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LCA methodology for detecting environmental impacts on natural gas drilling process

Masayu Rosyidah[1], Andiyan Andiyan[2*], Haniek Listyorini[3], Pranoto Hadi Prayitno[4], Yuswardi Yuswardi[5], Yuhanah Yuhanah[6]

[1]Universitas Muhammadiyah Palembang, Palembang, Indonesia
[2]Universitas Faletehan, Bandung, Indonesia
[34]Sekolah Tinggi Ilmu Ekonomi Pariwisata Indonesia, Semarang, Indonesia
[5]Universitas Jabal Ghafur, Aceh, Indonesia
[6]Universitas Sembilan Belas Nopember Kolaka, Kolaka, Indonesia

*andiyanarch@gmail.com

Abstract. This study uses LCA analysis to monitor potential damage to eco-efficiency. This approach uses an environmental life cycle assessment (LCA) to detect ecological impacts in natural gas production systems. The study results found that the lowest environmental impact on the production process at PT was seen. X is located on the Ozone layer and Resp. Organics are 4.71E-06 DALY and 3.22E-05 DALY. The highest impact lies in Resp. Inorganics, Fossil fuels, and Climate change. This shows that the drilling system hurts the environment, especially in the climatic conditions of soil, plants, and fossil fuels which continue to decrease. In addition, because the drilling process is carried out using generator power, it causes air pollution that can interfere with the respiratory system (respiratory inorganics).

1. Introduction

Natural gas usage in Indonesia has grown significantly since 1974, when PERTAMINA started delivering natural gas through pipes from the Prabumulih natural gas resource in South Sumatra to the Palembang fertilizer facilities Pusri II, Pusri III, and Pusri IV. Simultaneously, in 1974, PERTAMINA provided natural gas to fertilizer plants and medium and heavy industries in West Java and Cilegon Banten through gas pipes from natural gas reserves off the Java Sea and Cirebon regions. The natural gas pipeline that extends from Cirebon to Cilegon, Banten, provides natural gas to a variety of industries, including cement plants, fertilizer plants, ceramic plants, steel plants, and gas and steam power plants.

In addition to local use, natural gas is exported in the form of LNG in Indonesia (Liquefied Natural Gas)[1]. One of the companies that process natural gas is PT. XYZ. The company is located in Muara Enim Regency. The natural gas exploration process uses only simple technology. Gas waste at PT. The combustion process removes XYZ[2]. The results of this combustion are predicted to have an impact on the surrounding environment.

Therefore, it is very important to analyze the potential environmental effects in the raw gas production system. The problem in this research is how much potential ecological impact is produced in the crude gas production process using the Life Cycle Assessment (LCA) method. The aim is to find out and identify what potential will impact the environment as a result of the production process that occurs[3].

2. Literature Review

Raw natural gas comes from several adjacent wells and is collected, and the first treatment process that occurs is removing water content and natural gas condensate. Condensation usually flows to the oil refinery, and the water is disposed of as wastewater. The raw natural gas is then sent to a processing plant, where the initial purification usually removes the acid content (H2S and CO2). The process used in general is Amine Treating which is commonly called Amine Plant. The next process is to remove moisture using the adsorption process in liquid trimethylene glycol (TEG). The next phase is to convert into liquefied natural gas (NGL), which is the most complex process and uses modern gas processing plants, shown in figure 1[4].

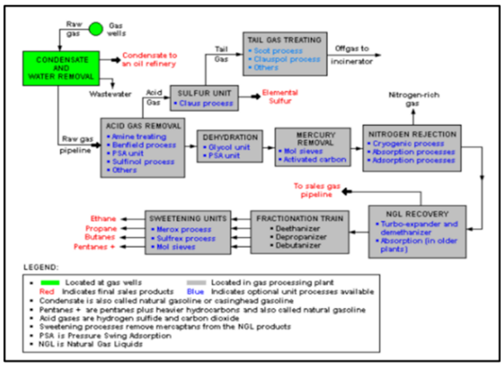
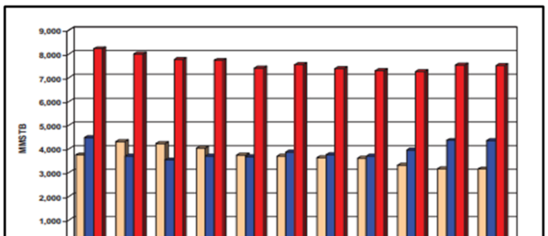


Figure 1. Natural Gas Production Process [4]

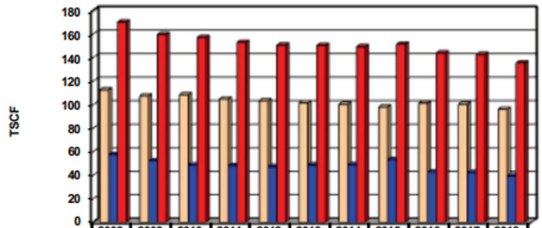
According to Marques and Silva, 2019, natural gas is a non-renewable energy commodity that plays an important role in meeting the world's primary energy needs. In 2017, natural gas demand worldwide reached 23.4% of the total global, immediate energy demand. Natural gas is one of the energies needed for every country, wherein developing a nation. It takes a certain amount of energy which will grow more and more every year.

Natural gas has a very important role as the third most widely used primary energy in the country after oil and coal, supporting people's lives and driving the Indonesian economy. In everyday life, natural gas is used as fuel for cooking, heating water, welding, driving turbines and generators to produce fertilizers and electricity, fuel gas for transportation (BBG), petrochemical raw materials, steel smelting, glass industry, ceramics. Additives and so on [5].



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Proven	3747.5	4303.1	4230.2	4039.6	3741.3	3692.5	3624.3	3602.5	3306.91	3170.9	3154.3
Potential	4471.7	3695.4	3534.3	3692.7	3666.9	3857.3	3750.9	3702.5	3944.2	4364	4357.9
Total	8219.2	7998.5	7764.5	7732.3	7408.2	7549.8	7375.1	7305	7251.11	7534.9	7512.2

Figure 2. Graph of Indonesia's Petroleum Reserves for the Last 10 Years Based on MMSTB



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Proven	112.5	107.34	108.4	104.7	103.3	101.5	100.3	98.0	101.2	100.4	96.1
Potential	57.6	52.29	48.74	48.2	47.4	48.9	49.0	53.3	42.8	42.4	39.4
Total	170.1	159.63	157.14	152.9	150.7	150.4	149.3	151.3	144.0	142.7	135.5

Figure 3. Graph of Indonesia's Petroleum Reserves for the Last 10 Years Based on TSCF

Although some areas produce just natural gas, oil and natural gas are often discovered in the same field. In general, Indonesia's oil and gas reserves have been declining during the past decade. From 8.21 billion barrels in 2008, oil reserves dropped to a range of 7.5 billion barrels in 2018.[6].Reserve to Production (as a percentage of Proven Reserves) is in the range of ten to eleven years. The extension to 12 years occurred in 2014 as a result of substantial additions to prove oil reserves, particularly from the Banyu Urip Cepu Field.

Following that, the fall in global oil prices in 2015, which is still being felt today, is cited as one of the reasons for the low rate of new resource finding. In Indonesia, KKKS are more cautious and have a smaller footprint when it comes to oil and gas exploration and production. Indonesia's natural gas reserves are also diminishing. Natural gas reserves peaked at 170 TSCF in 2008 and have since declined to a range of 136 TSCF in 2018.

However, Indonesia's Reserve to Production ratio of natural gas (as a percentage of Proven Reserves) has been relatively constant during a 34-year period from 2009 to 2018, after falling substantially from 41 years in 2008. This is partially because proved reserves can be maintained while production continues at its current pace[7]. One method that can be used to analyze environmental impacts is the Life Cycle Assessment (LCA) method. Life Cycle Assessment (LCA) is a mechanism to analyze and calculate the total environmental impact at each stage of its life cycle. Life Cycle Assessment (LCA) uses an overall "cradle to grave" approach that starts with taking raw materials from the earth to make products and ends at the point where all materials return to the world [8]. There must be an in-depth study to identify the best environmental management scenario, particularly to reduce potential environmental impacts [9].

Life Cycle Assessment (LCA) is a process for analyzing and quantifying a product's overall environmental effect throughout its life cycle. Beginning with the preparation of raw materials, manufacturing processes, sales and transportation, and product disposal. The idea of Life Cycle Assessment (LCA) is often referred to as the "cradle to grave" concept. The Existence Cycle Assessment (LCA) method employs a quantitative approach to assessing environmental effects by quantifying all exchange fluxes between the system and the environment at each stage of the system's life. LCA operates from four locations: Definition of the objective and scope of work, life cycle inventory, assessment of the life cycle impact, and interpretation[10].

With many phases of study, life cycle assessment (LCA) is a tool or technique for identifying environmental effects. Life cycle assessment (LCA) is a technique or tool for analyzing the environmental effects associated with the manufacturing process of a product. The benefit of LCA is that it is exhaustive since it can evaluate the possible environmental consequences of the life cycle activities.[11].

With LCA, it is possible to observe how resources are used (input) and materials are created (output) during a process. LCAs are often focused on contributions to regional and global-scale effects, which include resource use. Life Cycle Analysis (LCA), or more commonly referred to as Life Cycle Assessment, is a cradle to grave method (an analysis of the entire cycle from raw materials to waste treatment) that is used to determine the amount of energy, costs, and environmental impacts associated with the various stages of a product's life cycle—from the time raw materials are obtained to the time consumers use the finished product.

Each stage of the LCA process is specified in international standards (ISO 14040, ISO 14041). This phase is repeated, with varying degrees of detail and effort in accordance with the study goals (World Business Council for Sustainable Development, 2002). The stages are as follows: (1) establishing goals and scope, (2) doing an inventory analysis, (3) conducting an impact analysis/assessment, and (4) conducting an interpretation (ISO 14040, 2006)[10].

According to Pujadi (2013), Life Cycle Assessment (LCA) has the following principles:

- We see the life cycle as a perspective, in other words, considering the entire physical life cycle of a product (or service), starting from the extraction of raw materials, the use of energy and production materials, the production process, the use of the product, to the end of the product's life. Another perspective is to look at the life cycle of a particular method currently being carried out as research.
- Cover all environmental aspects into one general assessment so that environmental impacts can be identified.
- Provide transparency to ensure the correct interpretation of the results obtained by calculations.
- Narrative in nature consists of four stages, namely determining the purpose and scope of the research, Life Cycle Inventory (LCI), Life Cycle Impact Assessment (LCIA), and interpretation.
- Focus on the environment by studying the environmental aspects of the production system and leaving economic and social elements aside from research.
- It is a science-based method, even though scientific circumstances are always changing. LCA provides an overview of a certain state at a certain time.

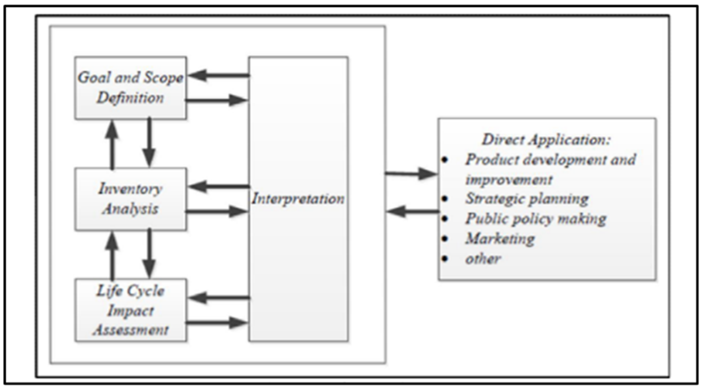


Figure 4. Fasel Life Cycle Assessment

3. Methods

The research took place from March to July 2020. The study was conducted on the natural gas production process in the Muara Enim district[12]. Data were collected from primary data obtained from interviews and observations. The research approach uses quantitative and qualitative methods (mixed method)[13]. Integrated Methods Research (MMR) is a research method applied when researchers have questions that need to be tested in terms of results and processes and involves a combination of quantitative and qualitative methods in one study[14].

Because it focuses on developments and techniques, MMR designs are commonly used in program evaluation research. The stages of the LCA method used are LCA procedures according to ISO 14040, which consist of four steps, namely goal and scope definition, life cycle inventory, life cycle impact assessment, and interpretation, assisted by the Simapro program [10].

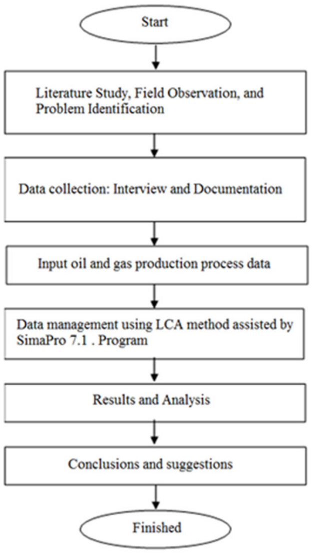


Figure 5. Research Flowchart

4. Result

PT. XYZ produces oil and gas. The gas produced is condensate, a liquid hydrocarbon obtained from gas wells or oil wells mixed with gas. Production of crude gas and oil from wells to collection stations is carried out by natural flow (not aspirated using machines). After entering the collection station, filtering is carried out by flowing it into the high separator, then flowing back into the low partition. After that, the dry gas is filtered back into the scrubber, then the gas is sent to the main Pertamina to be produced further, and the waste from the Production is flowed to the disposal by burning. From the production process, there are no chemicals used by PT. XYZ[15].

However, in the production process, there is waste from the rest of the disposal and the production process. Producing crude gas and oil begins with determining the point of the well to be drilled. After that, from the borehole directly into the collection station, filtering is carried out by flowing it into a high separator. Next, it has rushed back to the low partition[16]. The next stage is to filter into the scrubber. The results from the filtration are sent to the main Pertamina to be produced further, and the waste from the Production is sent to disposal by burning.

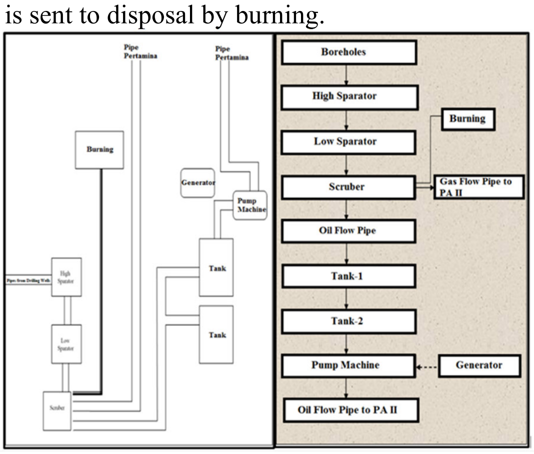


Figure 6. Production Process Flow of PT. XYZ

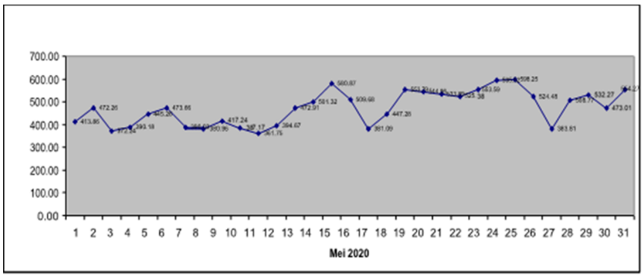


Figure 7. Oil output histogram of PT. XYZ Period May 2020 can be seen in the image below

Table 1. Total KWh Engine Generator Usage PT. XYZ (Period May 2020)

No.	K
1	43.07
2	46.19
3	36.28
4	37.12
5	53.42
6	55.29
7	42.12
8	36.27
9	48.56
10	52.72
11	32.18
12	34.46
13	62.43
14	78.21
15	81.05
16	63.34
17	57.18
18	68.45
19	70.07
20	80.13
21	76.24
22	78.61
23	82.3
24	88.27
25	92.14
26	76.08
27	62.14
28	74.08
29	83.92
30	75.42
31	84.17
Amount	1951.91
Average	62.96

The total output of PT. XYZ in the May 2020 Period was 1951.91 KWh/day, with an average of 62.96 KWh/day.

Table 2. Total Fluid Combustion PT. XYZ (Period May 2020)

No.	Barrel
1	4.71
2	5.36
3	3.59
4	3.28

5	**3.65**
6	**4.98**
7	**3.19**
8	**3.65**
9	**4.32**
10	**3.54**
11	**3.19**
12	**3.25**
13	**3.25**
14	**5.36**
15	**6.25**
16	**5.24**
17	**3.28**
18	**4.25**
19	**5.98**
20	**5.65**
21	**5.32**
22	**4.39**
23	**5.14**
24	**6.32**
25	**6.95**
26	**6.54**
27	**3.25**
28	**3.95**
29	**5.08**
30	**5.32**
31	**6.32**
Amount	**144.55**
Average	**4.66**

Table 3. Input and Output Data PT. Bama Bima Sentosa Pagar Dewa Village, Lubai District (May 2020 Period)

Type	***Output***	
	Amount per month	**Average per day**
Raw Gas (CH4)	538.54 MMSCFD	**17.37 MMSCFD**
Crude Oil	14674.42 Barrel	**473.37 Barrel**
Hydrogen fluoride	144.55 Barrel	**4.66 Barrel**
Natural Gas	**1951.91 KWh**	**62.96 KWh**

Description :
1 kWh = 1.000 watt
1 barrel = 158.99 liters
MMSCFD = Million Standard Cubic Feet per Day (gas)

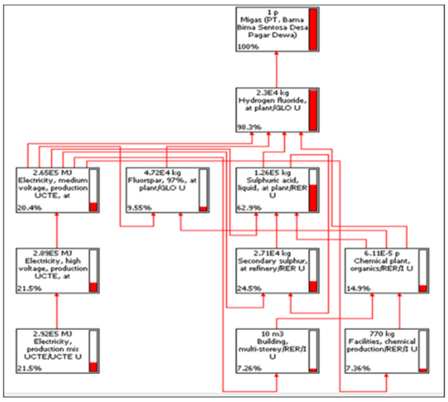


Figure 8. Production Process Diagram of PT. XYZ with Simapro

Table 4. Environmental Impact Based on Damage Assessment

Impact category	Unit	Total
Carcinogens	DALY	**0.006415**
Resp. organics	DALY	**3.22E-05**
Resp. inorganics	DALY	**0.171476**
Climate change	DALY	**0.013872**
Radiation	DALY	**0.000704**
Ozone layer	DALY	**4.71E-06**
Ecotoxicity	PDF*m2yr	**2909.298**
Acidification/ Eutrophication	PDF*m2yr	**3651.186**
Land use	PDF*m2yr	**1074.951**
Minerals	MJ surplus	**7646.472**
Fossil fuels	**MJ surplus**	**72521.72**

(Source: SimaPro 7.1.8 Data Processing)

Based on the table above, it can be seen that the lowest environmental impact on the production process at PT. XYZ is the Ozone layer and Resp. Organics are 4.71E-06 and 3.22E-05[17]. This is because of the production process at PT. XYZ does not damage the ozone layer and organic response. The Ozone layer has almost no impact. That is the use of materials in the production process by PT. XYZ does not damage the ozone layer[18].

Furthermore, it can be seen that the highest environmental impact on the production process at PT. XYZ is in Resp. Inorganics and climate change. This is due to the drilling carried out by PT. XYZ hurts the environment, especially in the climatic conditions of the soil and plants[19].

Furthermore, the environmental impact based on a single score can be seen in the table below.

Table 5. Environmental Impact Based on Single Score

Impact category	Unit	Total
Carcinogens	Pt	167.0443
Resp. organics	Pt	0.837839
Resp. inorganics	Pt	4465.243
Climate change	Pt	361.2335
Radiation	Pt	18.34125
Ozone layer	Pt	0.12263
Ecotoxicity	Pt	226.9252
Acidification/ Eutrophication	Pt	284.7925
Land use	Pt	83.8462
Minerals	Pt	181.986
Fossil fuels	Pt	1726.017

The table above shows that the highest impact lies in Resp. Inorganics, Fossil Fuels, and Climate Change[20]. This indicates that PT carried out the drilling. XYZ hurts the environment, especially on the climatic conditions of soil, plants, and fossil fuels that continue to decrease[21].

5. Conclusion

a. Based on the study results, it was found that the lowest environmental impact on the production process at PT. XYZ is the ozone layer and Resp. Organics are 4.71E-06 and 3.22E-05. This is because the production process at PT. XYZ does not damage the ozone layer and organic response. The ozone layer has almost no impact. That is the use of materials in the production process by PT. XYZ does not damage the ozone layer.
b. Based on the study results, it was found that the highest impact was on respiratory inorganics of 4,465,243, fossil fuels of 361,234, and climate change of 1,726,017. This shows that PT carried out the drilling. XYZ hurts the environment, especially on the climatic conditions of soil, plants, and fossil fuels that continue to decrease. In addition, drilling carried out using a generator can pollute the air to interfere with breathing (respiratory inorganics).

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