPPs accounting for 14.2 GW (23%); PPUs, accounting for 2.4 GW (4%), and the remaining 2.4 GW (4%) belonging to the holders of non-fossil fuel operating party (IO Non-BBM). As such the majority of power- generating assets in Indonesia are controlled by PLN including its subsidiaries such as *Indonesia Power, Pembangkit Jawa Bali ("PJB")* and *PLN Batam*.

Jawa Bali electrical line system that connected put many gas-based power generators in East Java as the base load. In 2018, the amount that Region IV need was 318.21 MMSCFD.

With the addition of power generator in PLTGU Jawa 3, PLTGU Grati Peaker, and PLTGU Madura, the capacity of gas supply to this sector might be reconsidered. In the near term, supply gas from nearest field still can be relied, but in the next few years region IV need much more from other region.

Table 2.2 East Java Gas Consumption (Source: Neraca Gas Indonesia 2018)

Information	**Consumption**	**Units**
Governtment Program		
Transportation	12,2	MMSCFD
House Hold	1,1	MMSCFD
Fertilizer and Petrochemical	150	MMSCFD
Electrical	318,21	MMSCFD
Industry		
Retail Industry	153,62	MMSCFD
Total Demand	635,14	MMSCFD

2.3 Gas Infrastructures

Infrastructure is one of the most important part on any distribution chain. In gas distribution chain for instance, every stream of this business type, upstream mid-stream, and down-stream, they all need infrastructure to run the flow. There are several types of infrastructures, relating to the function and condition. Pipeline, LNG terminal, LPG terminal, and other are one of the infrastructures types. Most of it is handled by state owned company or share with the production sharing contract (PSC) with private company.

Figure 2.6 East Java Oil and Gas Infrastructure (Source: Pwc Indonesia's Oil and Gas Map Analysis)

Table 2.3 Top 10 Indonesia Gas Producer 2018 (Source: Pwc Oil and Gas in Indonesia Investment and Taxation 10th edition 2018)

No	Company	Quantity	Unit
1	BP Berau	192000	BOEPD
2	Conoco Phillips	150000	BOEPD
3	Pertaminal Hulu Mahakam	149000	BOEPD
4	Pertamina EP	145000	BOEPD
5	Eni Muara Bakau	119000	BOEPD
6	JOB Pertamina-Medco Tomori Sulawesi	52000	BOEPD
7	Premier Oil Indonesia	40000	BOEPD
8	PetroChina International Jabung	32000	BOEPD
9	Kangean Energy Indonesia	30000	BOEPD
10	Medco E&P Natuna	29000	BOEPD

Indonesia as one of the pioneers of LNG exports, have 4 liquification units spread across Indonesia with the top 4 are Donggi Senoro (PT DSLNG), Tangguh (BP), Bontang (PT. Badak) and Arun (PT. Arun). At the same time, Indonesia still exporting their gas with pipeline, and the amount is still bigger than the LNG vessel transport type.

Furthermore, Indonesia has many gas fields that has been located and produced. The location is dispersed in many regions in Indonesia. The biggest one is located in Tangguh and operated by British Petroleum. Meanwhile, in East Java, despite of not having any liquification unit, they have several gas fields that so far handled the needs on East Java and Madura regions. The fields are located in Kangean, Sampang, West Madura offshore, Brantas and many others.

Table 2.4 East Java Gas Producer 2018 (Source: Neraca Gas Indonesia 2018)

No	Company	Field	Capacity	Units
1	Kangean Energy Indonesia	Kangean	201,77	MMSCFD
2	PHE WMO	West Madura Offshore	140	MMSCFD
3	Husky CNOOC Madura Ltd	Madura Strait	100	MMSCFD
4	Petronas (Bukit Tua)	Ketapang	35,43	MMSCFD
5	SANTOS	Sampang Offshore	66,04	MMSCFD
		Madura Offshore		
6	SAKA Pangkah	Pangkah	23,96	MMSCFD
7	Pertamina EP - Poleng	Poleng	14,44	MMSCFD
8	LAPINDO	Brantas	13,81	MMSCFD
9	JOB Pertamina-PetroChina East Java (Sukowati)	Tuban	1,97	MMSCFD

2.4 System

System is a collection of elements or components that are organized for a common purpose. A system contains of elements that used to observe what the system wanted to. The term can be very useful because so many things can be described as systems but further specific term is needed when it narrowing to certain specific objective

2.5 Systen Dynamics Method

System Dynamic is method that fits to determine a feedback behavior of complex model that represent a real-world system which in each element is affected to the other. This system characteristic can cover the gap from previous method such linear model like regression with its circular structure.

(Jingchun, Ding and Fan, 2010) did a research about natural gas supply and demand in china and the result is china have a gradually enlargement of demand condition which lead to a recommendation to increase the gas supply.

In other study, a policy analysis and fulfilment scenarios can be obtained by modeling the desired system using system dynamics. (Daneshzand *et al.*, 2018) analyzed the future natural gas supply demand condition in Iran, resulting new proposed policy regarding the export of natural gas and three scenarios to increase their effectiveness in fulfilling the gap between supply and demand.

In more recent study, system dynamic has been applied in East Java condition. (Kusuma, 2019) forecasted the natural gas balance in East Java, finding that East Java will face a deficit in the upcoming year despite of the new Teluk Lamong LNG Terminal. In (Kusuma, 2019) study, the proposed infrastructure is not simulated yet.

In this study, based on the previous research, a system dynamic is use not only for forecasting the supply and demand condition but also simulating the infrastructure fulfilment scenario.

2.6 System Dynamics Modelling

Adapted from (Alif, 2019) in order to generate a model that represent the real condition and having a structure that give a pictured on variable behavior inside the system, there are 4 major components:

2.6.1. Closed System (Endogeneity)

A dynamic model will work if there were at least an interaction within the components inside the system (intervariable). Assuredly the variable need to be the significant one. The characteristic of the closed system model brings through interactions only occur in the inside of the system only without considering other outside variable that has been stated that it’s not takes any effect to the system.

2.6.2. Feedback Effect

The second component is the unique characteristic of system dynamic which is a model that give a feedback that show an affect to other variable when another variable that connected is change. In this case it can be tested with extreme points to know the extent to which changes in a variable affect other variables.

2.6.3. Level and Rate Variable

Level variable is the result of accumulation from entire rate variable inside the model. From that accumulation an information obtained that show a value change from time to time. For example, the number of a population is a level variable while the reduction number of a population in year is a rate variable.

2.6.4. Parameter of Model

Parameter of model is used to measure how far that the model has represented the real condition so that the research can be explored more and more by adding or reducing variables.

2.7 Causal Loop Diagram

According to (Sterman, 2000) the causal loop diagram is a representation of a conceptualization of the system dynamics model that will be built. Through causal loop diagram, system dynamics model that will be developed, is explained by showing the causal relationship between variables entered in the model before entering the stage of model development. By showing the big picture of each relationship between variables inside the system, a causal loop diagram might show us the hypothetical result of a system that modeled with system dynamic.

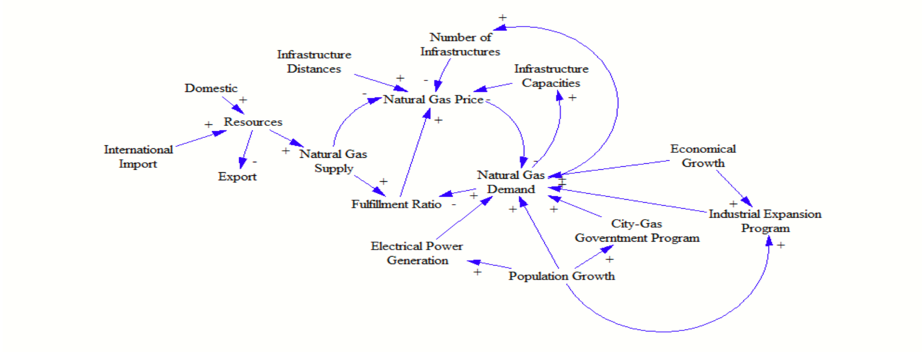


Figure 2.7 Example of Causal Loop Diagram

Inside a causal loop diagram, the connection between two variables is represented by an arrow that mark the relation between those two variables. Moreover, there are also the positive mark (+) and negative mark (-) which show how the relation is going on between the two variables. The positive mark showed us the positive effect, meaning that if there are any changes in certain variables will affect other variable that connected with a positive arrow and it will change in to same direction. On the other hand, the negative mark showed us the negative effect where if there are any changes in certain variables will affect other variables but in different directions of change (Yücel and Barlas, 2011).

Table 2.5 Explanation on causal loop diagram polarity

Symbol	Explanation	Example
A-->+B	If B is increasing (decreasing), so B will increase (decrease). And if its an accumulative than A adding B	Demand -->+ Product Price
A-->-B	If B is increasing (decreasing), so B will increase (decrease). And if its an accumulative than A adding B	Product Price -->- Selling

On the diagram above, there are several examples to understand the connection between two variables. For the positive relationship or positive effect, as the demand of certain product keep increasing than the price can keep increasing too, because the more the product needed than the more benefits that the seller can obtain. While for the negative relationship or negative effect, the higher the price has been set than the lower selling frequency will be.

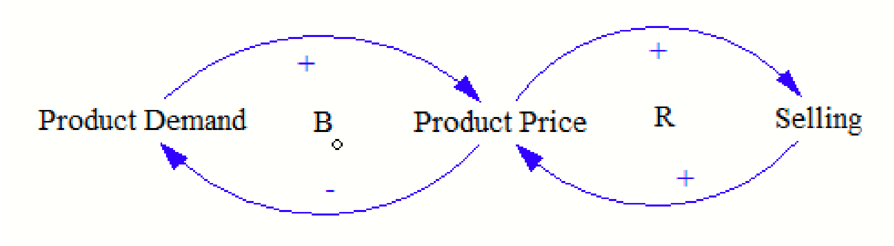


Figure 2.8 Loop Diagram

Besides having polarity, a causal loop diagram also forms a closed loop which mean that the connection in certain variables can form a feedback connection to the origin variables after going through several variable and creating a reinforcing loop or balancing loop depend on the polarity. In picture below, it showed us the example of a causal loop diagram that has closed loop and having both reinforcing loop and balancing loop. The reinforcing loop is represented with symbol of ‘R’ and the balancing loop with symbol of ‘B’. Reinforcing loop is a loop that explained a strengthen connection between each variable while balancing loop explained a balance connection between connected variables.

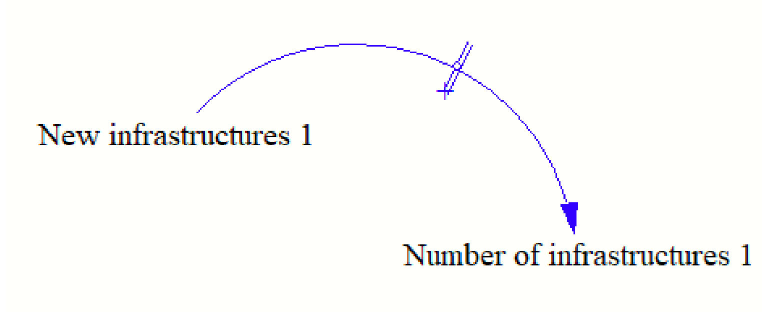


Figure 2.9 The Delay Factor

Other main concept of system dynamics is the delay factor within variables. The presence of delay factor in the connection between two variables represented with two short straight line which located in the arrow that connected those two variables. This factor explained that the effect of certain variable will be affected to other variables in certain delay of time because of the delay factor presence.

2.8 Stock and Flow Diagram

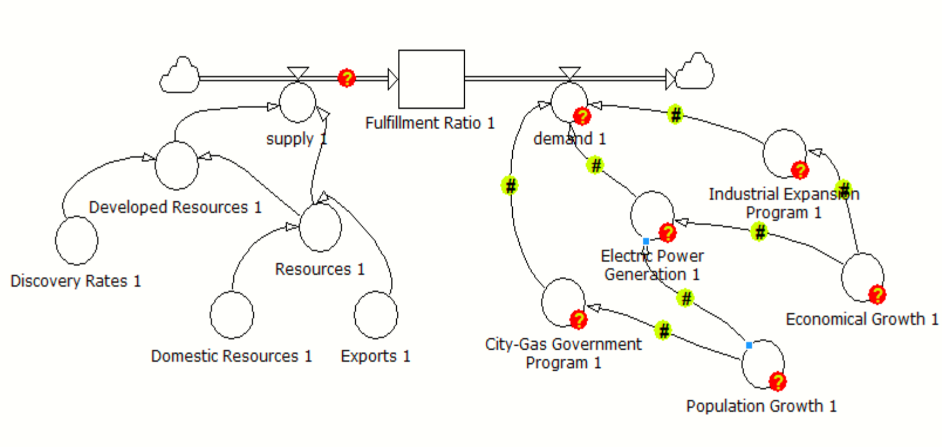


Figure 2.10 Example of System Dynamics Modul

According to (Sterman, 2000), Stock flow diagram is a concept from system dynamics model that functioned to represent the stock and flow of certain system. Stock and flow diagram can be described as a tub that accumulated the flow of water that come inside through a valve and the volume of the water can be decrease by opening the valve below the tub. The bathtub represents as a ‘stock’ in the stock flow diagram while the flow of water that flows either in or out of the tube distorted by the valve is a ‘flow’ in the stock flow diagram.

The structure of stock flow diagram has four main structure components, which are stock, inflow/outflow, valve, and clouds with the explanation below:

2.8.1. Stock

Formed in a rectangular shape inside the stock flow diagram that has a function to accumulated the inflow and outflow.

2.8.2. Inflow and Outflow

Represented as pipe or arrow shape that pointing either in or out of the stock. This flow showed us a flow that enters the stocks for arrows or pipes entering the stock box or going out for pipes coming out of a stock. This flow will change the level of stock every time.

2.8.3. Valve

This valve representing the flow both in and out of the stock box.

2.8.4. Clouds

The clouds on the stock flow represent the source and objective of a flow that affect stock. The source and objective from this flow are outside observe system that the source and destination of the flow are cut off by the observed system boundary and represented by a cloud.

Another important structure in a stock flow diagram is an auxiliary and constant. Constant is a variable which is usually an exogeneous variable because the numbers used in constant as parameters are usually obtained from outside the model and the numbers will usually not change in the simulation. Whereas auxiliary can be an endogenous variable when its value will be influenced by other variables in the model and will be an exogeneous variable if the value comes from outside the model and is not influenced by other variables in the model. This auxiliary value can change at any time different from the constant whose value will remain during the simulation process.

2.9 System Dynamics Model Behavior

A dynamic system model has a different behavior depending on the structure of the model it makes. Normally there are six types of behavior in dynamic system model. The first is a constant behavior where the elements observed in the system dynamic model are moving constantly each time. The next is a growth behavior, this type has several types of growth categories, namely linear exponential, logarithmic, and form the curve ‘s’. Additionally, there are some properties that are mostly found include the grow and decrease or decrease and grow to the properties that represent as a wave (oscillatory).

"This page intentionally left blank"

CHAPTER 3
METHODOLOGY

3.1 Research Scheme

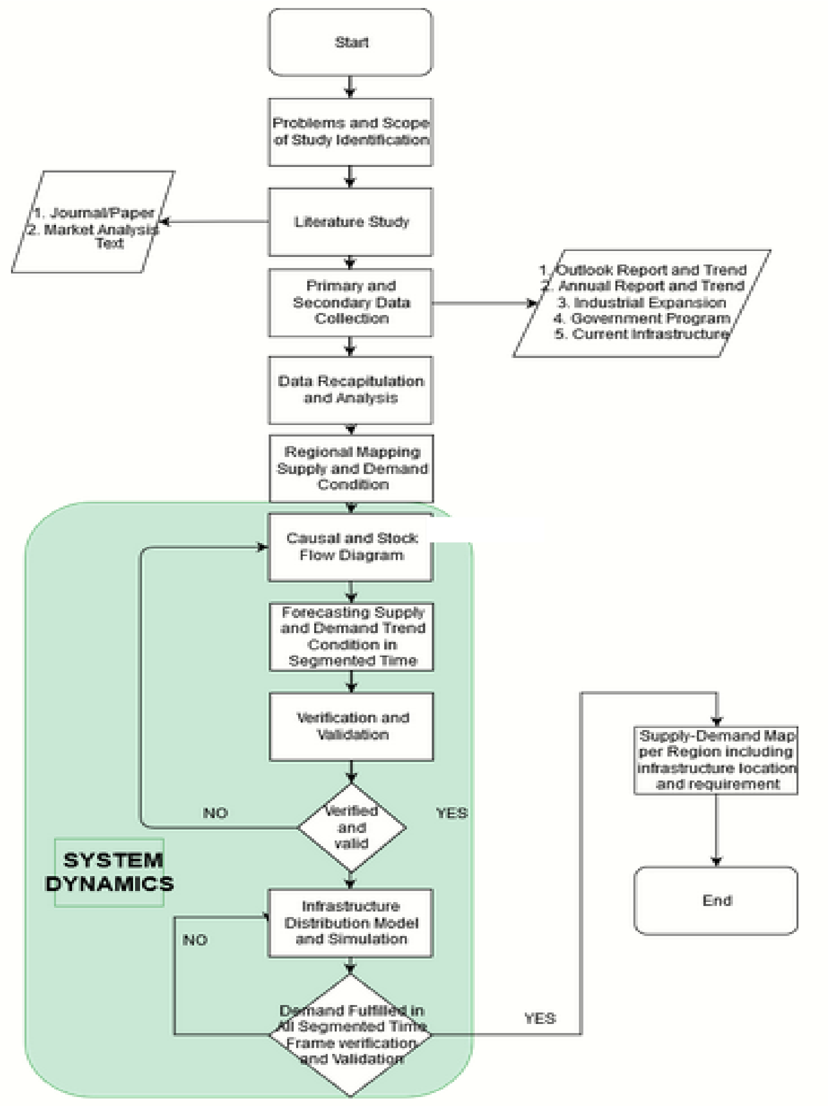


Figure 3.1 Methodology Flow Chart

3.2 Problems and Scope of Study Identification

In the first step of this research, the author will hold an observation regarding the current natural gas distribution in East Java. The research process will be derived on observation, literature and discussion with lecturers. From this step of process, the parameter, data analysis, method, and limitation of this research will be resolved.

3.3 Literature Study

The next action of this research step is studying literatures. The study needs to be related to the problem focus and in line with the aim of the study. The purpose of this step is to have a better understanding by obtaining any knowledge and information that related to the problem of this research and to support the fruitfulness of the research aim. This data can be obtained from journals, papers, and market analysis documents

3.4 Data Collection Method

In this step, the author will search and obtain for any data that concerned with the problem stated. The data will be used as the baseline of the supply – demand, infrastructures, and distribution chain condition. The data shall be consisting of trends in past few years, industrial expansion programs, and other government programs (city gas) that still appurtenant to the problems. The source of data in this research are divided into two, which are primary data and secondary data.

The primary data is data that been received from the original or first-hand source. The data will be obtained by doing research through any resource or expert that are competent and experienced in their field. The information will be sent towards main stakeholders within the chain, in this case the most dependable source will be coming not only from the background of government authority such as Ministry of Energy and Mineral Resource or Directorate of Oil and Gas, but also verified organization such as National Energy Council. Other information sector can also be obtained from Ministry of Industry and East Java Development Plan. Through many documents stated by those stakeholders and interview the author will receive the information that will be used to process this research.

The secondary data is acquired from indirect source meaning it can be obtained from the second or third hand source. This type of data usually used as references. Documentation, journals and books can act as a supplementary for the primary data.

3.5 Data Recapitulation and Analyzing

At this step, all the data that has been occurred will be compiled. Those trend data will be regressed into mathematical formula before it can be simulated using the System Dynamics. The simulation aim is to know the condition of supply – demand in 12 years ahead.

3.6 Regional Mapping of Supply and Demand Condition

At this step, an additional analysis of natural gas distribution in East Java will carried out by mapping the supply and demand. The region will be diverted into several regions with the largest demand condition.

The function of mapping is to help visualize and understand the form of natural gas flow in East Java. From the data obtained, the most area that must be considered is clearly visualized. The author can also determine a recommendation on potential market modification, including an establishment of new natural gas facilities

3.7 Causal Loop and Stock Flow Diagram

At this step, a causal loop diagram will be modeled, and must be referred to real situation and previous study. The connection between variables must be correct. The loop and delay factor must be placed according to the problems and goal.

Stock flow diagram will be modeled after the causal loop is finished. The stock flow diagram must be match with the causal loop diagram so the goal will be obtained. The variables and the connection have to be connected correctly and consistently so the simulation can run smoothly

3.8 Forecasting Supply and Demand Trend Condition

At this step, by using the system dynamics, an analysis of supply – demand condition in East Java will carried out in form of trend. The 12 years of supply – demand condition will be segmented into 3 phases by dividing it per 4 years.

In each phase, the data obtained will be simulated, along with the condition that might happen in those phases. The outcome of this simulation is a picture of East Java natural gas condition in each phase, either deficit or surplus. The depiction will be form as a trend graph.

3.9 Verification and Validation

In this step we also verified and validate both conceptual scenario and forecasted value result. The verification is done to verified whether the model is suitable with the conceptual model (Sterman, 2000). The validation is a step to determine either our model is successfully representing the real condition or not (Sterman, 2000). In this research we will use three methods to validate the simulation.

3.9.1. Structural Scoring Test

This test aim is to determine whether the structural model is already representing the conceptual model, causal loop diagram. The model that will be built must look to the previous structural model as references and when it traced, we will find a loop there.

3.9.2. Test of Dimensional Consistency

This test has the objective to determine whether the units used in the equation are consistent. The software used to simulate can detect the problematic units.

3.9.3. Extreme Condition Test

Extreme condition test is carried out in order to test the model with predetermined boundaries in the causal loop diagram. When the test run, a variable will be entered in extreme values to see how the variable that have relationships. Seen after extreme testing, the ratio between the two levels of production is similar where it means the model can be considered valid.

3.10 Infrastructure Simulation

In this step, several scenarios for natural gas infrastructures and distribution chain optimization will be made and tested using System Dynamic. The model verification is performed is performed simultaneously with the model simulation process. The simulation is done to resolved the best condition that meet up the needs in each time period and location with suitable price

3.11 Demand Fulfilled in All Segmented Time Frame and Validation

At this step, this research needs the best-suited result from the simulation before. If the scenario is not meet the deed, then the simulation must be re-run with other possible scenario and it will be repeated until the condition needed is fulfill. If the scenario that have been simulated already give the problems a solution than the research goes to the next stage.

In this step we also verified and validate both conceptual scenario and forecasted value result. The verification is done to verified whether the model is suitable with the conceptual model. The validation also done with the same steps as the previous verification and validation. The result from the simulation needs to meet the goal, verified, and valid.

3.12 Supply-Demand Map per Region Including Infrastructure Requirement (location and capacity) and Conclusion

The final step is to conduct a conclusion from whole process that had been done. Not only conclusion and recommendations will be appraised the final result from the simulation but the maps also will be shown as the result product. This step consists of a short resolve of the problems stated in this research and the product from the simulation. After conclusion, a recommendation can be given according to the result so that the next project may have a better result.

3.13 Schedule

NO	Activity	Week No-															
		First Month				Second Month				Third Month				Fourth Month			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	Problems Identification	■	■														
2	Literature Study		■	■	■	■	■										
3	Data Collection			■	■	■	■	■	■	■							
4	Supply and Demand Forecasting				■	■	■	■	■	■							
5	S & P Trend Analysis					■	■	■	■	■	■						
6	S & P Map Visualizing					■	■	■	■	■	■						
7	Distribution Scenario Developing							■	■	■	■						
8	Simulation Running											■	■	■	■		
9	Conclusion and Recommendations												■	■	■		
10	Report Drafting		■	■	■	■	■	■	■	■	■	■	■	■	■		
11	Final Report														■	■	■

"This page intentionally left blank"

CHAPTER 4
CALCULATION AND ANALYSIS

4.1. Demand Data Collection and Processing

East Java is one of Indonesia province that consume gas which stand above other provinces in term of the amount of gas consumed. As a gate for eastern Indonesia side, there is no surprise that East Java region hold up many sectors of economical matter to its optimal form. This matter not only stand for domestic need but others related island too. With more than 30 million of life living in East Java region, people life become the government concern in term of energy consumed, not included the other island that sustained by East Java energy supply. From what this research can gather, the needs of gas energy consumption can be diverse into household, electrical generation, and industrial consumption.

For household, PT Perusahaan Gas Negara has established the gas distribution pipeline across some of East Java region, and East Java has been consumed the gas as their daily basis ever since. Now days, only several cities in East Java that facilitated with direct gas housing pipeline while the other still consuming gas in LPG form. Those cities are Surabaya, Sidoarjo, and Mojokerto. Even though at this very moment not all cities are provided with the pipeline facilities, there is no doubt that other cities will be facilitated soon. As the need keep increase then there is no stop on developing to fulfill the supply gap.

As East Java has that many people live in across the area, then the electricity generation must be in an excellent form, even more so for other island that still depended on East Java electricity like Bali for instance. At this moment, most East Java electricity generation units still managed by coal energy followed by gas energy. From the government vision, gas energy will soon be the main source of electricity generation, and because of that the demand of the gas will soon increase year by year.

In city gas program, transportation become one of the biggest points concerned. In Surabaya, one of the biggest cities in the province, is already establishing several infrastructures for gas transportation. We can see several gas stations across the city to provide the city needs. For now, the gas station that owned by PT Perusahaan Gas Negara is used for public transportation such as the city bus, but in the future, it might use for public use.

In industrial matter, there is no doubt that gas come out as the major material needed for several industry. Normally the gas will be used as the source of boiler or heater, but that not rule out other possibilities. In East Java, the industry that consumed gas is categorized in to two type of industry, there are manufactural and non-manufactural industry. Across East Java, PT Petrokimia Gresik is the biggest consumer of all other industries and still that is not stopping other industries to increase the gas consumed in the upcoming future exceedingly the government vision on the industrial expansion.

4.1.1. Household Demand

In this research, the household consumption is defined as number of gas consumed by people live in East Java that diverse in every district. The number people live in every district will converted with the gas consumption of each person can consumed. The flow of population grow will also be forecasted using certain formula to obtain the closest prediction so the consumption of each year can be correctly obtained. And the 2016 – 2020 data of East Java population is used as the basis as we can see at the table.

The household consumption forecasted result will positively affect the fulfillment ratio with negative relation. As the demand increase, the fulfillment ratio will decrease if the supply value is not adjusted.

From Table 4.1, we have our raw data material, but further adjustment is needed to make this raw data applicable. We will use regression analysis to predict the consumption of all city and district in East Java. We use excel feature to instantly find the right prediction formula for all area.

As regression is the analysis of dependent and independent variable, then we choose the years and the population number as our variable. We choose linear regression as our analytical regression method because of the condition we have which is we only have two variables connected. Each area has their own formula as we can see in the example at Table 4.2.

After the prediction formula is obtained than we can input the x variable in the formula with the n-year to get the number of populations in 15 years ahead. We will do the same step to other area as well. Then the number of populations in all area within 15 years is obtained as stated in the attachment

Table 4.1 Population Number Base Data

District/City	Population Number				
	2016	2017	2018	2019	2020
District					
Pacitan	552 307	553 388	554 394	555 304	555 984
Ponorogo	868 814	869 894	870 705	871 370	871 825
Trenggalek	691 295	693 104	694 902	696 295	697 600
Tulungagung	1 026 101	1 030 790	1 035 290	1 039 284	1 043 182
Blitar	1 149 710	1 153 803	1 157 500	1 160 677	1 163 789
Kediri	1 554 385	1 561 392	1 568 113	1 574 272	1 580 092
Malang	2 560 675	2 576 596	2 591 795	2 606 204	2 619 975
Lumajang	1 033 698	1 036 823	1 039 794	1 042 395	1 044 718
Jember	2 419 000	2 430 185	2 440 714	2 450 668	2 459 890
Banyuwangi	1 599 811	1 604 897	1 609 677	1 613 991	1 617 814
Bondowoso	765 094	768 912	772 297	775 715	778 789
Situbondo	673 282	676 703	679 993	682 978	685 776
Probolinggo	1 148 012	1 155 214	1 162 092	1 168 503	1 174 890
Pasuruan	1 593 683	1 605 307	1 616 578	1 627 396	1 637 682
Sidoarjo	2 150 482	2 183 682	2 216 804	2 249 476	2 282 215
Mojokerto	1 090 075	1 099 504	1 108 718	1 117 688	1 126 392
Jombang	1 247 303	1 253 078	1 258 618	1 263 814	1 268 504
Nganjuk	1 045 375	1 048 799	1 051 900	1 054 611	1 057 011
Madiun	677 993	679 888	681 394	682 684	683 784
Magetan	627 984	628 609	628 924	628 977	629 020
Ngawi	829 480	829 899	830 090	830 108	830 134
Bojonegoro	1 240 383	1 243 906	1 246 927	1 249 692	1 252 020
Tuban	1 158 374	1 163 614	1 168 277	1 172 790	1 177 016
Lamongan	1 188 193	1 188 478	1 188 913	1 189 106	1 189 380
Gresik	1 270 702	1 285 018	1 299 024	1 312 881	1 326 420
Bangkalan	962 773	970 894	978 892	986 672	994 212
Sampang	947 614	958 082	968 520	978 875	989 001
Pamekasan	854 194	863 004	871 497	879 992	888 214
Sumenep	1 076 805	1 081 204	1 085 227	1 088 910	1 092 387

District/City	Population Number				
	2016	2017	2018	2019	2020
City					
Kediri	281 978	284 003	285 582	287 409	289 109
Blitar	139 117	139 995	140 971	141 876	142 798
Malang	856 410	861 414	866 118	870 682	874 890
Probolinggo	231 112	233 123	235 211	237 208	239 024
Pasuruan	196 202	197 696	199 078	200 422	201 585
Mojokerto	126 404	127 279	128 282	129 014	129 891
Madiun	175 607	176 099	176 697	177 007	177 399
Surabaya	2 862 406	2 874 699	2 885 555	2 896 195	2 904 751
Batu	202 319	203 997	205 788	207 490	209 125

Table 4.2 Regression Formula of Population Number

District/City	Population Number					Regression Formula (Linear)
	2016	2017	2018	2019	2020	
District						
Pacitan	552 307	553 388	554 394	555 304	555 984	1079,9x + 548802
Ponorogo	868 814	869 894	870 705	871 370	871 825	996,18x + 865417
Trenggalek	691 295	693 104	694 902	696 295	697 600	1794,8x + 685560
Tulungagung	1 026 101	1 030 790	1 035 290	1 039 284	1 043 182	4535,75x + 1012115,7143

Table 4.3 PGN unit conversion

Component	Unit	MMSCFD
Industry	1	0,01818
Commercial	1	0,001818
Household	250	0,01066

The next thing to do is to change our population data into consumption data. A certain conversion formula is needed. In the previous study between ITS and PGN, we obtained the conversion table for household consumption as we see in Table 4.3. We will need to convert population into household since the conversion is in per household unit. The author assume that each household consist of four persons, then we just simply divide the population number by 4. Now the household consumption is in the right form to continue the simulation.

Table 4.4 Household consumption from several area

District/City	Household Gas Consumption (MMSCFD)				
	2020	2021	2022	2023	2024
District					
Pacitan	16,49	16,57	16,64	16,72	16,78
Ponorogo	27,12	27,30	27,47	27,63	27,78
Trenggalek	10,98	11,02	11,05	11,08	11,11
Tulungagung	25,66	25,79	25,91	26,02	26,12

4.1.2. Electrical Generation Demand

As for Electrical Generation stated in this research defined as the value of gas consumption that been consumed per Gas Based Electrical Generation units. The data will be provided form RUPTL 2017 – 2028 by PT Perusahaan Listrik Negara. The research only focused on the Electrical Generation Units that located in East Java. The data is already in gas consumption unit so there is no need to convert it.

The electrical generation consumption value result will positively affect the fulfillment ratio with negative relation. As the demand increase, the fulfillment ratio will decrease if the supply value is not adjusted.

Table 4.5 Electrical Generation Demand

No	Power Generation Unit	Gas Consumption (MMSCFD)											
		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
1	PLTGU Grati 1, PLTGU Grati 2 ,PLTGU Grati Add on Blok 2	89,744	89,744	74,252	77,991	77,991	77,991	77,991	77,991	137,073	177,457	177,457	225
	PLTGU/PLTU Gresik, PLTGU Jawa 3	261,75	261,75	241,88	183,76	137,61	175,75	213,89	213,89	282,692	282,692	282,692	282,69
3	PLTGU Madura	0	0	0	0	0	0	0	16,453	16,453	16,453	315,171	33,654

4.1.3. Transportation Demand

As for transportation demand, the definition for this research regarding the transportation consumption is the value of gas consumed by every district in East Java. The number of vehicles will convert with the equivalent number of gas needed per vehicles. In this research, the vehicles are divided into car and motorcycle that existed across all districts in East Java. The flow of vehicles grow will also be forecasted using certain formula to obtain the closest prediction so the consumption of each year can be correctly obtained. For base analysis, the 2015 – 2017 data of vehicles grow from DISHUB of East Java is used as we can see at the table below.

The transportation consumption value result will positively affect the fulfillment ratio with negative relation. As the demand increase, the fulfillment ratio will decrease if the supply value is not adjusted.

From Table 4.7, we have our raw data material, but further adjustment is needed to make this raw data applicable. We will use regression analysis to predict the consumption of all city and district in East Java. We use excel feature to instantly find the right prediction formula for all area.

As regression is the analysis of dependent and independent variable, then we choose the years and the vehicle number as our variable. We choose linear regression as our analytical regression method because of the condition we have which is we only have two variables connected. Each area has their own formula as we can see in the example at Table 4.6.

Table 4.6 Vehicle regression formula

No	Districts	No of 4 wheels vehicle			Regression (Linear)
		2015	2016	2017	
1	Sumenep	10216	11722	12602	1193x + 9127,33
2	Bangkalan	16178	18231	19460	1641x + 14674,33
3	Sampang	9998	77466	12189	1095x + 9026,667
4	Pamekasan	20161	22691	23898	1868,5x + 18513

Table 4.7 Transportation Base demand value

No	Districts	No of 4 wheels vehicle		
		2015	2016	2017
1	Sumenep	10216	11722	12602
2	Bangkalan	16178	18231	19460
3	Sampang	9998	11466	12189
4	Pamekasan	20161	22691	23898
5	Banyuwangi	48974	55166	59182
6	Situbondo	14790	16340	17416
7	Bondowoso	16975	18794	20024
8	Jember	59832	65807	69457
9	Lumajang	29199	32527	34409
10	Probolinggo	39640	43847	46603
11	Pasuruan	52198	58473	62369
12	Batu	21254	23840	25249
13	Malang	86091	90058	95320
14	Nganjuk	18276	20738	37820
15	Trenggalek	19332	21891	23276
16	Tulungagung	53040	58904	62414
17	Blitar	54913	62266	66655
18	Kediri	84794	93049	98178
19	Pacitan	4865	5537	5730
20	Ponorogo	35089	39740	42355
21	Magetan	29138	32669	34554
22	Widodaren	4622	5242	5647
23	Ngawi	16493	18433	19531
24	Madiun	43312	47748	50547
25	Tuban	30208	33829	36084
26	Lamongan	27151	30990	33498
27	Bojonegoro	28828	32410	34424
28	Jombang	41435	46141	48805
29	Mojokerto	58133	65635	70190
30	Sidoarjo	169977	187013	198214
31	Gresik	61624	68687	73204
32	Surabaya	348115	546911	570571

After the prediction formula is obtained than we can input the x variable in the formula with the n-year to get the number of vehicles in 12 years ahead. We will do the same step to other area as well. Then the number of vehicles in all area within 12 years is obtained

The next thing to do is to change our population data into consumption data. A certain conversion formula is needed. Based on previous study by Barry Nur Setyanto, author assuming that all vehicles are using diesel and having the same type of car. Each vehicle travel about 40 km a day and spending 7,3 km per liters.

Table 4.8 Gas conversion for vehicle

No	Base Data	Convert into
1	1 liters of diesel	1,008 m3 of gas
2	1 m3 of gas	0,04333 MMBTU
3	1 MMBTU	TPDLNG x 52
4	1 TPDLNG	MMSCFD x 18

Then another conversion is needed to find the equivalent between diesel oil liters to MMSCFD of Gas. From PGN we will have the conversion from liters of oil into MMBTU of gas. Then we will quote Mr. Ketut Buda Artana classes in *Teknologi LNG* about the conversion of natural gas unit so that the final product will be in MMSCFD unit as we can see in Table 4.8. Now the vehicle consumption is in the right form to continue the simulation.

4.1.4. Industrial Demand

As for industrial demand, the definition for this research regarding the industrial gas consumption is the value of gas consumed by industries. The data has been obtained in MMSCFD unit per industry. The flow of industrial consumption growth will also be forecasted using certain formula based on government program to obtain the closest prediction so the consumption of each year can be correctly obtained. For base analysis, the 2018 data of industrial gas consumption from BPH Migas is used as we can see at the Table 4.9.

The industrial gas consumption value result will positively affect the fulfillment ratio with negative relation. As the demand increase, the fulfillment ratio will decrease if the supply value is not adjusted.

For industrial demand data we have two sources which are from *BPH Migas* in Table 4.9 and *Rencana Pembangunan Industri Jawa Timur* which will be stated in the attachment. For the data that obtained from Ministry of Industry we need a conversion to obtained the same consumption unit. We use PGN conversion as stated in Table 4.3.

After that, we can combine both industrial demands to get the complete demand value in the same manner of unit. Then continuing the simulation will be possible.

Table 4.9 Industrial baseline demand

No	Company Name	Source	Area	Consumer	Capacity (MMSCFD)
1	PT Bayu Buana Gemilang	Lapangan Gas Terang Sirasun dan Batur (KEIL)	Surabaya, Sidoarjo, Gresik	PT Asahimas Flat Glass (sdrj) PT Platinum Ceramics Industry (gresik) PT Citra Nusantara Energi (sdrj) PT Keramik Diamond Industries (gresik)	80
2	PT INDOGAS KRIYA DWIGUNA	Lapangan Gas Tanggulangin, Blok Brantas, Lapindo Brantas Inc.	Sidoarjo	PT BaskaraAsri Ghas	6
3	PT SADIKUN NIAGAMAS RAYA	Lapangan Gas Terang Sirasun dan Batur (KEIL)	Gresik	PT Java Energi Semesta	50
				PT Gresik Power Indonesia (LINDE GROUP)	4,6
				PT MASTER STEEL	1,3
4	PT GRESIK MIGAS	Lapangan Lepas pantai Madura (PHE WMO)	Gresik	PT Alas Energy Indonesia PT Nusa Trans Energy PT Niaga Gema Teknologi PT Surya Cipta Internusa	30

Table 4.10 Industrial baseline demand value (continue)

No	Company Name	Source	Area	Consumer	Capacity (MMSCFD)
5	PT SURYA CIPTA NUSANTARA	Lapangan Gas Terang Sirasun Batur (Pertagas Niaga)	Gresik	PT Prime Energy Supply	80
				PT Media Karya Sentosa	
				PT Green Gas Energy	
		Lapangan Gas TSB/Ex Pertagas Niaga (PT Java Gas Indonesia)		PT Gresik Power Indonesia (LINDE GROUP)	
				PT Java Energy Semesta	
				PT Petro Oxo Nusantara	
		PHE WMO/Ex PT Gresik Migas (PT Alas Energy)		PT Smelting	
				PT Pembangkitan Jawa Bali	
				PT Ishizuka Maspion	
				PT Petrocentral	
		PHE WMO/Ex PT Gresik Migas PT Nugas Trans Energy		PT Tunas Jaya Sentosa	
				PT Tulus Tri Tunggal	
				PT Sarana Cepu Energy	
				PT Cemindo Gemilang	
6	PT SARANA CEPU ENERGI	PHE WMO - Gresik	Gresik	PT Wilmar Nabati	5
7	PT PERTAGAS NIAGA	Lapangan Terang Sirasun Batur (KEIL)	Sidoarjo	PT Dharma Pratama Sejati (PT OPS)	36
				PT Ispat Indo	
8	PT DHARMA PRATAMA SEJATI	Lapangan Gas Terang Sirasun	Sidoarjo	PT ROMAN CERAMIC INTERNATIONAL	20
9	PT PETROGAS JATIM UTAMA	Lapangan Bukit Tua Wilayah Kerja Ketapang	Surabaya	PT Pembangkit Jawa - Bali	70

4.2. Supply Data Collection and Processing

Having a tremendous amount of gas reserves with 142.71 trillion standard cubic feet (TSCF), Indonesia still have many large gas resources that are still undeveloped such as offshore East Natuna Block which hold 49.6 TSCF. Indonesia gas resource area has been separates in several region.

As Indonesia Ministry of Energy stated, Per January 2017, East java which known as the region iv has 4.66 TSCF of gas reserves. Both are proven reserves with 2.54 TSCF and 2.12 TSCF of possible reserves. The ownership of this region is dominated by Kangean Energy Indonesia with 1.48 TSCF followed by Husky with 0.9 TSCF and PHE WMO with 0.53 TSCF. The rest 1.75 TSCF is divided into many reserves and ownership such as Pertamina EP, Cepu, and many more.

Indonesia has many gas fields that has been located and produced. The location is dispersed in many regions in Indonesia. The biggest one is located in Tangguh and operated by British Petroleum. Meanwhile, in East Java, despite of not having any liquification unit, they have several gas fields that so far handled the needs on East Java and Madura regions. The fields are located in Kangean, Sampang, West Madura offshore, Brantas and many others as we can see in Table 4.11

Table 4.11 East Java gas supply

No	Company	Field	Capacity	Units
1	Kangean Energy Indonesia	Kangean	201,77	MMSCFD
2	PHE WMO	West Madura Offshore	140	MMSCFD
3	Husky CNOOC Madura Ltd	Madura Strait	100	MMSCFD
4	Petronas (Bukit Tua)	Ketapang	35,43	MMSCFD
5	SANTOS	Sampang Offshore Madura Offshore	66,04	MMSCFD
6	SAKA Pangkah	Pangkah	23,96	MMSCFD
7	Pertamina EP - Poleng	Poleng	14,44	MMSCFD
8	LAPINDO	Brantas	13,81	MMSCFD
9	JOB Pertamina-PetroChina East Java (Sukowati)	Tuban	1,97	MMSCFD
	Total Existing Supply		597,42	MMSCFD

No	Company	Field	Capacity	Units
1	PHE WMO	West Madura Offshore	11,42	MMSCFD
	Total Project Supply		11,42	MMSCFD
1	PHE WMO	West Madura Offshore	19,82	MMSCFD
	Total Potential Supply		19,82	MMSCFD
	Total Supply Region 4		628,66	MMSCFD

4.3. Model Formulation

After all data required has been obtained, next thing to do is to model the natural gas existing system condition based on constraint and parameter that has been set before. Variables from causal loop diagram will indicate the relation between elements. These variables must be determined in order to obtained accurate model. Causal loop diagram will stand as the guide line to model the real condition into stock flow diagram. To make sure if the model is adequate with the real system, we need to verified and validate the model.

4.3.1. Causal Loop Diagram

The causal loop diagram is a representation of a conceptualization of the system dynamics model that will be built. Through causal loop diagram, system dynamics model that will be developed, is explained by showing the causal relationship between variables entered in the model before entering the stage of model development. By showing the big picture of each relationship between variables inside the system, a causal loop diagram might show us the hypothetical result of a system that modelled with system dynamic. In this study, the causal loop was created using VENSIM software.

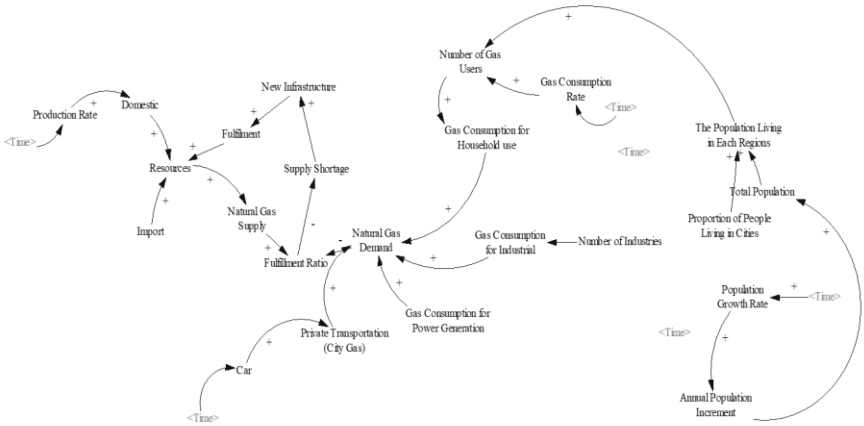


Figure 4.1 Causal Loop Diagram

As we see in the Figure 4.1 above, there are four main sectors in demand section, those are Transportation, Power Generation, Industrial and household. Each of this sector has several relationships with variables. In Transportation sector the consumption will be related to the growth of the car each year and the percentage of car which used gas as their fuel. In this case we use 5% for the percentage of car gas based from *Neraca Gas Bumi* and data conversion from PGN for the gas consumption.

For Power Generation sector the consumption is connected with the growth of its consumption per year. The data obtained is already useable so there is no need to use any form of conversion. In this case we use the yearly consumption from PT PLN Persero. While Industrial sector the consumption is related to the consumption of each industry and its growth. We use 1,1%/year for the growth as *Neraca Gas Bumi* and *BPH Migas* stated. There is no need to make a conversion because the data is already in useable unit. For the last sector, household, the consumption is related to the growth of the population, the consumption rate, and the growth of the consumption each year. We need to make certain conversion from as Artana and PGN developed because the data is not in useable unit. The consumption growth is depended to the population growth which we use regression analytical. For the percentage of the household that used gas line we assume it with 5700 household for mostly all district and city which currently don’t have the gas line, in the other hand we use PGN data resource for the city that already facilitated with the gas line.

In supply section, there are 3 main factor that are affect to the final supply. Those are Domestic Production, International Import and International Export. For Domestic Production, the variable connected is the production rate from each reservoir in East Java. The data is already in a useable form so there is no need to convert it. We use *Neraca Gas Bumi* as the data source. For International import, we assume that there is no fulfilment from outside stated source. And for International Export, as the Indonesia government state that all gas production is used for domestic need only, so there is no export in this study.

4.3.2. Stock and Flow Diagram

After making the causal loop diagram and knowing all the connection with all variables, the next step is to make the stock and flow diagram. Stock flow diagram is a concept from system dynamics model that functioned to represent the stock and flow of certain system. In this case we use stock flow diagram to know the current condition of supply and demand in, also to know how well the fulfilment could be in East Java. We use POWERSIM software to build the model.

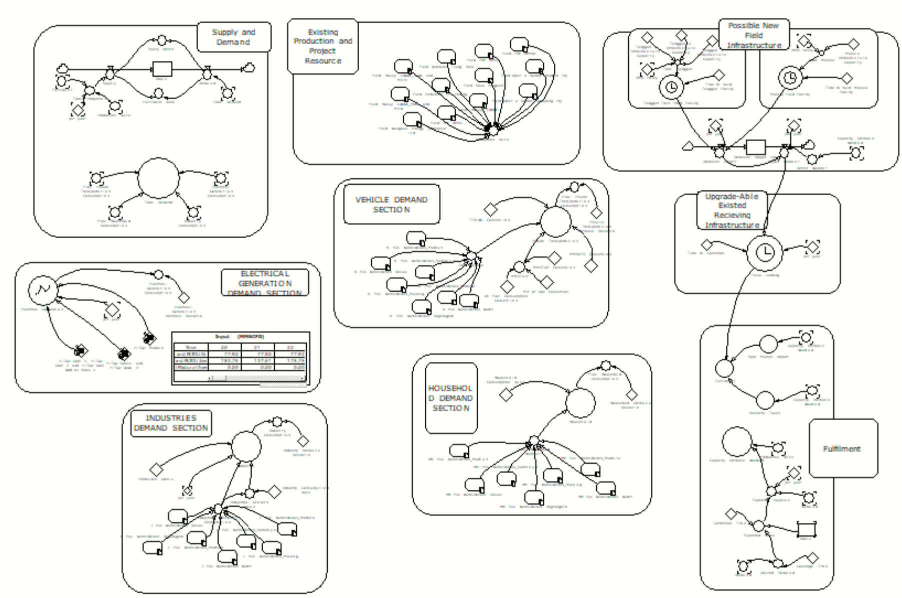


Figure 4.2 Current Stock Flow Diagram

The Figure 4.2 describe all the connection between variables in this simulation. As we can see there are 9 groups of diagrams that connected to each other and containing particular formula on each diagram. Supply and Demand group is the center of this simulation where the other diagram flow through them and make a loop.

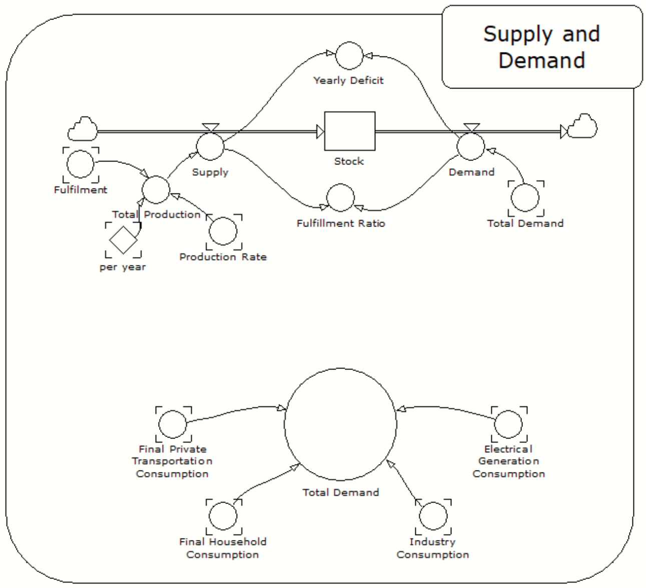


Figure 4.3 Supply and Demand Main Diagram

Figure 4.3 is the main diagram on this simulation. It accumulated all the supply from all resources diagram and flow it according to the demand number from the demand diagram. This diagram work based on certain formula.

Stock = +dt'Supply' – dt*'Demand'*

Yearly Deficit = 'Demand' – 'Supply'

Fulfilment Ratio = 'Supply' / 'Demand'

Demand = 'Total Demand'

Supply = 'Total Production'

Total Production = ('Fulfilment' + 'Production Rate') / 'per year'

Total demand diagram is the diagram that accumulate all demand number from all 4 sectors. There are Private Transportation, Household, Industry, and Electrical Generation. In each sector, it calculates the demand from all regions and cities in East Java. This diagram formula basically is the addition of all demand sector.

Total Demand

= 'Final Private Transportation' + 'Final Household Consumption' + 'Industry Consumption' + 'Electrical Generation Consumption'

4.3.3. Production Rate

The main supply diagram is divided into two sources, '*Production Rate'* and *'Fulfilment'*. '*Production Rate'* is the variable that consisted of all existing project of sources in East Java. The existing sources can be seen in Table 4.11. While *'Fulfilment'* is the number of additional resources that needed based on the demand that cannot be fulfilled.

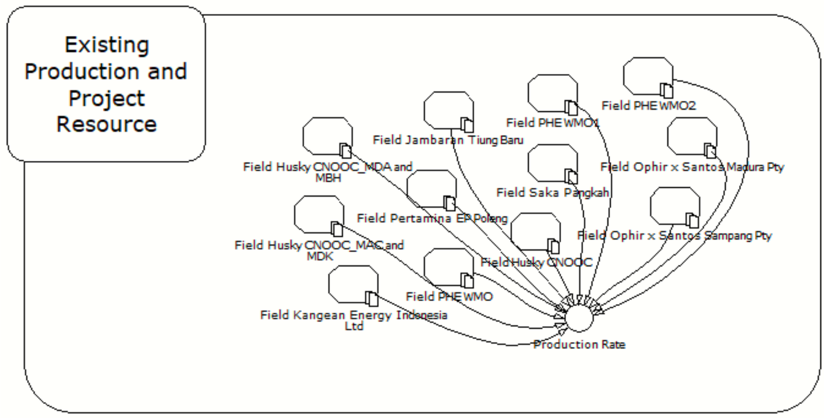


Figure 4.4 Existing and Project Resources

As we see in Figure 4.4 Existing and Project Resources there are 12 fields that are currently existed and supplied gas for East Java use. Not all those fields are producing full-time in all our time frame, they start and stop according to the data sources. Each field is sub-modeled, meaning the field is modeled in different pages but still connected to the main page. All fields that connected are cumulated in the *'Production Rate'* variable.

Production Rate

= 'Field Husky CNOOC' 'Supply of Field' + 'Field Husky CNOOC_MAC and MDK' 'Supply of Field' + 'Field Husky CNOOC_MDA and MBH' 'Supply of Field' + 'Field Jambaran Tiung Baru' 'Supply of Field' + 'Field Kangean Energy Indonesia Ltd' 'Supply of Field' + 'Field Ophir x Santos Madura Pty' 'Supply of Field' + 'Field Ophir x Santos Sampang Pty' 'Supply of Field' + 'Field PHE WMO' 'Supply of Field' + 'Field PHE WMO1' 'Supply of Field' + 'Field PHE WMO2'.'Supply of Field' + 'Field Pertamina EP Poleng' 'Supply of Field' + 'Field Saka Pangkah' 'Supply of Field'

As we know the '*Production Rate'* is consisted of all fields sub model. The variable in each sub-model is the production rate from the field itself. The depletion rate is used by modelling the data from the forecast data in *Neraca Gas Bumi Nasional 2018 – 2027*. It happens that each field has their own depletion rate. For instance, Field that run by Kangean Energy Indonesia Ltd., that produced in Kangean Island, Madura, East Java.

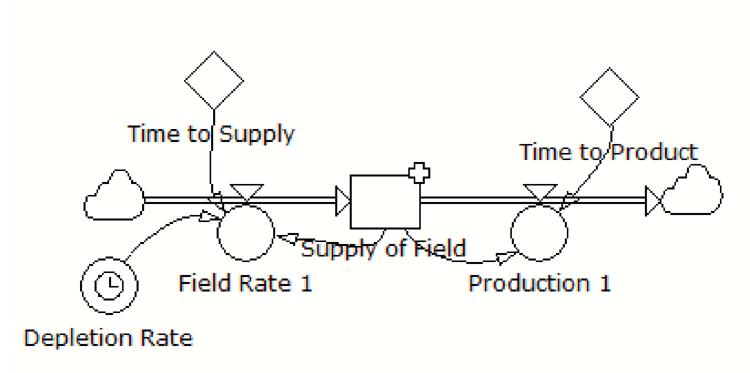


Figure 4.5 Production Model

The formula for the model is the initial supply times the depletion rate, because the data of actual remaining reserve and production are restricted due to the field owner.

Supply of Field = +dt'Field Rate 1' – dt*'Production 1'*

Production 1 '= 'Supply of Field'/'Time to Product'

Field Rate 1

= (('Supply of Field''Depletion Rate') + 'Supply of Field')/'Time to Supply'*

For the '*Depletion Rate'*, it uses the *STEP*, *STARTIME*, and *STOPTIME* function to run the calculation. The depletion rate is calculated in percentage (%) unit. The percentage data is obtained from *Neraca Gas Bumi Nasional 2018 – 2027*.

Depletion Rate

=(-16,2658099<<%>> + STEP(16,2658099<<%>>;STOPTIME-11<<yr>>)) + STEP(-36,41449058<<%>>;STARTTIME+2<<yr>>) + STEP(36,41449058<<%>>;STOPTIME-8<<yr>>) + STEP(-36,41449058<<%>>;STARTTIME + 5<<yr>>)

Assuming that there is no gas usage except for domestic market. The model diagram and formula will same for all other fields.

4.3.4. Fulfilment

As we know from Figure 4.3 we have other sources which is *'Fulfilment'*. All import number from the determined source is cumulated in this variable. There are many variables that connect each other, and this variable main purpose is to always fulfilled the demand needed.

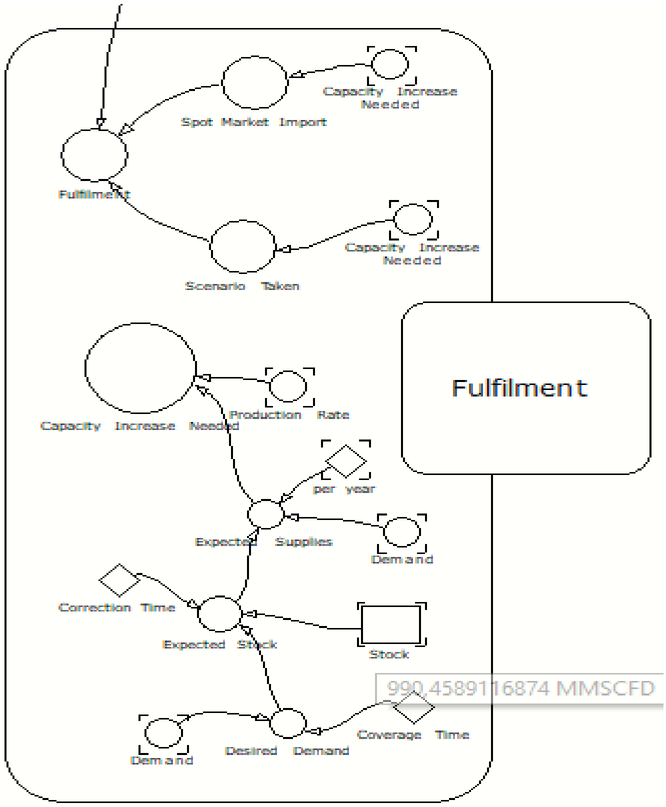


Figure 4.6 Fulfilment Model

From Figure 4.6 we see that fulfilment come from 2 sources which are *'Spot Market Import'* and *'Teluk Lamong'*. Each variable may have the same sources but it has different formula. *'Scenario Taken'* is a variable that show us which scenario that will be taken based on the condition. It will be shown in the table at the user interface page. *'Spot Market Import'* is the import number where the determined sources cannot fulfil the gas needs, while '*Teluk Lamong'* is the import number from the determined sources because it is assumed that all import is come from teluk lamong terminal.

Fulfilment

= IF('Scenario Taken'=1<<condition>>;CEIL('Teluk Lamong'+(IF('Teluk Lamong'<200<<MMSCFD>>;'Spot Market Import'-'Teluk Lamong';0<<MMSCFD>>)));IF('Scenario Taken'=2<<condition>>;CEIL('Teluk Lamong')+(IF('Teluk Lamong'<200<<MMSCFD>>;'Spot Market Import'-'Teluk Lamong';0<<MMSCFD>>));IF('Scenario Taken'=3<<condition>>;CEIL('Spot Market Import'))))

Spot Market Import

= IF('Capacity Increase Needed'>0<<MMSCFD>>;'Capacity Increase Needed';0<<MMSCFD>>)

Teluk Lamong

= (40<<MMSCFD/yr>>+STEP('Import Number';STARTTIME+'Time to Construct'))/'per year'

‘Capacity Increase Needed’ is a number of how much number of gas that we need to increase. It helps to autogenerate the number of imports, which scenario of import do the case has to choose and it help to stabilize the supply and demand condition. It uses a certain formula and this variable stay as the bridge in the supply and demand loop.

Capacity Increase Needed = 'Expected Supplies'-'Production Rate'

Expected Supplies = (‘Demand’+'Expected Stock')/'per year'

Expected Stock = ('Desired Demand'-Stock)/'Correction Time'

Desired Demand = ‘Demand’

‘Expected Supplies’ make this simulation know how to make sure the supply and demand condition is not in deficit situation by showing how much gas we need to import in each year. It uses the basic definition in Stock Flow diagram, where the stock stand as ‘storage’ so the outflow will take out the value from storage not from the supply directly. By doing that, the number that we need to import is effective and efficient.

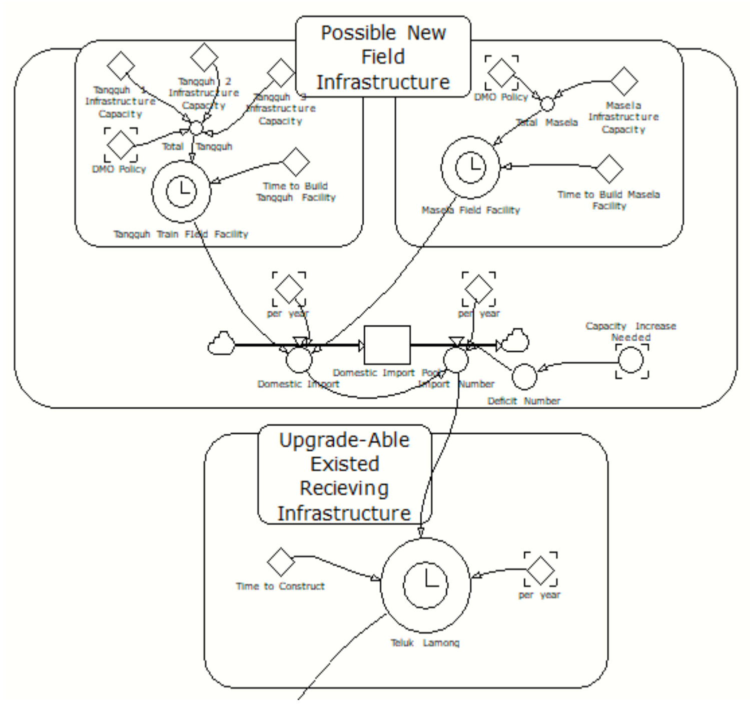


Figure 4.7 New Infrastructure Model

As we know from the information before, all determined import sources are flow through Teluk Lamong. In this simulation we have 3 import sources, which are Spot market, Masela and Tangguh. Spot market is a panic buying import scenario where the sources is not specified, the number is according to the capacity needed and other sources are currently available. Masela and Tangguh here are the possible upcoming sources. It will not produce and flowing gas from the start of simulation. It has a delay for '*Time to Build Tangguh Facility' and 'Time to Build Masela Facility'* as we see in the Figure 4.7. Each facility has their own time to build and formula for each variable.

Import Number

= IF('Domestic Import'>0<<MMSCFD/yr>>;'Deficit Number''per year';0<<MMSCFD/yr>>)*

Deficit Number

= IF('Capacity Increase Needed'>0<<MMSCFD>>;'Capacity Increase Needed';0<<MMSCFD>>)

Domestic Import

= ('Masela Field Facility'+'Tangguh Train FIeld Facility')'per year'*

Tangguh Train Field Facility

= 0<<MMSCFD>>+STEP('Total Tangguh';STARTTIME+'Time to Build Tangguh Facility')

Masela Field Facility

= 0<<MMSCFD>>+STEP('Total Masela';STARTTIME+'Time to Build Masela Facility')

4.3.5. Demand Sector

As we see in the Figure 4.3 the total demand is accumulated from 4 major sectors which are Electrical Generation, Industrial, Household, and Transportation. Each sector using their own diagram and formulation based on the real condition in real life.

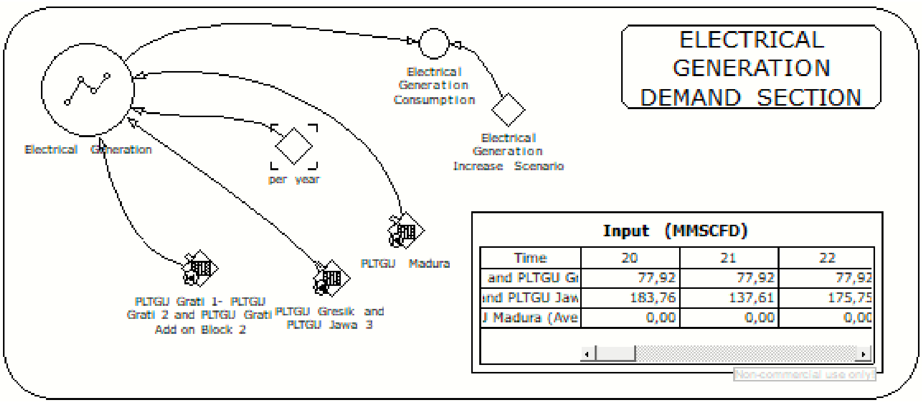


Figure 4.8 Electrical Demand Model

For this Electrical Generation section, the data is accumulated from 3 Gas-Fueled Power Generation Facilities that is located in East Java. PLTGU GRATI 1, PLTGU GRESIK JAWA 3 and PLTGU MADURA are the facilities. The data from RUPTL is inserted to the input table and showing the determined gas consumption for each year. The accumulated data formula is stated below.

Electrical Generation

= ('PLTGU Grati 1- PLTGU Grati 2 and PLTGU Grati Add on Block 2'+'PLTGU Gresik and PLTGU Jawa 3'+'PLTGU Madura')'per year'*

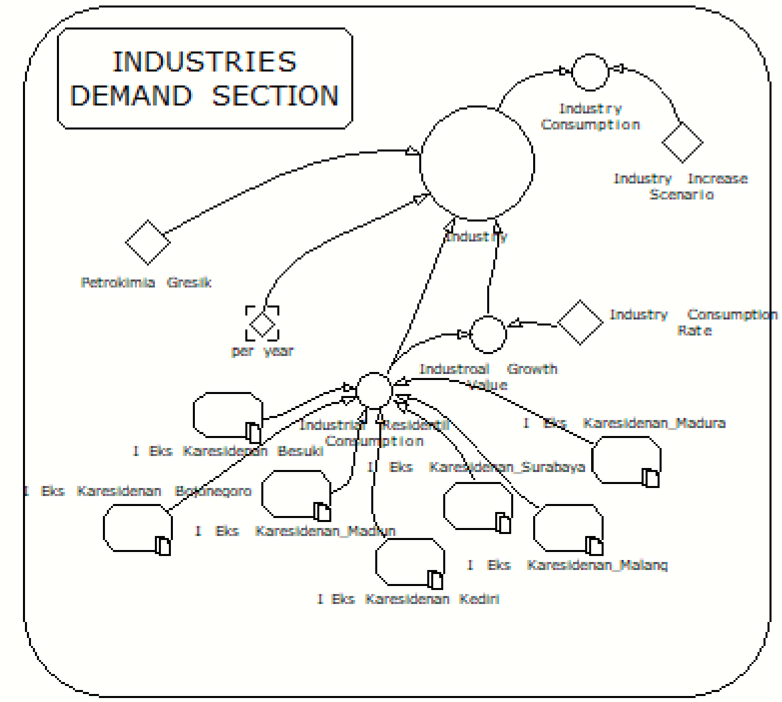


Figure 4.9 Industries Demand Model

For this Industrial Section, the data is accumulated from all region and cities in East Java that grouped in to 7 big area and Petrokimia Gresik as addition. Those areas are 7 ex-karesidenan which consist of Besuki, Bojonegoro, Madiun, Kediri, Surabaya, Malang and Madura. There is also 'Indutrial Growth Value' that shown and control the growth percentage that this simulation use. The data from Neraca Gas Bumi *Nasional 2018 – 2027* is used which is 1,1 % per year. Each area has their own sub-model to determine the number of demand because each cities or district has their own number of industries.

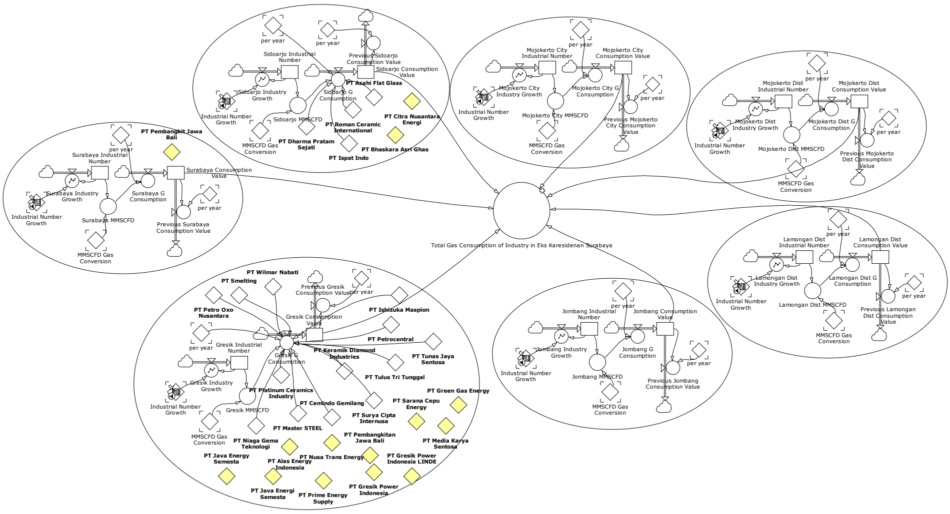


Figure 4.10 Surabaya Residences Industrial Model

For instance, in *karesidenan Surabaya* Sidoarjo and Surabaya will have a different diagram because of the industries number consisted in that city. As we stated back before we use 2 data for the industrial. The first is from BPH Migas book and *Rencana Pembangunan Industri Jawa Timur*.

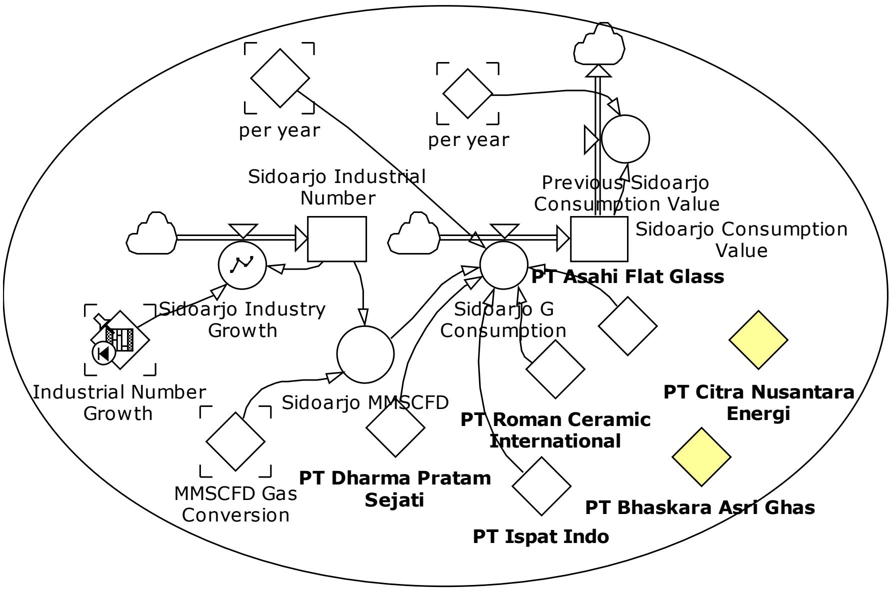


Figure 4.11 Sidoarjo Industrial Model

As we see in the above, there are 2 type of industry variable, the first one is using a growth because the data only shown the total number of industry in Sidoarjo without the consumption, while the second one is the company that stated by BPH Migas along with its gas consumption. The yellow variable is the company that run its business in distribution sector so the gas not being consumed directly and it is not included in our calculation. For each variable, specific formulation is used and stated below.

Industry

= ('Petrokimia Gresik'+'Industroal Growth Value'+'Industrial Residentil Consumption')'per year'*

Industrial Growth Value

= 'Industrial Residentil Consumption''Industry Consumption Rate'*

Industrial Residentil Consumption

= 'I Eks Karesidenan Besuki'.'Total Gas Consumption of Industry in Eks Karesidenan Besuki'+'I Eks Karesidenan Bojonegoro'.'Total Gas Consumption of Industry in Eks Karesidenan Bojonegoro'+'I Eks Karesidenan Kediri'.'Total Gas Consumption of Industry in Eks Karesidenan Kediri'+'I Eks Karesidenan_Madiun'.'Total Gas Consumption of Industry in Eks Karesidenan Madiun'+'I Eks Karesidenan_Madura'.'Total Gas Consumption of Industry in Eks Karesidenan Madura'+'I Eks Karesidenan_Malang'.'Total Gas Consumption of Industry in Eks Karesidenan Malang'+'I Eks Karesidenan_Surabaya'.'Total Gas Consumption of Industry in Eks Karesidenan Surabaya'

Total Gas Consumption of Industry in Eks Karesidenan Surabaya

= 'Gresik Consumption Value'+'Jombang Consumption Value'+'Lamongan Dist Consumption Value'+'Mojokerto City Consumption Value'+'Mojokerto Dist Consumption Value'+'Sidoarjo Consumption Value'+'Surabaya Consumption Value'

Sidoarjo Consumption Value

= +dt'Sidoarho G Consumption'-dt*'Previous Sidoarjo Consumption Value'*

Previous Sidoarjo Consumption Value

= 'Sidoarjo Consumption Value''per year'*

Sidoarjo G Consumption

= ('Sidoarjo MMSCFD'+'PT Asahi Flat Glass'+'PT Dharma Pratam Sejati'+'PT Ispat Indo'+'PT Roman Ceramic International')'per year'*

Sidoarjo MMSCFD

= 'MMSCFD Gas Conversion''Sidoarjo Industrial Number'*

Sidoarjo Industrial Number

= +dt'Sidoarjo Industry Growth'*

Sidoarjo Industry Growth

= 'Industrial Number Growth''Sidoarjo Industrial Number'*

All the data will be inserted to the constant variable so the formula can be run. The model diagram and formula are identical to the other area and city, except for the number of industries.

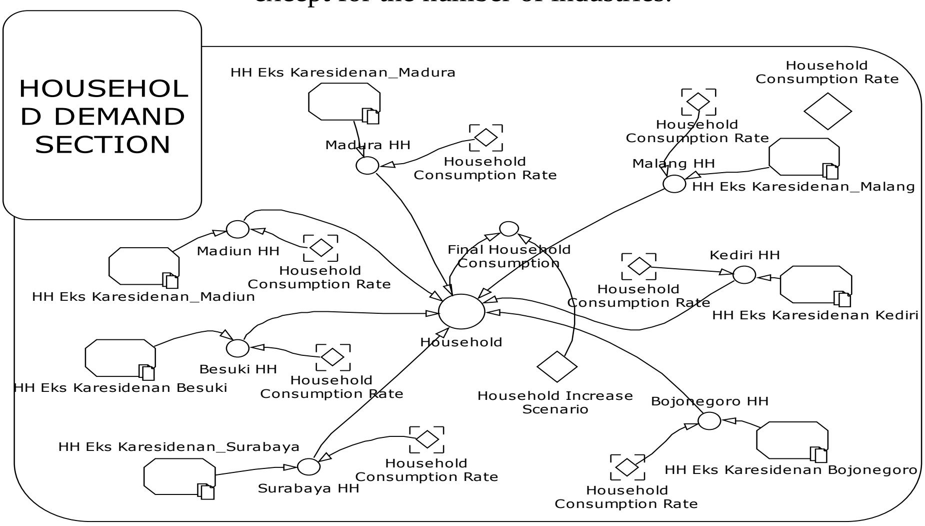


Figure 4.12 Household Demand Model

For this household Section, the data is accumulated from all region and cities in East Java that grouped in to 7 big area. Those areas are 7 ex-*karesidenan* which consist of Besuki, Bojonegoro, Madiun, Kediri, Surabaya, Malang and Madura. Each area has their own sub-model to determine the number of demand because each cities or district has their own number of populations. We have the constant for '*Household Consumption Rate'* that come from the conversion from PGN. The diagram model is not much different from one to the other.

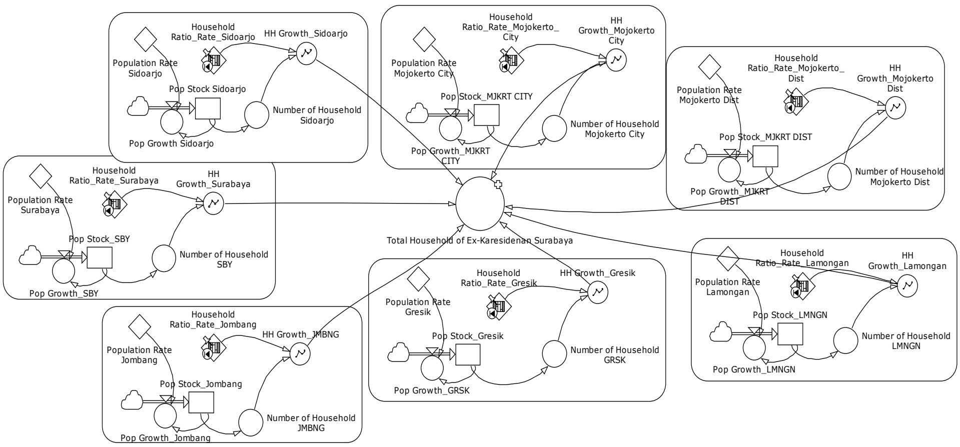


Figure 4.13 Surabaya Household Demand Model

For instance, in *karesidenan Surabaya* Sidoarjo and Surabaya will have a same diagram despite of the population number consisted in that city. As we stated back before we use BPS data for forecasting the population number.

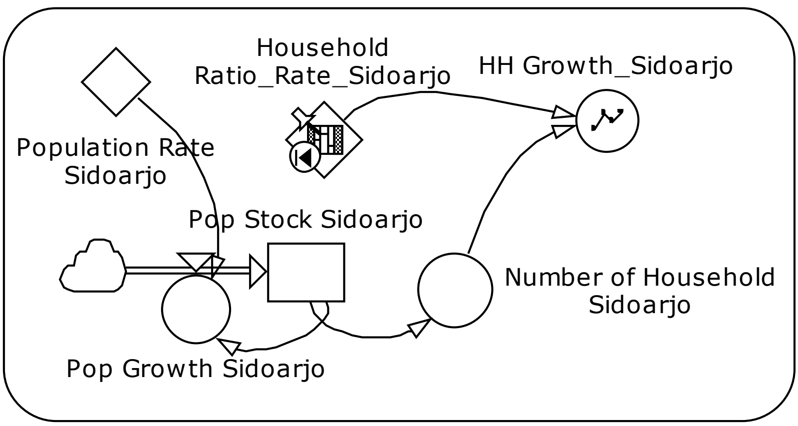


Figure 4.14 Sidoarjo Household Demand Model

As we see in the figure above, the stock flow diagram of population is attached. Starting with the initial number of populations from certain year and ended with the Household growth. For each variable, specific formulation is used and stated below.

Household

= ('Household Consumption Rate'*(('Total Household Number')/250))/1<<yr>>

Total Household Number

= 'HH Eks Karesidenan Besuki'.'Total Household of Ex-Karesidenan Besuki'+'HH Eks Karesidenan Bojonegoro'.'Total Household of Ex-Karesidenan Bojonegoro'+'HH Eks Karesidenan Kediri'.'Total Household of Ex-Karesidenan Kediri'+'HH Eks Karesidenan_Madiun'.'Total Household of Ex-Karesidenan Madiun'+'HH Eks Karesidenan_Madura'.'Total Household of Ex-Karesidenan Madura'+'HH Eks Karesidenan_Malang'.'Total Household of Ex-Karesidenan Malang'+'HH Eks Karesidenan_Surabaya'.'Total Household of Ex-Karesidenan Surabaya'

Total Household of Ex-Karesidenan Surabaya

= 'HH Growth_Gresik'+'HH Growth_JMBNG'+'HH Growth_Lamongan'+'HH Growth_Mojokerto City'+'HH Growth_Mojokerto Dist'+'HH Growth_Sidoarjo'+'HH Growth_Surabaya'

HH Growth_Sidoarjo

= 'Household Ratio_Rate_Sidoarjo'*'Number of Household Sidoarjo'

Number of Household Sidoarjo = 'Pop Stock Sidoarjo'/4

Pop Stock Sidoarjo = +dt'Pop Growth Sidoarjo'

Pop Growth Sidoarjo

= 'Pop Stock Sidoarjo'*'Population Rate Sidoarjo'/1<<yr>>

All the data will be inserted to the constant variable so the formula can be run. The model diagram and formula are identical to the other area and city.

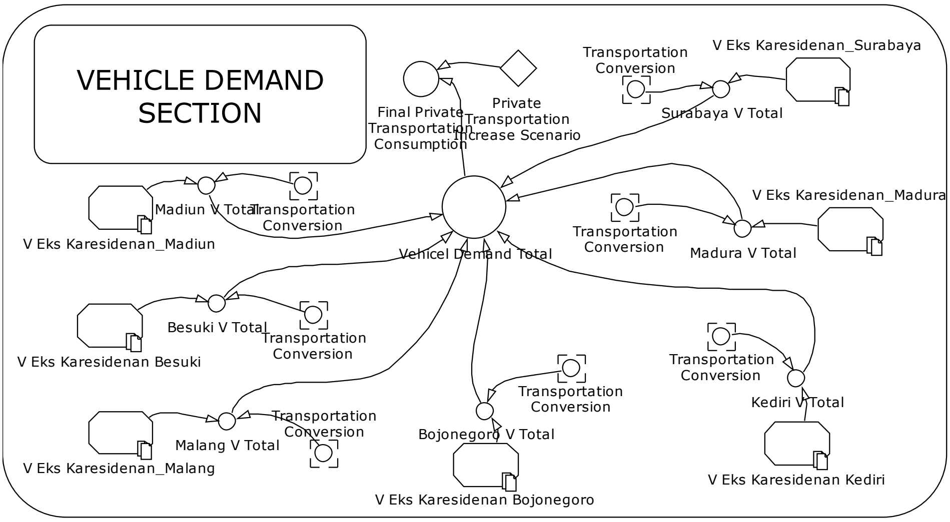


Figure 4.15 Vehicle Demand Model

For this vehicle demand Section, the data is accumulated from all region and cities in East Java that grouped in to 7 big area. Those areas are 7 ex-*karesidenan* which consist of Besuki, Bojonegoro, Madiun, Kediri, Surabaya, Malang and Madura. Each area has their own sub-model to determine the number of demand because each cities or district has their own number of vehicles. We have many constants that functioned as a conversion because we need to convert from number of vehicles to consumption of fuel oil to consumption of gas. As we have stated before in data recapitulation section the conversion is stated by PGN. The diagram model is not much different from one to the other.

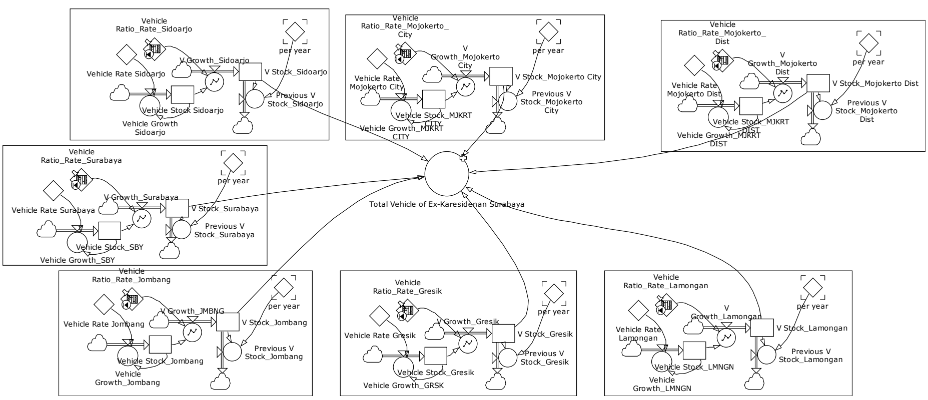


Figure 4.16 Surabaya Residence Vehicle Demand Model

For instance, in *karesidenan Surabaya,* Sidoarjo and Surabaya will have a same diagram despite of the vehicle number consisted in that city. As we stated back before we use *DISHUB* data for forecasting the population number.

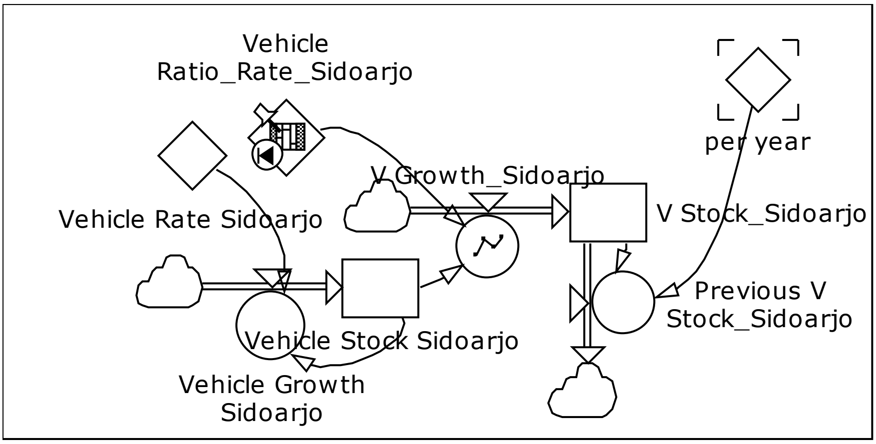


Figure 4.17 Sidoarjo Vehicle Demand Model

As we see in the figure above, the stock flow diagram of vehicle is attached. Starting with the initial number of vehicles from certain year and ended with the vehicle stock. For each variable, specific formulation is used and stated below.

Private Transportation

= ((MMBTUD/'TPDLNG Conversion'/'MMSCFD Conversion')('Total Vehicle'))/1<<yr>>*

MMBTUD

= 'M3 of Gas Conversion''MMBTUD Conversion'*'Oil Fuel Consumption Conversion'*

Total Vehicle

= 'V Eks Karesidenan Besuki'.'Total Vehicle of Ex-Karesidenan Besuki'+'V Eks Karesidenan Bojonegoro'.'Total Vehicle of Ex-Karesidenan Bojonegoro'+'V Eks Karesidenan Kediri'.'Total Vehicle of Ex-Karesidenan Kediri'+'V Eks Karesidenan_Madiun'.'Total Vehicle of Ex-Karesidenan Madiun'+'V Eks Karesidenan_Madura'.'Total Vehicle of Ex-Karesidenan Madura'+'V Eks

Karesidenan_Malang'.'Total Vehicle of Ex-Karesidenan Malang'+'V Eks Karesidenan_Surabaya'.'Total Vehicle of Ex-Karesidenan Surabaya'

Total Vehicle of Ex-Karesidenan Surabaya

= 'V Stock_Gresik'+'V Stock_Jombang'+'V Stock_Lamongan'+'V Stock_Mojokerto City'+'V Stock_Mojokerto Dist'+'V Stock_Sidoarjo'+'V Stock_Surabaya'

V Stock Sidoarjo = +dt'V Growth Sidoarjo'-dt'Previous V Stock Sidoarjo'*

Previous V Stock Sidoarjo = 'V Stock_Sidoarjo''per year'*

V Growth Sidoarjo = 'Vehicle Ratio_Rate_Sidoarjo''Vehicle Stock Sidoarjo'*

Vehicle Stock Sidoarjo = +dt'Vehicle Growth Sidoarjo'

Vehicle Growth Sidoarjo

= 'Vehicle Stock Sidoarjo''Vehicle Rate Sidoarjo'/1<<yr>>*

All the data will be inserted to the constant variable so the formula can be run. The model diagram and formula are identical to the other area and city.

User Interface is used to control all desire-able variable inside the simulation. It will make the analysis of the simulation easier because we only need to see what we need to see. As we can see in the figure below, we control all demand sector with a slider switch to be able to increase the percentage of the growth. The data can be seen in both graphical and table. It can directly compare each variable in graph or table form.

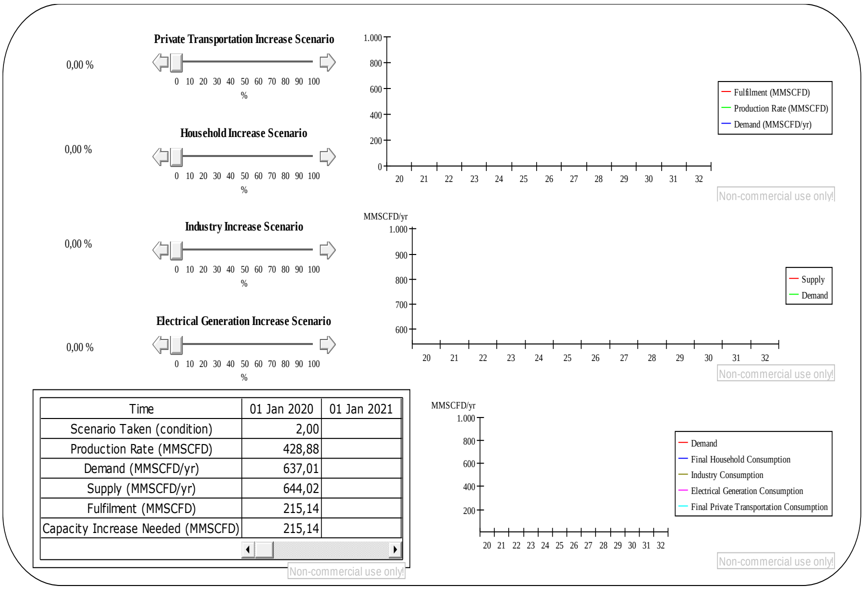


Figure 4.18 User Interface Preview

4.4. Model Verification and Validation

4.4.1. Verification

Verification is done to ascertain whether the model is in accordance with the conceptual model (Sargent, 2010). From there, we can check either a model is having an error or no when it run.

In this research, Powersim Studio 8 is used. This software is already equipped with automatically verification check features. If the operation appears a warning sign that the model still does not have a clear or undefined, it will appear as a red question mark. At the same time, if several variables are connected but do not yet have an interconnected formula, a yellow hedge will appear. The sign where a model has been verified is the absence of both of these warning signs so that the model can be run according to a certain time period.

4.4.2. Validation

Validation is a step to determine the accuracy of the model representing reality (Sargent, 2005). The validation methods used by the authors are there methods including:

1. Structural Scoring

This test aims to determine whether the structure of the model is the same as the causal loop diagram conceptualization model. The model built is adapted to the reference structure of the model from previous studies with the looping that occurs when traced.

2. Dimensional Consistency Scoring

This test aims are to settle whether the units of this model are consistent. Powersim 8 Studio is equipped with that feature, so there will be a sign if the model is inconsistent. If the mark is gone, it can be concluded that the model is valid. As we can see in Figure 4.2 there are no inconsistency mark, so our model is valid.

3. Extreme Condition Scoring

Extreme condition test is done in order to test the model with constraint that have been set in the causal loop diagram. In the test, a variable will be inserted with extreme value to know how the variable affect others. As we can see in the figure below, the ratio between this two-industry value is the same. Therefore, our model can be stated as a valid model.

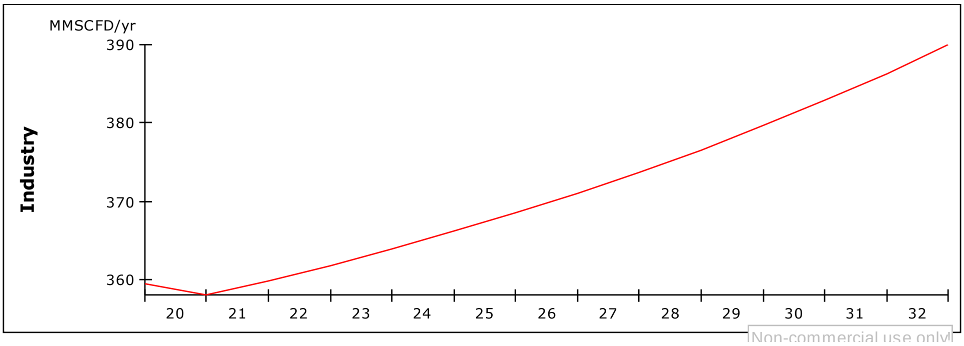


Figure 4.19 Normal Condition Running

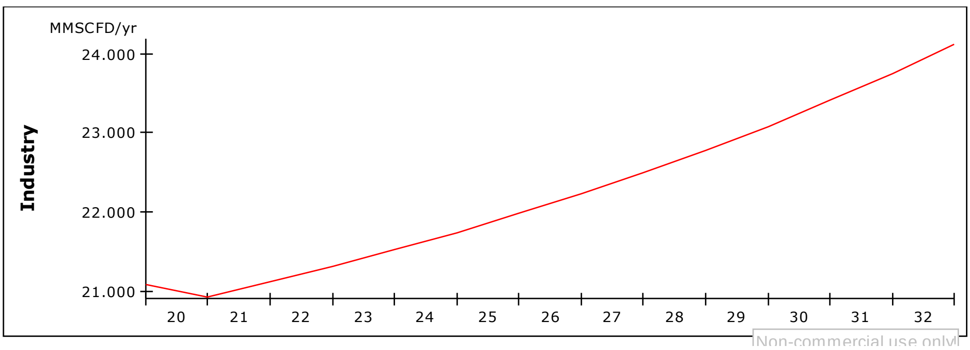


Figure 4.20 Extreme Condition Running

4.5. Demand Scenario Explanation

Scenario is made to know how a combination of certain variable can reacting to each other and resulting a certain result. By changing one or more value of certain constant, it can show a different behavior model and results. In addition, from analyzing scenarios, we get the interaction and feedback between variables in the system. In this study, we run the simulation with 2 scenarios. It diverse in to three-time phases with each phase is 4 years.

In Table 4.12 it seen that the scenario is related to demand sector for each area in East Java. There are Industrial Sector, Transportation Sector, Household Sector and Electrical Generation Sector. In the first scenario the industry growth is 1,1%/year according to the growth number by Neraca Gas Bumi. For Transportation, this scenario is using 5% vehicle growth in each potential area namely Surabaya, Sidoarjo, Mojokerto. While household sector, in this scenario it uses 5700 household as the starting value for each particular area, and then it is converted into percentage according to the ratio of population. The next is electrical generation sector which the scenario is follow the *RUPTL* from Indonesian government.

Table 4.12 Demand Scenario 1

Industry			Transportation			Household			Electrical Generation		
Phase											
1	2	3	1	2	3	1	2	3	1	2	3
1,1%/yr			5% of vehicle growth in each particular area			5700 RT which was then converted into a percentage according to the ratio of the population of each particular region			RUPTL		

The scenario in Table 4.13 is the second scenario. In industrial sector, this scenario is using the industrial growth from *Neraca Gas Bumi* which is 1,1 %/year. Transportation sector in the other hand, in this scenario for each phase it grows 5% for each particular area. For area that has been facilitated with gas station, it will grow 5% in the next time phases and so on. Household sector scenario is quite similar with transportation sector, but it grows 10 % for each time phases. For household sector it is also started with 5700 household. The area will grow according to the Figure 4.21. Meanwhile, electrical generation sector is following the RUPTL same like scenario 1.

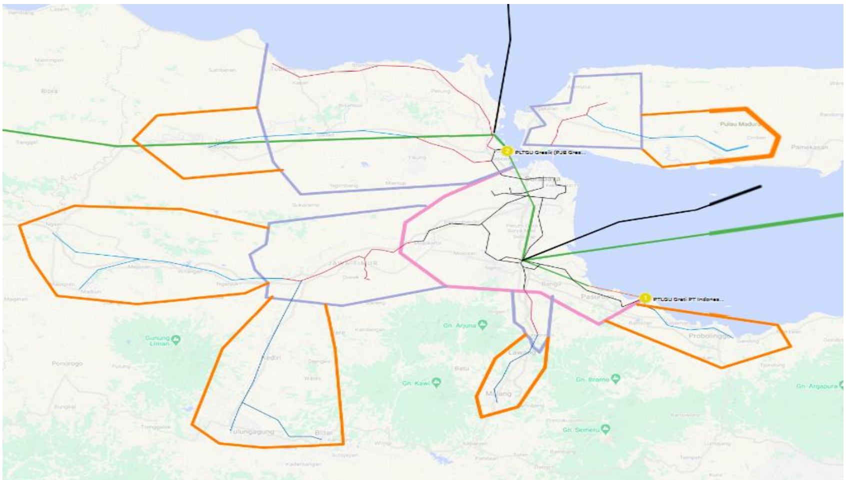


Figure 4.21 Household Growing Area

Figure 4.21 show the grow phases of area that will facilitated with household gas pipeline in the scenario. It shows the line and the area that will expanded. For the first phase or existed area is represented with the purple area. The area that consisted in that phase are Surabaya, Pasuruan, Sidoarjo and Mojokerto. The second expansion is represented with blue color. The area that included in that phase are Tuban, Gresik, Bangkalan, and Purworejo. For the last Time phases which represented with orange color, it is consisted from many areas which are Kediri, Tulungagung, Blitar, Malang, Probolinggo, Bojonegoro, Ngawi, Madiun, and Sampang. This condition is applied to both scenario 1 and 2. The area selection is based on the closest area to the area in the first phase.

For transportational sector, it is similar like what the author did with household sector. There are phases that show the grow of private transportational use gas facilities in certain area. The first phase are Surabaya dan Gresik. For the second phase are Malang and Sidoarjo. For the last phase are Kediri dan Mojokerto. This condition is applied to both scenario 1 and 2. The area selection is based on the number of vehicle and the closest area to the area in the first phase.

Table 4.13 Demand Scenario 2

Industry			Transportation			Household			Electrical Generation		
Phase											
1	3	3	1	2	3	1	2	3	1	2	3
1,1%/yr			5% of vehicle growth in each region	10% of vehicle growth in each region 5% of vehicle growth in each region	15% of vehicle growth in each region 10% of vehicle growth in each region 5% of vehicle growth in each region	5700 RT which was then converted into a percentage according to the ratio of the population of each particular region	5% additional of population that used the service in each particular area 5700 RT which was then converted into a percentage according to the ratio of the population of each particular region	10% additional of population that used the service in each particular region area. 5% additional of population that used the service in each particular area. 5700 RT which was then converted into a percentage according to the ratio of the population of each particular region	RUPTL		

4.6. Supply and Demand Result

4.6.1. Supply Demand Scenario 1 Result

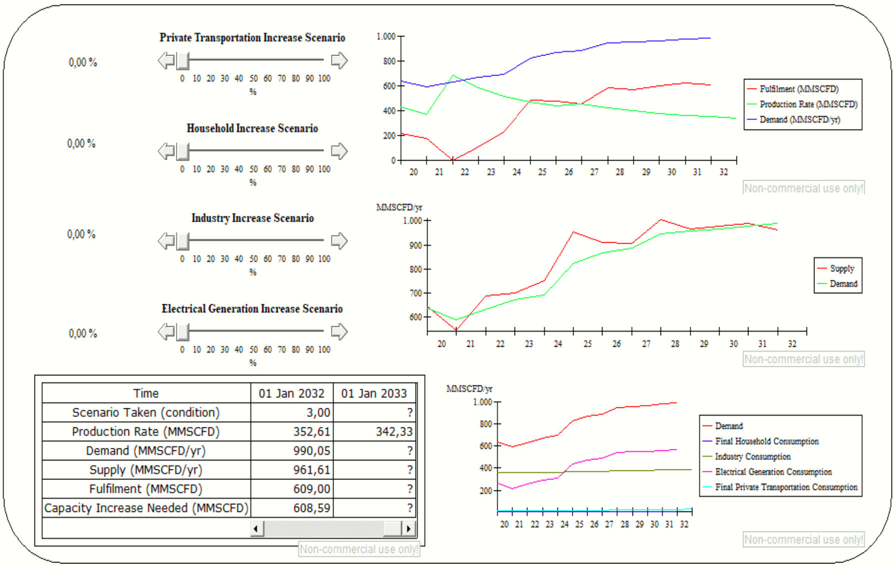


Figure 4.22 Result in userinterface of Scenario 1

This is the look of the user interface after running the simulation 1 in scenario 1 for 12 years. As seen in the figure above, the percentage lever is on 0 % level. It is 0 % because it purposed for additional scenario and cover all area in the simulation. The scenario that have been determined before already inserted in the system inside the diagram model but not showed in the user interface.

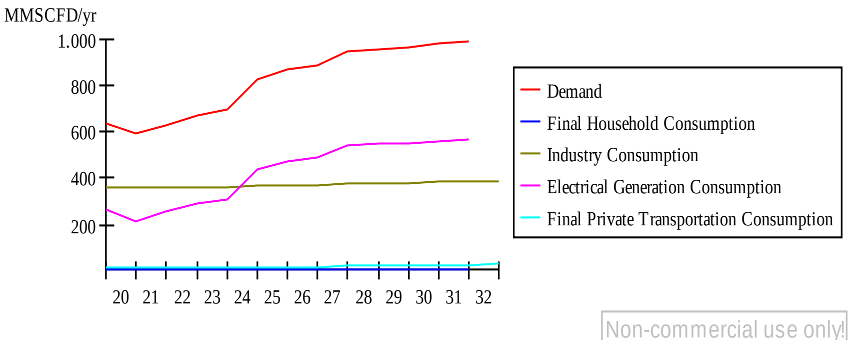


Figure 4.23 Scenario 1 Total Demand

Figure 4.23 is the result of total demand simulation from scenario 1. As we see the total demand is increasing throughout the year. It starts from little bit above 600 MMSCFD and continuously rise until above 1000 MMSCFD at the end of simulation time frame. From each sector demand, the biggest contributor is electrical generation and followed by industrial sector at the end of the simulation. Actually, the other demand sectors are also increasing, but comparing to the electrical generation and industrial sector it may seem unprogressive.

The number for each area is different according to the base data that has been collected. The biggest area for total demand is in Surabaya district which Sidoarjo, Surabaya, and Gresik become the biggest contributors in almost every demand sector.

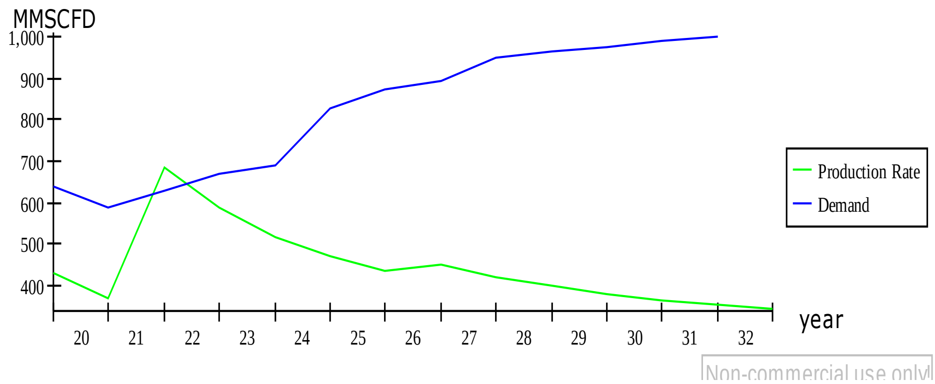


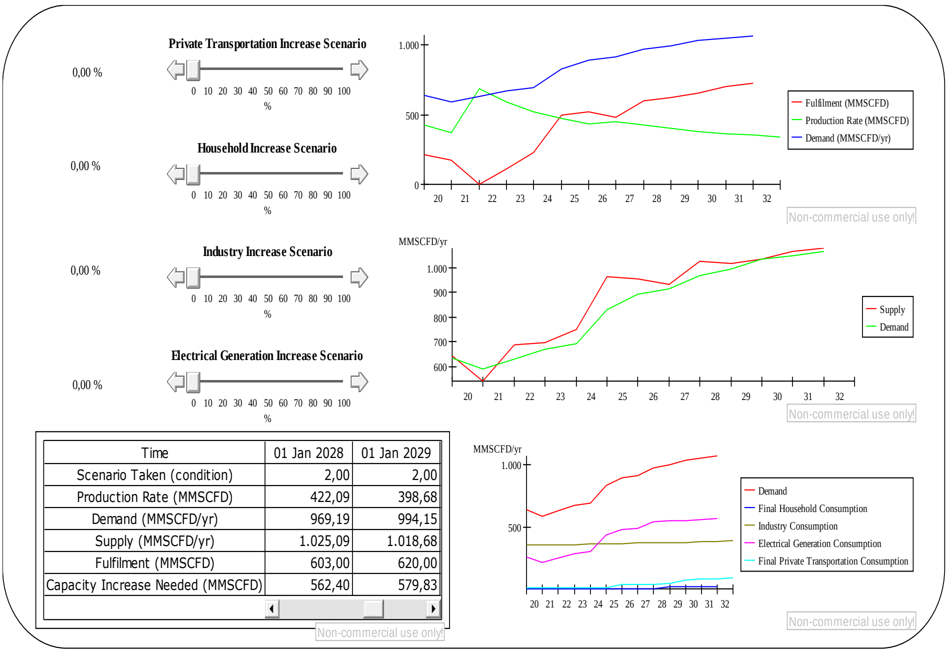
Figure 4.24 Scenario 1 Supply and Demand Condition

In the Figure 4.24 it shows that most of the time in the simulation time frame, East Java facing a hard deficit condition which increasing in every year and the supply-demand gap is keep rising in every year. The current production value is represented by Production Rate inside the simulation. It shows that only in 2021 – 2022 that East Java finally fulfill the demand due to the start of the new project field such as MAC and MDA fields. It is also seen that the production fields are decreasing each year. The decreasing of the productions value is caused by the condition that East Java facing which is the absence of new field resource.

4.6.2. Supply Demand Scenario 2 Result

After simulation the same data with different demand scenario, it is obtained a different result. The trend is quite similar but the graph increased in different scale. It is not surprising because the scenario itself is showing higher percentage for certain sector. As seen in the figure above, the percentage lever is on 0 % level. It is 0 % because it purposed for additional scenario and cover all area in the simulation. The scenario that have been determined before already inserted in the system inside the diagram model but not showed in the user interface.

Figure 4.26 is the result of total demand simulation from scenario 2. As we see the total demand is also increasing every year. It starts from 637.01 MMSCFD and continuously rise until 1064.3 MMSCFD at the end of simulation time frame. From each sector demand, the biggest contributor is still electrical generation and followed by industrial sector at the end of the simulation. But the other demand sectors are also increasing, but more significantly this time. For Transportation and Household, the number are increasing more higher due to the additional area and percentage that included in the scenario 2.



Time	01 Jan 2028	01 Jan 2029
Scenario Taken (condition)	2,00	2,00
Production Rate (MMSCFD)	422,09	398,68
Demand (MMSCFD/yr)	969,19	994,15
Supply (MMSCFD/yr)	1.025,09	1.018,68
Fulfilment (MMSCFD)	603,00	620,00
Capacity Increase Needed (MMSCFD)	562,40	579,83

Figure 4.25 Result in userinterface of Scenario 2

Figure 4.27 shows that in second scenario, East Java is still facing a hard deficit from the first year until the end of the simulation year like the first scenario. The only year that is free from deficit condition is in 2022 and after that it is back to deficit condition. The production rate value is exactly the same like in the scenario 1.

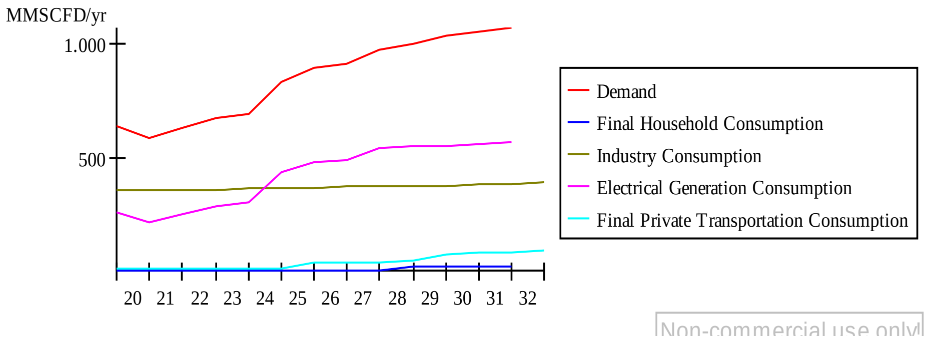


Figure 4.26 Scenario 2 Total Demand

The cause of why the surplus in 2022 happen is because there are several supply projects that happen to start close to that year and so new supply is added. But soon after that the down trend continues to run because of the demand that won't stop to rise, and the lack of supply that East Java can provide. The result from scenario 2 is quite similar like what scenario 1 resulted. The differences lay on the total of demand needed by the end of the simulation time range, also in the demand of Household and Transportation sector.

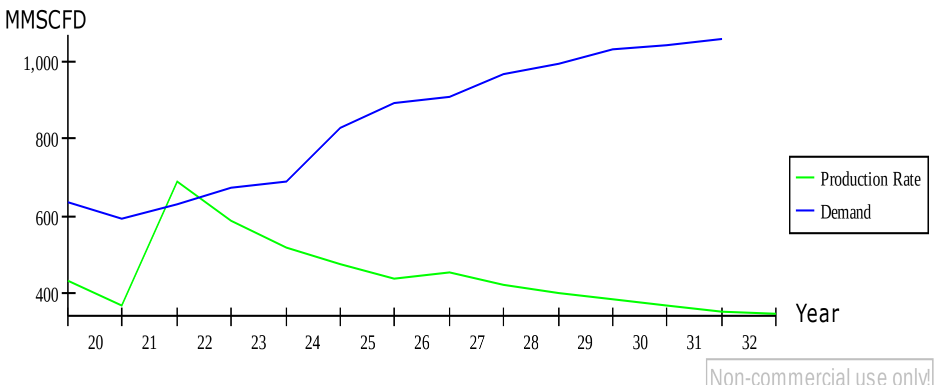


Figure 4.27 Scenario 2 Supply and Demand Condition

4.6.3. Demand Mapping

This section is existed to know the condition of each *eks karesidenan* areas. By having the maps, the determination of the fulfilment scenario will be more accurate. The mapping will also divide into 2, one for scenario 1 and one for scenario 2. We use Google Earth Pro software to map the demand and fulfilment for this simulation. We also use G.E Graph extension to be able to insert a graph so that the result presentment be clearer.

Figure 4.28 Scenario 1 Demand Map Excluding Power Generation Demand

Figure 4.28 is showing the result of total demand simulation that using the first scenario. Each area is showing 4 results from all time frame. The bars represent 4 year from the time frame which are, 2021, 2025, 2029 and 2032. As shown in the title bar, this map is not showing the electrical generation demand and it will show in separate maps.

The biggest consumer in East Java is Surabaya Residences with 245.55 MMSCFD at the end of the simulation time range while the lowest is Madura Residences with 1.71 MMSCFD. The connection between Industrial demand and Total demand is quite big. For instance, Surabaya Residences, this area having a lot of industrial area that existed in Surabaya City, Sidoarjo District, and Gresik District, that is why the number for Surabaya Residences is skyrocketed and vice versa.

Figure 4.29 showing the demand diversity for electrical generation in East Java. Same as the previous figure, the bars represent the values from 4 year which 2021, 2025, 2029 and 2032. As we can see, electrical generation sector is consuming gas in a mass number same like industrial sector. The biggest consumer from those plants is PLTGU Gresik with 295.34 MMSCFD at the end of simulation. While the lowest one, PLTGU Madura, only start their operational in 2024 that is why in the bar it shows zero value and at the end of the simulation the value showing 35.16 MMSCFD. This electrical generation sector applies to both scenario 1 and 2.

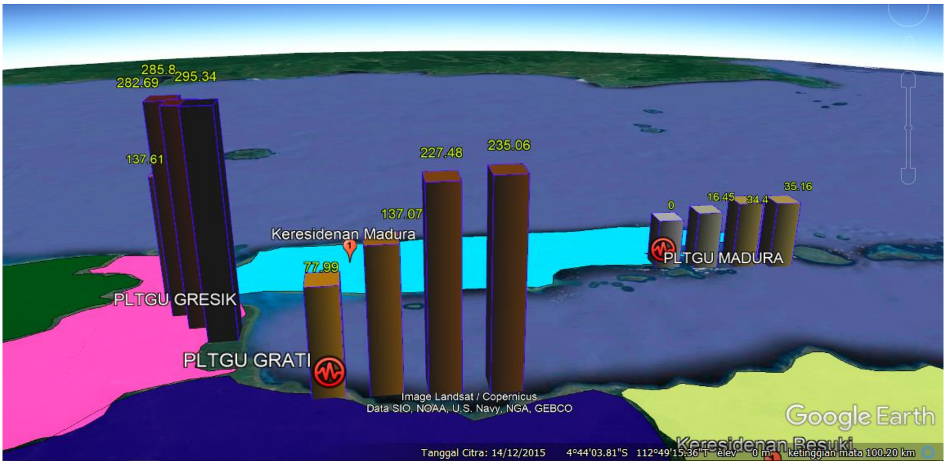


Figure 4.29 Power Generation Demand

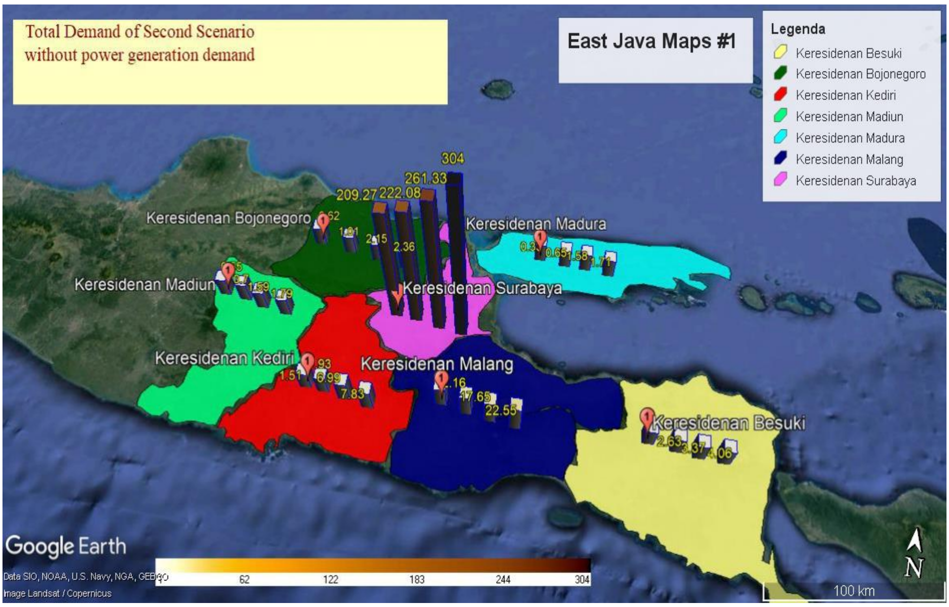


Figure 4.30 Scenario 2 Demand Map Excluding Power Generation Demand

Figure 4.30 is showing the result of total demand simulation that using the second scenario. There are not much different with the first scenario in Figure 4.28 beside the demand condition result. As shown in the title bar, this map is not showing the electrical generation demand and it showed in Figure 4.29

As we have the result in the figure, the biggest consumer from second scenario is still Surabaya Residence with 304 MMSCFD. It is 58.45 MMSCFD bigger than the first scenario. It caused by the ration percentage of household and vehicle that using gas are bigger than the first scenario. Most of the changes that happen in scenario 2 is majorly affect the Surabaya Residence, unlike other area, Surabaya Residences considered as most upgradable area so that is affecting the number of demands there.

In the lowest consuming area, Madura Residence start with 0.3 MMSCFD and end with 1.71 MMSCFD looks identical like the first scenario but actually it is not. It can happen because there is no transportation demand in both scenarios, no changes in industrial demand. So that is only household demand sector that differ the first scenario from the second. In the first scenario, it ends with 2.64 MMSCFD while in the second scenario it ends with 2.87 MMSCFD for household sector.

4.7. Fulfilment Scenario

As we know from the mapping in the previous section, Surabaya Residence is the biggest gas consumer in East Java and followed by residences surround it like Malang and Bojonegoro Residences. From previous section we also found that East Java is facing a hard deficit condition in almost every year except for 2022. In this section, the fulfilment scenario is explained. It uses one scenario until the scenario cannot fulfill the demand condition.

The scenario that this study use is the upcoming Teluk Lamong Gas Terminal and unspecified new infrastructure. It is true that currently Teluk Lamong Gas Terminal is not ready for its operational. So that in the first year when Teluk Lamong Gas Terminal is not ready this study uses the gap between what East Java itself can handle and the demand, and it fulfilled from spot market. When the Teluk Lamong Terminal cannot fulfill the demand, then the unspecified new infrastructure must be added.

Teluk Lamong is scheduled to normally operate in 2023 with 180 MMSCFD and can be upgraded to 600 MMSCFD. But in 2020 Teluk Lamong Gas Terminal can be use with capacity up to 40 MMSCFD until 2023. Teluk Lamong is a receiving terminal which mean there will be sources that will be fulfilled East Java demand through Teluk Lamong. We considered Bontang LNG and also the upcoming Masela and Tangguh Fields. It will officially be operated in 2025 and 2028, while before it this study is using Bontang field that flow through Teluk Lamong. So, this spot market is an import that this study not considered where the source is come from and it used when the number from the current production number is not sufficient and other scenario is not available at that time.

As the previous section stated before, this study uses a configuration in our simulation that this fulfilment model will never be unable to fulfil the demand, only the number of the value will be adjusted according to the demand needed in that year. At this study we use Stock – Demand auto scheme to fulfill the gas gap condition.

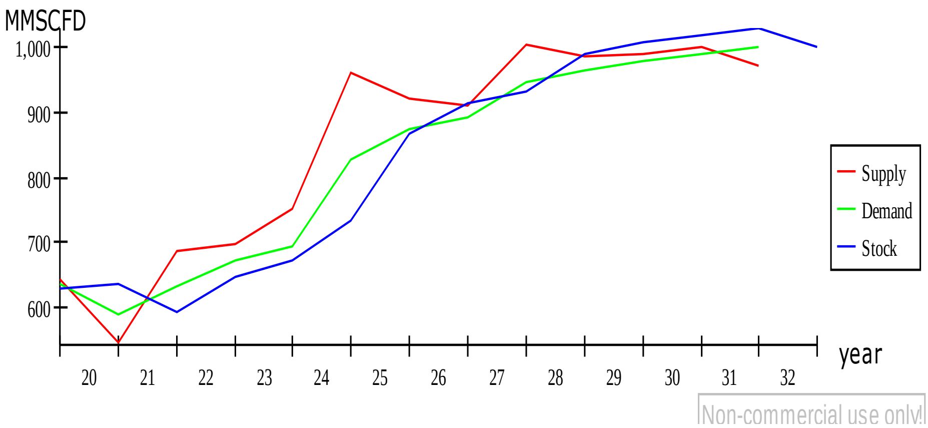


Figure 4.31 Scenario 1 Final Result with Fulfilment

As we see in the Figure 4.31 and the Table 4.14, from the first scenario it can be seen that almost every year, the supply demand condition is now fulfilled according to the simulation. The simulation is run according on constraint condition that has been stated before. In 2021 the fulfilment is looks unsuccessful because the additional gas supplement added with the production rate is below the demand value. But it is actually completed, as we can see in the stock graph, the number of gas stock is higher than the demand, meaning that the demand at that year can be fulfilled by the stock from the previous year. It is applied for 2032 too. For the other year stated as fulfilled as we see at the table, meaning that the fulfilment is happen from the additional resource at that year and not from the previous year, which in a real life that event is more acceptable than by using the previous stocks.

Table 4.14 Scenario 1 Final Result with Fulfilment

Year	Fulfilment (MMSCFD)	Production Rate (MMSCFD)	Demand (MMSCFD)	Action Taken	Condition
2021	175	369.15	590.33	Spot Market	Unfulfilled
2022	0	686.97	631.25	No Import	Fulfilled
2023	111	587.64	672.35	Bontang Via TTL	Fulfilled
2024	232	519.75	692.18	Bontang Via TTL	Fulfilled
2025	488	472.02	852.79	Bontang to TTL	Fulfilled
2026	484	437.39	873.85	Bontang/Tangguh to TTL	Fulfilled
2027	460	452.02	892.95	Bontang/Tangguh to TTL	Fulfilled
2028	581	422.09	947.73	Bontang/Tangguh/Masela to TTL	Fulfilled
2029	586	398.68	966.2	Bontang/Tangguh/Masela to TTL	Fulfilled
2030	608	380.05	977.25	Bontang/Tangguh/Masela to TTL and New Infrastructure	Fulfilled
2031	635	364.98	988.68	Bontang/Tangguh/Masela to TTL and New Infrastructure	Fulfilled
2032	620	352.61	1000.51	Bontang/Tangguh/Masela to TTL and New Infrastrcutre	Unfulfilled

The graph showing a quite fluctuate condition throughout the twelve years. The fluctuation happens to be a result of the fulfilment model this study use, which use to automatically fulfill the demand whatever the condition might happen and pursuing enough amount of stock, not too much not too few so that the simulation will have the best result. This condition is applied for both scenario 1 and scenario 2 as we can see in the Figure 4.31 and Figure 4.32

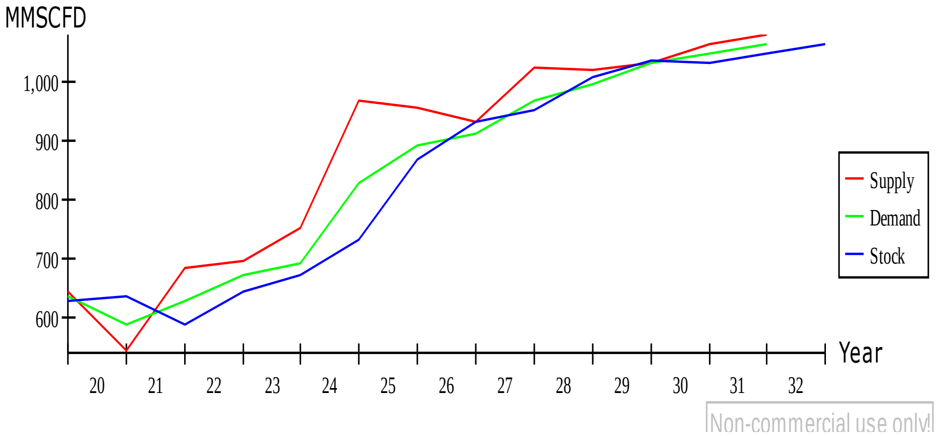


Figure 4.32 Scenario 2 Final Result with Fufilment

For second scenario, supply demand condition also has already fulfilled. The simulation is run according on constraint condition that has been stated before. In this second scenario, only 2021 when the fulfilment is looks unsuccessful. The cause is the same as the first scenario which is the additional gas supplement added with the production rate is below the demand value. The actual value is complete, as we can see in the stock graph, the number of gas stock is higher than the demand, meaning that the demand at that year can be fulfilled by the stock from the previous year. For the other year that stated as fulfilled, same like the previous scenario, it happens that the fulfilment can be completed by the additional source that we can see at the table such as Bontang, Masela and Tangguh that flow through Terminal Teluk Lamong.

From scenario 1 result, it can be seen that the new infrastructure is needed to have at least 40 MMSCFD, and ready before 2030. While in scenario 2, the result show us that the new infrastructure must have at least 125 MMSCFD and ready to operate before 2028.

Table 4.15 Scenario 2 Final Result with Fulfilment

Year	Fulfilment (MMSCFD)	Production Rate (MMSCFD)	Demand (MMSCFD)	Action Taken	Condition
2021	175	369.15	590.33	Spot Market	Unfulfilled
2022	0	686.97	631.25	No Import	Fulfilled
2023	111	587.64	672.35	Bontang Via TTL	Fulfilled
2024	232	519.75	692.18	Bontang Via TTL	Fulfilled
2025	495	472.02	829.51	Bontang/Tangguh to TTL	Fulfilled
2026	517	437.39	892.05	Bontang/Tangguh to TTL	Fulfilled
2027	481	452.02	912.27	Bontang/Tangguh to TTL	Fulfilled
2028	602	422.09	968.26	Bontang/Tangguh/Masela to TTL and New Infrastructure	Fulfilled
2029	622	398.68	994.4	Bontang/Tangguh/Masela to TTL and New Infrastructre	Fulfilled
2030	650	380.05	1032.55	Bontang/Tangguh/Masela to TTL and New Infrastructre	Fulfilled
2031	697	364.98	1047.18	Bontang/Tangguh/Masela to TTL and New Infrastructure	Fulfilled
2032	725	352.61	1062.44	Bontang/Tangguh/Masela to TTL and New Infrastructure	Fulfilled

4.8. Fulfilment Mapping

Based on the demand simulation in that stated in the previous section, Tuban is on number 5 based on how much the residences consume the gas. Despite the chance that Tuban might increase its Industrial number because of the project of Tuban industrial area, the location of Tuban that makes it become the Unspecified New Infrastructure Project. The location can help to stabilize the prize of natural gas, so that Kediri, Madiun and Bojonegoro Residences will not experience an overpriced gas condition. By locating a new Infrastructure in Tuban, there will be a new gas channel so that the cost will not be much different with Surabaya and other area that close to the gas channel. With having Terminal Teluk Lamong to handle the eastern side of East Java (Surabaya, Malang, Madura and Besuki Residences) and Tuban terminal to handle the western side of East Java (Bojonegoro, Madiun and Kediri Residences), East will not be facing a deficit condition anymore.

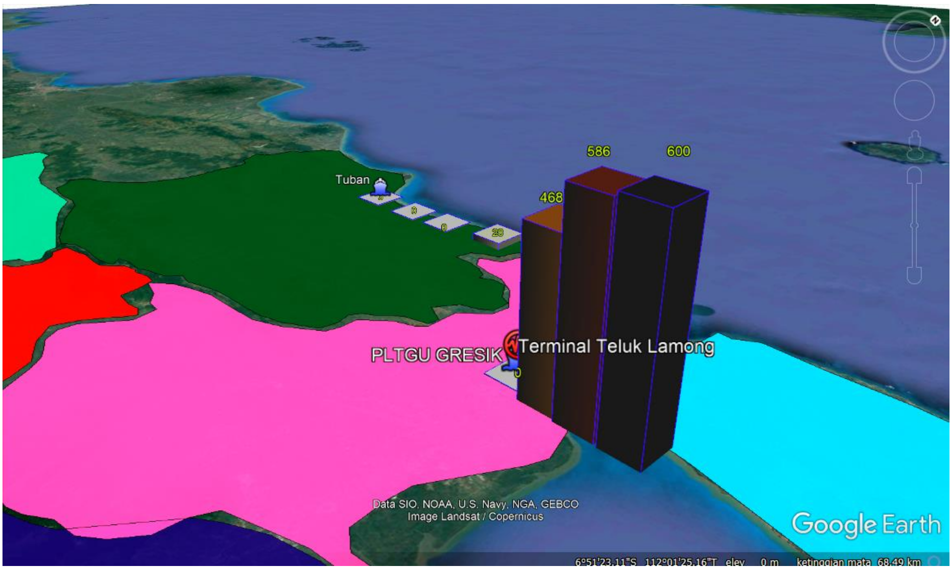


Figure 4.33 Fulfilment Mapping 1

In the picture above we can see that after the simulation run based on scenario 1, we come to a result that we need another infrastructure beside Terminal Teluk Lamong. From previous explanation, Tuban become another solution to support Terminal Teluk Lamong. Because the demand is centered in Surabaya, Terminal Teluk Lamong is maximized to its fully potential. Teluk Lamong will handling Eastern side of East Java and Tuban is handling the Western side of East Java. Based on the simulation of scenario 1, Tuban will have to start to operate in 2030 while Teluk Lamong will start effectively in 2023.

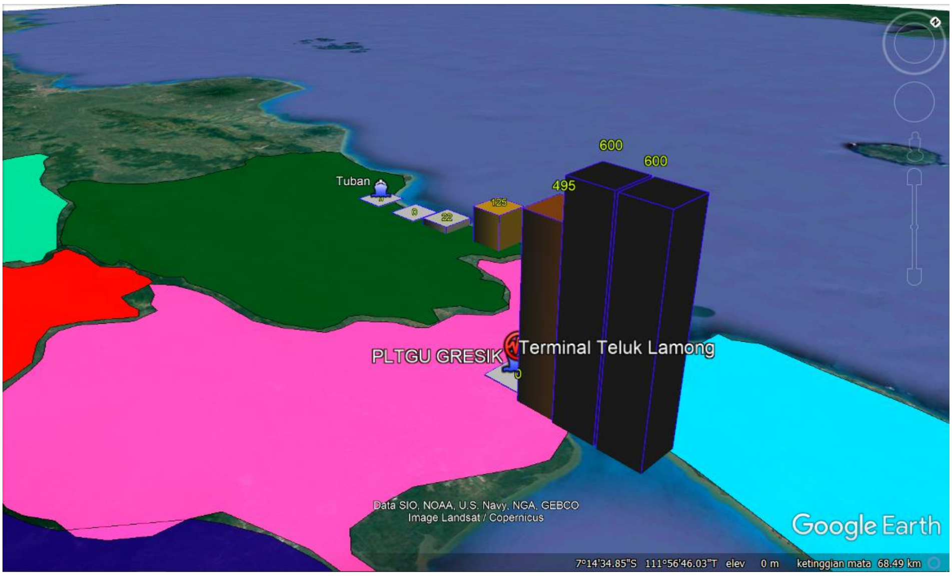


Figure 4.34 Fulfilment Mapping 2

Meanwhile, in the picture above we can see that after the simulation run based on scenario 2, we come to a result that we need another infrastructure beside Terminal Teluk Lamong same as scenario 2. From previous explanation, Tuban become another solution to support Terminal Teluk Lamong. Because the demand is still centered in Surabaya, Terminal Teluk Lamong is maximized to its fully potential. Teluk Lamong will handling Eastern side of East Java and Tuban is handling the Western side of East Java. Based on the simulation of scenario 2, Tuban will have to start to operate in 2028 while Teluk Lamong will start effectively in 2023.

4.9. Midstream Distribution Consideration

	Midstream Distribution Pipe	Vessel
Cost	The initial cost might be extremely costly, because the sources that this study used are crossing a different island. Currently there is no pipeline that facilitated that route.	The initial cost is lower because ship charter cost is not as expensive as establishing a new pipeline.
Safety	Safety enough since its using underwater piping type	Safety enough since an external factor that might cause a failure can be avoided
Implementation	Since currently there is no pipeline established in that area, then the implementation might take a longer time compared to a vessel as the transportation mode	More visible compare to underwater pipeline, since the vessel can be used immediately after (charter not new build)

As we know at the previous section, East Java will be using *terminal teluk lamong* as their receiving terminal and also build a new infrastructure in Tuban to complete the unfulfilled demand throughout East Java. At **Error! Reference source not found.**, it is explained the consideration of what gas transportation that will be used. As stated in the previous section, the additional supply will be obtained from outside java island. It considered 2 type of facilities, the first one is pipe and second one is vessel, with three consideration factors which are cost, safety and implementation.

For pipeline, the cost is extremely high, since this study is using bontang (East Kalimantan), Masela (Maluku) and Tangguh (Papua) looking from the distance to East Java, the cost for building this infrastructure might be imposible because the initial cost that will be spent is going to be enourmous. From safety, actually underwater piping system is quite safety because the location is far from human settlement, but still there is an external factor that might cause a failure such as a damage pipe from vessel’s anchor. For the implementation, since currently there is no available pipeline that installed in that route, the time for establishing those facility comparing to what East Java condition, the demand will not be fulfilled in time.

In the other hand, for vessel, the initial cost will be much lower for both new build vessel and also charter on available vessels. For the safety itself, vessel might be little bit more safety than using a pipeline but the risk on the human is bigger because the vessel still operated by human, but as long as the external factor that threat the safety of the vessels can be avoided then this facitilty is safe enough. For the implementation, using a vessel in the condition that East Java have might be the most possible yet visible option. The vessel can also be use immediately (charter) unlike pipeline that need to be build with a long procedure.

“This page intentionally left blank”

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the research and analysis of natural gas supply and demand condition in East Java, there are several conclusions that the author would summarize:

1. The supply and demand of East Java are unacceptable and inadequate. It will always be faced with hard deficit condition except for 2022. The maximum deficit condition that is East Java facing are 620 MMSCFD in 2031 from scenario 1 and 725 MMSCFD in 2032 basen on scenario 2 with Surabaya Residences became the biggest consumer from both scenarios

2. From the fulfilment simulation, based on the option available East Java need Terminal Teluk Lamong and Tuban as the new infrastructure to sustain the natural gas chain condition and because the distribution pipeline of East Java around those area is well developed. From scenario 1 Terminal Teluk Lamong is contribute with up to 600 MMSCFD while Tuban only up to 35 MMSCFD. Terminal Teluk Lamong will operate effectively in 2022, while tuba new infrastructure is need to be ready atleast in 2030. Meanwhile based on Scenario 2, Terminal Teluk Lamong is also support the gas balance with the value up to 600 MMSCFD while Tuban with 125 MMSCFD. From scenario 2, Terminal Teluk Lamong will operate in 2022, while Tuban new infrastructure need to start running in 2028. The supply is come from areas in Indonesia that not experiencing a deficit condition such as Bontang, New coming project Tangguh Train 3 and Masela.

5.2 Recommendation

Based on the research and analysis regarding the use of system dynamics on determining the pathways of East Java Gas infrastructures, there are some recommendation that the author would suggest:

1. More thorough on using time elements on every variables and level that might contribute to the system, for example the time on delivering the gas from one island to another island or the delay time for build certain infrastructures.

2. Adding more scenario both for the increment of demand and the options for fulfilment. More variables and relations can be added in the future study.
3. More technical and economical aspect can be added in the future study.

REFERENCES

Katili, A. M. F., Artana, K. B. and D.P, A. A. B. D. (2017) ‘Kajian Teknis dan Ekonomis Distribusi Gas Alam dari FSRU Menuju Superblok’, *Jurnal Teknik ITS*, 5(2), pp. 522–527. doi: 10.12962/j23373539.v5i2.19519.

Priyambodo (2018) ‘Analisis Korelasi Jumlah Kendaraan dan Pengaruhnya Terhadap PDRB di Provinsi Jawa Timur Correlation Analytic of Vehicles and GDP on East Java Province’, *Warta Penelitian Perhubungan*, 30, pp. 59–65.

Kementerian ESDM (2013) ‘Pembangunan Jaringan Gas Bumi’, p. 134. Available at: http://www.esdm.go.id/ diunduh tanggal 3 Agustus 2015.

Duggan, J. (2016) ‘System Dynamics Modeling with R’, *An Introduction to System Dynamics System Dynamics Modeling with R*, (June 2016), pp. 1–24. doi: 10.1007/978-3-319-34043-2.

Mu, X. Z., Li, G. H. and Hu, G. W. (2018) ‘Modeling and scenario prediction of a natural gas demand system based on a system dynamics method’, *Petroleum Science*. China University of Petroleum (Beijing), 15(4), pp. 912–924. doi: 10.1007/s12182-018-0269-3.

Daneshzand, F. *et al.* (2018) ‘A System Dynamics Model for Analyzing Future Natural Gas Supply and Demand’, *Industrial and Engineering Chemistry Research*, 57(32), pp. 11061–11075. doi: 10.1021/acs.iecr.8b00709.

ESDM (2019) ‘Indonesia Energy Out Look 2019’, *Journal of Chemical Information and Modeling*, 53(9), pp. 1689–1699. doi: 10.1017/CBO9781107415324.004.

KESDM (2018) ‘Neraca Gas Bumi Indonesia’.

Pejic-Bach, M. and Ceric, V. (2007) ‘Development and Validation of System Dynamics’, *Journal of Information and Organizational Sciences*, 31(1), pp. 171–185.

Prastiwi, R. W. and Suryani, E. (2013) ‘Model Simulasi Sistem Dinamik Dalam Perencanaan Kapasitas Supply Gas Di Sektor Industri dan Rumah Tangga Untuk Memenuhi Pasokan Gas di Masa Mendatang (Studi Kasus: Jawa Timur)’, *Jurnal Teknik Pomits*, 1(1), pp. 1–8.

Jingchun, S., Ding, L. and Fan, W. (2010) ‘The simulated system dynamics analysis of the natural gas supply and demand’, *Kybernetes*, 39(8), pp. 1262–1269. doi: 10.1108/03684921011063547.

PwC (2016) ‘Oil and Gas in Indonesia. Taxation Guide’, (May).

Kusuma, J. (2019) *Market Analysis Of Natural Gas Supply And Demand In Java Island To Enable A Sustainable Scenario With System*.

PT PLN (Persero) (2017) ‘Ruptl Pln 2017-2026’, p. 644. doi: 10.1016/j.ijleo.2015.04.048.

Kinerja, L. and Perindustrian, K. tahun 2015 (2016) ‘Kementerian Perindustrian’.

Sarstedt, M. and Mooi, E. (2014) *A Concise Guide to Market Research - Chapter 7 Regression Analysis, Springer Texts in Business and Economics*. doi: 10.1007/978-3-642-53965-7.

Alif, J. (2019) *Pemodelan Produksi Berkelanjutan Industri Semen Dengan Sistem Dinamis*.

N., R. *et al.* (2001) ‘Natural Gas : Natural Gas ’:, *The New York Times*, (May), pp. 27–30. doi: 10.5772/9804.

Pospíšil, J. *et al.* (2019) ‘Energy demand of liquefaction and regasification of natural gas and the potential of LNG for operative thermal energy storage’, *Renewable and Sustainable Energy Reviews*, 99(September 2018), pp. 1–15. doi: 10.1016/j.rser.2018.09.027.

Sterman, J. (2000) ‘Business Dynamics, System Thinking and Modeling for a Complex World’, *http://lst-iiep.iiep-unesco.org/cgi-bin/wwwi32.exe/[in=epidoc1.in]/?t2000=013598/(100)*, 19.

Yücel, G. and Barlas, Y. (2011) ‘Automated parameter specifi cation in dynamic feedback models based on behavior pattern features’, *System Dynamics Review*, 27, pp. 195–215. doi: 10.1002/sdr.

APPENDIX A

DATA

No	Districts	4 wheels		
		2015	2016	2017
1	Sumenep	10216	11722	12602
2	Bangkalan	16178	18231	19460
3	Sampang	9998	11466	12189
4	Pamekasan	20161	22691	23898
5	Banyuwangi	48974	55166	59182
6	Situbondo	14790	16340	17416
7	Bondowoso	16975	18794	20024
8	Jember	59832	65807	69457
9	Lumajang	29199	32527	34409
10	Probolinggo	39640	43847	46603
11	Pasuruan	52198	58473	62369
12	Batu	21254	23840	25249
13	Malang	86091	90058	95320
14	Nganjuk	18276	20738	37820
15	Trenggalek	19332	21891	23276
16	Tulungagung	53040	58904	62414
17	Blitar	54913	62266	66655
18	Kediri	84794	93049	98178
19	Pacitan	4865	5537	5730
20	Ponorogo	35089	39740	42355
21	Magetan	29138	32669	34554
22	Widodaren	4622	5242	5647
23	Ngawi	16493	18433	19531
24	Madiun	43312	47748	50547
25	Tuban	30208	33829	36084
26	Lamongan	27151	30990	33498
27	Bojonegoro	28828	32410	34424
28	Jombang	41435	46141	48805
29	Mojokerto	58133	65635	70190
30	Sidoarjo	169977	187013	198214
31	Gresik	61624	68687	73204
32	Surabaya	348115	546911	570571

No	Districts	Regression (Linear)	R sqr Value	Growth Percentage
1	Sumenep	1193x + 9127,33	0.97757	5.0667534
2	Bangkalan	1641x + 14674,33	0.9794209	4.7428784
3	Sampang	1095x + 9026,667	0.9628906	4.9125579
4	Pamekasan	1868,5x + 18513	0.959897	4.5274609
5	Banyuwangi	5104x + 44232,67	0.9850794	4.8084293
6	Situbondo	1313x + 13556	0.9892563	4.440673
7	Bondowoso	1524,5x + 15548,67	0.9877136	4.4664088
8	Jember	4812,5x + 55407	0.9809209	4.2108626
9	Lumajang	2605x + 26835	0.9749661	4.4453971
10	Probolinggo	3481,5x + 36400,33	0.9857315	4.4141008
11	Pasuruan	5085,5x + 47509	0.9820902	4.6511731
12	Batu	1997,5x + 19452,67	0.9718803	4.5637816
13	Malang	4614,5x + 81260,67	0.9934797	3.3333059
14	Nganjuk	9772x + 6067,33	0.8427943	8.2091075
15	Trenggalek	1972x + 17555,67	0.971312	4.7522245
16	Tulungagung	4687x + 48745,33	0.9794123	4.4252743
17	Blitar	5871x + 49536	0.9792019	4.864227
18	Kediri	6692x + 78623	0.9821409	4.1681832
19	Pacitan	432,5x + 4512,33	0.9072634	4.4185889
20	Ponorogo	3633x + 31795,33	0.9744951	4.7879162
21	Magetan	2708x + 26704,33	0.9701316	4.5374059
22	Widodaren	512,5x + 4145,33	0.9855461	4.9519452
23	Ngawi	1519x + 15114,33	0.9750341	4.5185001
24	Madiun	3617,5x + 39967,33	0.9832216	4.2977417
25	Tuban	2938x + 27497,67	0.9823045	4.6472951
26	Lamongan	3173,5x + 24199,33	0.985553	5.0735592
27	Bojonegoro	2798x + 26291,33	0.9744967	4.6389719
28	Jombang	3685x + 38090,33	0.9750494	4.4381947
29	Mojokerto	6028,5x + 52595,67	0.9804747	4.7944453
30	Sidoarjo	14118,5x + 156831	0.9859659	4.2863457
31	Gresik	5790x + 56258,33	0.9841424	4.5685513
32	Surabaya	111288x + 266076,33	0.8287715	7.0736486

No	Districts	No of 4 wheels vehicle																	
		Year																	
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
1	Sumenep	10216	11722	12602	13899.33	15092.33	16285.33	17478.33	18671.33	19864.33	21057.33	22250.33	23443.33	24636.33	25829.33	27022.33	28215.33	29408.33	30601.33
2	Bangkalan	16178	18231	19460	21238.33	22879.33	24520.33	26161.33	27802.33	29443.33	31084.33	32725.33	34366.33	36007.33	37648.33	39289.33	40930.33	42571.33	44212.33
3	Sampang	9998	11466	12189	13406.667	14501.667	15596.667	16691.667	17786.667	18881.667	19976.667	21071.667	22166.667	23261.667	24356.667	25451.667	26546.667	27641.667	28736.667
4	Pamekasan	20161	22691	23898	25987	27855.5	29724	31592.5	33461	35329.5	37198	39066.5	40935	42803.5	44672	46540.5	48409	50277.5	52146
5	Banyuwangi	48974	55166	59182	64648.67	69752.67	74856.67	79960.67	85064.67	90168.67	95272.67	100376.67	105480.67	110584.67	115688.67	120792.67	125896.67	131000.67	136104.67
6	Situbondo	14790	16340	17416	18808	20121	21434	22747	24060	25373	26686	27999	29312	30625	31938	33251	34564	35877	37190
7	Bondowoso	16975	18794	20024	21646.67	23171.17	24695.67	26220.17	27744.67	29269.17	30793.67	32318.17	33842.67	35367.17	36891.67	38416.17	39940.67	41465.17	42989.67
8	Jember	59832	65807	69457	74657	79469.5	84282	89094.5	93907	98719.5	103532	108344.5	113157	117969.5	122782	127594.5	132407	137219.5	142032
9	Lumajang	29199	32527	34409	37255	39860	42465	45070	47675	50280	52885	55490	58095	60700	63305	65910	68515	71120	73725
10	Probolinggo	39640	43847	46603	50326.33	53807.83	57289.33	60770.83	64252.33	67733.83	71215.33	74696.83	78178.33	81659.83	85141.33	88622.83	92104.33	95585.83	99067.33
11	Pasuruan	52198	58473	62369	67851	72936.5	78022	83107.5	88193	93278.5	98364	103449.5	108535	113620.5	118706	123791.5	128877	133962.5	139048
12	Batu	21254	23840	25249	27442.67	29440.17	31437.67	33435.17	35432.67	37430.17	39427.67	41425.17	43422.67	45420.17	47417.67	49415.17	51412.67	53410.17	55407.67
13	Malang	86091	90058	95320	99718.67	104333.17	108947.67	113562.17	118176.67	122791.17	127405.67	132020.17	136634.67	141249.17	145863.67	150478.17	155092.67	159707.17	164321.67
14	Nganjuk	18276	20738	37820	45155.33	54927.33	64699.33	74471.33	84243.33	94015.33	103787.33	113559.33	123331.33	133103.33	142875.33	152647.33	162419.33	172191.33	181963.33
15	Trenggalek	19332	21891	23276	25443.67	27415.67	29387.67	31359.67	33331.67	35303.67	37275.67	39247.67	41219.67	43191.67	45163.67	47135.67	49107.67	51079.67	53051.67
16	Tulungagung	53040	58904	62414	67493.33	72180.33	76867.33	81554.33	86241.33	90928.33	95615.33	100302.33	104989.33	109676.33	114363.33	119050.33	123737.33	128424.33	133111.33
17	Blitar	54913	62266	66655	73020	78891	84762	90633	96504	102375	108246	114117	119988	125859	131730	137601	143472	149343	155214
18	Kediri	84794	93049	98178	105391	112083	118775	125467	132159	138851	145543	152235	158927	165619	172311	179003	185695	192387	199079
19	Pacitan	4865	5537	5730	6242.33	6674.83	7107.33	7539.83	7972.33	8404.83	8837.33	9269.83	9702.33	10134.83	10567.33	10999.83	11432.33	11864.83	12297.33
20	Ponorogo	35089	39740	42355	46327.33	49960.33	53593.33	57226.33	60859.33	64492.33	68125.33	71758.33	75391.33	79024.33	82657.33	86290.33	89923.33	93556.33	97189.33
21	Magetan	29138	32669	34554	37536.33	40244.33	42952.33	45660.33	48368.33	51076.33	53784.33	56492.33	59200.33	61908.33	64616.33	67324.33	70032.33	72740.33	75448.33
22	Widodaren	4622	5242	5647	6195.33	6707.83	7220.33	7732.83	8245.33	8757.83	9270.33	9782.83	10295.33	10807.83	11320.33	11832.83	12345.33	12857.83	13370.33
23	Ngawi	16493	18433	19531	21190.33	22709.33	24228.33	25747.33	27266.33	28785.33	30304.33	31823.33	33342.33	34861.33	36380.33	37899.33	39418.33	40937.33	42456.33
24	Madiun	43312	47748	50547	54437.33	58054.83	61672.33	65289.83	68907.33	72524.83	76142.33	79759.83	83377.33	86994.83	90612.33	94229.83	97847.33	101464.83	105082.33
25	Tuban	30208	33829	36084	39249.67	42187.67	45125.67	48063.67	51001.67	53939.67	56877.67	59815.67	62753.67	65691.67	68629.67	71567.67	74505.67	77443.67	80381.67
26	Lamongan	27151	30990	33498	36893.33	40066.83	43240.33	46413.83	49587.33	52760.83	55934.33	59107.83	62281.33	65454.83	68628.33	71801.83	74975.33	78148.83	81322.33
27	Bojonegoro	28828	32410	34424	37483.33	40281.33	43079.33	45877.33	48675.33	51473.33	54271.33	57069.33	59867.33	62665.33	65463.33	68261.33	71059.33	73857.33	76655.33
28	Jombang	41435	46141	48805	52830.33	56515.33	60200.33	63885.33	67570.33	71255.33	74940.33	78625.33	82310.33	85995.33	89680.33	93365.33	97050.33	100735.33	104420.33
29	Mojokerto	58133	65635	70190	76709.67	82738.17	88766.67	94795.17	100823.67	106852.17	112880.67	118909.17	124937.67	130966.17	136994.67	143023.17	149051.67	155080.17	161108.67
30	Sidoarjo	169977	187013	198214	213305	227423.5	241542	255660.5	269779	283897.5	298016	312134.5	326253	340371.5	354490	368608.5	382727	396845.5	410964
31	Gresik	61624	68687	73204	79418.33	85208.33	90998.33	96788.33	102578.33	108368.33	114158.33	119948.33	125738.33	131528.33	137318.33	143108.33	148898.33	154688.33	160478.33
32	Surabaya	348115	546911	570571	711228.33	822516.33	933804.33	1045092.33	1156380.33	1267668.3	1378956.3	1490244.3	1601532.3	1712820.3	1824108.3	1935396.3	2046684.3	2157972.3	2269260.3

No	Districts	Percentage of Vehicle that uses gas (%)												
		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
1	Sumenep	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Bangkalan	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Sampang	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Pamekasan	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Banyuwangi	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Situbondo	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Bondowoso	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Jember	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Lumajang	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Probolinggo	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Pasuruan	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Batu	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Malang	0	0	0	0	0	5	5	5	5	5	5	5	5
14	Nganjuk	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Trenggalek	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Tulungagung	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Blitar	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Kediri	0	0	0	0	0	0	0	0	0	5	5	5	5
19	Pacitan	0	0	0	0	0	0	0	0	0	0	0	0	0
20	Ponorogo	0	0	0	0	0	0	0	0	0	0	0	0	0
21	Magetan	0	0	0	0	0	0	0	0	0	0	0	0	0
22	Widodaren	0	0	0	0	0	0	0	0	0	0	0	0	0
23	Ngawi	0	0	0	0	0	0	0	0	0	0	0	0	0
24	Madiun	0	0	0	0	0	0	0	0	0	0	0	0	0
25	Tuban	0	0	0	0	0	0	0	0	0	0	0	0	0
26	Lamongan	0	0	0	0	0	0	0	0	0	0	0	0	0
27	Bojonegoro	0	0	0	0	0	0	0	0	0	0	0	0	0
28	Jombang	0	0	0	0	0	0	0	0	0	0	0	0	0
29	Mojokerto	0	0	0	0	0	0	0	0	0	5	5	5	5
30	Sidoarjo	0	0	0	0	0	5	5	5	5	5	5	5	5
31	Gresik	5	5	5	5	5	5	5	5	5	5	5	5	5
32	Surabaya	5	5	5	5	5	5	5	5	5	5	5	5	5

No	Districts	Percentage of Vehicle that uses gas (%)												
		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
1	Sumenep	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Bangkalan	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Sampang	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Pamekasan	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Banyuwangi	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Situbondo	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Bondowoso	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Jember	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Lumajang	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Probolinggo	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Pasuruan	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Batu	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Malang	0	0	0	0	0	5	5	5	5	5	5	5	5
14	Nganjuk	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Trenggalek	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Tulungagung	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Blitar	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Kediri	0	0	0	0	0	0	0	0	0	5	5	5	5
19	Pacitan	0	0	0	0	0	0	0	0	0	0	0	0	0
20	Ponorogo	0	0	0	0	0	0	0	0	0	0	0	0	0
21	Magetan	0	0	0	0	0	0	0	0	0	0	0	0	0
22	Widodaren	0	0	0	0	0	0	0	0	0	0	0	0	0
23	Ngawi	0	0	0	0	0	0	0	0	0	0	0	0	0
24	Madiun	0	0	0	0	0	0	0	0	0	0	0	0	0
25	Tuban	0	0	0	0	0	0	0	0	0	0	0	0	0
26	Lamongan	0	0	0	0	0	0	0	0	0	0	0	0	0
27	Bojonegoro	0	0	0	0	0	0	0	0	0	0	0	0	0
28	Jombang	0	0	0	0	0	0	0	0	0	0	0	0	0
29	Mojokerto	0	0	0	0	0	0	0	0	0	5	5	5	5
30	Sidoarjo	0	0	0	0	0	5	5	5	5	10	10	10	10
31	Gresik	5	5	5	5	5	10	10	10	10	15	15	15	15
32	Surabaya	5	5	5	5	5	10	10	10	10	15	15	15	15

Kab/Kota	Uraian Industri	Jumlah IB	Jumlah Kebutuhan Gas (m3/day)	Jumlah Kebutuhuan Gas (mmscfd)
Kab Bangkalan	Industri Makanan	1		
	Industri Barang Galian Bukan Logam	1		
	Industri Alat Angkut Lainnya	1		
		3	**1500**	**0.05454**
Kab Banyuwangi	Industri Makanan	23		
	Industri Pengolahan Tembakau	1		
	Industri Tekstil	4		
	Industri Pakaian Jadi	1		
	Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	1		
	Industri Kertas dan Barang dari Kertas	1		
	Industri Farmasi, Produk Obat Kimia dan Obat Tradisional	6		
	Industri Karet, Barang dari Karet dan plastik	6		
	Industri Barang Galian Bukan Logam	1		
	Industri Barang Logam Bukan Mesin dan Peralatannya	2		
	Industri Furnitur	2		
		48	**24000**	**0.87264**
Kab Blitar	Industri Kertas dan Barang dari Kertas	2		
	Industri Bahan Kimia dan Barang dari Bahan Kimia	4		
	Industri Barang Galian Bukan Logam	1		
	Industri Furnitur	1		
		8	**4000**	**0.14544**
Kab Bojonegoro	Industri Makanan	1		
	Industri Minuman	1		
	Industri Pengolahan Tembakau	10		
	Industri Pakaian Jadi	2		
	Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	1		
	Industri Barang Galian Bukan Logam	2		
	Industri Furnitur	2		
	Industri Pengolahan Lainnya	1		
		20	**10000**	**0.3636**
Kab Bondowoso	Industri Makanan	5		
	Industri Pengolahan Tembakau	6		
	Industri Furnitur	2		
		13	**6500**	**0.23634**
Kab Gresik	Industri Makanan	21		
	Industri Tekstil	8		
	Industri Pakaian Jadi	6		
	Industri Kulit, Barang dari Kulit dan Alas Kaki	4		
	Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	22		
	Industri Kertas dan Barang dari Kertas	10		
	Industri Percertakan dan Reproduksi Media Rekaman	2		
	Industri Produk dari Batu Bara dan Pengilangan Minyak Bumi	2		
	Industri Bahan Kimia dan Barang dari Bahan Kimia	18		
	Industri Farmasi, Produk Obat Kimia dan Obat Tradisional	3		
	Industri Karet, Barang dari Karet dan plastik	15		
	Industri Barang Galian Bukan Logam	11		
	Industri Logam Dasar	11		
	Industri Barang Logam Bukan Mesin dan Peralatannya	8		
	Industri Komputer, Barang Elektroik dan Optik	1		
	Industri Peralatan Listrik	2		
	Industri Mesin dan Perlengkapan Ytdl	4		
	Industri Kendaraan Bermotor, Trailer dan Semi Trailer	4		
	Industri Alat Angkut Lainnya	1		
	Industri Furnitur	17		
		170	**85000**	**3.0906**

No	Kab/Kota	Uraian Industri	Jumlah IB		Jumlah Kebutuhuan Gas (m3/day)	Jumlah Kebutuhuan Gas (mmscfd)
7	**Kab Jember**	Industri Makanan	12			
		Industri Pengolahan Tembakau	10			
		Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	1			
		Industri Kertas dan Barang dari Kertas	1			
		Industri Karet, Barang dari Karet dan plastik	16			
		Industri Barang Galian Bukan Logam	1			
		Industri Mesin dan Perlengkapan Ytdl	1			
				42	**21000**	**0.76356**
8	**Kab Jombang**	Industri Makanan	8			
		Industri Pengolahan Tembakau	3			
		Industri Pakaian Jadi	1			
		Industri Kulit, Barang dari Kulit dan Alas Kaki	6			
		Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	3			
		Industri Farmasi, Produk Obat Kimia dan Obat Tradisional	1			
		Industri Karet, Barang dari Karet dan plastik	3			
		Industri Furnitur	2			
		Industri Pengolahan Lainnya	2			
				29	**14500**	**0.52722**
9	**Kab Kediri**	Industri Makanan	10			
		Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	3			
		Industri Pencetakan dan Reproduksi Media Rekaman	2			
		Industri Farmasi, Produk Obat Kimia dan Obat Tradisional	1			
		Industri Karet, Barang dari Karet dan plastik	1			
		Industri Barang Logam Bukan Mesin dan Peralatannya	2			
		Industri Furnitur	3			
		Industri Pengolahannya Lainnya	1			
				23	**11500**	**0.41814**
10	**Kab Lamongan**	Industri Makanan	7			
		Industri Tembakau	3			
		Industri Tekstil	2			
		Industri Kulit, Barang dari Kulit dan Alas Kaki	1			
		Industri Bahan Kimia dan Barang dari Bahan Kimia	1			
		Industri Karet, Barang dari Karet dan plastik	4			
		Industri Barang Galian Bukan Logam	1			
		Industri Alat Angkut Lainnya	1			
		Industri Pengolahan Lainnya	1			
				21	**10500**	**0.38178**
11	**Kab Lumajang**	Industri Makanan	4			
		Industri Pengolahan Tembakau	1			
		Industri Tekstil	1			
		Industri Pakaian Jadi	1			
		Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	9			
		Industri Karet, Barang dari Karet dan plastik	2			
				18	**9000**	**0.32724**
12	**Kab Madiun**	Industri Makanan	1			
		Industri Pengolahan Tembakau	1			
		Industri Farmasi, Produk Obat Kimia dan Obat Tradisional	1			
		Industri Barang Galian Bukan Logam	1			
				4	**2000**	**0.07272**
13	**Kabupaten Magetan**	Industri Makanan	2			
		Industri Minuman	1			
		Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	2			
				5	**2500**	**0.0909**

No Kab/Kota	Uraian Industri	Jumlah IB	Jumlah Kebutuhuan Gas (m3/day)	Jumlah Kebutuhuan Gas (mmscfd)
14 **Kab Malang**	Industri Makanan	11		
	Industri Minuman	1		
	Industri Pengolahan Tembakau	27		
	Industri Tekstil	4		
	Industri Pakaian Jadi	4		
	Industri Kulit, Barang dari Kulit dan Alas Kaki	6		
	Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	3		
	Industri Kertas dan Barang dari Kertas	6		
	Industri Bahan Kimia dan Barang dari Bahan Kimia	1		
	Industri Farmasi, Produk Obat Kimia dan Obat Tradisional	2		
	Industri Karet, Barang dari Karet dan plastik	3		
	Industri Barang Galian Bukan Logam	7		
	Industri Barang Logam Bukan Mesin dan Peralatannya	3		
	Industri Kendaraan Bermotor, Trailer dan Semi Trailer	9		
	Industri Furnitur	5		
	Industri Pengolahan Lainnya	4		
		96	**48000**	**1.74528**
15 **Kab Mojokerto**	Industri Makanan	7		
	Industri Minuman	4		
	Industri Pengolahan Tembakau	4		
	Industri Tekstil	3		
	Industri Pakaian Jadi	1		
	Industri Kulit, Barang dari Kulit dan Alas Kaki	1		
	Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	2		
	Industri Kertas dan Barang dari Kertas	6		
	Industri Produk dari Batu Bara dan Pengilangan Minyak Bumi	1		
	Industri Bahan Kimia dan Barang dari Bahan Kimia	8		
	Industri Karet, Barang dari Karet dan plastik	12		
	Industri Barang Galian Bukan Logam	9		
	Industri Logam Dasar	7		
	Industri Barang Logam Bukan Mesin dan Peralatannya	5		
	Industri Komputer, Barang Elektroik dan Optik	1		
	Industri Peralatan Listrik	1		
	Industri Kendaraan Bermotor, Trailer dan Semi Trailer	1		
	Industri Alat Angkut Lainnya	1		
	Industri Furnitur	12		
	Industri Pengolahan Lainnya	2		
		88	**44000**	**1.59984**
16 **Kab Nganjuk**	Industri Makanan	2		
	Industri Minuman	2		
	Industri Pengolahan Tembakau	4		
	Industri Pencetakan dan Reproduksi Media Rekaman	1		
		9	**4500**	**0.16362**
17 **Kab Ngawi**	Industri Makanan	2		
	Industri Pengolahan Tembakau	2		
	Industri Karet, Barang dari Karet dan plastik	1		
	Industri Furnitur	1		
		6	**3000**	**0.10908**
18 **Kab Pacitan**	Industri Pengolahan Tembakau	2		
	Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	3		
		5	**2500**	**0.0909**
19 **Kab Pamekasan**	Industri Makanan	3		
	Industri Minuman	1		
	Industri Pengolahan Tembakau	6		
		10	**5000**	**0.1818**

No	Kab/Kota	Uraian Industri	Jumlah IB	Jumlah Kebutuhuan Gas (m3/day)	Jumlah Kebutuhuan Gas (mmscfd)
20	**Kab Pasuruan**	Industri Makanan	42		
		Industri Minuman	13		
		Industri Pengolahan Tembakau	17		
		Industri Tekstil	17		
		Industri Pakaian Jadi	8		
		Industri Kulit, Barang dari Kulit dan Alas Kaki	16		
		Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	11		
		Industri Kertas dan Barang dari Kertas	5		
		Industri Produk dari Batu Bara dan Pengilangan Minyak Bumi	1		
		Industri Bahan Kimia dan Barang dari Bahan Kimia	7		
		Industri Karet, Barang dari Karet dan plastik	13		
		Industri Barang Galian Bukan Logam	8		
		Industri Logam Dasar	5		
		Industri Barang Logam Bukan Mesin dan Peralatannya	3		
		Industri Komputer, Barang Elektroik dan Optik	2		
		Industri Peralatan Listrik	5		
		Industri Mesin dan Perlengkapan Ytdl	1		
		Industri Kendaraan Bermotor, Trailer dan Semi Trailer	3		
		Industri Alat Angkut Lainnya	2		
		Industri Furnitur	24		
		Industri Pengolahan Lainnya	4		
			207	**103500**	**3.76326**
21	**Kab Ponorogo**	Industri Makanan	1		
		Industri Pengolahan Tembakau	2		
		Industri Bahan Kimia dan Barang dari Bahan Kimia	1		
			4	**2000**	**0.07272**
22	**Kab Probolinggo**	Industri Makanan	7		
		Industri Minuman	1		
		Industri Pengolahan Tembakau	2		
		Industri Pakaian Jadi	3		
		Industri Kertas dan Barang dari Kertas	1		
		Industri Bahan Kimia dan Barang dari Bahan Kimia	1		
			15	**7500**	**0.2727**
23	**Kab Sampang**	Industri Makanan	1		
			1	**500**	**0.01818**
24	**Kab Sidoarjo**	Industri Makanan	68		
		Industri Minuman	1		
		Industri Pengolahan Tembakau	13		
		Industri Tekstil	9		
		Industri Pakaian Jadi	4		
		Industri Kulit, Barang dari Kulit dan Alas Kaki	27		
		Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	8		
		Industri Kertas dan Barang dari Kertas	13		
		Industri Pencetakan dan Reproduksi Media Rekaman	11		
		Industri Bahan Kimia dan Barang dari Bahan Kimia	20		
		Industri Farmasi, Produk Obat Kimia dan Obat Tradisional	7		
		Industri Karet, Barang dari Karet dan plastik	35		
		Industri Barang Galian Bukan Logam	12		
		Industri Logam Dasar	8		
		Industri Barang Logam Bukan Mesin dan Peralatannya	17		
		Industri Komputer, Barang Elektroik dan Optik	1		
		Industri Peralatan Listrik	9		
		Industri Mesin dan Perlengkapan Ytdl	3		
		Industri Kendaraan Bermotor, Trailer dan Semi Trailer	3		
		Industri Alat Angkut Lainnya	3		
		Industri Furnitur	20		
		Industri Pengolahan Lainnya	8		
			300	**150000**	**5.454**

No	Kab/Kota	Uraian Industri	Jumlah IB	Jumlah Kebutuhuan Gas (m3/day)	Jumlah Kebutuhuan Gas (mmscfd)
25	**Kab Situbondo**	Industri Makanan	7		
		Industri Bahan Kimia dan Barang dari Bahan Kimia	1		
		Industri Barang Galian Bukan Logam	2		
			10	**5000**	**0.1818**
26	**Kab Sumenep**	Industri Makanan	3		
		Industri Pengolahan Tembakau	1		
			4	**2000**	**0.07272**
27	**Kab Trenggalek**	Industri Makanan	1		
		Industri Pengolahan Tembakau	1		
		Industri Pakaian Jadi	3		
		Industri Barang Galian Bukan Logam	1		
			6	**3000**	**0.10908**
28	**Kab Tuban**	Industri Makanan	3		
		Industri Pengolahan Tembakau	4		
		Industri Tekstil	1		
		Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	1		
		Industri Kertas dan Barang dari Kertas	1		
		Industri Produk dari Batu Bara dan Pengilangan Minyak Bumi	1		
		Industri Bahan Kimia dan Barang dari Bahan Kimia	1		
		Industri Barang Galian Bukan Logam	2		
			14	**7000**	**0.25452**
29	**Kab Tulungagung**	Industri Makanan	7		
		Industri Pengolahan Tembakau	13		
		Industri Tekstil	1		
		Industri Kertas dan Barang dari Kertas	1		
		Industri Kendaraan Bermotor, Trailer dan Semi Trailer	1		
			23	**11500**	**0.41814**
30	**Kota Batu**	Industri Makanan	1		
			1	**500**	**0.01818**
31	**Kota Blitar**	Industri Pengolahan Tembakau	3		
			3	**1500**	**0.05454**
32	**Kota Kediri**	Industri Makanan	7		
		Industri Pengolahan Tembakau	1		
		Industri Pakaian Jadi	1		
		Industri Farmasi, Produk Obat Kimia dan Obat Tradisional	1		
		Industri Karet, Barang dari Karet dan plastik	1		
			11	**5500**	**0.19998**
33	**Kota Madiun**	Industri Makanan	2		
		Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	1		
		Industri Bahan Kimia dan Barang dari Bahan Kimia	1		
		Industri Karet, Barang dari Karet dan plastik	1		
		Industri Alat Angkut Lainnya	1		
			6	**3000**	**0.10908**
34	**Kota Malang**	Industri Makanan	6		
		Industri Minuman	1		
		Industri Pengolahan Tembakau	26		
		Industri Tekstil	1		
		Industri Pakaian Jadi	3		
		Industri Kulit, Barang dari Kulit dan Alas Kaki	3		
		Industri Kertas dan Barang dari Kertas	2		
		Industri Pencetakan dan Reproduksi Media Rekaman	2		
		Industri Bahan Kimia dan Barang dari Bahan Kimia	1		
		Industri Farmasi, Produk Obat Kimia dan Obat Tradisional	1		
		Industri Karet, Barang dari Karet dan plastik	6		
		Industri Barang Galian Bukan Logam	2		
		Industri Barang Logam Bukan Mesin dan Peralatannya	3		
		Industri Peralatan Listrik	4		
		Industri Mesin dan Perlengkapan Ytdl	1		
		Industri Kendaraan Bermotor, Trailer dan Semi Trailer	1		
		Industri Alat Angkut Lainnya	2		
		Industri Furnitur	2		
		Industri Pengolahan Lainnya	1		
			68	**34000**	**1.23624**

No	Kab/Kota	Uraian Industri	Jumlah IB	Jumlah Kebutuhuan Gas (m3/day)	Jumlah Kebutuhuan Gas (mmscfd)
35	**Kota Mojokerto**	Industri Makanan	1		
		Industri Pengolahan Tembakau	1		
		Industri Kulit, Barang dari Kulit dan Alas Kaki	4		
		Industri Kertas dan Barang dari Kertas	1		
		Industri Furnitur	1		
			8	**4000**	**0.14544**
36	**Kota Pasuruan**	Industri Makanan	1		
		Industri Pakaian Jadi	4		
		Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	3		
		Industri Barang Logam Bukan Mesin dan Peralatannya	1		
			9	**4500**	**0.16362**
37	**Kota Probolinggo**	Industri Makanan	4		
		Industri Tekstil	2		
		Industri Pakaian Jadi	7		
		Industri Kulit, Barang dari Kulit dan Alas Kaki	1		
		Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	3		
		Industri Bahan Kimia dan Barang dari Bahan Kimia	2		
		Industri Barang Galian Bukan Logam	3		
			22	**11000**	**0.39996**
38	**Kota Surabaya**	Industri Makanan	38		
		Industri Minuman	1		
		Industri Pengolahan Tembakau	7		
		Industri Tekstil	7		
		Industri Pakaian Jadi	8		
		Industri Kulit, Barang dari Kulit dan Alas Kaki	15		
		Industri Kayu, Barang Dari Kayu dan Gabus (tidak termasuk furnitur) dan Barang Anyaman Dari Bambu, Rotan dan Sejenisnya	10		
		Industri Kertas dan Barang dari Kertas	11		
		Industri Pencetakan dan Reproduksi Media Rekaman	3		
		Industri Bahan Kimia dan Barang dari Bahan Kimia	20		
		Industri Farmasi, Produk Obat Kimia dan Obat Tradisional	4		
		Industri Karet, Barang dari Karet dan plastik	30		
		Industri Barang Galian Bukan Logam	15		
		Industri Logam Dasar	9		
		Industri Barang Logam Bukan Mesin dan Peralatannya	18		
		Industri Komputer, Barang Elektroik dan Optik	3		
		Industri Peralatan Listrik	6		
		Industri Mesin dan Perlengkapan Ytdl	5		
		Industri Kendaraan Bermotor, Trailer dan Semi Trailer	6		
		Industri Alat Angkut Lainnya	5		
		Industri Furnitur	10		
		Industri Pengolahan Lainnya	4		
		Industri Reparasi dan Pemasangan Mesin dan Peralatan	5		
			240	**120000**	**4.3632**
		East Java Total	**1570**	**785000**	**28.5426**

No	District/City	Population Number 2014	2015	2016	2017	2018	2019	2020	Regression Formula (Linear)
District									
1	Pacitan	549481	550986	552307	553388	554394	555304	555984	1079,9x + 548802
2	Ponorogo	865809	867393	868814	869894	870705	871370	871825	996,18x + 865417
3	Trenggalek	686781	689200	691295	693104	694902	696295	697600	1794,8x + 685560
4	Tulungagung	1015974	1021190	1026101	1030790	1035290	1039284	1043182	4535,75x + 1012115,7143
5	Blitar	1140793	1145396	1149710	1153803	1157500	1160677	1163789	3833,5714x + 1137761,1429
6	Kediri	1538929	1546883	1554385	1561392	1568113	1574272	1580092	6856,9643x + 1533153
7	Malang	2527087	2544315	2560675	2576596	2591795	2606204	2619975	15484,3571x + 2513297,8571
8	Lumajang	1026378	1030193	1033698	1036823	1039794	1042395	1044718	3054,2857x + 1024068,4286
9	Jember	2394608	2407115	2419000	2430185	2440714	2450668	2459890	10880,9285x + 2385359,1428
10	Banyuwangi	1588082	1594083	1599811	1604897	1609677	1613991	1617814	4959,9286x + 1584212
11	Bondowoso	756989	761205	765094	768912	772297	775715	778789	3629,392857x + 753911,14286
12	Situbondo	666013	669713	673282	676703	679993	682978	685776	3304,6428x + 663132,5714
13	Probolinggo	1132690	1140480	1148012	1155214	1162092	1168503	1174890	7025,9286x + 1126450,714
14	Pasuruan	1569507	1581787	1593683	1605307	1616578	1627396	1637682	11379,929x + 1559043,143
15	Sidoarjo	2083924	2117279	2150482	2183682	2216804	2249476	2282215	33056,751x + 2051181,857
16	Mojokerto	1070486	1080389	1090075	1099504	1108718	1117688	1126392	9319,9641x + 1061756,143
17	Jombang	1234501	1240985	1247303	1253078	1258618	1263814	1268504	5677,9289x + 1229688,714
18	Nganjuk	1037723	1041716	1045375	1048799	1051900	1054611	1057011	3220,6785x + 1035279,429
19	Madiun	673988	676087	677993	679888	681394	682684	683784	16428x + 672833,5714
20	Magetan	626614	627413	627984	628609	628924	628977	629020	403,07146x + 626607,8571
21	Ngawi	827829	828783	829480	829899	830090	830108	830134	363,39280x + 828021,1429
22	Bojonegoro	1232386	1236607	1240383	1243906	1246927	1249692	1252020	3272x + 1230043,571
23	Tuban	1147097	1152915	1158374	1163614	1168277	1172790	1177016	4978,9282x + 1142953,286
24	Lamongan	1187084	1187795	1188193	1188478	1188913	1189106	1189380	365,35716x + 1186959,857

No	District/City	Population Number							Regression Formula (Linear)
		2014	2015	2016	2017	2018	2019	2020	
25	Gresik	1241613	1256313	1270702	1285018	1299024	1312881	1326420	14138,538x + 1228013,143
26	Bangkalan	945821	954305	962773	970894	978892	986672	994212	8072,3572x + 938220,4286
27	Sampang	925911	936801	947614	958082	968520	978875	989001	10511,577x + 915782,8571
28	Pamekasan	836224	845314	854194	863004	871497	879992	888214	8665,3219x + 827972,8571
29	Sumenep	1067202	1072113	1076805	1081204	1085227	1088910	1092387	4198,9643x + 1063753,857
City									
71	Kediri	278072	280004	281978	284003	285582	287409	289109	1840,1786x + 276376
72	Blitar	136903	137908	139117	139995	140971	141876	142798	9816x + 136013,2857
73	Malang	845973	851298	856410	861414	866118	870682	874890	4829,5356x + 841651,1429
74	Probolinggo	226777	229013	231112	233123	235211	237208	239024	2043,9286x + 224891,1429
75	Pasuruan	193329	194815	196202	197696	199078	200422	201585	1387,7856x + 192038,4286
76	Mojokerto	124719	125706	126404	127279	128282	129014	129891	856x + 123897,8571
77	Madiun	174373	174995	175607	176099	176697	177007	177399	506,85716x + 173997,8571
78	Surabaya	2833924	2848583	2862406	2874699	2885555	2896195	2904751	11816,216x + 2825037
79	Batu	198608	200485	202319	203997	205788	207490	209125	1751,0716x + 196968,8571

No	District/City	Population Number											
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
District													
1	Pacitan	557441.2	558521.1	559601	560680.9	561760.8	562840.7	563920.6	565000.5	566080.4	567160.3	568240.2	569320.1
2	Ponorogo	873386.44	874382.62	875378.8	876374.98	877371.16	878367.34	879363.52	880359.7	881355.88	882352.06	883348.24	884344.42
3	Trenggalek	699918.4	701713.2	703508	705302.8	707097.6	708892.4	710687.2	712482	714276.8	716071.6	717866.4	719661.2
4	Tulungagung	1048401.7	1052937.5	1057473.2	1062009	1066544.7	1071080.5	1075616.2	1080152	1084687.7	1089223.5	1093759.2	1098295
5	Blitar	1168429.7	1172263.3	1176096.9	1179930.4	1183764	1187597.6	1191431.1	1195264.7	1199098.3	1202931.9	1206765.4	1210599
6	Kediri	1588008.7	1594865.7	1601722.6	1608579.6	1615436.6	1622293.5	1629150.5	1636007.5	1642864.4	1649721.4	1656578.4	1663435.3
7	Malang	2637172.7	2652657.1	2668141.4	2683625.8	2699110.1	2714594.5	2730078.9	2745563.2	2761047.6	2776531.9	2792016.3	2807500.6
8	Lumajang	1048502.7	1051557	1054611.3	1057665.6	1060719.9	1063774.1	1066828.4	1069882.7	1072937	1075991.3	1079045.6	1082099.9
9	Jember	2472406.6	2483287.5	2494168.4	2505049.4	2515930.3	2526811.2	2537692.1	2548573.1	2559454	2570334.9	2581215.9	2592096.8
10	Banyuwangi	1623891.4	1628851.4	1633811.3	1638771.2	1643731.1	1648691.1	1653651	1658610.9	1663570.9	1668530.8	1673490.7	1678450.6
11	Bondowoso	782946.29	786575.68	790205.07	793834.46	797463.86	801093.25	804722.64	808352.04	811981.43	815610.82	819240.21	822869.61
12	Situbondo	689569.71	692874.36	696179	699483.64	702788.29	706092.93	709397.57	712702.21	716006.86	719311.5	722616.14	725920.78
13	Probolinggo	1182658.1	1189684.1	1196710	1203735.9	1210761.9	1217787.8	1224813.7	1231839.6	1238865.6	1245891.5	1252917.4	1259943.4
14	Pasuruan	1650082.6	1661462.5	1672842.4	1684222.4	1695602.3	1706982.2	1718362.1	1729742.1	1741122	1752501.9	1763881.9	1775261.8
15	Sidoarjo	2315635.9	2348692.6	2381749.4	2414806.1	2447862.9	2480919.6	2513976.4	2547033.1	2580089.9	2613146.6	2646203.4	2679260.1
16	Mojokerto	1136315.9	1145635.8	1154955.8	1164275.7	1173595.7	1182915.7	1192235.6	1201555.6	1210875.6	1220195.5	1229515.5	1238835.5
17	Jombang	1275112.1	1280790.1	1286468	1292145.9	1297823.9	1303501.8	1309179.7	1314857.6	1320535.6	1326213.5	1331891.4	1337569.4
18	Nganjuk	1061044.9	1064265.5	1067486.2	1070706.9	1073927.6	1077148.2	1080368.9	1083589.6	1086810.3	1090031	1093251.6	1096472.3
19	Madiun	804257.57	820685.57	837113.57	853541.57	869969.57	886397.57	902825.57	919253.57	935681.57	952109.57	968537.57	984965.57
20	Magetan	629832.43	630235.5	630638.57	631041.64	631444.71	631847.79	632250.86	632653.93	633057	633460.07	633863.14	634266.21
21	Ngawi	830928.29	831291.68	831655.07	832018.46	832381.86	832745.25	833108.64	833472.03	833835.43	834198.82	834562.21	834925.61
22	Bojonegoro	1256219.6	1259491.6	1262763.6	1266035.6	1269307.6	1272579.6	1275851.6	1279123.6	1282395.6	1285667.6	1288939.6	1292211.6
23	Tuban	1182784.7	1187763.6	1192742.6	1197721.5	1202700.4	1207679.4	1212658.3	1217637.2	1222616.1	1227595.1	1232574	1237552.9
24	Lamongan	1189882.7	1190248.1	1190613.4	1190978.8	1191344.1	1191709.5	1192074.9	1192440.2	1192805.6	1193170.9	1193536.3	1193901.6

No	District/City	Population Number											
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
25	Gresik	1341121.4	1355260	1369398.5	1383537.1	1397675.6	1411814.1	1425952.7	1440091.2	1454229.8	1468368.3	1482506.8	1496645.4
26	Bangkalan	1002799.3	1010871.6	1018944	1027016.4	1035088.7	1043161.1	1051233.4	1059305.8	1067378.1	1075450.5	1083522.9	1091595.2
27	Sampang	999875.47	1010387.1	1020898.6	1031410.2	1041921.8	1052433.4	1062944.9	1073456.5	1083968.1	1094479.7	1104991.2	1115502.8
28	Pamekasan	897295.43	905960.75	914626.08	923291.4	931956.72	940622.04	949287.36	957952.69	966618.01	975283.33	983948.65	992613.97
29	Sumenep	1097345.6	1101544.5	1105743.5	1109942.5	1114141.4	1118340.4	1122539.4	1126738.3	1130937.3	1135136.3	1139335.2	1143534.2
City													
71	Kediri	291097.43	292937.61	294777.79	296617.96	298458.14	300298.32	302138.5	303978.68	305818.86	307659.04	309499.21	311339.39
72	Blitar	214541.29	224357.29	234173.29	243989.29	253805.29	263621.29	273437.29	283253.29	293069.29	302885.29	312701.29	322517.29
73	Malang	880287.43	885116.96	889946.5	894776.03	899605.57	904435.11	909264.64	914094.18	918923.71	923753.25	928582.78	933412.32
74	Probolinggo	241242.57	243286.5	245330.43	247374.36	249418.29	251462.21	253506.14	255550.07	257594	259637.93	261681.86	263725.79
75	Pasuruan	203140.71	204528.5	205916.28	207304.07	208691.86	210079.64	211467.43	212855.21	214243	215630.78	217018.57	218406.36
76	Mojokerto	130745.86	131601.86	132457.86	133313.86	134169.86	135025.86	135881.86	136737.86	137593.86	138449.86	139305.86	140161.86
77	Madiun	178052.71	178559.57	179066.43	179573.29	180080.14	180587	181093.86	181600.71	182107.57	182614.43	183121.29	183628.14
78	Surabaya	2919566.7	2931382.9	2943199.2	2955015.4	2966831.6	2978647.8	2990464	3002280.2	3014096.5	3025912.7	3037728.9	3049545.1
79	Batu	210977.43	212728.5	214479.57	216230.64	217981.72	219732.79	221483.86	223234.93	224986	226737.07	228488.15	230239.22

No	District/City	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
		Percentage of Household That Uses Gas Line												
District														
1	Pacitan	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Ponorogo	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Trenggalek	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Tulungagung	0	0	0	0	0	0	0	0	0	2	2	2	2
5	Blitar	0	0	0	0	0	0	0	0	0	1.8	1.8	1.8	1.8
6	Kediri	0	0	0	0	0	0	0	0	0	7.3	7.3	7.3	7.3
7	Malang	0	0	0	0	0	0	0	0	0	0.8	0.8	0.8	0.8
8	Lumajang	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Jember	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Banyuwangi	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Bondowoso	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Situbondo	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Probolinggo	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Pasuruan	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
15	Sidoarjo	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
16	Mojokerto	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
17	Jombang	0	0	0	0	0	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
18	Nganjuk	0	0	0	0	0	0	0	0	0	1.7	1.7	1.7	1.7
19	Madiun	0	0	0	0	0	0	0	0	0	2.3	2.3	2.3	2.3
20	Magetan	0	0	0	0	0	0	0	-	0	0	0	0	0
21	Ngawi	0	0	0	0	0	0	0	0	0	2.7	2.7	2.7	2.7
22	Bojonegoro	0	0	0	0	0	0	0	0	0	1.8	1.8	1.8	1.8
23	Tuban	0	0	0	0	0	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
24	Lamongan	0	0	0	0	0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9

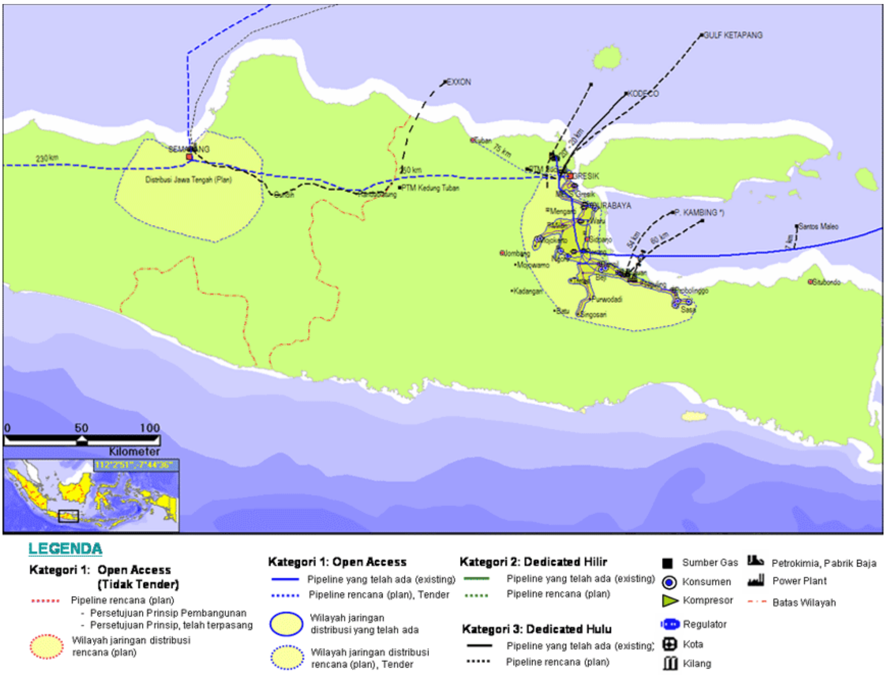
No	District/City	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
		Percentage of Household That Uses Gas Line												
	Gresik	0	0	0	0	0	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
26	Bangkalan	0	0	0	0	0	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
27	Sampang	0	0	0	0	0	0	0	0	0	2	2	2	2
28	Pamekasan	0	0	0	0	0	0	0	0	0	0	0	0	0
29	Sumenep	0	0	0	0	0	0	0	0	0	0	0	0	0
City														
71	Kediri	0	0	0	0	0	0	0	0	0	7.3	7.3	7.3	7.3
72	Blitar	0	0	0	0	0	0	0	0	0	7.2	7.2	7.2	7.2
73	Malang	0	0	0	0	0	0	0	0	0	1.4	1.4	1.4	1.4
74	Probolinggo	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7
75	Pasuruan	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
76	Mojokerto	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
77	Madiun	0	0	0	0	0	0	0	0	0	12	12	12	12
78	Surabaya	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84
79	Batu	0	0	0	0	0	0	0	0	0	0	0	0	0

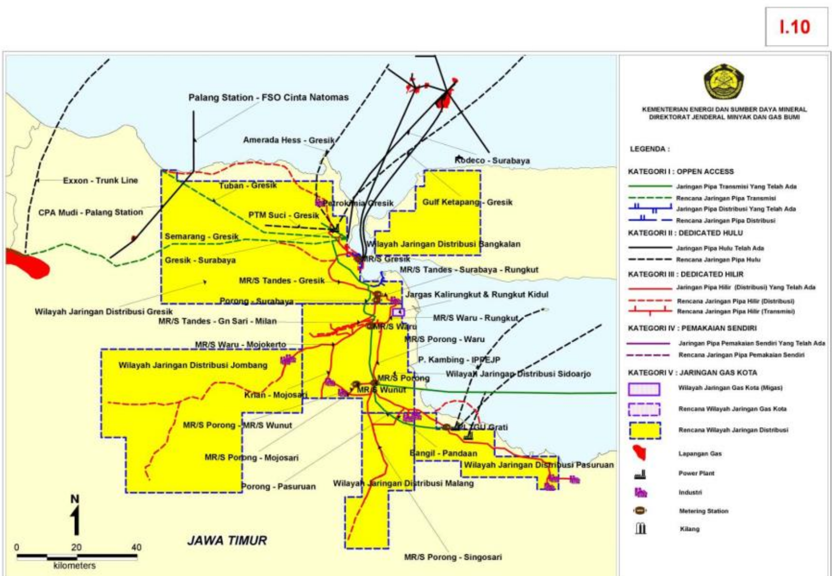
No	District/City	Percentage of Household That Uses Gas Line												
		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
District														
1	Pacitan	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Ponorogo	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Trenggalek	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Tulungagung	0	0	0	0	0	0	0	0	0	2	2	2	2
5	Blitar	0	0	0	0	0	0	0	0	0	1.8	1.8	1.8	1.8
6	Kediri	0	0	0	0	0	0	0	0	0	7.3	7.3	7.3	7.3
7	Malang	0	0	0	0	0	0	0	0	0	0.8	0.8	0.8	0.8
8	Lumajang	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Jember	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Banyuwangi	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Bondowoso	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Situbondo	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Probolinggo	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Pasuruan	0.35	0.35	0.35	0.35	0.35	5.35	5.35	5.35	5.35	10.35	10.35	10.35	10.35
15	Sidoarjo	1.8	1.8	1.8	1.8	1.8	6.8	6.8	6.8	6.8	11.8	11.8	11.8	11.8
16	Mojokerto	8.5	8.5	8.5	8.5	8.5	13.5	13.5	13.5	13.5	18.5	18.5	18.5	18.5
17	Jombang	0	0	0	0	0	1.7	1.7	1.7	1.7	6.7	6.7	6.7	6.7
18	Nganjuk	0	0	0	0	0	0	0	0	0	6.7	6.7	6.7	6.7
19	Madiun	0	0	0	0	0	0	0	0	0	2.3	2.3	2.3	2.3
20	Magetan	0	0	0	0	0	0	0	-	0	0	0	0	0
21	Ngawi	0	0	0	0	0	0	0	0	0	2.7	2.7	2.7	2.7
22	Bojonegoro	0	0	0	0	0	0	0	0	0	1.8	1.8	1.8	1.8
23	Tuban	0	0	0	0	0	1.8	1.8	1.8	1.8	6.8	6.8	6.8	6.8
24	Lamongan	0	0	0	0	0	1.9	1.9	1.9	1.9	6.9	6.9	6.9	6.9

No	District/City	Percentage of Household That Uses Gas Line 2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
	Gresik	0	0	0	0	0	1.6	1.6	1.6	1.6	6.6	6.6	6.6	6.6
26	Bangkalan	0	0	0	0	0	2.1	2.1	2.1	2.1	2.6	2.6	2.6	2.6
27	Sampang	0	0	0	0	0	0	0	0	0	2	2	2	2
28	Pamekasan	0	0	0	0	0	0	0	0	0	0	0	0	0
29	Sumenep	0	0	0	0	0	0	0	0	0	0	0	0	0
City														
71	Kediri	0	0	0	0	0	0	0	0	0	7.3	7.3	7.3	7.3
72	Blitar	0	0	0	0	0	0	0	0	0	7.2	7.2	7.2	7.2
73	Malang	0	0	0	0	0	0	0	0	0	1.4	1.4	1.4	1.4
74	Probolinggo	8.7	8.7	8.7	8.7	8.7	13.7	13.7	13.7	13.7	18.7	18.7	18.7	18.7
75	Pasuruan	0.35	0.35	0.35	0.35	0.35	5.35	5.35	5.35	5.35	10.35	10.35	10.35	10.35
76	Mojokerto	8.5	8.5	8.5	8.5	8.5	13.5	13.5	13.5	13.5	18.5	18.5	18.5	18.5
77	Madiun	0	0	0	0	0	0	0	0	0	12	12	12	12
78	Surabaya	5.84	5.84	5.84	5.84	5.84	10.84	10.84	10.84	10.84	15.84	15.84	15.84	15.84
79	Batu	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX B

Pipeline Map





AUTHOR BIODATA

Muhammad Haekal, Born in Jakarta, June 19th 1999. The author was take formal education at PB Soedirman Elementary School, 41 National Junior High School, and 28 National Senior High School. After gratuated from senior high school in 2016, author continuing his study at Join Degree Bachelor Program Marine Engineering, Faculty of Marine Technology, Sepuluh Nopember Institute of Technology and registered under student registration number 04211641000024. During the study period, the writer was active in various committee and organizational activities, such as being a Staff of the Department of Internal Affairs in the ITS HIMASISKAL 2017/2018, the Steering Committee of the HIMASISKAL FTK ITS 2018/2019, Staff and Head of Internal Affairs Department of NACE-SC ITS SC 2017/2018 2018/2019, Staff of the Oil Rig Design Competition of Petrolida 2017, Liaison Officer Coordinator of PETROLIDA 2018 and Vice Project Officer of Marine Icon 2019. The practical work experience that has been taken by the author at Samudera Shipyard Semarang and PT Samudera Sarana Logistic Surabaya. In the fourth year of college, the author took the concentration of Final Projects in the field of Reliability Availibility Management and Safety (RAMS).