Green manufacturing design in palm oil mills Sei Mangkei PTPN III

Dina Lestari\textsuperscript{1*}, Rahim Matondang\textsuperscript{2} and Nazaruddin Matondang\textsuperscript{2}
\textsuperscript{1}Magister Industrial Engineering, Universitas Sumatera Utara, Medan 20155.
\textsuperscript{2}Department of Industrial Engineering, Faculty of Engineering, Universitas Sumatera Utara

\textsuperscript{*}Email: dinalestary85@yahoo.com

Abstract. Sei Mangkei Mill which has a capacity of 75 tons of FFB/hour treated the waste according to applicable procedures and has complied with the provisions of the Simalungun BLH. Liquid waste (POME) has not been fully utilized because it still causes environmental damage, where POME deposited in open ponds contains methane and carbon dioxide which causes a greenhouse effect. Utilizing renewable energy optimally is one of government programs to create energy independence. Researchers are interested in processing liquid waste in the form of POME into environmentally friendly products that have economic value using the green manufacturing method at the mill. The results obtained are biogas products can be used as a source of renewable energy. Smallest value was obtained by the intensity of the amount of hazardous substances / chemicals of 0.24\% and the largest was obtained in the form of the amount of renewable material at 98.04\% based on product cycle analysis related to eighteen types of environmental performance indicators. This value shows that all waste has been used for the benefit of the factory itself and renewable energy is not harmful to the environment. The eco-efficiency value of biogas products stated that the efficiency level of the product was 99.76\%.

1. Introduction
1.1. The Problem

Sei Mangkei Mill PT. Perkebunan Nusantara III (Persero), also has its own oil palm plantation so that the processing of FFB can be carried out to the maximum extent possible. PTPN III Sei Mangkei Mill which has a capacity of 75 tons of FFB/hour which is divided into 2 processing, namely the capacity of 30 tons of FFB/hour and 45 tons of FFB/hour.

The rapid development of the manufacturing industry creates many environmental problems due to waste generated in the manufacturing process. Therefore, environmental issues related to the scarcity of natural resources, global warming, waste management and increasingly stringent environmental regulations are challenges that must be faced by the industrial world in addition to competition and changes in the business environment that is very fast and dynamic. PTPN III Sei Mangkei Mill is the Mill with the largest processing capacity. The large capacity of processed palm oil causes the amount of waste generated in the manufacturing process. The amount of CPO and FFB production processed during 2018 at Sei Mangkei mill is 231,000 tons and the total CPO produced is 46,200 tons.

Indonesia's CPO production will continue to increase in the next few decades. With the predicted increase in land area reaching 5\% per year, it is estimated that the area of Indonesian palm oil will reach
13.3 Ha in 2020 [1]. Palm oil mills is still constrained by environmental problems that have not been resolved. The problem is the existence of waste products produced during the CPO production process in the form of solid waste and liquid waste that have not been resolved. Based on the percentage of waste weight in percent, mill releases solid waste in the form of: empty fruit bunches 22% of the portion of FFB, 13% fibre, 4.5% shell and palm oil mill effluent (POME) liquid waste around 0.62-0.77 m³ / tons of FFB [2].

Waste generated from palm oil processing and CPO production has not been managed optimally so that it can have an impact on the environment. The amount of waste produced by Sei Mangkei Mill in 2018 is liquid waste in the form of POME 150,150 m³, solid waste 80,850 tons, SO2 gas waste 8,889 Ug / m³, CO 8,064 Ppm, NO2 584 Ug / m³ and hazardous and toxic waste materials 4,445 kg.

Based on the results of direct observation and interviews can be seen in the table above the total amount of waste generated during the 2018 period by Sei Mangkei Mill. Sei Mangkei Mill has utilized “80,850” tons of waste for factory needs, namely 32,340 tons of shell and fibre solid waste from the total waste that has been used for boiler fuel to meet Sei Mangkei’s electricity supply needs. For fibre waste sometimes there is still difference use of boiler fuel in small amounts but the disposal of residual fibre is still in the area around the factory so that it disturbs the environment and decreases the aesthetic / beauty value of the Sei Mangkei VFD area. But that can be overcome by stockpiling the fibre near the boiler to become a better fuel because the drier the fibre used, the higher the heating value for combustion. While the rest of the solid waste in the form of empty bunches which amounts to” 48,510” tons of the total amount of waste produced is piled on the land of PTPN III oil palm plantations to be used as mulch/fertilizer so that FFB waste is not a problem because it has been directly used. For hazardous and toxic waste, the total amount is 4445 kg, while it has been given to the certified management for further information.

Hazardous and toxic waste is considered safe and meets environmental standards (BLH). Similar to the waste gas produced in the form of SO2, CO, NO2 already meets the standards of BLH and for the greenhouse gas effect produced is also very small because of the small value of the emission factor only occasionally the smoke produced is black out of the “boiler” but it is not a problem because it has met BLH standard. For liquid waste, Sei Mangkei Mill has not used it at all. Liquid waste in the form of POME 150,150 m³ produced is only deposited in an open pond of 6 units where the sediment is just dumped after being piled for a year while the water is piped to th

---

**Table 1. The characteristics of POME [4, 5]**

| Parameters       | Range      | Standard |
|------------------|------------|----------|
| Temperature      | 80-90      | 45       |
| pH               | 3.4-5.2    | 6.0-9.0  |
| Oil (mg/L)       | 130-18,000 | 30       |
| BOD (mg/L)       | 10.250-43.750 | 100   |
| COD (mg/L)       | 15,000-100,000 | 500  |
| Dissolved solids (mg/L) | 5,000-54,000 | 300  |
| Total N (mg/L)   | 180-1,400  | 200      |
From the high value of COD and BOD content, the effort to process POME waste into renewable energy is a very promising effort. The results of the study show that POME waste management efforts produce 2 benefits, namely the benefits of additional renewable energy and participation in reducing greenhouse gas emissions [6]. The projection of power potential that can be generated from POME based on Mill capacity can be seen from Table 2.

| MCC Capacity (tons of FFB/jam) | Me resulting from m³/hour | Power Potential (MWe) |
|-------------------------------|---------------------------|-----------------------|
| 30                            | 21                        | 400                   | 1.1                    |
| 45                            | 31.5                      | 600                   | 1.6                    |

POME is the second largest source of greenhouse gas emissions in the palm oil industry, after emissions from land use change. The degradation of organic content in POME produces methane released into the atmosphere. Capturing the methane released from POME helps reduce greenhouse gas emissions, this is a goal of an environmentally sustainable pillar [7]. Responding to liquid waste in the form of POME which is still untapped so that it can be useful and can help the economy of the community, a green manufacturing concept is needed. Green manufacturing is an environmentally friendly manufacturing system that minimizes negative impacts on the environment, saves energy and natural resources, is safe for the community and has economic value.

Sei Mangkei mill in managing its activities has implemented the RSPO and CSPO management system so that it is already feasible for green manufacturing planning. Green aspects that occur in industrial areas generally focus on waste management and energy efficiency. The industrial estate makes it easy for the government to monitor the management of industrial waste, but overlapping regulations and not yet firmly implemented have led to the implementation of the concept of green manufacturing in the industrial estate not running properly [8]. Green manufacturing is a production process using lower environmental impact inputs or no waste or pollution [9].

Yunanto's research (2014) shows that by applying the concept of green manufacturing has raised the image of Batik UKM regarding energy use, water use, the greenhouse gas intensity and air pollution which are considered not green in this study [10].

Based on the facts that there are still wastes that have an impact on the environment while the waste can still be recycled to produce renewable energy, the researchers tried to provide solutions to make green manufacturing design in Sei Mangkei Mill PTPN III.

1.2. Problem Formulation
The problem to be solved in this research is how to process the Sei Mangkei POME mill liquid waste into an environmentally friendly product that has economic value using the green manufacturing method.

1.3. Research Objectives
Based on the formulation of the problem outlined above, the purpose of the author in this research is
1. Provide a proposal regarding the processing of POME liquid waste into environmentally friendly products that have economic value by using the green manufacturing method in the Sei Mangkei Mill where the products produced are no longer a problem for the environment.
2. Obtain an overview of the product cycle related to environmental performance in Sei Mangkei Mill.
3. Make the product as efficient as possible in the use of costs without reducing the sale value of the product.
2. Methodology

This research is a descriptive study. Descriptive research describes systematically, factually, and accurately about the facts and properties of a particular object or population [11]. The conceptual framework of this research can be seen in Figure 1.

![Figure 1. Conceptual Framework for Research](image)

Research methodology is the stage of research subjects relating to a specific condition in conducting a search for a problem and determining the solution of a research problem. This research was conducted using a green manufacturing method to process POME liquid waste into an environmentally friendly product. This research was conducted using direct observation and interviews to get the data needed.

After all the data needed, both primary and secondary data are collected, then the data processing is done to find a solution to the existing problem including:
1. Material and Energy Aspects
2. Process Aspects
3. Product’s Aspects
4. Environmental Performance Indicators
5. Value’s of Efficiency [12]

For material and energy aspects and process aspects in the form of a description of the material used and the production process of POME wastewater treatment into biogas.

3. Results and Discussion

3.1. Material and Energy Input Aspects

Input material used in the biogas production process are POME, mesophilic bacteria, urea, cow dung and water.

3.2. Production Process Aspects

The steps that must be taken in carrying out the Biogas’s production process as previous research [13, 14].

3.3. Product Aspect Analysis

Biogas produced from POME liquid waste can become renewable energy in the form of electricity generation that can be used by humans. For the type of technology selected in the process of making biogas, anaerobic decomposition technology was chosen with CAL because of the consideration of investment costs and payback period.

| Table 3. Calculate the Renewable Energy Potential from POME |
|---------------------------------|-----------------|---------------|
| Parameter                       | Unit            | Information   |
| Capacity                        | Tonnes FFB/ hours | 75            |
| Operating per day               | Hours           | 24            |
| Operating per year              | Day             | 300           |
| FFB Processed                   | Tonnes FFB/ year | 231,000       |
| Ratio POME of FFB               | m³/tonnes FFB   | 0,65          |
| COD                             | mg/l            | 54,500        |

From table 3. it can be produced power generating capacity about 1,32 MWe.
Table 4. Product and Sales Details

| Parameter                                  | Information                          |
|--------------------------------------------|--------------------------------------|
| Biogas Sei Mangkei Machine                 | GE Jenbacher                         |
| Installed Capacity (Gross)                 | 1.320 kW                             |
| Plant Efficiency                           | 95%                                  |
| Self & Other Losses                        | 5%                                   |
| Available Capacity (the net)               | 1191 kW                              |
| Available Operating Hours per year         | 24 x 300 = 7.200 jam                 |
| Production per year                        | 8.575.200 kwh                        |
| Plant lifetime                             | 20 year                              |
| Sales                                      | Rp. 1.500 /kilo Watt hour            |
| **Annual Revenue**                         | **Rp. 12.862.800.000,-**             |

3.4. Analysis of Environmental Performance Indicators

The environmental performance of the manufacturing process of POME processing into biogas can be measured on 18 indicators (Input-process-Output). From these environmental performance indicators it can be concluded that the content of renewable materials has the largest percentage compared to other “indicators” which is 99.76%, while that of hazardous chemicals is only 0.24%. Thus the biogas derived from POME liquid waste is an environmentally friendly product.

3.5. Analysis of the Value of Efficiency

Eco-efficiency is a strategy that combines the concepts of economic efficiency and the concept of ecological efficiency based on the principle of efficient use of natural resources. The efficiency value of biogas products can be seen in table 5.

Table 5. Efficiency Value

| Indicator                                  | Value                        |
|--------------------------------------------|------------------------------|
| Calculation of eco-cost values             | Rp 32.682.256,-              |
| Cost of Production (HPP)                   | Rp. 872.192.800,-           |
| Net value                                  | Rp 11.990.607.200,-         |
| Calculation of Eco Efficiency Index (EEI)  | 13.25                        |
| Calculation of Eco-Costs Value Rate (EVR)  | 0.003                        |
| Calculation of Eco Efficiency Ratio (EER)  | 99.76 %                      |

From the calculation that has been done, it is obtained the EEI value of biogas with a value of 13.25, it can be said that biogas products are affordable and sustainable.

4. Conclusions

The conclusions of the research carried out include the following:

1. Products produced by the Green Manufacturing method of the POME liquid waste treatment process in the form of biogas which can be used as an environmentally friendly renewable energy source.

2. The results of the product cycle analysis relating to environmental performance include (a) the intensity of non-renewable material (non-renewable material) of 0% (b) The intensity or amount of hazardous substances / chemicals of 0.24% (c) The amount of material content renewable or recyclable material 99.76% (d) The intensity or amount of water use is 10.25 m³ (e) The intensity or amount of energy use is “76,826.88MJ” (f) The proportion of renewable energy use is 6, 2% (g) The intensity or amount of greenhouse gas generation (NO2, SO2, HC, etc.) of 0% (h) The intensity or amount of residual material (waste) of 0% (i) The intensity or amount of clean air released or untapped by 0% (j) The intensity or amount of clean water not utilized by 0% (k) Proportion of natural land use (6% (l) Amount of material content that can / has been reused or reused material can
have recycled by 2% (m) Ability to recycle by 0% (n) Total renewable material content by 99.76% (o) Intensity of non-renewable material by 0% (p) Content of hazardous chemicals by 0.24% (q) The intensity or amount of energy consumption is “76,826.88MJ” (r) The intensity of greenhouse gas emissions is 0%

3. The calculation of the efficiency value products includes: (a) Eco-cost result of Rp 32,682,256, - (b) The Cost of Production (HPP) of Rp. 872,192,800 (c) The Net Value of Rp 11,990,607,200 (d) The calculation of Eco Efficiency Index (EEI) of 13.25 (e) The calculation of Eco-Costs Value Rate (EVR) of 0.003 (f) Calculation of Eco Efficiency Ratio (EER) of 99.7%. Based on the calculation of efficiency, it can be said that biogas products are affordable and sustainable.

References
[1] Misran E, Sarah M, Irvan, Dina SF, Harahap SAA, and Nazar A 2020 IOP Conf. Ser: Journal of Physics 1542(1) 012068
[2] Ginting MHS, Irvan, Misran E, Maulina S. 2020 IOP Conf. Ser: Mater. Sci. Eng. 801(1) 012045
[3] Irvan, Trisakti B, Maulina S and Daimon H 2018 Rasayan Journal of Chemistry 11 (1) 378-385
[4] Haryani N, Harahap H, Taslim, Irvan 2020 IOP Conf. Ser: Mater. Sci. Eng. 801(1) 012051
[5] Trisakti B, Mhardela P, Husaini T, Irvan and Daimon H 2018 IOP Conf. Ser: Mater. Sci. Eng. 309(1) 012093.
[6] Trisakti B, Irvan, Mahdalena, Taslim and Turmuzi M 2017 IOP Conf. Ser.: Mater. Sci. Eng. 206(1) 012027
[7] Trisakti B, Irvan, Zahara I, Taslim and Turmuzi M 2017 AIP Conf. Proc. 1840 050004
[8] Maulina S, Irvan, Trisakti B and Daimon H 2018 Rasayan J. Chem, 11(3) 1151-1158
[9] Octiva CS, Irvan, Sarah M, Trisakti B and Daimon H 2018 Rasayan J. Chem, 11(2) 791-797
[10] Irvan, Trisakti B, Naingggolan R M, Hasibuan R and Daimon H 2019 AIP Conf. Proceed. 2085 020027
[11] Trisakti B, Irvan, Adipasah H, Taslim and Turmuzi M 2017 IOP Conf. Ser: Mater. Sci. Eng. 180(1) 012127
[12] Sidabutar R, Trisakti B, Husin A, Irvan 2020 IOP Conf. Ser: Mater. Sci. Eng. 801(1) 012053
[13] Irvan, Trisakti B, Sosanty F and Tomiuchi Y 2016 Asian J. Chem. 28(2) 377-380
[14] Bani O, Taslim, Irvan and Iriany 2015 Journal of Engineering Science and Technology Special Issue 5 29-39