FINAL PROJECT – TI 141501

PROFIT MAXIMIZATION BY UTILIZING EXCESS COKE OVEN GAS AND BLAST FURNACE GAS IN PT X

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Surabaya 2016

TUGAS AKHIR – TI 141501

MEMAKSIMALKAN PROFIT DENGAN MEMANFAATKAN KELEBIHAN GAS *COKE OVEN* DAN GAS *BLAST FRUNACE* DI PT X

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Surabaya 2016

Legalization Page

Profit Maximization by Utilizing Excess Coke Oven Gas and Blast Furnace Gas in PT X

Undergraduate Thesis

Proposed to fulfill one of several requirements to obtain
bachelor of engineering
Study Program of Bachelor Industrial Engineering Department
Industrial Technology Faculty
Institut Teknologi Sepuluh Nopember
Surabaya

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KEMENTERIAN RISET, TEKNOLOGI, DAN PENDIDIKAN TINGGI
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
FAKULTAS TEKNOLOGI INDUSTRI
JURUSAN TEKNIK INDUSTRI

Surabaya, July 2016

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ABSTRACT

PT X is currently struggling on its steel business since the price of steel has been going worse due to Chinese's steel oversupply and natural gas (NG) price has been going high and it has been getting noncompetitive, whereas NG cost takes up to 49% of the expense in production that company should spend. To overcome the critical matters, on early of July 2012, PT X desired to execute expansion program by constructing Blast Furnace Complex. There will be 32,600 NCMH excess gas coming from Blast Furnace Complex named Blast Furnace Gas (BFG) and 11,722 NCMH from Coke Oven Plant named Coke Oven Gas (COG). The company thinks of utilizing the excess COG and BFG to combustion process in their plants. But the problem are that the calorific of BFG, COG, and natural gas are different, there will be investment and operational cost that are different for each plant if they are to get the allocation of the excess gas, and the limited amount of excess COG and BFG. This research aims to build optimization model of excess Coke Oven Gas and Blast Furnace Gas allocation to maximize total profit of production plants. Based on the valuation and optimization model and comparison between location scenario A and B, the result is to allocate the gas to Billet Steel Plant (NG 7,276 NCMH, 5,035 NCMH BFG, and 3,677 NCMH COG), Cold Rolling Mill (NG 9,513 NCMH, 6,584 NCMH BFG, and 4,808 NCMH COG), and Wire Rod Mill (NG 4,406 NCMH, 3,218 NCMH BFG, and 2,404 NCMH COG) with total profit USD 44,900,365.69.

Keywords: blast furnace gas, coke oven gas, financial modeling, optimization, profit

MEMAKSIMALKAN PROFIT DENGAN MEMANFAATKAN KELEBIHAN GAS *COKE OVEN* DAN GAS *BLAST FURNACE* DI PT X

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ABSTRAK

PT X sedang mengalami kesulitan dalam bisnis bajanya sejak harga baja turun secara drastis akibat suplai berlebihan dari Cina dan harga gas alam semakin tinggi, yang membuat produk baja tidak kompetitif, padahal gas alam memakan hingga 49% pada biaya produksi yang perusahaan habiskan. Untuk mengatasi masalah kritis ini, pada bulan Juli 2012, PT X memutuskan untuk menjalankan program ekspansi dengan membangun *Blast Furnace Complex*. Akan ada 32,600 NCMH kelebihan gas yang datang dari *Blast Furnace Complex* bernama *Blast Furnace Gas* (BFG) dan 11,722 NCMH dari pabrik *Coke Oven* bernama *Coke Oven Gas* (COG). Perusahaan berpikir untuk memanfaatkan kelebihan COG dan BFG pada proses pembakaran di pabrik-pabriknya. Namun permasalahannya adalah kalor pada BFG, COG, dan gas alam berbeda, akan ada investasi dan biaya operasi yang berbeda untuk setiap pabrik jika mereka akan mendapat alokasi kelebihan gas, dan keterbatasan jumlah kelebihan COG dan BFG. Penelitian ini bertujuan untuk membangun model optimasi alokasi kelebihan COG dan BFG untuk memaksimalkan total profit pabrik produksi. Berdasarkan hasil model keuangan dan optimasi, juga perbandingan antara skenario lokasi A dan B, hasilnya adalah mengalokasikan gas ke pabrik baja billet (gas alam 7,276 NCMH, 5,035 NCMH BFG, and 3,677 NCMH COG), pabrik baja lembaran dingin (gas alam 9,513 NCMH, 6,584 NCMH BFG, and 4,808 NCMH COG), dan pabrik baja kawat (gas alam 4,406 NCMH, 3,218 NCMH BFG, and 2,404 NCMH COG), dengan total profit USD44,900,365.69.

Kata kunci: *blast furnace gas*, *coke oven gas,* model keuangan, optimasi, profit

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CHAPTER I
INTRODUCTION

This chapter consists of background of the research, problem formulation, objectives, benefit, boundary, and writing systematics.

1.1 Background

PT X is the largest steel producer and the only integrated-steel plant company in Indonesia, which has a steel production capacity of 3.15 million tones per year. As of 2015, PT X has six plants, which are Direct Reduction Plant to process iron ore pallets, Slab Steel Plant and Billet Steel Plant, Hot Strip Mill, Cold Rolling Mill, and Wire Rod Mill.

As of now, all the plants in PT X are using natural gas and electricity. But in recent years, natural gas price has been going high and it has been getting non-competitive, whereas fuel cost takes up to 49% of the expense in production that company should spend. On the other hand, Direct Reduction Plant as the only iron making plant in PT X can only process high quality iron ore, which the price also is higher than the regular one, whereas raw material takes up to 50% of the production cost. Moreover, steel industry in general is suffering since the price of steel has been going worse, too, due to Chinese's steel oversupply. Those problems make the production cost of the company gets higher while the demand goes down quite drastically.

To overcome the critical matters, on early of July 2012, PT X desired to execute its expansion program by constructing Blast Furnace Complex, consisting of Blast Furnace Plant, Sintering Plant, Coke Oven Plant, Pig Iron Caster, Stockyard & Material/Hot Metal Handling, Hot Metal Treatment Plant, and Utilities to produce 1,200,000 (one million and two hundred thousand) tons per year of hot metal and pig iron to be charged into its existing steel-making facilities.

The new plants will be using coal as the main fuel, in hope that it can take back the company in competitive offers for the products as the fuel cost will be lower and some process related to melting in their current plants can be skipped.

Coal price has been observed competitive and lower than natural gas they are currently using. Another advantage of constructing Blast Furnace is that it can process regular iron ore, which means lower expense in raw material.

The purpose of a blast furnace is to chemically reduce and physically convert iron oxides into liquid iron called hot metal. The blast furnace is a huge, steel stack lined with refractory brick, where iron ore, coke and limestone are dumped into the top, and preheated air is blown into the bottom. The raw materials require 6 to 8 hours to descend to the bottom of the furnace where they become the final product of liquid slag and liquid iron. These liquid products are drained from the furnace at regular intervals. The hot air that was blown into the bottom of the furnace ascends to the top in 6 to 8 seconds after going through numerous chemical reactions (American Iron and Steel Institute, 2005). This blast furnace function will not replace Direct Reduction planning albeit the same purpose of the plant, but it will support the process of iron making instead.

A blast furnace operation demands the high quality of raw materials, operation, and operators. Coke is the most important raw material fed into the blast furnace in terms of its effect on blast furnace operation and hot metal quality. A high quality coke should be able to support a smooth descent of the blast furnace burden with as little degradation as possible while providing the lowest amount of impurities, highest thermal energy, highest metal reduction, and optimum permeability for the flow of gaseous and molten products. The coke-making process involves carbonization of coal to high temperatures (1100°C) in an oxygen deficient atmosphere in order to concentrate the carbon (American Iron and Steel Institute, 2005).

Based on the construction plan and engineering calculation, there will be excess waste gas coming from Blast Furnace Complex, specifically in Blast Furnace and Coke Oven Plant named Blast Furnace Gas (BFG) and Coke Oven Gas (COG). The total of excess gas will be 32,600 NCMH of BFG and 11,722 NCMH of COG.

Coke-oven gas is a fuel gas having a medium calorific value that is produced during the manufacture of metallurgical coke by heating bituminous coal to temperatures of 900°C to 1000°C in a chamber from which air is excluded

(Thermopedia, 2011). Raw coke oven gas is a flammable gas with lower explosive limit of 4 % and upper flammability limit of 75 %. CO gas has a calorific value ranging between 4000 to 4600 Kcal/N Cum. It has a theoretical flame temperature of 1982 degree Celsius and a rate of flame propagation that allows its actual flame temperature to be close to its theoretical flame temperature. (Satyendra, 2015).

Meanwhile, According to Ruj (2010), BFG is a by-product of blast furnaces, also a hazardous gas that is generated when the iron ore is reduced with coke to metallic iron. It has a very low heating value, about 93 BTU/cubic foot, because it consists of about 56% nitrogen,16.5% carbon dioxide, which are not flammable. Hydrogen 2% and methane 0.5 % are also present in this gas. The rest 25% is carbon monoxide, which has a fairly low heating value. It is commonly used as a fuel within the steel works, but it can be used in boilers and power plants equipped to burn it. It may be combined with natural gas or coke oven gas before combustion or a flame support with richer gas or oil is provided to sustain combustion.

By looking at the composition and advantage of the gas, the company sees good opportunity to utilize the excess COG and BFG to combustion process in their plants to reduce the consumption of natural gas or saving on the cost of fuel. But the problem are that the calorific of BFG, COG, and natural gas are different that makes their flammability are also different, there will be investment and operational cost that are different for each plant if they are to get the allocation of the excess gas, and the limited amount of excess COG and BFG that makes it impossible to allocate it to all plants with combustion process.

Thus, this research is conducted to analyze the most optimum allocation of COG and BFG that makes the highest value for the company.

1.2 Problem Formulation

The problem of the company in utilizing the excess Coke Oven Gas and Blast Furnace Gas as fuel is solving the optimum gas allocation scenario for plants that will maximize the profit of PT X.

1.3 Objectives

The objectives of this research are:

1. Building optimization model of excess Coke Oven Gas and Blast Furnace Gas allocation to maximize the profit of the company.
2. Conducting sensitivity analysis to identify critical financial elements that affect the chosen scenario's profit.

1.4 Benefits

The benefits obtained from conducting this research for the author are:

1. The company will get recommendation of the most optimum allocation they can consider to maximize the profit of the project.
2. The author can get to know more about the applied knowledge of the study in this research.
3. The reader can get the knowledge of maximizing value of the project by optimization in allocation and use this undergraduate thesis report for further research.

1.5 Boundary

The boundary of this research includes limitations and assumptions used in the study.

1.5.1 Limitations

Limitations applied in this research are:

1. Blast Furnace Gas and Coke Oven Gas as the object of this research is one that is in Blast Furnace Complex owned by PT X.
2. Utilization of Blast Furnace Gas and Coke Oven Gas as power fuel is only for internal use of the company.
3. The remaining Blast Furnace Gas and Coke Oven Gas after allocation will be flared.

1.5.2 Assumptions

Parameters used in this research are based on the development plan of company.

1.6 Writing Systematics

This sub-chapter explains the systematics of writing that is used in this research. Hereby is the arrangement:

CHAPTER I FOREWORD

This chapter contains background of the research, problem formulation that will be solved in the study, the boundary, objectives, benefits, and the writing systematics of the research.

CHAPTER II LITERATURE REVIEW

This chapter contains the fundamental of the research using various literature reviews from previous researches to help author determining the suitable method as well as to analyze the result of the problem solving.

CHAPTER III RESEARCH METODOLOGY

This chapter elaborates research methodology that contains of systematic steps of research that has to be done by the author to solve the problem properly.

CHAPTER IV DATA COLLECTION AND PROCESSING

This chapter contains all the data needs and data that will be used in calculation process as well as the processing that aims to solve the problem and achieve the objective of the research. The data is taken in form primary and secondary, either from expert or company's management.

CHAPTER V DATA ANALYSIS AND INTERPRETATION

This chapter consists of the elaborations of analysis and data interpretation from the result of data processing. Meanwhile, data interpretation will be about the detail explanation of the data processed. The result obtained from data processing will be the answer of the problem and become the fundamental of the drawing conclusion as well as suggestion/recommendations.

CHAPTER VI CONCLUSION AND RECOMMENDATIONS

This chapter will elaborate the conclusion of the research based on the result of data processing and the analysis to answer the problem and accomplish the objectives, as well as giving the company recommendations for improvements and opportunities for potential research.

CHAPTER II
LITERATURE REVIEW

This literature review chapter will be about the blast furnace and its emission, coke oven and its emission, financial model, optimization, specifically linear programming, project valuation, Net Present Value, Internal Rate of Return (IRR), and WACC as the fundamental to conduct the data processing and the analysis of processed data.

2.1 Blast Furnace

A blast furnace is a huge steel container many meters high and lined with heat-resistant material. The solid raw materials (iron ore, coke and limestone) are added from top, and hot air is blasted in from the bottom. The blast furnace is hottest at the bottom where the coke burns/ it is coolest at the top where the iron forms and trickles down to the bottom, from where it is tapped off (BBC, 2007).

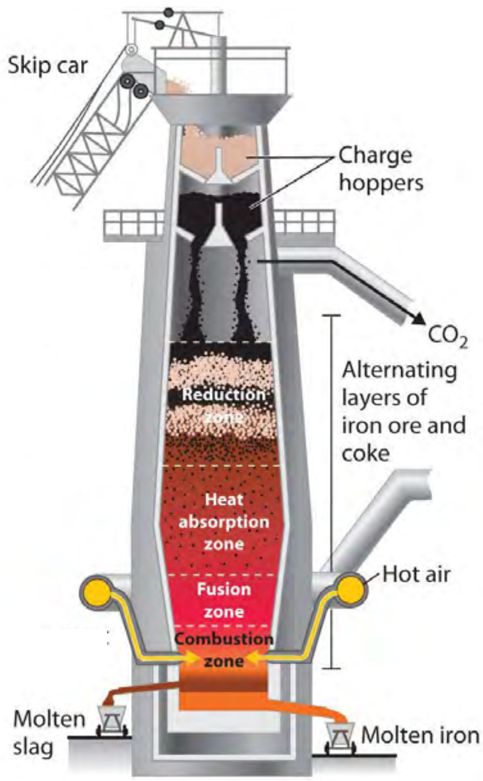

Figure 2.1 Blast Furnace
(Source: UCDavis, 2016)

In the blast furnace there are several chemical reactions taking place; that eventually result in the desired product (iron) being extracted. As it is shown in figure 2.1, the coke (carbon) burns with oxygen to produce carbon dioxide. This reaction is exothermic. The CO2 then reacts with more coke to give carbon monoxide. It results reducing agent. It reacts with the iron ore to give molten iron, which trickles to the bottom of the furnace where it is collected. The limestone in the furnace decomposes, forming calcium oxide. This is a fluxing agent, and combines with impurities to make slag, which floats on top of the molten iron is removed (Science Aid, 2007).

The purpose of a blast furnace is to chemically reduce and physically convert iron oxides into liquid iron called "hot metal". The blast furnace is a huge, steel stack lined with refractory brick, where iron ore, coke and limestone are dumped into the top and preheated air is blown into the bottom. The raw materials require 6 to 8 hours to descend to the bottom of the furnace where they become the final product of liquid slag and liquid iron. These liquid products are drained from the furnace at regular intervals. The hot air that was blown into the bottom of the furnace ascends to the top in 6 to 8 seconds after going through numerous chemical reactions. Once a blast furnace is started it will continuously run for four to ten years with only short stops to perform planned maintenance (American Iron and Steel Institute, 2005).

2.1.1 Blast Furnace Gas

Blast furnace (BF) gas is a gaseous by product which is generated while producing hot metal (liquid iron) in a blast furnace. The operation of the blast furnace is controlled to produce hot metal of a specified quality and during this production BF gas comes out from the furnace top (Satyendra, 2013).

During production of hot metal in a blast furnace, hot air blast is blown in the furnace through the tuyeres. The oxygen of the blast reacts with the coke. The gas produced by this reaction moves up the furnace shaft which has been charged with ores, fluxes and coke. After a number of chemical reactions and a travel of around 25-30m the BF gas comes out of the furnace as a heated, dust laden and lean combustible gas. Around 1500-1700 Cu m/ton of hot metal of BF gas is generated during the process. Though the purpose of partial combustion of carbon in a blast furnace is to remove the oxygen from the ore but the volume of gas generated in a blast furnace makes the blast furnace as a gas producer. The percentage of CO and CO2 in BF gas is directly related to the amount of carbon in the charged coke and amount of CO2 in the charged flux (Limestone and dolomite). The coke rate (The rate of carbon consumption) in the blast furnace depends mainly upon the type of the hot metal to be made, the chemical and the physical characteristics of the charged materials, the distribution of the materials in the furnace stack, the temperature and the oxygen enrichment of the hot air blast (Satyendra, 2013).

The total amount of CO+CO2 gases by volume in the BF gas at the furnace top is around 40% of the total gas volume. The CO/CO2 ratio can vary in a blast furnace from 1.25:1 to 2.5:1. Higher percentage of CO in the gas makes the BF gas hazardous.

The hydrogen content of the gas can vary from 2% to 5% depending upon the type and amount of fuel injected in the tuyeres of the blast furnace. The balance component of the BF gas is nitrogen. Methane (CH4) can also be present in the BF gas up to 0.2% (Satyendra, 2013).

In blast furnace some hydro cyanide (HCN) and Cyanogen gas (CN2) can also formed due to the reaction of nitrogen in the hot air blast and carbon of the coke. The reaction is catalyzed by the alkali oxides. These gases are highly poisonous. BF gas can contain these cyano compounds in the range of 200 mg to 2000 mg/Cu m (Satyendra, 2013).

BF gas leaves the BF top at a temperature of approximately 120 degree C to 370 degree C and a pressure of 345 mm to 2500 mm mercury gauge pressure. It carries at this stage around 20 to 115 grams per Cu m of water vapor and 20 to 40 grams per Cu m of dust commonly known as Flue dust. The particle size of the flue dust can vary from a few microns to 6 mm. BF gas has the following characteristics

1. Very low calorific value (CV) in the range of 700 to 850 Kcal/Cu m (2930 to 3556 Kilojoules/Cu m). CV is very much dependent on the coke rate.

2. It has a high density. It is around 1.250 Kg/Cu meter at the standard temperature and pressure (STP) which is 0 degree Celsius and 1 atm. Pressure. This density is highest amongst all the gaseous fuel. Since the density is higher than the density of air it settles in the bottom in case of a leakage.
3. It has low theoretical flame temperature, which is around 1455 degree Celsius.
4. It has low rate of flame propagation. It is lower than any other common gaseous fuel.
5. BF gas burns with a non-luminous flame.
6. Auto ignition point of BF gas is around 630 degree Celsius.
7. BF gas has lower explosive limit (LEL) of 27% and upper explosive limit (UEL) of 75% in an air gas mixture at normal temperature and pressure.

The high top pressure of BF gas is utilized to operate a generator (Top gas pressure Recovery Turbine – i.e. TRT in short). TRT can generate electrical energy (Power) up to 35 kWh/ ton of hot metal without burning any fuel. Dry type of TRT can produce more power then wet type (Satyendra, 2013).

The sensible heat in the blast furnace top gases was first utilized in 1832 to transfer heat to the cold blast. Originally, this heat exchanger was mounted on the top of the furnace. In 1845, the first attempts were made to make use of heat of combustion of BF gas, but the burning of BF gas was not successful till 1857. It is probable that the progress in the utilization of BF gas was delayed due to its high dust content, the problems of cleaning and handling, and the low cost of solid fuel. Increasing cost of other fuels and competition forced its use (Satyendra, 2013).

In the past BF gas use was restricted to the heating of hot blast stoves in the blast furnaces and using it in multi fuel boilers. It was not considered to be economical for other uses because of its various characteristics. However in the recent years several factors have contributed to its enlarged use. The factors, which have contributed to the enlarged use of gas, are as follows:

1. Increase in the cost of the purchased fuels.

2. Technical improvement in gas cleaning thus improving the cleanliness of the gas.
3. Technology development for BF gas preheating

In integrated steel plants, BF gas is normally being used mixed with either coke oven gas or converter gas or both. The mixed gas is used as a fuel in various furnace of the plant. BF gas without mixing and without preheat can be used in BF stoves, soaking pits, normalizing and annealing furnaces, foundry core ovens, gas engines for blowing, boilers for power generation, gas turbines for power generation (Satyendra, 2013).

The thermal advantage of using BF gas in gas engines for blowing and for power generation has to overcome the heavy investment and maintenance expense required for such equipment. The modern boiler house utilizes high steam pressure and temperature with efficient turbo-blowers and generators. This has sufficiently reduced the thermal advantage of gas engines and hence their use has become difficult to get justified. Some steel plants in Asia and Europe have been successful in the use of direct connected gas turbines for driving generators (Satyendra, 2013).

Preheated BF gas along with preheated air has been used successfully in coke-oven heating, soaking pits, and reheating furnaces. When BF gas is preheated, it should have a minimum cleanliness of 0.023 grams per cubic meter and in all cases where this gas is used, extra precautions is needed to prevent the escape of unburned BF gas into the surroundings since it contains a large percentage of toxic CO gas (Satyendra, 2013).

BF gas is used for many applications in a steel plant and, in addition, is used frequently for heating coke ovens and sometimes is mixed with other gases as a fuel. In blast furnace operations, where the blast-furnace gas has a heating value approaching a low value of 700 Kcal per cubic meter, it is necessary to switch the gas with other fuels to obtain very high hot-blast temperature from the stove (Satyendra, 2013).

2.2 Coke Oven Plant

A world class blast furnace operation demands the highest quality of raw materials, operation, and operators. Coke is the most important raw material fed into the blast furnace in terms of its effect on blast furnace operation and hot metal quality. Due to the development of iron and steel industry coke oven plant has become an integral part of iron and steel industry. Due to increasing demand of iron and steel, there has been a considerable increase in the coke oven capacity which resulted increase output of coal chemicals (Coopers Creek Chemichal Corporation, 2006).

Figure 2.8 Coke Oven
(Source: Vizag Steel, 2016)

Coke oven plant as captured in figure 2.2 consists of Coke oven batteries containing number of oven (around 65 ovens in each battery). The coal is charged to the coke oven through charging holes. The coal is then carbonized for 17-18 hours, during which volatile matter of coal distills out as coke oven gas and is sent to the recovery section for recovery of valuable chemicals. The ovens are maintained under positive pressure by maintaining high hydraulic main pressure of 7 mm water column in batteries. The coking is complete when the central temperature in the oven is around 950-1000 oC. At this point the oven is isolated from hydraulic mains and after proper venting of residual gases, the doors are opened for coke pushing. At the end of coking period the coke mass has a high volume shrinkage which leads to detachment of mass from the walls ensuring easy pushing. The coke is then quenched and transferred to coke sorting plant (NPTEL, 2013).

The control of oven pressure is quite important because lower pressure leads to air entry while higher pressure leads to excessive gassing, leakage of doors, stand pipe etc. Proper leveling of coal is important and care is taken so that free board space above (300 mm) is maintained to avoid choking (NPTEL, 2013).

Coke oven plants are integral part of a steel plant to produce coke, which is used as fuel in the blast furnace. Coke oven plant produces important by product coal chemical tar, ammonia, crude benzoyl which is fractionated to produce aromatics-benzene toluene, xylene (NPTEL, 2013).

2.2.1 Coke Oven Gas

During the carbonization of coking coal in a coke oven battery for the production of coke, around 25-30% of the coal charged is driven off as effluent gases rich in volatile matter and moisture. This gas is known as coke oven gas (CO gas). In the non-recovery or heat recovery coke ovens this gas is burnt in the oven itself and provides the required heat for the carbonization of coal. In case of by product battery, the evolved gas is removed as raw gas and is treated in a byproduct plant to give a clean fuel gas. In the byproduct plant, condensable, corrosive and economically valuable components are removed. During the cycle of coking, the gas is produced during majority of the coking period. The composition and rate of evolution of the CO gas changes during the period and the evolution of CO gas is normally complete by the time the coal charge in the battery reaches 700 degree C. The final yield of clean coke oven gas after treatment in the byproduct plant is around 300 N Cum per ton of dry coal. The yield of gas is dependent upon i) volatile matter in the charge coal and ii) carbonization condition. The density of CO gas at standard temperature and pressure is 0.545 Kg/Cum (Satyendra, 2013).

The raw CO gas may contain hydrogen and methane, ammonia, carbon monoxide, carbon dioxide, ethane, ethylene, benzene, oxygen and nitrogen, hydrogen sulfide, water vapor, cyclopentadiene, toluene, naphthalene, hydrogen cyanide, cyanogen, and nitric oxide. Raw Coke oven gas contains many chemical contaminants. They are:

16. Tar vapors
17. Light oil vapors (aromatics) consisting mainly of benzene, toluene and xylene (Generally known as BTX fraction)
18. Naphthalene vapor
19. Hydrogen sulphide gas
20. Hydrogen cyanide gas

After drying the raw gas and separating the above chemical contaminants in a byproduct plant coke oven gas (COG) is obtained (Satyendra, 2013).

Coke oven gas is normally used in coke oven battery heating, heating in other furnaces and for power generation. Coke oven gas can be used as such or can be mixed with BF gas and/or Converter gas before being used as fuel in the furnace (Satyendra, 2013).

According to a 2007 study by International Energy Agency approximately 70% of the COG was used in iron and steel making processes, 15% for coke oven heating, and 15% for electricity production. Further the report states that by using more of the COG for power generation (preferably by more efficient combined cycle power generation technique that can provide efficiencies of around 42% as opposed to use in boiler based power plants working on steam cycles with an average efficiency of around 30%) improvements in energy efficiencies can be achieved (Satyendra, 2013).

CO gas injection at tuyere level has been successfully tried in the blast furnace in some plants where there is excess of CO gas availability. An integrated steel plant in USA has reported an annual saving of USD 6.1 million by using CO gas as supplementary fuel in blast furnace. They have reported a payback period of just over one year (Satyendra, 2013).

2.3 Financial Models

Financial model is a quantitative representation of company's past, present, and future business operations. This quantitative representation is expressed through the use of accounting, the language of business. Finance, which may be broadly defined as the science of managing money and other assets, is based on accounting. As such, it is important to recognize the central role accounting, or the enumeration of business transactions, plays in building financial models. While this book does not cover or address accounting concepts in any level of detail, it is worth nothing that the consolidated financial statements (Balance Sheet, Income Statement, and Statement of Cash Flows) represent the product of a series of accounting transaction (Balakrishnan et al, 2007).

2.4 Optimization

In utilizing the excess Coke Oven Gas and Blast Furnace Gas from Blast Furnace Complex, limited amount of supply has become one of the constraints of allocating the gas to the plants currently owned by the company, since the electricity needed for the processes in each plant to be generated by the fuel is also different. Besides, some investment will be needed to implement the project, which one plant and another will result in different cost. Both combination of constraint will affect the number of saving company can obtain, thus, an optimization is conducted in this case to find optimum solution for the project's objective.

Optimization is a process to achieve ideal result or optimization (effective value can be obtained). Optimization can be translated as a form of optimizing current case or designing and creating something optimally. There are several ways to do optimization and of them is linear programming that will be used in this research.

2.4.1 Decision Modeling

In this research, the optimization is actually a decision modeling using spreadsheet. Decision modeling is a scientific approach to managerial decision-making. Alternatively, it can be defined as the development of a model (usually mathematical) of a real-world problem scenario or environment. Decision model can be used to provide insights into the solution of the managerial problem. It is also commonly referred to as quantitative analysis or operation research.

It is important to note that decision modeling commonly has an iterative process before the final solution is obtained. The steps mainly consists of three (Proctor, 1999):

1. Formulation

   Formulation is the process by which each aspect of a problem scenario is translated and expressed in terms of a mathematical model. The aim of formulation is to ensure that the mathematical model completely addresses all the issues relevant to the problem. Formulation can be further classified into three parts: a) Defining problem, b) Developing model, and c) Acquiring input data.

2. Solution

   Solution step is when the mathematical expression resulting from the formulation process are actually solved to identify the optimal solution. The solution step can be further classified into two parts: a) Developing solution, and b) Testing the solution

3. Intepretation and Sensitivity Analysis

   Anlyzing the result starts with determining the implications of the solution. In most cases, a solution to a problem will result in some kind of action or change in the way an organization is operating. The implications of these actions or changes must be determined and analyzed before the results are implemented. Because a model is only an approzimation of reality, the sensitivity of the solution to changes in the model and input data is an important part of analyzing the results. Sensitivity analysis is used to determine how much the solution will change if there are changes in the input data and the model specification.

2.4.2 Linear Programming

To achieve the objective of determining excess Coke Oven Gas and Blast Furnace Gas optimum allocation for PT X's plants to maximize energy cost saving and minimize cost, an accountable and proper method is needed. Linear programming as one of the ways in doing optimization can accommodate the case and help to find the best solution. A linear program is an optimization problem where all involved functions are linear in x; in particular, all the constraints are linear inequalities and equalities (Zhang, 2015).

According to Siringoringo (2005), linear programming is a mathematical method of allocating limited resources to achieve a goal such as maximize profits and minimize costs. Linear programming is widely applied in the economic, industrial, military, social and others. Linear programming deals with an explanation of a case in the real world as a mathematical model consisting of a linear objective function with multiple linear constraints.

All linear programming models have the following properties in common (Proctor, 1999):

a) All problems seek to maximize or minimize some quantity, usually profit or cost.

b) Linear Programming models usually include restrictions, or constraints, that limit the degree to which it can pursue the objective.

c) There must be alternative courses of action from which it can be chosen.

d) The objective and constraints in linear programming problems must be expressed in terms of equations or inequalities.

Technically, there are four additional requirements of a linear programming problem of which it should be aware (Proctor, 1999):

a) It is assumed that the conditions of certainty exist. That is, numbers used in the objective function and constraints are known with certainty and do not change during the period being studied.

b) It assumed that proportionality exist in the objective function and constraints.

c) The third assumption deals with additivity, meaning that the total of all activities equals to the sum of individual activities.

d) Solutions need not necessarily be in while numbers (integers).

General Structure of Linear Programming

In each issue, it is determined the decision variables, objective function, and constraints, which together form a mathematical model of real world. The general

(2.1)

form of the linear program is (Lieberman and Hillier, 1990):

Maximize Z = $c_1x_1 + c_2x_2 + \ldots + c_nx_n$,

subject to the restrictions

$$a_{11}x_1 + a_{12}x_2 + \ldots + c_{1n}x_n \leq b_1$$
$$a_{21}x_1 + a_{22}x_2 + \ldots + c_{2n}x_n \leq b_2$$
$$\vdots$$
$$a_{m1}x_1 + a_{m2}x_2 + \ldots + c_{mn}x_n \leq b_m$$

and $x_1 \geq 0, \quad x_2 \geq 0, \quad \ldots \quad x_n \geq 0.$

2.5 Project Valuation

Value can be defined as an estimate of the desired price by the seller and the buyer of an item or service and a number of economic benefits which is based on the fair market value to be derived from the objects valuation on the valuation date (cut-off date); while business valuation itself can be defined as activity or process to produce an opinion or estimate of the fair market value of the object of assessment. This assessment is used by the business or investor to determine the value in the price they will pay, or they receive from the transaction of the assessed object. (*Keputusan Ketua Keuangan Badan Pengawas Pasar Modal dan Lembaga Keuangan Nomor: Kep-196/BL/2012 tentang Pedoman Penilaian dan Penyajian Laporan Penilaian Usaha di Pasar Modal*). The valuation itself can be described as value to the valuated objects assessment by each subject, which is in many cases in the form of monetary value (Matschke, Brosel, & Matschke, 2010).

For a profit-oriented organization such as steel making industry, the basic principle is to select alternatives that offer higher financial benefits or profit for the organizations. Nonetheless, because the real financial result is not yet available during the decision making timeline, then, a financial model is necessary to estimate the expected revenue or income and projects costs, which is under consideration. The existence of financial modeling is really necessary since this model can provide the decision maker the expected performance value for each project or the business valuation of each project.

2.5.1 Free Cash Flow

Free cash flow of a company represents the amount of cash available for investors, either to provide debt or capital after the company pay off all the operational costs and pay out net investments for fixed assets and current assets (Gitman & Zutter, 2012). A net cash flow will represent overall value from a company fund flow because net cash is a fund that can be allocated for several importances and has been subtracted by company expenses for the same period. Besides, net cash flow also acknowledges time value of money concept fully, and at the same time, this technique determines return of the whole investment.

There are two approaches in calculating free cash flow, which is asset based and funding based. Herewith is the calculation of free cash flow using asset based (Gunarta, 2013):

$$\begin{aligned} &Free\ cash\ flow \\ &= EAT + depreciation + \big(interest \times (1 - tax)\big) \\ &- (working\ capital\ investment \\ &+ fixed\ asset\ and\ other\ asset\ investment) \end{aligned} \quad (2.2)$$

2.5.2 Weighted Average Cost of Capital

Basically, WACC (Weighted Average Cost of Capital) can be described as the average of return that the enterprise should pay to stockholder and creditor. This usually can be said as the discount rate in accordance with risk of cash flow from related company. Hereby is the pattern or formula in calculating the WACC: (Prawoto, 2004).

$$WACC = (K_e \times W_e) + (K_d[1 - t] \times W_d) \quad (2.3)$$

With notes:

Ke = Cost of capital equity

Kd = Cost of capital debt

We = Percentage of capital equity in capital structure

Wd = Percentage of capital debt in capital structure

2.5.3 Net Present Value (NPV)

Based on Suliyanto (2010), Net Present Value (NPV) can be described as the method used by comparing the present value of net cash inflows and the present value of an investment expenses. This method is related to when an enterprise wants to decide whether they make an investment or not, in which in this case the enterprise will have expenses on COG and BFG utilization project. The owner of the company definitely wants to have return from the investments, then, the project should manage to create bigger cash flow (in present value) compared to the initial investment.

Net Present Value basically is a method used to value the investment plan by considering the time value of money. Therefore, the cash flow used is the one that has been discounted based on cost of capital / interest rate / required return rate. Hereby is the pattern in calculating the NPV,

$$NPV = \frac{CF_1}{(1+i)^\wedge 1} + \frac{CF_2}{(1+i)^\wedge 2} + \cdots + \frac{CF_n}{(1+i)^n} - OI \quad (2.4)$$

Description:

CF1, CF2, ..., CFn	= Cash flow of year 1, 2, …, n
i	= Cost of capital/required rate of return
n	= Year of investment
OI	= Original investment

2.5.4 Internal Rate of Return (IRR)

Internal Rate of Return is interest rate that causes balance acceptance with cash flow to match equal distribution with cash flow (Thuesen & Fabricky, 2011).

Internal rate of return is cost of capital/interest rate/result return rate that is needed to make NPV equal to zero. The amount of cost of capital/interest rate/result return rate that is needed to make NPV equal to zero represents the value of IRR from a proposed investment. This method also considers time value of money, thus discounted cash flow that is used based on cost of capital/interest rate/result return rate needed. General equation of IRR is:

$$NPV = \frac{CF_1}{(1+i)^\wedge 1} + \frac{CF_2}{(1+i)^\wedge 2} + \cdots + \frac{CF_n}{(1+i)^n} - OI \quad (2.5)$$

Description:

CF1, CF2, ..., CFn	= Cash flow of year 1, 2, …, n
i	= Cost of capital/required rate of return
n	= Year of investment
OI	= Original investment

Steps on how to calculate IRR are:

1. Calculate the net present value of proposed investment by using random interest rate
2. Compare the result in point 1 with the value of OI.
   a. If the result is negative, try to reduce the value of interest rate.
   b. If the result is positive, try to increase the value of interest rate.
3. Continue step 2 until net present value approaches OI (= difference of net present value with initial investment = -1 and + 1)

An investment is said to be accepted if IRR is bigger or equal to the cost of capital/interest rate/result interest rate needed. If the proposed investment is more than one and mutually exclusive, the biggest one will be accepted.

CHAPTER III
RESEARCH METHODOLOGY

This chapter explains about steps undertaken in solving the identified problems of the research. The aim is to guide the author to be able to conduct a systematic, structured and right on target research and will eventually come up with solutions and achieved goals as the order process is shown in figure 3.1.

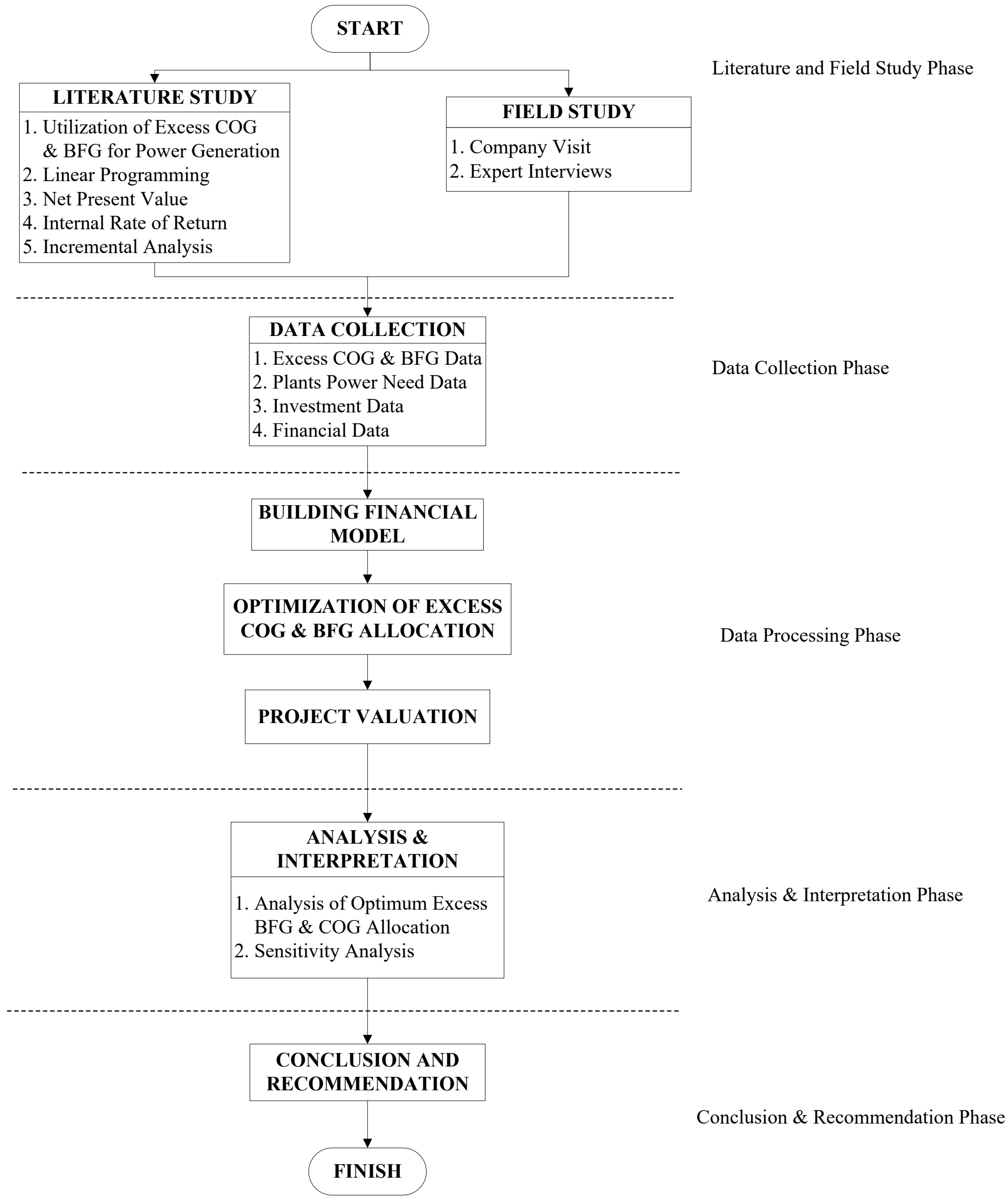

Figure 3.1 Methodology Flowchart

3.1 Flowchart Research Explanation

Herewith is further explanation of the steps taking in this research.

3.1.1 Literature and Field Study Phase

In the first phase of the research, following the problem identification and formulation, author seeks for basic knowledge in books and literatures to construct a rich idea of how the research will be conducted and what methods should be used to address the problem, as well as the previous researches in the same or related topics, which are Blast Furnace Gas and Coke Oven Gas utilization to give idea how established steel making industry converts their waste gas to become profit, linear optimization to grasp the understanding of the goal and its following constraints, and financial analysis consists of Net Present Value to assess the value of project. Simultaneously, field study is also conducted to help author understand the existing condition of the company and the plants they own as the object of the research.

3.1.2 Data Collection Phase

At this phase, author collects the data of the under constructing Blast Furnace Complex excess gas as well as natural gas needs for built plants. The data of Blast Furnace Gas and Coke Oven Plant gas is obtained from the developer of the project, meanwhile the built plants natural gas need data is all owned by the management of the company. Besides that, the cost of implementing the idea will also be collected from several resources, which are: the developer of the project, the company, and reliable reference information. Those data collected will be used to make the optimization model of the allocation for excess COG and BFG. Later on, the financial data that follows the assumptions used by the company in business development is processed into financial model to assess the worth of the project implementation and to see the saving gained by the company.

3.1.3 Data Processing Phase

This phase begins with making profit and loss statement to get the constraints of optimization model. After all the constraints are obtained, optimization model using simplex linear programming, the allocation for the excess COG and BFG gas to the plants is built; which plants make the most revenue to be the target of gas transfer, how much gas transferred, and how much the investment cost needed to implement the project. There will be two scenarios that are differentiated by the location of the facility. Scenario that gives the higher value in the objective will be chosen. The value indicator of the project will be reflected in the total profit of the production plants. Then, there is valuation model to know how much worth the investment makes and the project added value to the company.

3.1.4 Data Analysis and Interpretation Phase

In the data analysis and interpretation phase, author will mainly discuss about key takeaways of data processing results and the substances of it. There will be two analyses in the research; which are analyses of allocation obtained from running the optimization model, the value resulted from the valuation model with that optimum allocation and sensitivity analysis to get critical elements, which affect the objective and decision of project. Those analyses objective is aligned with the objective of the research; maximizing energy cost saving for the plants which leads to more profit for the company.

3.1.5 Conclusion and Recommendation Phase

After all the phases of problem solving in the research, conclusion and suggestions are drawn in purpose that it will achieve the objective of the research. Conclusion of the research is obtained from the analysis of processing data that imply the answer of problem formulation and suggestions that might be useful for the company and the next research.

CHAPTER IV
DATA COLLECTION AND PROCESSING

This fourth chapter will provide supporting data that will be used in constructing financial model and optimizing the mathematical model, general overview of the company as the object of the research, and the process of constructing optimization and financial model.

4.1 General Overview of Research Object

This sub-chapter explains the general overview of the company as the research object, in which the general information comprised the company profile and business development planning.

4.1.1 Company Profile

PT X is one of steel-making companies in Indonesia. The company engages in several businesses besides their main function as steel producers, which are power generator, water purification, port, and telecommunication system, thus, the company is claimed to be the only integrated steel-making company with complete supporting facilities in Indonesia. For the steel-making itself, PT X produces sponge iron, billet steel, wire steel, hot strip steel, and cold rolling steel.

The steel-making plant of PT X is located in industry area near port to make it easy distributing and delivering their products, which requires sea transportation method for their heavy products, it also is surrounded by joint venture companies of PT X and its partners, as well as other businesses PT X owned to support their main business.

Figure 4.1 is the satellite image of steel-making plant of the company. The plant is surrounded by other industries in the same area and port.

As of 2014, PT X owns steel production capacity of 3.15 million ton each year (unaudited). Besides market the products to domestic customers, they also market the products overseas. The company expertise to produce steel with special specification, includes to national defense, strengthens its position as one of strategic industries in Indonesia.

Figure 4.1 Satellite Map of PT X
(Source: Google Earth, 2016)

4.2 Data Collection

Before constructing the optimization and profit and loss statement, specifically only in its utilization of Coke Oven Gas and Blast Furnace Gas, several data from historical record of the company is collected and analyzed. The data needed for the process are revenue and cost of the company.

4.2.1 Existing Steel Production Business of PT X

The company currently produces six kinds of steel products, which are produced by three plants: Hot Strip Mill (HSM), Cold Rolling Mill (CRM), and Wire Rod Mill (WRM). Although there are other three main plants of steel production, but those plants are predecessor processes to convert raw material to become liquid steel and their outputs are not for sale.

Hot Strip Mill Plant produces hot strip mill or plated steel or sheet steel. Hot strip mill is mostly used to make ship construction, pipe, building, general construction, etc. Hot Strip Mill Plant predecessors are Direct Reduction Plant (DRP) and Slab Steel Plant (SSP). At the last plant of integrated slab steel process, hot strip mill enters Cold Rolling Mill Plant for further processing of making different finish product. Cold Rolling Mill Plant produces cold rolled strip, which is commonly applied to make vehicle's spare parts, can, home appliances, etc.

On the other line, which is integrated billet steel production, the main product is produced by Wire Rod Mill Plant in the last process after Direct Reduction Plant and Billet Steel Plant. Wire rod as the product is frequently utilized as industrial fasteners, automobile springs, industrial springs, welding, auto components, roller bearing, ball bearings, industrial chains, automobile chains, etc.

In table 4.1, listed all the finished products as PT X revenue stream from its steel-making business. The selling price of each product is given as well.

Table 4.1 Selling Price of Steel Products in PT X

Products	Price (per ton)
Hot Strip Mills	$427.00
Cold Rolling Mill	$771.00
Wire Rod Mill	$609.00
Others	$274.00

The selling price of each product is then deployed into selling price of each plant the finished products go through as in table 4.2. The selling price is the quantification of added value each plant gives and the margin distribution. The production volume in each plant tells about the number of output each plant produced.

Table 4. 2 Production Volumes and Selling Price of Each Plant in PT X

Plants	Production Volume (ton)	Selling Price (per ton)
Direct Reduction Plant	1,740,000	$103.00
Blast Furnace	1,200,000	$74.00
Slab Steel Plant	2,383,200	$107.00
Billet Steel Plant	556,800	$171.00
Hot Strip Mill	2,383,200	$143.00
Cold Rolling Mill	517,154	$344.00
Wire Rod Mill	183,744	$335.00

To run the process, PT X uses natural gas and electricity as the power. Their first line, which is started from Direct Reduction Plant to Cold Rolling Mill mostly is run by combustion with natural gas, meanwhile the second line with Wire Rod Mill as the end plant, it is mostly dominated by electricity.

Natural gas as the fuel for some plants in the first line plants to run is accounted in the raw material cost. It takes up to 49% of the raw material cost in production cost of the steel products. The needs of natural gas in plant are drawn in table 4.3.

Table 4.3 Natural Gas Usage in Production Machines in PT X

Plants	Natural Gas Need (Nm3/hour) per ton
Direct Reduction Plant	306
Blast Furnace	-
Billet Steel Plant	26
Slab Steel Plant	130
Hot Strip Mill	74
Cold Rolling Mill	182
Wire Rod Mill	344

Those amount of natural gas is used to produce per ton of the output in each plant, with data of production in each plant is shown in table 4.4. The assumption is that the defect output of the product in each plant is neglected.

Table 4. 4 Production Volume of Plants

Plants	Production Volume (ton)	Selling Price (per ton)
Direct Reduction Plant	1,740,000	$103.00
Blast Furnace	1,200,000	$74.00
Slab Steel Plant	2,383,200	$107.00
Billet Steel Plant	556,800	$171.00
Hot Strip Mill	2,383,200	$143.00
Cold Rolling Mill	517,154	$344.00
Wire Rod Mill	183,744	$335.00

4.2.2 Business Development Project of PT X

In the development plan of PT X, specifically in the steel-making business, the company has signed contract on 2012 to construct blast furnace complex to support the raw material processing, especially to lessen dependency towards imported raw material and to anticipate the lack of natural gas that tends to increase year by year. The project is estimated to cost around USD 621,81 million.

The project consists of three main plants, which are Sintering Plant with production capacity of 1.8 million ton per year, Coke Oven Plant with capacity of 500 thousands ton per year, and Blast Furnace Plant (BF Plant) with the capacity of 1.2 million ton per year. Sintering Plant function is to produce raw material such as iron ore fines, return fines, and flux for Blast Furnace, meanwhile Coke Oven Plant produces coke fuel for Blast Furnace as well as reduces iron ore.

By building those plants, the company can increase the iron making and steel making capacity, thus the production capacity of iron making, steel making, and rolling mill balanced. Besides, PT X also decrease electric energy in Electric Arc Furnace (EAF) which is already available in Slab Steel Plant, because final product of the project is hot metal that will help to reduce processing energy consumption significantly. The company also can be more flexible in terms of energy usage and raw material, because Blast Furnace can receive various kind of pallet, and enables the usage of local raw material, such as iron ore and coking coal.

Alongside with the operational activities of the soon to be new plants, Blast Furnace and Coke Oven Plant will dispose waste gas from its production process. 249.900 Normal Cubic Meter Hour (NCMH) of Blast Furnace Gas and 27,800 Normal Cubic Meter Hour (NCMH) Coke Oven Gas released as the gas waste of the process. The company plans to utilize the disposal gas by recycling it as combustion fuel for their internal processes. It has been decided that 217,300 NCMH Blast Furnace Gas will be used for Blast Furnace Complex internal uses together with 16,078 NCMH Coke Oven Gas. The rest of the disposal gas is the amount that will be distributed to their current plants to reduce the usage of Natural Gas as one of the higher spending of the company in production cost.

The detail information of the disposal gas from both of the plants that will be processed in the calculation is in the table 4.5. These gases, Blast Furnace Gas and Coke Oven Gas, which are then going to be distributed to the plants for recycling as a combustion fuel.

Table 4.5 Disposal Gas of Blast Furnace Complex

No.	Plants	Disposal	Amount	Unit
1	Blast Furnace	Blast Furnace Gas	32,600	Normal Cubic Meter per Hour (NCMH)
2	Coke Oven Plant	Coke Oven Gas	11,722	Normal Cubic Meter per Hout (NCMH)

Both gases are known to be combustible due to its calorific value. Although one another has different amount that will also make the energy produced during the combustion different than natural gas, but combining the disposal gas and natural gas can help the company reducing its consumption on natural gas, which leads to saving of expense.

As of now, all the plants include Direct Reduction Plant, Slab Steel Plant, Hot Strip Mill, Cold Rolling Mill, Billet Steel Plant, and Wire Rod Mill. Those plants are integrated and dedicated to produce strip and billet shaped steel as some of main products of PT X. The project of utilizing the waste gas aims to reduce the usage of natural gas on the mentioned plants to eventually maximize company's profit.

In table 4.6, there are several important information to ensure that the mix of natural gas, coke oven gas, and blast furnace gas can scientifically fulfill the demand of current natural gas in the plants. Lower Heating Value is the calorific value of the gas when it performs perfect combustion per unit. Lower Heating Value of the gas will result in the mixture of the gas that can be used as the replacement of single natural gas usage.

Table 4. 6 Lower Heating Value of NG, BFG, And COG

Gas	Lower Heating Value	Unit
Natural Gas	8,400	Kcal/Nm3
Coke Oven Gas	4,000	Kcal/Nm3
Blast Furnace Gas	700	Kcal/Nm3

It can be seen that the higher lower heating value is in natural gas, which means that it produces highest calorie in the combustion than the other two. Blast Furnace Gas with the significantly low LHV can only support combustion since it is unable to perform high calorie combustion as mostly plants need.

Another information regarding to the usage of gas is that the price of natural gas is determined at constant value of USD0.245 Nm3/hour and assumption on working day is 300 per year. Further assumptions are explained in macro and micro assumptions of the research.

Macro Assumptions

There are several macro assumptions data that are applied in the data processing, which are tax, price escalation each year, exchange rate, natural gas price, and electricity rate. All of these assumptions would be used in the financial modeling.

- There is one tax assumption that applies to non-retained asset, that is, Income Tax for Enterprise, or in Indonesia the term is Pajak Penghasilan. The amount of this tax is 25% from the gross profit due to the policy, in which enterprises with more than 5 billion rupiah revenue should pay 25% constant tax.
- Price Escalation

  Looking at the reality, cost and price of goods and service might never stay the same each year. This means that there is always increasing of the cost expense and the price of natural gas every year in which this might also be affected by the dollar currency to rupiah. In the financial model, the escalation rate applies on this research is 2%. This escalation applies on the cost of natural gas and cost of maintenance, and operational cost.
- Exchange Rate

  Since the company's business activities do not only involve rupiah but also dollar, which applies in buying imported material, exporting finished products, and the price of natural gas, the exchange rate that changes daily should be determined constant to simplify the model. In this research, the exchange rate will be IDR13,900 per USD1 as the project is signed to be constructed.
- Natural Gas Price

  Natural Gas Price moves along with the supply and demand rules, but besides the microeconomics aspect, there are also country's laws and policy that affects the price. In the base value of the project, natural gas is determined USD0.245 as the project is started and will change based on the price escalation each year.

- Electricity Rate

  The base cost of electricity used in the financial model is IDR1191 as the project is signed and will change along with the price escalation each year. The electricity cost will be used in operational cost calculation.

Micro Assumptions

There are several micro assumptions that are used for the financial model, that are maintenance cost, salvage value, and the selling volume of the business.

- Maintenance Cost

As some investments are made in form machines and equipments, there will be maintenance cost spent for the company to maintain the asset. This cost is determined 1.5% from the total investment spent on the fixed assets as the base value and the change each year follows the price escalation assumption.

- Salvage Value

Asset economic-life lasts for 20 years and at the year 20 the fixed assets are assumed to still have salvage value, in which if it is sold as used machines and equipment it will still be valuable 25% from its initial cost.

4.2.3 Project Scenario

In the process of deciding which plants should get the disposal gas, PT X offers two options in terms of facility location planning, specifically Blast Furnace Gas Holder and Coke Oven Gas Holder. The difference of the scenario is in the distance of the facility to the receiver plans that directly affects the amount of investment of the project. The scenario is there to see which location from the option that will give the highest profit for the company and how the distance affects the result of the allocation by comparing both of the scenarios that will be created.

4.2.3.1 Scenario A

The first scenario is to put the holders in Blast Furnace Complex area that is illustrated as the yellow area in figure 4.2. Blast Furnace Complex takes a quite wide land of the whole plant and it is surrounded by all other current plants. The satellite view of the whole plant will be used to calculate the length of pipe from the holders to the plants.

Figure 4.2 BFG and COG Holders Location For Scenario A
(Source: Google Earth 2016)

The structure of investment, if scenario A generates the highest net profit, consists of investment from gas resource, which are Blast Furnace Complex and Coke Oven Plant to the holders and from the holders to receiver plants. Table 4.7 shows the investment of pipe for building the transfer system from the plants, which dispose the gas, to the holder of Blast Furnace Gas and Coke Oven Gas.

Table 4.7 Pipe Investment of Scenario A From Resources To Holders

From Resource to Holder	Length	Unit	Cost per unit	Total
Length of pipe COG	1250	meter	$85.37	$75,808.56
Length of pipe BFG	888	meter	$85.37	$75,808.56
TOTAL				$151,617.12

The calculation of the pipe investment of scenario A from resources to holders is in equation 4.1.

$$Total\ pipe\ investment\ cost = (length\ of\ pipe\ COG \times (pipe\ per\ unit\ cost + installation\ cost) + (length\ of\ pipe\ BFG \times pipe\ per\ unit\ cost + installation\ cost) \quad (4.1)$$

After the gas stored in the holder, when it is used for the combustion fuel in the candidate plants, the gas will be transferred farther to the machines in the plant. From the holder to the plant also requires transfer of the gas with pipe, since there are two possibilities of mixed gas that will be received by the plants, the investment of both mixed gas is differentiated and table 4.8 is for the first mixed (NG+COG+BFG).

Table 4.8 Pipe Investment of Scenario A From Holders To Receivers (Mix 3)

From holder plan A to plants (Mix 2)	Length	Unit	Cost per Unit	Machine replacement cost	Total
Length of Pipe COG+NG+BFG to DRP	1,225	meter	$109.27	$1,415,156	$1,549,011
Length of Pipe COG+NG+BFG to SSP	725	meter	$105.00	-	$76,125
Length of Pipe COG+NG+BFG to HSM	500	meter	$133.37	-	$66,685
Length of Pipe COG+NG+BFG to CRM	1,675	meter	$83.56	$1,004,957	$1,144,920
Length of Pipe COG+NG+BFG to BSP	1,400	meter	$105.00	-	$147,000
Length of Pipe COG+NG+BFG to WRM	1,925	meter	$83.56	-	$160,853

When one of the plants selected to get the allocation, in investment cost calculation, the total cost that is constructed by the length of the pipe times the cost per unit will appear.

There is also machine replacement cost since some machines is technologically old that it can only use natural gas as its combustion fuel, so when that particular machine is chosen as the allocation decision, there should be the cost of machine replacement which includes the installation.

So in the total cost of each plant, there are the cost of the pipe from holder to the plants and the machine replacement cost when it is necessary. The same calculation applies to the third mix, since basically the length and the cost of the pipe per unit is the same. Table 4.9 is for second mix, which consists of Natural Gas and Blast Furnace Gas.

Table 4.9 Pipe Investment of Scenario A From Holders to Receivers (Mix 2)

From holder plan A to plants (Mix 3)	Length	Unit	Cost per unit	Machine Replacement cost	Total
Length of Pipe NG+BFG to DRP	1,225	meter	$109.27	$1,415,156	$1,549,011
Length of Pipe NG+BFG to SSP	725	meter	$105.00	-	$76,125
Length of Pipe NG+BFG to HSM	500	meter	$133.37	-	$66,685
Length of Pipe NG+BFG to CRM	1,675	meter	$83.56	$1,004,957	$1,144,920
Length of Pipe NG+BFG to BSP	1,400	meter	$105.00	-	$147,000
Length of Pipe NG+BFG to WRM	1,925	meter	$83.56	-	$160,853

4.2.3.2 Scenario B

Different with scenario A, the location of holders in scenario B will be around Hot Strip Mill, as illustrated in figure 4.3. This second scenario might change the result of the allocation since the distance of the holder to the Direct Reduction Plant and Wire Rod Mill plant get closer, which will be proven in the data processing. The holders are illustrated as two green tubes in the left up corner of the company satellite image.

Overall, the structure of both scenario in terms of investment in pipe are the same, the difference will only be in the route of how the gas from the holder will reach the plants that in the calculation of the cost will affect the length of the pipe and at the edge of the calculation, pipe investment and the costs that are generated from the amount of investment cost will be different with the previous scenario, which is scenario A.

Figure 4.3 BFG and COG Holders Location for Scenario B
(Source: Google Earth, 2016)

Table 4.10 is the investment of pipe from resource plants of the disposal gas to the holders.

Table 4.10 Pipe Investment of Scenario B from Resources to Holders

From resource to holder	Length	Unit	Cost per unit	Total
Length of pipe COG	425	meter	$59.32	$75,810.96
Length of pipe BFG	600	meter	$59.32	$75,810.96
TOTAL				$151,621.92

Table 4.11 is about the pipe investment from the holder to the plants with second mixed gas as well as the machine replacement cost when needed.

Table 4.11 Pipe Investment of Scenario B from Holders to Plants (Mix 2)

From holder plan B to plants (Mix 2)	Length	Unit	Cost per Unit	Machine replacement cost	Total
Length of Pipe COG+NG+BFG to DRP	750	meter	$109.27	$1,415,156	$1,497,108
Length of Pipe COG+NG+BFG to SSP	1,100	meter	$105.00	-	$115,500

Table 4.11 Pipe Investment of Scenario B from Holders to Plants (Mix 2) (Con't)

From holder plan B to plants (Mix 2)	Length	Unit	Cost per Unit	Machine replacement cost	Total
Length of Pipe COG+NG+BFG to HSM	1,475	meter	$133.37	-	$196,720
Length of Pipe COG+NG+BFG to CRM	1,750	meter	$83.56	$1,004,957	$1,151,187
Length of Pipe COG+NG+BFG to BSP	1,400	meter	$105.00	-	$147,000
Length of Pipe COG+NG+BFG to WRM	1,900	meter	$83.56	-	$158,764

Third mixed gas pipe investment from holder to plants is in the table 4.12. The costs are the same since the pipe can convey both mixtures.

Table 4.12 Pipe Investment of Scenario B from Holders to Plants (Mix 3)

From holder plan B to plants (Mix 3)	Length	Unit	Cost per unit	Machine Replacement cost	Total
Length of Pipe NG+BFG to DRP	750	meter	$109.27	$1,415,156	$1,497,108
Length of Pipe NG+BFG to SSP	1,100	meter	$105.00	-	$115,500
Length of Pipe NG+BFG to HSM	1,475	meter	$133.37	-	$196,720
Length of Pipe NG+BFG to CRM	1,750	meter	$83.56	$1,004,957	$1,151,187
Length of Pipe NG+BFG to BSP	1,400	meter	$105.00	-	$147,000
Length of Pipe NG+BFG to WRM	1,900	meter	$83.56	-	$158,764

The project will not use all the investment since the decision will be based on the result of optimization model to fulfill the constraint of limited supply from both of disposal gases.

Besides investment cost, there will be operational cost, which is about the energy of transferring the gas. The summary of energy needs for pumping the gas to the plants per gas is shown in table 4.13 with the rate of 80%. The calculation will only appear if the plant gets the disposal gas allocation.

Table 4. 13 Electricity Needs to Transfer Gas to Plants

Plants	COG (kwh)	BFG (kwh)
Direct Reduction Plant	47.00	79.00
Billet Steel Plant	45.00	96.00
Slab Steel Plant	58.00	75.00
Hot Strip Mill	36.00	60.00
Cold Rolling Mill	45.00	96.00
Wire Rod Mill	36.00	60.00

4.3 Data Processing

The first step to process all the data collected is to make the financial model of the project in terms of Profit and Loss Statement elements. The value of each element is gotten from making then running optimization model that results the allocation of gas. At last, there will be valuation calculation of the project in terms of free cash flow to know the value of the project up to 20 years of planning horizon as its investment lifetime.

4.3.1 Optimization Model

The optimization in the process is very essential to determine the receiver of gas disposal since there are several constraints that only can be solved by using linear programming. Data using in the model-making is the amount of natural gas demand in each plant and the recapitulation of investment cost per plant per mix. In table 4.14, recapitulation of investment is provided for scenario A. The value of investment cost refers to the table of pipe investment from the holders to the plants classified in each scenario.

Table 4.14 Investment Recapitulation of Scenario A

Plant	Mix 1	Mix 2	Mix 3
Direct Reduction Plant	-	$1,549,011	$1,549,011.90
Slab Steel Plant	-	$76,125	$76,125.00
Hot Strip Mill	-	$66,685	$66,685.00
Cold Rolling Mill	-	$1,144,920	$1,144,920.00
Billet Steel Plant	-	$147,000	$147,000.00

Table 4.14 Investment Recapitulation of Scenario A (Con't)

Plant	Mix 1	Mix 2	Mix 3
Wire Rod Mill	-	$160,853	$160,853.00
Fixed Investment	$3,250,713.87		

For scenario B, the recapitulation of the investment that will be called once the plant gets the allocation is provided in table 4.15.

Table 4.15 Investment Recapitulation of Scenario B

Plant	Mix 1	Mix 2	Mix 3
Direct Reduction Plant	-	$1,497,108.65	$1,497,108.65
Slab Steel Plant	-	$115,500.00	$115,500.00
Hot Strip Mill	-	$196,720.75	$196,720.75
Cold Rolling Mill	-	$1,151,187.00	$1,151,187.00
Billet Steel Plant	-	$147,000.00	$147,000.00
Wire Rod Mill	-	$158,764.00	$158,764.00
Fixed Investment	$3,250,718.67		

The cost of fixed investment consists of the investment cost of each facility from resources to holders as it has been provided in table pipe investment from resources to holders for each scenario and the cost of building the facility in the holder itself that is elaborated in table 4.16.

Table 4. 16 Fixed Investment Cost

Activity	Cost
Preliminary Construction	$100,539.57
Foundation Pipe Rack	$79,015.23
Gas Mixing Ejector and Gas Mixing Booster Compressor Building	$106,487.09
Equipments and Material Handling	$78,901.87
Holders Building	$355,847.75
Procurement and Installation of Gas Jet Gas Ejector for Mixing Gas	$1,392,086.33
Steel Structure	$462,922.42
Electrical and Protection	$495,232.85
Comissioning and Finisihing	$28,063.64
Total	$3,099,096.75

The cost of building the fixed facility to implement the plan is started from the preliminary construction until the commissioning and finishing. Those costs are what make the holders built and also other supporting machines of the holders before it is transferred to the plants.

Table 4.17 gives the recapitulation of current flow of natural gas in each plant. The natural gas usage is gotten from calculating the natural gas usage in production machines in table 4.1 and the production volume of each plant in table 4.2 with assumption of working days 300 and continuous process. The calculation is in the equation: 4.2.

$$Current\ NG\ flow\ rate\ \left(\frac{NM3}{hour}\right) = production\ volume\ \div\ working\ day\ per\ year\ \div\ working\ hour\ per\ day\ \times\ natural\ gas\ need\ per\ ton \quad (4.2)$$

Table 4. 17 Natural Gas Usage in Machine Candidates

Plant	Current NG (Nm3/hour)
Direct Reduction Plant	73,950
Blast Furnace	-
Billet Steel Plant	10,023
Slab Steel Plant	8,641
Hot Strip Mill	24,339
Cold Rolling Mill	13,106
Wire Rod Mill	8,771

Current Natural Gas flow rate data will be used to know how much gas needed for each plant if they are to get the allocation and to get the difference of the current flow rate of Natural Gas with the future allocation of mixing Coke Oven Gas, Blast Furnace Gas, and Natural Gas.

4.3.1.1 Determination of Optimization Model Objective

The result of the optimization model is to get the most optimum allocation decision of limited disposal gas to the available targeted plants, thus there will be profit gained by PT X due to not spending money in buying natural gas as much as the company doing currently. Therefore, the objective of the optimization model is to maximize the net profit of the project by implementing the decision result.

4.3.1.2 Determination of Optimization Model Variable

To achieve the maximum net profit on the project, the most important thing is to decide in which the supply gas is to transfer among all the options and which gas mixture specifically to the plants. Maximum value can be obtained by allocating the gas to particular plants that give the highest benefit to the company, by eliminating some of its cost in fuel.

4.3.1.3 Determination of Optimization Model Constraints

The constraints obtained in this optimization model are taken based on the real case of the company regarding the resources and the targeted plants receiver. Herewith the lists of the constraints:

1. Total of Natural Gas Allocated Should be Less Than The Availability
   Since the supply of the disposal gas is limited compared to the total of natural gas needed to fulfill all the plants demand of natural gas, there can only be several plants that can receive the gas, thus the model should fulfill the constraint.
2. Number of Gases Allocated Should Follow The Rules Of Mixture
   Mixture of gas is based on the calculation in lower heating value of those three different gases to able to perform the same LHV as single natural gas, which is:
   - Mix 1: 100% Natural Gas
   - Mix 2: 72.59% Natural Gas, 36.69% Coke Oven Gas, and 50.24% Blast Furnace Gas
   - Mix 3: 79.44% Natural Gas and 238.33% Blast Furnace Gas

     To reach the lower heating value of natural gas as much as the the need in each plant, it requires more than 100% of the flow rate of total natural gas need, since in the unit of NCMH, the lower heating value of BFG can not fulfill the need of calorific value of the plant in the same flow rate as NG which has bigger LHV.
3. A Plant Should Only Receive One Kind of Gas Mixture
   Since it is not possible for one plant to receive different kinds of mixture to run its process, the receiver of disposal gas should only get one of the mixtures listed in the second constraint.

4.3.1.4 Mathematical Model of Allocation Optimization

Herewith is the mathematical model of the optimization:

- Objective Function

$$Maximize\ Profit = \sum_{i=1}^{m} R_i - CN_i - CG_i - GA_i \quad (4.3)$$

With note that i = 1, 2, 3, …, m, where m is number of plants

R_i = Revenue of plant i

CN_i = Non-gas COGS of plant i

CG_i = Gas COGS of plant i

GA_i = G&A of plant i

- Revenue

$$R_i = PV_i \times SP_i \quad (4.4)$$

PV_i = Production volume of plant i

SP_i = Unit selling price of plant i

- Cost Components

$$CN_i = RFD_i + M_i + A_i + OC_i + D_i \quad (4.5)$$

$$CG_i = FF_i \times GP \times WD \times WH \quad (4.6)$$

$$M_i = \sum_{j=1}^{n} 1.5\% \times x_{ij} \times I_{ij} \quad (4.7)$$

$$A_i = \sum_{j=1}^{n} \left[\frac{0.5\% + t + 1}{2t}\right] I_{ij} \times x_{ij} \quad (4.8)$$

$$OC_i = \sum_{j=1}^{n} x_{ij} O_{ij} \quad (4.9)$$

$$D_i = \sum_{j=1}^{n} \left(\frac{x_{ij} I_{ij} - SV_i}{t}\right) \quad (4.10)$$

RFD_i = Raw material, fabrication, direct labor of plant i

M_i = Investment maintenance cost of plant i

A_i = Investment assurance fee of plant i

OC_i = Investment operational cost of plant i

D_i = Depreciation of investment of plant i

FF_i = Future natural gas flowrate of plant i

GP = Gas price/Nm3

WD = Working days/year

WH = Working hours/day

t = Economic life of asset

O_{ij} = Investment operational cost of plant i; utilizing future flow rate option j

SV_i = Salvage value of investment of plant i

- Decision Variable

$$x_{ij}\begin{cases}1 & \textit{Plant i utilizes future flow rate option j}\\ 0 & \textit{Otherwise}\end{cases} \quad (4.11)$$

$$y\begin{cases}1 & \textit{At least one plant utilizes future flow rate option 2 or 3}\\ 0 & \textit{Otherwise}\end{cases} \quad (4.12)$$

j = Index of future flow rate options (j = 1, 2, 3) in which 1, 2, and 3 represents its choice of mixture

- Investment Constraint

$$\sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij}I_{ij} \leq M \times y \quad (4.13)$$

This constraint forces y = 1 if at least one plant utilizes future flow rate option 2 or 3

M = Large positive number

I_{ij} = Investment of machine; utilizing future flow rate of option j

- Future Flow rate Constraint

$$FF_i = x_{i1} \times CF_i + 0.7259 \times x_{i2} \times CF_i + 0.7944 \times x_{i3} \times CF_i \quad (4.14)$$

$$FFB_i = x_{i2} \times CF_i \times 0.3669 + x_{i3} \times CF_i \times 2.3833 \quad (4.15)$$

$$FFC_i = x_{i2} \times CF_i \times 0.50242 \quad (4.16)$$

Future flow rate of each plant will follow selected future flow rate option

$$\sum_{i=1}^{m} FFB_i \leq AB \quad (4.17)$$

Total future flow rate of BFG ≤ availability

$$\sum_{j=1}^{m} FFC_i \leq AC \quad (4.18)$$

Total future flow rate of COG ≤ availability

$$\sum_{j=1}^{m} x_{ij} = 1 \quad (4.19)$$

1 plant can only utilize 1 future flow rate option

FF_i = Future natural gas flow rate of plant i

CF_i = Current natural gas flow rate of plant i

FFB_i = Future BFG flow rate of plant i

FFC_i = Future COG flow rate of plant i

AB = Availability of BFG flow rate

AC = Availability of COG flow rate

4.3.1.5 Optimization Result

With all the constraints, the result of optimization consists of three, the first is the flow rate allocation, the second is the total investment cost spent based on the first result, and the saving produced by the usage of BFG and COG. The result is obtained by using Solver add in on Microsoft Excel and figure 4.4 shows that the model obeys all the mathematical rules in the software and successfully found the optimum solution based on the objective and all the constraints. In other words, it is verified that the solver has met requirements that fulfills its purpose.

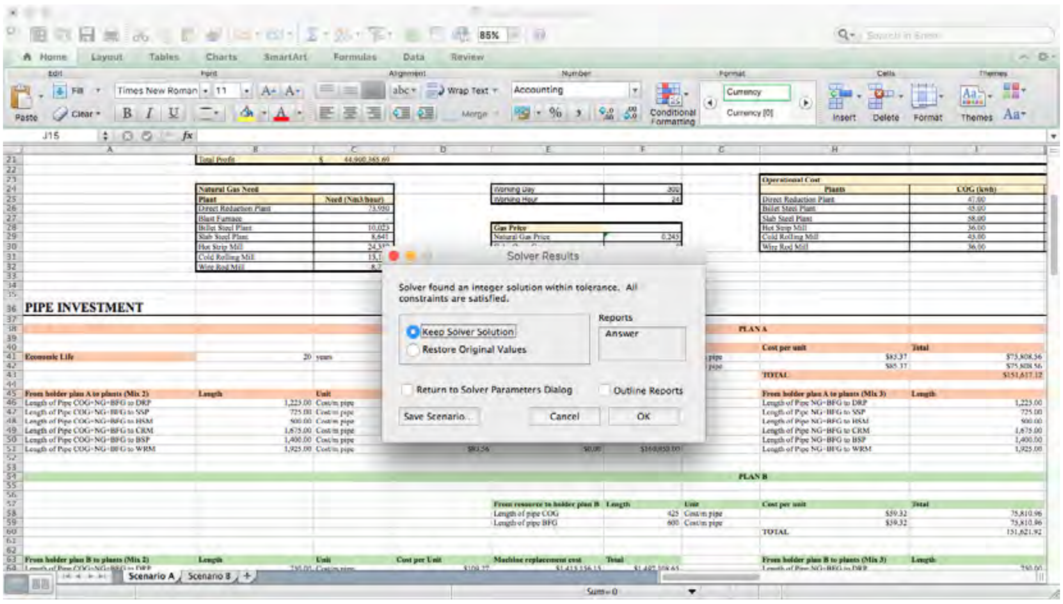

Figure 4. 4 Screen capture of Solver Result Dialog

Table 4.18 is the first result of allocation in form of flow rate for scenario A. The result is obtained from simplex linear programming with constraints and objective as mentioned previously in the optimization model. It can be seen that Solver found solution and all the constraints are satisfied.

Table 4.18 Flow Rate of Optimization Model Result for Scenario A

Plant	Current NG	Future Flowrate (Nm3/hour)			
		NG	BFG	COG	NG Saving
Direct Reduction Plant	73,950	73,950	-	-	-
Blast Furnace	-	-	-	-	-
Billet Steel Plant	10,023	7,276	5,036	3,677	2,747
Slab Steel Plant	8,641	8,641	-	-	-
Hot Strip Mill	24,339	24,339	-	-	-
Cold Rolling Mill	13,106	9,514	6,585	4,809	3,592
Wire Rod Mill	8,771	6,367	4,407	3,218	2,404
	Total	130,086	16,027	11,704	8,744

For scenario B optimization model, the result of disposal gas allocation is provided in table 4.19.

Table 4.19 Flow Rate of Optimization Model Result for Scenario B

Plant	Current NG	Future Flowrate (Nm3/hour)			
		NG	BFG	COG	NG Saving
Direct Reduction Plant	73,950	73,950	-	-	-
Blast Furnace	-	-	-	-	-
Billet Steel Plant	10,023	7,276	5,036	3,677	2,747
Slab Steel Plant	8,641	8,641	-	-	-
Hot Strip Mill	24,339	24,339	-	-	-
Cold Rolling Mill	13,106	9,514	6,585	4,809	3,592
Wire Rod Mill	8,771	6,367	4,407	3,218	2,404
	Total	130,086	16,027	11,704	8,744

The second result, which is investment as the effect of allocation, is in table 4.20 for scenario A. The investment cost is called by the result of optimization based on the targeted plant and the mixture it gets for the allocation.

Table 4.20 Total Investment of Allocation Result for Scenario A

Plant	Investment
Direct Reduction Plant	-
Blast Furnace	-
Billet Steel Plant	$147,000.00
Slab Steel Plant	-
Hot Strip Mill	-
Cold Rolling Mill	$1,144,920.00
Wire Rod Mill	$160,853.00
Fixed Investment	$3,250,713.87
Total	$4,703,486.87

Table 4.21 is on the other hand is the result of scenario B investment cost based on the allocation result in optimization model. The allocation decision is the same as the scenario A but the recapitulation of the investment is different due to the difference in the location and distance between two scenarios.

Table 4.21 Total Investment of Allocation Result for Scenario B

Plant	Investment
Direct Reduction Plant	-
Blast Furnace	-
Slab Steel Plant	$115,500.00
Hot Strip Mill	-
Cold Rolling Mill	-
Billet Steel Plant	$147,000.00
Wire Rod Mill	$158,764.00
Fixed Investment	$3,250,713.87
Total	$4,707,664.87

The last result of the optimization is cost saving as another impact from allocation, by not buying natural gas yearly and replace it with the new mixture using either BFG and COG or only COG, is provided in table 4.22 for scenario A.

The existing cost of the Natural Gas purchase is calculated with equation:

$$\begin{aligned} &Existing\ cost \\ &= Current\ Natural\ Gas\ flow\ rate \times Natural\ Gas\ price \\ &\times working\ day\ per\ year \times working\ hour\ per\ day \end{aligned} \tag{4.20}$$

Meanwhile, the saving amount is gotten from calculation:

$$\begin{aligned} &Saving \\ &= (Existing\ NG\ cost - Future\ NG\ cost) \\ &\times Natural\ Gas\ price \end{aligned} \tag{4.21}$$

Table 4.22 Total Saving of Allocation Result for Scenario A

Plant	Current NG Cost	Future NG Cost
Direct Reduction Plant	$130,447,800.00	$130,447,800.00
Blast Furnace	-	-
Billet Steel Plant	$17,680,572.00	$12,834,327.21
Slab Steel Plant	$15,242,724.00	$15,242,724.00
Hot Strip Mill	$42,933,996.00	$42,933,996.00
Cold Rolling Mill	$23,118,984.00	$16,782,070.49
Wire Rod Mill	$15,472,044.00	$11,231,156.74
Total	$244,896,120.00	$229,472,074.44
Saving	$15,424,045.56	

After calculating scenario A saving, then in table 4.23, the scenario B calculation of saving is summarized.

Table 4.23 Total Saving of Allocation Result for Scenario B

Plant	Current NG Cost	Future NG Cost
Direct Reduction Plant	$130,447,800.00	$130,447,800.00
Blast Furnace	-	-
Billet Steel Plant	$17,680,572.00	$12,834,327.21
Slab Steel Plant	$15,242,724.00	$15,242,724.00
Hot Strip Mill	$42,933,996.00	$42,933,996.00
Cold Rolling Mill	$23,118,984.00	$16,782,070.49
Wire Rod Mill	$15,472,044.00	$11,231,156.74
Total	$244,896,120.00	$229,472,074.44
Saving	$15,424,045.56	

4.3.2 Profit and Loss Statement

Profit and Loss Statement is a statement in financial term used to know the financial condition of the project regarding to the business activities they do, it is all about revenue and expense both in cash or account.

Revenue is gotten from the multiplication in the output of each plant the value of the product or total added value given for each plant or it is written in the Profit and Lost Statement as selling price. For the cost, Cost of Good Sold for non-gas uses the data from their current steel business. Meanwhile, investment cost, assurance cost, depreciation, and operational cost will only appear if the plant gets the allocation of excess gas. Revenue, Operational Cost, and Maintenance Cost follows the assumption of 2% price escalation per year, assets in form of machines and equipment in this research has 20 years economic of life, and the rate of electricity is 80%.

Calculation of the maintenance cost, operational cost, assurance cost, and depreciation is in equation 4.22, 4.23, 4.24, 4.25.

$$Maintenance\ cost = 1.5\% \times Investment\ cost \tag{4.22}$$

$$Assurance\ cost = \left((0.5\% + economical\ life\ of\ the\ asset + 1) \div (2 \times economical\ life\ of\ the\ asset)\right) \times total\ investment \tag{4.23}$$

$$Depreciation = (Investment\ cost - Salvage\ value\ of\ the\ asset) \div economical\ life\ of\ the\ asset \tag{4.24}$$

$$Operational\ cost = (kwh\ COG + kwh\ BFG) \times rate \times electricity\ rate \times working\ days\ in\ a\ year \times working\ hours\ in\ a\ day \div exchange\ rate \tag{4.25}$$

To get total profit there are several costs coming from fixed investment that is accounted to the whole plants besides profit coming from each plant as table 4.24, such as maintenance, assurance, and depreciation of fixed asset as it is calculated in table 4.25. The formula of calculating gross profit and total profit is in equation 4.26 and 4.27.

$$Total\ profit = Total\ profit\ plants - General\ and\ administration\ expense \tag{4.26}$$

$$Gross\ profit = (Output \times selling\ price) - COGS\ non\ gas - maintenance\ cost - assurance\ cost - operational\ cost - depreciation\ cost - COGS\ gas \tag{4.27}$$

In this research the Profit and Loss Statement is not the Profit and Loss that represents the whole company but only that represents the whole plants involved in the steel production.

Profit and Loss statement is made based on the result of the allocation in optimization model. The two models, optimization model and the profit and loss model, are connected one each other, in which when optimization model makes result or changes in anyway that it may affect the value in the Profit and Loss Statement, the model of Profit and Loss Statement will automatically change its result based on the formulation in the model.

The model is made for one-time event since the result may vary each year, but the strategic decision should be taken only once upfront to avoid significant changes. The data used in the profit and loss statement in this research is gotten from the company historical data and the time frame is in 2016. The result of the Profit and Loss Statement will be the determinant of the decision applied as long as the economic life of the assets lasts.

The result of Profit and Loss statement based on the optimization result for both scenario are in table 4.24 for the scenario A and 4.25 for the scenario B.

Table 4. 24 Profit and Loss Statement of Scenario A

Plants	Direct Reduction Plant	Blast Furnace	Billet Steel Plant	Slab Steel Plant	Hot Strip Mill	Cold Rolling Mill	Wire Rod Mill
Output	1,740,000	1,200,000	556,800	2,383,200	2,383,200	517,154	183,744
Selling price	103	74	171	107	143	344	335
Revenue	$179,220,000	$88,800,000	$95,212,800	$255,002,400	$340,797	$177,901,113	$61,554,240
COGS Non Gas (Raw Material, Fabrication, Direct labor)	($37,774,244)	($83,350,728)	($71,689,430)	($224,111,282)	($276,950,330)	($143,865,108)	($42,304,878)
Maintenance (COG&BFG)	-	-	($2,205.00)	-	-	($17,173)	($2,412)
Assurance (COG&BFG)	-	-	($77,193)	-	-	($601,226)	($84,467)
Operational (COG&BFG)	-	-	($69,588)	-	-	($69,588)	($47,379)
Depreciation (COG&BFG)	-	-	($5,512)	-	-	($42,934)	($6,031)
Total COGS Non Gas	($37,774,244)	($83,350,728)	($71,843,930)	($224,111,282)	($276,950,330)	($144,596,031)	($42,445,171)
COGS Gas	($130,447,800)	-	($12,834,327)	($15,242,724)	($42,933,996)	($16,782,070)	($11,231,156)
Total COGS	($168,222,044)	($83,350,728)	($84,678,257)	($239,354,006)	($319,884,326)	($161,378,102)	($53,676,327)
Gross Profit	$10,997,955	$5,449,271	$10,534,542	15,648,393.14	$20,913,273	$16,523,011	$7,877,912
G&A	($6,155,943)	($3,050,149)	($3,270,419)	($8,758,956)	($11,705,895)	($6,110,641)	($2,114,297)
Profit	$4,842,012	$2,399,122	$7,264,123	$6,889,437	$9,207,378.08	$10,412,370	$5,763,615

Table 4.255 Profit and Loss Statement of Scenario A (Con't)

Plants	Direct Reduction Plant	Blast Furnace	Billet Steel Plant	Slab Steel Plant	Hot Strip Mill	Cold Rolling Mill	Wire Rod Mill
Output	1,740,000	1,200,000	556,800	2,383,200	2,383,200	517,154	183,744
Selling price	103	74	171	107	143	344	335
Revenue	$179,220,000	$88,800,000	$95,212,800	$255,002,400	$340,797,600	$177,901,113	$61,554,240
COGS Non Gas (Raw Material, Fabrication, Direct labor)	($37,774,244)	($83,350,728)	($71,689,430)	($224,111,282)	($276,950,330)	($143,865,108)	($42,304,878)
Maintenance (COG&BFG	s Statement of Scena -	-	($2,205)	-	-	($2,381)	($2,381)
Assurance (COG&BFG)	-	-	($77,193)	-	-	($83,370)	($83,370)
Operational (COG&BFG)	-	-	($69,588)	-	-	($47,379)	($47,379)
Depreciation (COG&BFG)	-	-	($5,512)	-	-	($5,953)	($5,953)
Total COGS Non Gas	($37,774,244.61)	($83,350,728)	($71,843,930)	($224,111,282)	($276,950,330)	($42,443,964)	($42,443,964)
COGS Gas	($130,447,800)	-	($12,834,327)	($15,242,724)	($42,933,996)	($11,231,156)	($11,231,156)
Total COGS	($168,222,044)	($83,350,728)	($84,678,257)	($239,354,006)	($319,884,326)	($53,675,121)	($53,675,121)
Gross Profit	$10,997,955	$5,449,271	$10,534,542	$15,648,393	$20,913,273	$7,879,118	$7,879,118
G&A	($6,155,943)	($3,050,149)	($3,270,419)	($8,758,956)	($11,705,895)	($2,114,297)	($2,114,297)
Profit	$4,842,012	$2,399,122	$7,264,123	$6,889,437	$9,207,378	$5,764,821	$5,764,821

Table 4. 26 Total Profit of Scenario A

Maintenance (Fixed Asset)	($48,760.71)
Assurance (Fixed Asset)	($1,707,031.12)
Depreciation (Fixed Asset)	($121,901.77)
Total Profit Plants	$46,778,059.29
Total Profit	$44,900,365.69

Since the investment cost of scenario A and B is different, it affects mostly in Cost of Good Sold that is generated from the optimization result. The profit and loss statement for scenario B is in table 4.26. The calculation of total profit for scenario B is in the table 4.27.

Table 4. 27 Total Profit of Scenario B

Maintenance (Fixed Asset)	($48,760.71)
Assurance (Fixed Asset)	($1,707,031.12)
Depreciation (Fixed Asset)	($121,901.77)
Total Profit Plants	$46,775,645.97
Total Profit	$44,897,952.37

4.3.3 Valuation Model

The last process is to make valuation model of the project with chosen receiver plants. Before the model-making, Capital Asset Pricing Method of the project and Weighted Average Cost of Capital should be calculated as the project is using investment cost generated from assumptions as written in table 4.28.

Table 4.28 Debt and Equity Percentage

Debt	0
Equity	100%

The calculation of CAPM uses formula in of Beta Levered and CAPM and the result is in table 4.29, meanwhile the value of unlevered beta, risk premium, and default spread is taken from Damodaran (2016). CAPM is the calculation as the predecessor of calculating the WACC. CAPM is used to the cots of equity that will be used to calculate WACC.

$$\text{Beta Levered} = \text{Beta Unlevered} \times 1 + ((1 - \text{Tax Rate}) \times (\text{Debt to Equity Ratio})) \quad (4.28)$$

$$E(R_i) = R_f + \beta \times (RP_m) - Default\ Spread \quad (4.29)$$

With notes that:

E(Ri) = CAPM
Rf = Risk Free Return
RPm = Risk Premium

Table 4.29 CAPM of The Project

Unlevered beta	0.79
Debt to equity ratio	0%
Tax rate	25%
Beta (b)	0.79
Beta (b)	0.79
Risk-free return (Rf)	4.32%
Equity risk premium	9.65%
Default spread	2.86%
CAPM	9%

From the result of CAPM, WACC of the project is calculated; the result is summarized in table 4.30. The company decides to fund all the investment by themselves without having debt to bank.

Table 4.30 WACC of The Project

Debt portion (Wd)	0%
Cost of debt (kd)	4%
Equity portion (We)	100%
Cost of equity (ke)	9%
WACC	9%

The value of WACC is then used to discount the net present value of the project. Valuation of the project is made in form of free cash flow. The benefit of the project is coming from natural gas cost saving, the cost is coming from the costs of implementing and running the project, and the parameter of the value is in Net Present Value, with additional information of Internal Rate of Return.

Valuation model result is in table 4.31 and continued in table 4.32 for scenario A as the chosen scenario based on its value in profit.

The result valuation model is then used to know the additional value or benefit given from the project to the company in form of net present value the investment can be generated. The parameter of the valuation is NPV with IRR as the additional information. The result in table 4.33 shows that all the investment spent on the project is worth the benefit.

Table 4.31 Result in Valuation Parameter For Scenario A

NPV	$97,749,834
IRR	206%

Table 4. 322 Valuation Model for Scenario A

Year	Saving	Investment	Assurance	Operational	Maintenance	Depreciation
-	-	($3,634,691.87)	-	-	-	-
2017	$15,424,045.56	-	($1,908,667.57)	($186,556.87)	($54,520.38)	($136,300.95)
2018	$15,732,526.47	-	($1,908,667.57)	($190,288.01)	($55,610.79)	($136,300.95)
2019	$16,047,177.00	-	($1,908,667.57)	($194,093.77)	($56,723.00)	($136,300.95)
2020	$16,368,120.54	-	($1,908,667.57)	($197,975.64)	($57,857.46)	($136,300.95)
2021	$16,695,482.95	-	($1,908,667.57)	($201,935.15)	($59,014.61)	($136,300.95)
2022	$17,029, 392.61	-	($1,908,667.57)	($205,973.86)	($60,194.90)	($136,300.95)
2023	$17,369,980.46	-	($1,908,667.57)	($210,093.33)	($61,398.80)	($136,300.95)
2024	$17,717,380.07	-	($1,908,667.57)	($214,295.20)	($62,626.78)	($136,300.95)
2025	$18,071,727.67	-	($1,908,667.57)	($218,581.11)	($63,879.31)	($136,300.95)
2026	$18,433,162.23	-	($1,908,667.57)	($222,952.73)	($65,156.90)	($136,300.95)
2027	$18,801,825.47	-	($1,908,667.57)	($227,411.78)	($66,460.04)	($136,300.95)
2028	$19,177,861.98	-	($1,908,667.57)	($231,960.02)	($67,789.24)	($136,300.95)
2029	$19,561,419.22	-	($1,908,667.57)	($236,599.22)	($69,145.02)	($136,300.95)
2030	$19,952,647.60	-	($1,908,667.57)	($241,331.20)	($70,527.92)	($136,300.95)
2031	$20,351,700.56	-	($1,908,667.57)	($246,157.83)	($71,938.48)	($136,300.95)
2032	$20,758,734.57	-	($1,908,667.57)	($251,080.98)	($73,377.25)	($136,300.95)
2033	$21,173,909.26	-	($1,908,667.57)	($256,102.60)	($74,844.80)	($136,300.95)
2034	$21,597,387.44	-	($1,908,667.57)	($261,224.66)	($76,341.69)	($136,300.95)
2035	$22,029,335.19	-	($1,908,667.57)	($266,449.15)	($77,868.53)	($136,300.95)
2036	$22,469,921.90	-	($1,908,667.57)	($271,778.13)	($79,425.90)	($136,300.95)

Table 4. 33 Valuation Model for Secnario A (Con't)

Year	Net Cash Flow before Tax	Tax 0.25	Net Cash Flow after Tax	Depreciation Reversal	Annual Cashflow	Salvage Value
-	($3,671,977.87)		($3,671,977.87)	-	($3,671,977.87)	
2017	$13,116,462.47	($3,279,115.62)	$9,837,346.85	$137,699.17	$9,975,046.02	
2018	$13,420,110.65	($3,355,027.66)	$10,065,082.99	$137,699.17	$10,202,782.16	
2019	$13,729,831.80	($3,432,457.95)	$10,297,373.85	$137,699.17	$10,435,073.02	
2020	$14,045,747.36	($3,511,436.84)	$10,534,310.52	$137,699.17	$10,672,009.69	
2021	$14,367,981.24	($3,591,995.31)	$10,775,985.93	$137,699.17	$10,913,685.10	
2022	$14,696,659.80	($3,674,164.95)	$11,022,494.85	$137,699.17	$11,160,194.02	
2023	$15,031,911.92	($3,757,977.98)	$11,273,933.94	$137,699.17	$11,411,633.11	
2024	$15,373,869.09	$3,843,467.27)	$11,530,401.82	$137,699.17	$11,668,100.99	
2025	$15,722,665.41	($3,930,666.35)	$11,791,999.06	$137,699.17	$11,929,698.23	
2026	$16,078,437.65	($4,019,609.41)	$12,058,828.23	$137,699.17	$12,196,527.40	
2027	$16,441,325.33	($4,110,331.33)	$12,330,994.00	$137,699.17	$12,468,693.17	
2028	$16,811,470.77	($4,202,867.69)	$12,608,603.08	$137,699.17	$12,746,302.25	
2029	$17,189,019.11	($4,297,254.78)	$12,891,764.34	$137,699.17	$13,029,463.51	
2030	$17,574,118.43	($4,393,529.61)	$13,180,588.82	$137,699.17	$13,318,287.99	
2031	$17,966,919.73	($4,491,729.93)	$13,475,189.80	$137,699.17	$13,612,888.97	
2032	$18,367,577.05	($4,591,894.26)	$13,775,682.79	$137,699.17	$13,913,381.96	
2033	$18,776,247.52	($4,694,061.88)	$14,082,185.64	$137,699.17	$14,219,884.81	
2034	$19,193,091.41	($4,798,272.85)	$14,394,818.55	$137,699.17	$14,532,517.72	
2035	$19,618,272.17	($4,904,568.04)	$14,713,704.12	$137,699.17	$14,851,403.29	
2036	$20,051,956.54	($5,012,989.13)	$15,038,967.40	$137,699.17	$16,094,661.04	$917,994.47

CHAPTER V
DATA ANALYSIS AND INTEPRETATION

In this chapter, there will be explanations of the data processing results in chapter IV and analysis of it. The analysis consists of the result of optimum allocation and sensitivity analysis.

5. 1 Optimum Allocation of Blast Furnace Gas and Coke Oven Gas Analysis

Based on the profit and loss statement, scenario A generates total profit in the amount of $44,900,365.69, which means that in terms of the valuation parameter and objective function of the optimization model, scenario A gives a slightly better financial benefit than scenario B that is $44,897,952.37. This is due to the difference of the distance from holders to plant, which can be seen that scenario B is overall farther and it influences the amount of money spent for the investment. Although Hot Strip Mill plant and Wire Rod Mill gets closer in distance to the holder, which makes their investment is less than in scenario A, but it does not make much difference in the result of the allocation since the difference of distance for other plants are quite significant.

The result of allocation in form of flow rate of Blast Furnace Gas and Coke Oven Gas to the machines shows that the results is in the favor of fully utilizing the availability of both gases. In the chosen scenario, scenario A, the disposal gas allocation goes to Billet Steel Plant that receives gas mixture 2, Cold Rolling Mill receives gas mixture 2, and Wire Rod Mill receives gas mixture 2. From the lists of the receiver, Cold Rolling Mill is actually one of the most expensive investments if it ever gets the disposal gas, but it still gets the allocation. The reason is because overall, the investment of pipe in each machine and fixed investment is insignificant compared to the benefit of saving in all plants, thus the model works to minimize residue of utilizing the gas to give the most out of natural gas cost saving. It searches for the best combination to obtain the highest utilization in the amount of disposal gas, regardless of the investment it would take. The same logic applies to scenario B although the amount of investment is higher and the location of holders are different that makes its position to candidate plants also different. Therefore, the result of allocation in scenario B is exactly the same as scenario A.

When the amount of natural gas that can be saved by allocating the gas between two plants are close, the optimization then considers the cost, which one takes a lesser cost that significant enough to make the difference of saving and cost matters. If one plant has a slightly higher saving than another, but the investment cost is bigger than the difference of saving difference, the allocation will move to the one that gives a better benefit, with notes that the availability of the gas can still fulfill the demand.

This model is run under the assumption that the capacity and demand of the production in PT X will not change much, since as the process industry with made to stock production strategy. Thus, the revenue is assumed to be constant until the projective years in the valuation model and the price escalates 2%. By this assumption, the result of the optimization will fit and technically achieve the goal and for the price used in the P&L Statement is from 2016 as the research is conducted and the decision is taken. Further on the uncertainty of financial elements in the financial model is elaborated in sensitivity analysis.

5. 2 Sensitivity Analysis

Sensitivity analysis is sensitivity test towards macro and microeconomics assumptions used that can affect financial performance of the observed object. Specifically in this research, the sensitivity analysis is conducted towards the assumptions in both valuation model and optimization model, which can possibly change overtime and will significantly or not change the allocation result and the value of the project directly.

Investment cost and natural gas price is the chosen assumption that will be tested, since those are two of some elements that value most likely moves by period, meanwhile the mixture composition and the availability of the gas, which actually are very sensitive to the result can not be tested since the value is exact and will not change unless there is a new resource of the disposal gas.

Table 5.1 is the result of sensitivity analysis towards total profit as the objective of the optimization model by changing the price of natural gas gradually by 10%.

Table 5.1 Sensitivity Analysis of Natural Gas Price Change

Parameter	**Change**	**Total Profit**
NG Price	Decreased by 10%	$67,847,573.13
	Decreased by 20%	$90,794,780.57
	Decreased by 30%	$113,741,988.02
	Decreased by 40%	$136,689,195.46
	Decreased by 50%	$159,636,402.91
	Decreased by 60%	$182,589,147.86
	Base	$44,900,365.69
	Increased by 10%	$21,953,158.24
	Increased by 20%	$(994,049.20)
	Increased by 30%	$(23,941,256.65)
	Increased by 40%	$(46,888,464.09)
	Increased by 50%	$(69,835,671.53)
	Increased by 60%	$(92,782,878.98)
	Increased by 70%	$(115,730,086.42)
	Increased by 80%	$(138,677,293.87)
	Increased by 90%	$(161,624,501.31)
	Increased by 100%	$(184,571,708.75)
	Increased by 670%	$(1,492,562,533.06)

Sensitivity analysis towards natural gas price also is tested to see the result of allocation if it changes along with the change of natural gas price and the result is in table 5.2.

Table 5.2 Sensitivity Analysis of Natural Gas Price Change

Parameter	**Change**	**DRP**	**BF**	**BSP**	**SSP**	**HSM**	**CRM**	**WRM**
NG Price	Decreased by 10%	1	1	2	1	1	2	2
	Decreased by 20%	1	1	2	1	1	2	2
	Decreased by 30%	1	1	2	1	1	2	2
	Decreased by 40%	1	1	2	1	1	2	2
	Decreased by 50%	1	1	2	1	1	2	2
	Decreased by 60%	1	1	2	2	1	2	1
	Base	1	1	2	1	1	2	2
	Increased by 10%	1	1	2	1	1	2	2
	Increased by 20%	1	1	2	1	1	2	2
	Increased by 30%	1	1	2	1	1	2	2

Table 5.2 Sensitivity Analysis of Natural Gas Price Change (Con't)

Parameter	Change	DRP	BF	BSP	SSP	HSM	CRM	WRM
	Increased by 40%	1	1	2	1	1	2	2
	Increased by 50%	1	1	2	1	1	2	2
	Increased by 60%	1	1	2	1	1	2	2
	Increased by 70%	1	1	2	1	1	2	2
	Increased by 80%	1	1	2	1	1	2	2
	Increased by 90%	1	1	2	1	1	2	2
	Increased by 100%	1	1	2	1	1	2	2
	Increased by 670%	1	1	2	1	1	2	2

From the result of sensitivity in table 5.1 to 5.2, in which the natural gas price is changed gradually by 10%, from -60% to 670%, the change in the allocation decision happens when the natural gas price decreased by 60%, which makes the allocation of gas mixture 2 (natural Gas + Blast Furnace Gas) in Wire Rod Mill moves to Slab Steel Plant with the same mixture. The reason is because previously, the model works in a way that it maximizes the utilization of the Coke Oven Gas and Blast Furnace gas, and neglects the amount of investment, as it is insignificant compared to the benefit of saving. When the price of natural gas decreases significantly, the benefit of saving is no longer significant compared to the investment, which makes the model considers the amount of investment spent for allocation, although the disposal gas utilized is not as much as in the base price. Since the model objective is to maximize the total profit, there should be compromise between the saving and the cost, thus to reduce the amount of investment cost, the allocation changes to the less expensive machine one.

The second sensitivity analysis is towards the investment cost assumption. The result of the test to the objective of the optimization model is in table 5.3.

Table 5.3 Sensitivity Analysis of Investment Cost Change

Parameter	Change	Profit
Investment	Increased by 10%	$44,712,596.33
	Increased by 20%	$44,524,826.97
	Increased by 30%	$44,337,057.61
	Increased by 40%	$44,149,288.25
	Increased by 50%	$43,961,518.89
	Increased by 60%	$43,773,749.53
	Increased by 70%	$43,585,980.17
	Increased by 80%	$43,398,210.81

Table 5.3 Sensitivity Analysis of Investment Cost Change (Con't)

Parameter	Change	Profit
	Increased by 90%	$43,210,441.45
	Increased by 100%	$43,022,672.09
	Increased by 670%	$32,379,728.60
	Base	32,379,735.60
	Decreased by 10%	$45,088,135.05
	Decreased by 20%	$45,275,904.41
	Decreased by 30%	$45,463,673.77
	Decreased by 40%	$45,651,443.13
	Decreased by 50%	$45,839,212.49
	Decreased by 60%	$46,026,981.85
	Decreased by 70%	$46,214,751.21
	Decreased by 80%	$46,405,521.47

In table 5.4, sensitivity analysis of investment cost assumptions shows the impact to the allocation result.

Table 5.4 Sensitivity Analysis of Investment Cost Change (Con't)

Parameter	Change	DRP	BF	BSP	SSP	HSM	CRM	WRM
Investment	Increased by 10%	1	1	2	1	1	2	2
	Increased by 20%	1	1	2	1	1	2	2
	Increased by 30%	1	1	2	1	1	2	2
	Increased by 40%	1	1	2	1	1	2	2
	Increased by 50%	1	1	2	1	1	2	2
	Increased by 60%	1	1	2	1	1	2	2
	Increased by 70%	1	1	2	1	1	2	2
	Increased by 80%	1	1	2	1	1	2	2
	Increased by 90%	1	1	2	1	1	2	2
	Increased by 100%	1	1	2	1	1	2	2
	Increased by 670%	1	1	1	1	1	1	1
	Base	1	1	2	1	1	2	2
	Decreased by 10%	1	1	2	1	1	2	2
	Decreased by 20%	1	1	2	1	1	2	2
	Decreased by 30%	1	1	2	1	1	2	2
	Decreased by 40%	1	1	2	1	1	2	2
	Decreased by 50%	1	1	2	1	1	2	2
	Decreased by 60%	1	1	2	1	1	2	2
	Decreased by 70%	1	1	2	1	1	2	2
	Decreased by 80%	1	1	2	2	1	2	1

The same logic applies to the change in investment tested to the model. From table 5.3 and 5.4, the test is conducted by increasing and decreasing the cost of investment gradually started by -80% to 670% for the total amount as the percentage. In natural gas price sensitivity analysis, the result change once the natural gas price drops significantly, which means the saving decreases in significant amount, as the opposite of saving, which is cost, the result in sensitivity analysis of investment cost changes once it moves high to the amount that it is not much different with the saving benefit. That makes the model works on moving the allocation to the machine, which spends less cost in investment. Thus, the objective of giving the maximum net present value of the project can still be reached. In this matters, the investment cost is really insignificant compared to the benefit that makes it quite insensitive until the cost increases by 670%, in which the result does not allocate the gas to plants because the benefit no longer can cover the cost.

The change in allocation means that when the natural gas dropped by 60% and the investment cost lifts up to 670%, the allocation decision in the research is no longer relevant. The maximum profit will be in the new allocation mentioned in table 5.2 and 5.4. Although it is unlikely for the parameter to change drastically to the point of it is significant to the current model, but uncertainty is inevitable along the economic life of the asset. But as of on this period, the allocation that gives maximum profit has already been obtained.

CHAPTER VI
CONCLUSION AND RECOMMENDATION

This chapter will explain the conclusion and recommendation drawn from the conducted research.

6. 1 Conclusion

This research has successfully built optimization model that maximizes the value of the project with considerations of several aspects, such as macro-economics condition and the real internal condition of the company, especially in the chemical aspect of the Coke Oven Gas, Blast Furnace Gas, and Natural Gas, thus it is able to be mixed and combined to reach certain calorie with certain flow rate to fulfill the fuel demand of the machines. The model has been validated by management of the company by testing it with their business development plans. Therefore, the model of allocation optimization has been confirmed valid to solve the specified problem.

The model generates result in allocation with the maximum total profit of the project. Disposal gas of Blast Furnace and Coke Oven goes to Billet Steel Plant that receives gas mixture 2 (NG 5,036 NCMH, 3,677 BFG, and 2,747 COG), Cold Rolling Mill Plant receives gas mixture 2 (NG 6,585 NCMH, 4,809 NCMH BFG, and 3,592 NCMH COG), and Wire Rod Mill also receives gas mixture 2 (4,407 NCMH NG, 3,218 NCMH BFG, and 2404 NCMH COG) in scenario A. By implementing the result, this project reaches USD44,900,365.69 of total profit with additional value for the company on the net present value of the project, which is USD97,749,834 and IRR 206%.

Last but not least, sensitivity analysis conducted to the research. Sensitivity analysis is sensitivity test towards macro and microeconomics assumptions used that can affect financial performance of the observed object. In this matter, the assumptions tested are the natural gas price and investment cost. The result shows that the change in allocation happens when the natural gas price decreased by 60% and the investment cost increased by 670%. The reason is because initially the model works in a way, which it neglects the amount of cost as it is insignificant compared to the saving, but when the saving decreases or the cost increases, one another works on compromise to still reach maximum value on total profit by changing the allocation result to the plant which takes less investment cost.

6. 2 Recommendation

Recommendation that could be given related to this research is to consider making allocation targets per machines in each plant and giving the Blast Furnace Complex financial activities in the utilization of its disposal gas can give more comprehensive result in the valuation of the project.

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