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The Potential Utilization of Oil Palm Production Waste at PT. Tata Hamparan Eka Persada

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***Abstract*— Oil palm (Elaeis guineensis Jacq.) is one of the commodities that is expected to increase the economic income of the community, especially plantation farmers. The palm oil industry in Bangka district in 2020 is 41.88 thousand tons. The production process of crude palm oil produces waste that has the potential to pollute the environment, namely solid waste and liquid waste. Palm oil mill effluent (POME) contains methane gas (CH4) which has the potential to be a source of energy that can be processed into biogas and solid waste in the form of shells, fiber, EFB has the potential to become biomass. The results obtained from the calculation of the total power that can be generated for 2.5 years of liquid waste (POME) is 6.9462 MW in the category of high heat waste, followed by solid waste (TKS) of 1.4881 MW, fiber waste of 0.9864 MW and shell waste of 0.5646 MW. The total CO2 emissions generated from the generator for 2.5 years for solid waste are 73893.63 tons of CO2 in the category of high-heat waste, and for liquid waste, it is 65867.09 tons of CO2.**

Keywords*— *CO2 Emissions, Energy, Palm Oil Waste.

I. INTRODUCTION

Oil palm (Elaeis guineensis Jacq) is one of the commodities that is expected to increase the economic income of the community, especially plantation farmers. Plants with an average productive age of about 25 years and can be harvested for 12 months or one year make oil palm one of the leading plantation crops in the largest non-oil and gas foreign exchange generating sector in Indonesia. The province of the Bangka Belitung Islands has 47 large private plantations. Indonesia's oil palm plantation production in 2019 reached 48.42 million tons. For oil palm plantation production in Bangka district as much as 39.07 thousand tons in 2019 while in 2020 it rose to 41.88 thousand tons [1].

PT. Tata Hamparan Eka Persada (PT. THEP) is an industrial factory engaged in processing palm fruit with a capacity of 45 tons of FFB/hour from fresh fruit bunches (FFB) which are processed standardly to produce CPO (Crude Palm Oil). PT. The Eka Persada Overlay is located in Puding Besar Village, Puding Besar District, Bangka Regency, Bangka Belitung Islands Province with processing starting on August 1, 2011.

Biogas and biomass are alternative energy sources that are relatively simple and suitable for use as boiler fuels in the palm oil industry. Utilization of waste from palm oil processing as a source of electrical energy can help reduce Green House Gas (GHG) emissions that cause global warming. Optimizing the use of alternative energy resources is necessary considering that there are many palm oil mills that have not used the liquid waste from palm oil processing as a source of electrical energy plus the potential of the area that should be used as a source of electricity generation. Optimizing energy from palm oil processing waste can also encourage the development of national electricity, which is based on new and renewable energy (EBT). The plan to develop a power system in the Bangka Belitung Islands for projections from 2021-2030 uses the potential of new and renewable energy and one of the developments is PLTBio. The power plant that is planned to be built is PLTBio with a capacity of 2.0-5.0 MW[2].

II. LITERATURE REVIEW

A. *Biogas*

Biogas is a flammable gas produced by the process of decay or fermentation of organic materials by anaerobic bacteria. Anaerobic bacteria are bacteria that can live in conditions without oxygen in the air. In the palm oil industry, biogas is formed naturally from palm oil effluent (POME) which is broken down by anaerobic bacteria. Biogas is an alternative source that can be used as electrical energy. This is because biogas has a high organic matter content. 1 m3 of biogas has a heat/energy level of about 20-22 MJ (6 kWh equivalent). The highest content in biogas is methane (CH4) at 70% so if the fuel contains a large amount of methane, the heat produced is also large [3].

Optimizing the use of biogas with proper management can be used as an alternative fuel for power generation. Meanwhile, apart from being an alternative energy source, the waste produced as biogas can also be used as a natural fertilizer for use in agriculture and plantations. In addition, the benefits of using biogas also help reduce GHG emissions so that it can reduce the rate of global warming.

The potential of Biogas in Electrical Energy PKS is an industry that is full of processing residues. PKS only

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produces 25-30% of the main products in the form of 20-23% CPO and 5-7% palm kernel (kernel). While the remaining 70-75% is waste that can be classified into three groups, namely liquid waste, solid waste, and gas waste. The amount of solid waste produced by mills ranges from 40–41% of each tonne of palm oil processed. PKS waste is actually waste which is a pollutant component but can be utilized [4].

TABLE I. Biogas Composition [5]

Content	Composition (%)
Methane (CH4)	55-75
Carbon Dioxide (CO2)	30-45
Hydrogen Sulfide (H2S)	1-2
Nitrogen (N2)	0-1
Hydrogen (H2)	0-1
Carbon Monoxide (CO)	A little
Oxygen (O2)	A little

Liquid Waste Treatment System

The wastewater treatment system is classified into three classifications, namely:

1) *Primary Treatment System*.
   a) Preprocessing (*pretreatment*). This stage involves a physical process to remove suspended solids and oil from the wastewater.
   b) First stage processing (*primary treatment*). This stage aims to remove organic solid particles and organic oil with a physical process so that the solid particles will settle (sludge) so that the fat and oil particles will be on the surface (grease).
   c) *Aeration*. This treatment includes biological treatment which has many techniques, one of which is the activated sludge deposition process with oxygen aeration assisted by microorganisms in the processing process.

2) *Secondary Treatment*. Processing in this second stage uses chemicals to remove or change pollutant compounds in wastewater. In general, these pollutants are in the form of solid suspensions that do not naturally precipitate even though in a relatively long period of time so they require chemical assistance to assist the decomposition process.

3) *Territorial Treatment*. At this stage, the operating system uses biological operations due to high concentrations of pollutants or waste with many parameters that have relatively large volumes. This treatment method aims to remove pollutant compounds through biological activity on biological process equipment. In the biological process, the stages used are aerobic ponds, aeration, activated sludge, oxidation ponds, biological filters, and anaerobic ponds [6].

Converting Biogas to Electrical Energy

In general, liquid waste from the disposal of palm oil processing will be accommodated in a waste storage pond which scientifically will produce flammable gas. The gas is produced through a decomposition process by anaerobic bacteria whose working principle is a biological process that takes place in conditions without oxygen by certain microorganisms [7].

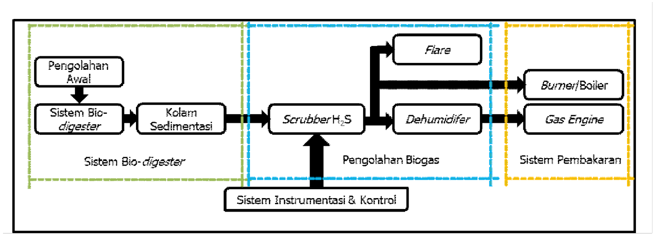

Fig. 1. Converting Biogas to Electrical Energy [7]

B. *Biomass*

Biomass is a bio-energy resource, which comes from plant and animal waste residues, both living and dead. One example of biomass is waste from palm oil processing, one of which is solid waste. Solid waste from the processing of Fresh Fruit Bunches (FFB) of oil palm in the form of a shell, fiber, and EFB (empty palm oil bunches). Proper waste management can provide good benefits for the surrounding environment and can be used as an alternative energy source. Solid wastes generated from the palm oil processing process include:

1) Fiber

Fiber palm oil waste produced from the processing of palm fruit squeezing during the pressing process is short in shapes like thread and brownish yellow in color. Each processing of 1 ton of FFB produces 120 kg or 12% of the processing yield per ton. Fiber is commonly used as a fuel source for boilers and has a heat range of 2637 kcal/kg-3998 kcal/kg.

2) Shell

Shell is a waste generated from the process of separating palm kernel kernels with a shape like a coconut shell but small in shape. Each processing of 1 ton of FFB produces 50 kg or 5% of the processing yield per tonne and the shell has a heat of 3500 kcal/kg-4100 kcal/kg.

3) Empty Fruit Bunches

EFB has an energy content equivalent to fiber when dried until the water content in it (MC) reaches less than 40%. The processing of TKS can be done by several methods and stages, one of which is chopping, pressing, then drying with a dryer. Another method is to put the EFB into the grinder dryer machine. EFB that has been dried and reduced in size mixed with shells can be used as boiler fuel for electric power generation. The abundant biomass of PKS (palm oil mill) waste, especially EFB, can be used as alternative energy for generating electrical energy. Because the water content in EFB is relatively high (MC 60%), the right technology is needed to use it as a source of electrical energy. The process of converting biomass energy into electricity can use gasification technology or direct combustion, but both have the same requirements, namely the water content of biomass should not be more than 40% [8].

Biomass Potential

Biomass potential can be seen from the assumption of mass balance and calorific value contained in each raw material. The calorific value or heat value that can be produced from biomass can be used as a classification standard in determining the type of raw material used.

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TABLE II. Biomass Balance of Palm Oil Waste [9]

Waste Type	Percentage (%)
Shell (Shell)	5-7
Fiber (Fibre)	11-12
Oil Palm Empty Fruit Bunches (TKS)	20-23

CO2 Emission Calculation

Carbon dioxide emissions are gases released from the combustion of all carbon-containing compounds such as CO_2, diesel, gasoline, LPG, and other fuels. Fuel derived from biomass-based fuel (such as wood, shells, agricultural residues, biogas, and others) can be used as an alternative fuel to replace fossil fuels. GHG emissions resulting from the burning of biomass-based fuels are similar to those of burning fossil fuels.

Carbon from biomass-based fuels is biogenic carbon contained in living and breathing tissues (plants), while carbon contained in fossil fuels is trapped in geological formations for millions of years. Thus, the inventory of CO_2 emissions from burning biomass-based fuel is 0 (zero) because it is considered to be reabsorbed by the plant concerned (carbon neutral). However, CO_2 emissions from burning biomass-based fuel are still calculated but are not considered in the total CO_2 emissions and are reported separately. Meanwhile, CH_4 and N2O emissions from biomass-based fuel combustion are still calculated and reported in the total CH_4 and N_2O emissions [10].

III. Results and Discussion

This study was conducted to determine how much potential the waste generated from the processing of fresh fruit bunches (FFB) is, namely palm oil liquid waste (POME) and solid waste (shell, fiber, TKS).

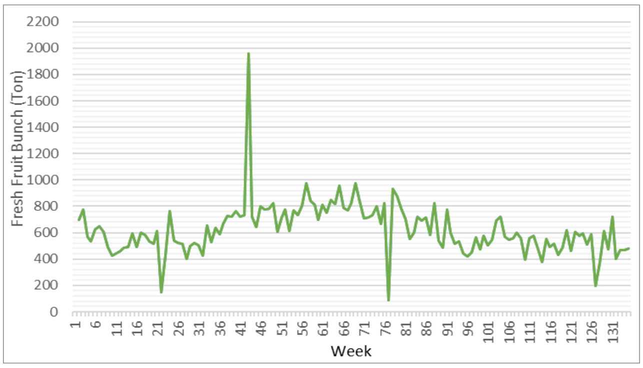

Fig. 2. Graph of Fresh Fruit Bunches processed in January 2020-June and 2022 (Source: Data of PT. THEP, 2022)

Based on Figure 2, it can be seen that the data graph goes down and up according to changes in the weekly fresh fruit bunches (FFB) receipts. In this study, the data taken for calculation is weekly data from January 2020 to June 2022. In that period the total fresh fruit bunches (FFB) processed were 83,640,510 tons with an average of fresh fruit bunches (FFB) processed per week being 624,183 tons. PT. Tata Hamparan Eka Persada's operates an average of 18 hours per week and has a processing capacity of 45 tons of FFB/hour. In the 42nd week, the highest increase from processed fresh fruit bunches (FFB) receipts was 1,960.18 tons while the lowest revenue from fresh fruit bunches (FFB) processing was in the 76th week at 89.47 tons.

TABLE III. Assumptions by Category of Waste Type and Heat of Palm Oil Waste

Waste Type	Waste Amount Category			Waste Heat Category			
	Low (%)	Currently (%)	Tall (%)	Low	Currently	Tall	
POME	28	58.3	67	5.254	5.732	8,569	
shell	5.5	6.4	8	3.840	4.105	4,900	
Fiber	11	13	14.4	2,309	2,943	4.756	
TKS	21	23	23	2,250	4.422	4.492	

Source: Data processed, 2022

Table 3 is the average for the low, medium, and high categories which is the source of assumptions from several journals that discuss the percentage of the amount of waste and waste heat.

TABLE IV. Average Potential Per Week of Palm Oil Waste from January 2020-June to 2022

Production (Tons)	Waste Type	Waste Amount		Electrical Energy (MWh)		Power output (MW)	
		Low	Tall	Low	Tall	Low	Tall
624,183	Liquid Waste (m3)						
	POME	104.863	250,922	224.306	875,217	1,780	6,946
	Solid Waste (Tons)						
	shell	34,330	49,935	38,329	71.141	0.304	0.565
	Fiber	68,660	89,882	46,094	124,290	0.366	0.986
	TKS	131.078	143.562	85,750	187,499	0.681	1,488
	Total			394,479	1,258,147	3.131	9,985

Source: Data processed, 2022

Based on table 4, it is known that the average fresh fruit bunches (FFB) processed is 624,183 tons per week and produces potential from palm oil liquid waste (POME) and solid waste (shell, fiber, and EFB) which are calculated by category the amount of waste is low in low heat and the amount of waste is high and heat is high. The highest potential for electrical energy is generated from the type of liquid waste (POME) which is 224.306-875.217 MWh with a power of 1.780-6.946 MW.

The highest potential of solid waste electrical energy is generated from TKS waste of 85,750-187,499 MWh with power reaching 0.681-1,488 MW, then from fiber waste of 46,094-124,290 MWh and the lowest is the energy potential of shell waste, which is 38,329-71.141 MWh. The total potential electrical energy generated from fresh fruit bunches (FFB) processing waste reaches 394,479-1,258,147 MWh.

A. Waste Count

The processing of fresh fruit bunches (FFB) produces waste in the form of liquid waste (POME) and solid waste (shell, fiber, and EFB). The calculation of the amount of waste uses each percentage category of the amount of waste from the assumptions contained in table 3.

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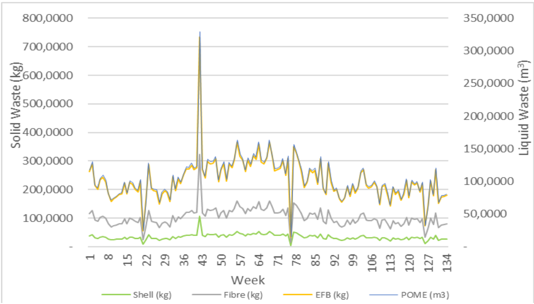

Fig. 3. Graph of Waste Amount in Low Category

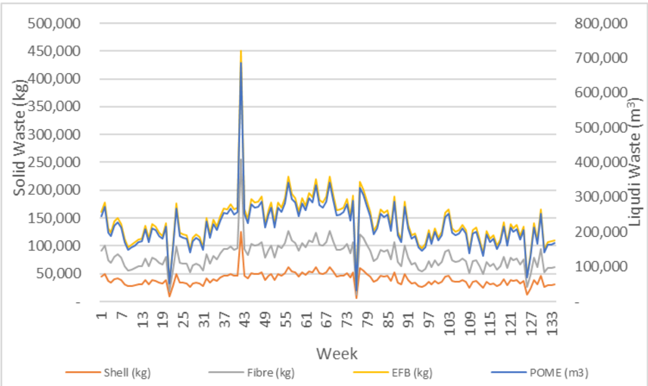

Fig. 4. Graph of Waste Amount with Medium Category

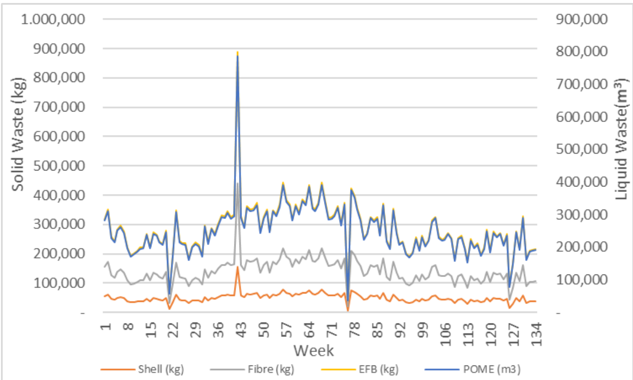

Fig. 5. Graph of Waste Amount with High Category (Source: Data processed, 2022)

TABLE V. Total Palm Oil Waste from January 2020-June to 2022

Waste Category	Waste Amount			
	Waste Type			
	POME (m3)	Shell (Tons)	Fiber (Tons)	TKS (Tons)
Low Waste	14,051.61	4,600,23	9200.46	17,564.51
Medium Waste	29,257.45	5,352.99	10,873.27	19,237.32
High Waste	33,623.49	6,691.24	12,044.23	19,237.32

Source: Data processed, 2022

B. Energy Potential Calculation

After calculating the amount of waste from the fresh fruit bunches (FFB) processing process, it is then converted into thermal energy according to each calorific value. To convert thermal energy into electrical energy that can be produced, the value of 1 kcal = 0.001163 kWh[11] with the efficiency of thermal energy for liquid waste (POME) of 0.35[12] and thermal energy efficiency of solid waste of 25%[13].

TABLE VI. Total Potential of Electrical Energy from January 2020-June to 2022

Waste Category	Total Electrical Energy (MWh)			
	Waste Type			
	POME	shell	Fiber	TKS
Low Waste Low Heat	30,051.34	5136.06	6,176.65	11,490.48
Medium Low Heat Waste	32,785.36	5,490.50	7,872.62	22,582.63
High Low Heat Waste	49,012.16	6,553.83	12,722.46	22,940.11
Medium Waste Low Heat	62,571.17	5,976.51	7,299.68	12584.81
Medium Waste Medium Heat	68.263.79	6,388.95	9304.01	24,733.35
Medium High Heat Waste	102,050.32	7,626.27	15,035.63	25,124.88
High Waste Low Heat	71,908.55	7,470.64	8085,80	12584.81
Medium High Heat Waste	78.450.67	7,986.19	10,305,98	24,733.35
High Waste High Heat	117,279.10	9,532.84	16,654.85	25,124.88

Source: Data processed, 2022

After the amount of electrical energy is obtained, for energy in the form of oil equivalent (OE) the electrical energy is converted into energy in the form of OE with 1 kWh = 0.086 kg OE[14].

TABLE VII. Total Energy Potential in OE from January 2020-June 2022

Waste Category	Total Energy Potential (TOE)			
	Waste Type			
	POME	shell	Fiber	TKS
Low Waste Low Heat	19.2867	3.2963	3.5238	4.2062
Medium Low Heat Waste	21.0413	3.9641	5.0526	8.1652
High Low Heat Waste	31.4556	7.3745	14.4933	14,7228
Medium Waste Low Heat	40.1576	3.8357	4.0966	4.8900
Medium Waste Medium Heat	43.7713	4.6849	5.9658	9.6410
Medium High Heat Waste	65.4355	8.0768	15.8592	16,1103
High Waste Low Heat	46,1503	4.7946	5.1255	6.1181
Medium High Heat Waste	50.3489	5.1894	6.6143	10.6889
High Waste High Heat	75.2687	8.0768	15.8736	16,1249

Source: Data processed, 2022

Table 7. represents the total potential energy generated from each waste and waste category for 2.5 years. From table 7. it can be seen that the highest energy value is liquid waste (POME) of 75.2687 TOE in the category of high-heat waste, followed by solid waste (TKS) of 16.1249 TOE, fiber waste of 15.8736 TOE and shell waste is 8,0768 TOE.

C. Power Potential Calculation

From the electric potential generated, it can be seen how much power can be generated. The calculation of power potential is the energy produced divided by time, in this case, the time used in one week is 126 hours. Based on Figure 6. is a graph of the power generated from the category of low waste amount with low, medium, and high heat calculations generated from liquid waste (POME). Figure 7. is a graph of the power generated from the category of low waste amount with low, medium, and high heat calculations generated from solid waste (shell, fiber, and EFB).

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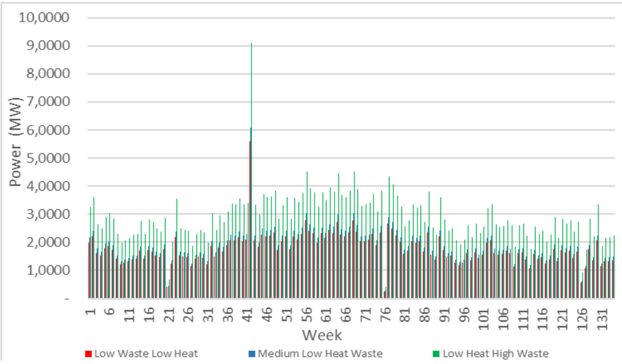

Fig. 6. Graph of Power Potential generated from Liquid Waste (POME)

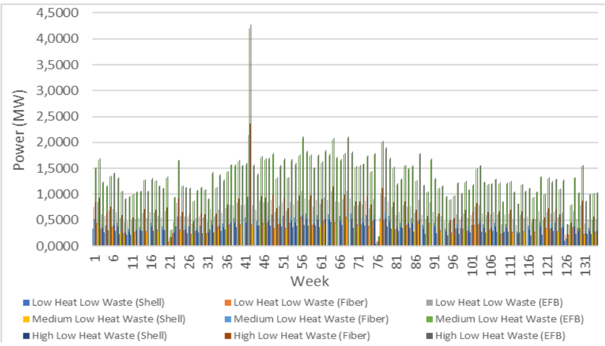

Fig. 7. Graph of Power Potential generated from Solid Waste (Shell, Fiber, EFB) Source: Data processed, 2022

TABLE VIII. Average Total Power Potential generated by Palm Oil Waste from January 2020-June 2022

Average Power (MW)				
Waste Category	Waste Type			
	POME	shell	Fiber	TKS
Low Waste Low Heat	1,7990	0.3042	0.3658	0.6806
Medium Low Heat Waste	1.9418	0.3252	0.4663	1.3375
High Low Heat Waste	2.9029	0.3882	0.7535	1.3587
Medium Waste Low Heat	3.7059	0.3540	0.4323	0.7454
Medium Waste Medium Heat	4.0431	0.3784	0.5511	1.4649
Medium High Heat Waste	6.0442	0.4517	0.8905	1.4881
High Waste Low Heat	4.2590	0.4425	0.4789	0.7454
Medium High Heat Waste	4.6465	0.4730	0.6104	1.4649
High Waste High Heat	6.9462	0.5646	0.9864	1.4881

Source: Data processed, 2022

Table 8. represents the average power generated from each waste and waste category for 2.5 years. From table 8. it can be seen that the highest power generated is liquid waste (POME) of 6.9462 MW in the category of high-heat waste, followed by solid waste (TKS) of 1.4881 MW, fiber waste of 0.9864 MW, and shell waste 0.5646 MW.

D. CO_2 Emission Calculation

Calculation of CO_2 emissions from waste from palm oil processing uses the same amount of internal energy (Joules). For biogas emission factor is 54,600 CO_2 kg/TJ, while for biomass the CO_2 emission factor is 100,000 CO_2 kg/TJ [15].

$E\ CO_2$ biogas = DA × FE
$E\ CO_2$ = 0.00259 × 54.600 CO_2 kg/TJ
$E\ CO_2$ = 141.17230 Tons CO_2
$E\ CO_2$ biomass = DA × FE
$E\ CO_2$ = 0.00275 × 100,000 CO_2 kg/TJ
$E\ CO_2$ = 274.67351 Tons CO_2

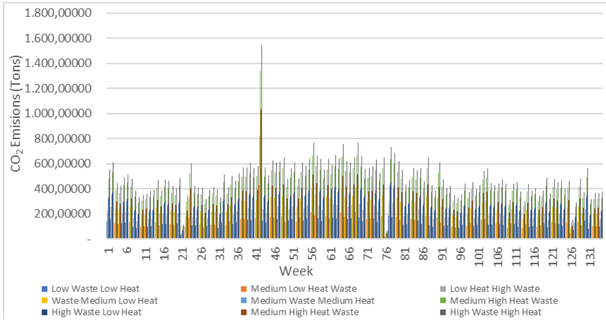

Fig. 8. Graph of Liquid Waste CO_2 Emissions (POME)

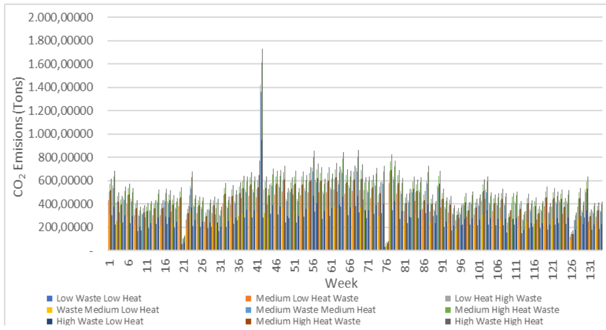

Fig. 9. Graph of Solid Waste CO_2 Emissions (Shell, Fiber, EFB) (Source: Data processed, 2022)

Based on Picture 6. is a graph of CO_2 emissions generated from the category of low waste amount with low, medium, and high heat calculations generated from liquid waste (POME). Figure 7. is a graph of CO_2 emissions generated from the category of low waste amount with low, medium, and high heat calculations generated from solid waste (shell, fiber, and EFB).

TABLE IX. Total CO_2 Emissions produced by Palm Oil Waste from January 2020-June 2022.

Total CO2 Emissions (Tons)		
Waste Category	Waste Type	
	Liquid Waste (POME)	Solid waste (Shell, Fiber, EFB)
Low Waste Low Heat	16,877.64	32,838,17
Medium Low Heat Waste	18,413.14	37,241.62
High Low Heat Waste	27,526.54	40,525.33
Medium Waste Low Heat	35,141.65	51,764.35
Medium Waste Medium Heat	38,338,78	58,216.67
Medium High Heat Waste	57,314.20	61,959.70
High Waste Low Heat	40,385,77	60,794.51
Medium High Heat Waste	44,060.00	68,816.25
High Waste High Heat	65,867.09	73,893.63

Source: Data processed, 2022

Table 9. represents the total CO2 emissions generated from each waste and waste category for 2.5 years. From table 9. it can be seen that the highest CO2 emissions produced were a solid waste of 73,893.63 tons of CO2 in the category of high-heat waste and liquid waste of 65,867.09 tons of CO2. The lowest total CO2 emissions from the low-heat waste

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category for solid waste are 32,838.17 tons CO2 while for the liquid waste it is 16,877.64 tons CO2. The calculation results of CO2 emissions produced during combustion are not included in the total greenhouse gas (GHG) emissions.

IV. Conclusion

PT. Tata Hamparan Eka Persada is a fresh fruit bunch processing factory with a production capacity of 45 tons of FFB/hour with an average processing rate of 18 hours per week which produces a large amount of liquid waste in the high heat high waste category of 33623.4851 m3, followed by solid waste of 19237.317 tons, solid waste (fiber) of 12044,2335 tons, and solid waste (shell) of 6691,2408 tons. For the average total power potential that can be generated for 2.5 years, liquid waste is 6.9462 MW in the category of high-heat waste, followed by solid waste of 1.4881 MW, fiber waste is 0.9864 MW and shell waste is 0.5646 MW.In calculating CO2 emissions the total emission generated from the power plant for 2.5 years for solid waste is 73893.63 tons of CO2 in the category of high-heat waste, and for the liquid waste, it is 65867.09 tons of CO2.

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BIOGRAPHIES OF AUTHORS

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