

Alternative scenarios to utilise excess biogas in Palm Oil Mill

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Abstract

Palm Oil Mill is a factory which converts Fresh Fruit Bunch (FFB) to Crude Palm Oil (CPO) and Palm Kernel Oil (PKO). Within FFB converting processes, two types of waste are produced: 1) liquid waste and 2) solid waste. Liquid waste, named Palm Oil Mill Effluent (POME), contributes up to 60% of total FFB. Solid waste includes palm kernel shell and meal, fibre and empty fruit bunch gives in aggregate around 20% of total FFB. Initially, Palm kernel shell (PKS) is commonly utilised as fuel for boiler. Then in some mills, POME was additionally used as biomass for biofuel production (biogas) to support power supply in the mill. Biogas is utilised to generate electricity for Kernel Crushing Plant (KCP). Field observation data shows that electricity demand for KCP is 19.5 MWh/day or equivalent with 45% of total biogas production. The excess biogas, equivalent with 11,000 kWh/day, is flared. An alternative scenario instead of flaring is to use biogas as fuel for boiler. Thus, the previous fuel (PKS) could potentially be allocated for selling. Another scenario is to utilise excess biogas electricity generation to be distributed to staff houses near the mill. Therefore, this research study aims to calculate excess biogas that could be used for those scenarios: 1) Fuel substitution in the mill with different type of process, 2) Household electricity. Result shows that biogas demand in each scenario can supply 1) Minimum 2,900 kWh/day for non-processing hours and 6,436.65 kWh/day for processing hours, 2) Electricity for 557 houses/day.

Keywords

biogas, flaring, POME, electricity, waste management

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1. INTRODUCTION

Indonesia is globally known as palm oil producer together with Malaysia. In 2019, Indonesia is seen that CPO production has escalated 9% compared to 2018, reaching 51.8 million tonnes (GAPKI, 2020). On the other side, an increasing production for both CPO and PKO also causes higher amount of waste output. Palm oil waste contributes around 75% of total processed FFB in the mill within 1 batch of CPO production (Hambali and Rivai, 2017). In general, palm oil waste can be classified into 2 groups: 1) Solid waste which covers empty fruit bunch, fibres and palm kernel shell, and 2) liquid waste, POME.

Palm oil waste treatment is currently being carried out in the mill to improve its added value and reduce waste disposal in open pond. For example, using POME as biomass for biogas production (Rajani et al., 2019). Palm kernel shells and fibres are used as boiler fuel. Empty fruit bunches are used as composting material (Singh et al., 2010). However, high amount of palm oil waste requires a more efforts and different plans so that all waste can be optimally utilised. Some palm oil mills in Indonesia have already installed bio-

gas plant and applied it to support FFB processing activities. For example, biogas is used as fuel for gas engine to generate electricity. The electricity is then delivered to KCP. However, some other mills have installed biogas plant with minimum end use. They flare the biogas due to incompatibility engines in mill to be integrated with biogas (Rahayu et al., 2015).

This study aims to provide alternative scenarios promoting the use of excess biogas, minimising biogas to be flared. In this case, excess biogas means certain amount of biofuel which no longer be used to bolster CPO or PKO production in mill. When biogas is surplus, flaring usually becomes as a solution because excess biogas cannot economically be stored or used. Flaring could rise the formation of undesirable combustion products such as carbon monoxide (CO), partially oxidised hydrocarbon, NO_x, dioxins and furans (Miller, 2016). Furthermore, flaring could also potentially lead to odor nuisance, visual and noise impact. Flaring could serve as a large loss of energy capacity or valuable products, as well as a contribution to global warming (Thurber, 2019).

There are 2 scenarios that will be covered in the analysis.

Table 1. The properties of POME. Source: (Rahayu et al., 2015)

Parameter	Unit	POME without processing		Parameter standard	
		Range*	Average	Water bodies**	Land application
BOD	mg/L	8,200 – 35,000	21,280	100	5,000
COD	mg/L	15,103 – 65,100	34,740	350	
TSS	mg/L	1,330 – 50,700	31,170	250	
Ammonia (NH ₃ -N)	mg/L	12 – 126	41	50***	
Oil and fat	mg/L	190 – 14,720	3,075	25	
pH		3.3 – 4.6	4	6 – 9	6 – 9
Max POME produced	m ³ /ton CPO			2.5	

*Source [Pertanian \(2016\)](#)** Source [Hidup \(2010\)](#)*** Total nitrogen = organic nitrogen + total ammonia + NO₃ + NO₂

Each scenario will mainly consider the amount of biogas demand if it would be allocated as: 1) Old-fuel substitution in mill for boiler, and 2) Mains electricity in staff houses.

1.1. Palm Oil Mill Effluent (POME) as biomass

POME is one of the palm oil waste which has been produced during oil extraction from FFB. POME counts for nearly 75% of total processed FFBs (Figure 1). Based on its properties (see Table 1), POME has a potential to be utilised as biomass. Previously, POME was placed in open pond before it was used as fertiliser for oil palm plantation. Putting POME in open pond had risk to naturally release methane gas CH₄ to the atmosphere. As a consequence, the risk of global warming will increase ([Enström et al., 2019](#)). According to its calorific value, methane has a similar characterisation with fossil fuel ([Pertiwiningrum et al., 2018](#)). Therefore in the last 5 years, some palm oil mills in Indonesia has started to feed POME into closed pond, named anaerobic digester to hold CH₄. Methane gas or CH₄ is commonly known as biogas ([Rahayu et al., 2015](#)).

In Indonesia, two types of anaerobic digester are used: covered lagoon and Continuous Stirrer Tank Reactor (CSTR). When POME starts to produce biogas in the digester, it contains 50 – 75% CH₄, 25 – 45% CO₂ and other trace gases ([Poh and Chong, 2009](#)). Biogas has calorific value 20 MJ/Nm³ or equivalent with around 6 kWh electricity ([Center, 2012](#)). Using biogas as fuel will lead to independent power generation in the mill. Moreover, utilising biomass is also seen as a contribution to tackle climate change.

1.2. Electricity demand of palm oil mill

Electricity usage in palm oil mill is generally allocated for two business activities: 1) CPO production and 2) PKO production in KCP. General parameter of electricity consumption in palm oil mill is between 17 kWh/ ton FFB

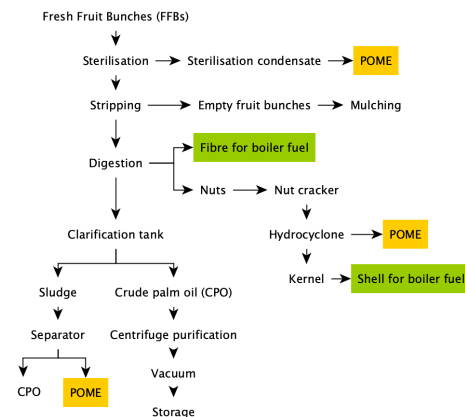


Figure 1. POME production in palm oil mill. Source of POME generally comes from sterilisation condensate, sludge separator and hydro cyclone. Adapted from ([Jayakumar et al., 2017](#)).

and 19 kWh/ ton FFB ([B, 2012](#)). In CPO production, electricity is distributed in two different periods namely non-processing hours and processing hours. Non-processing hours means that FFBs are not being processed for CPO extraction. Thus, processing hours starts to count when FFBs are processed. Either processing or non-processing hours can take around 9 up until 15 hours per day, alternately. Electricity demand relies on production capacity of the mill which varies between 30, 45 and 60 tonnes FFB/ day, whilst KCP production capacity for PKO typically either 7.5, 10 or 21 tonnes palm kernel/ day. Operational hours for KCP is approximately 22 hours/ day ([Yuliansyah et al., 2009](#)).

2. EXPERIMENTAL SECTION

2.1. Materials

Biogas monthly data was recorded and used as primary data for further calculation and analysis. Research flowchart of this study can be seen in the Figure 2. The research was conducted between January and April 2018 in a palm oil mill which has biogas plant installation. The capacity production of the mill is 60 tonnes of FFB/ hour. The mill also has KCP with 7.5 tonnes of palm kernel/ hour capacity production. Biogas plant is located near the mill and produces around 23,300 m³ biogas every day. Biogas was produced within anaerobic process by using Continuous Stirred Tank Reactor (CSTR) with average efficiency around 79% per month. The mill has 2 digester tanks with total volume of 9,110 m³. The temperature of anaerobic digestion was in mesophilic condition, 37 °C.

The electricity demand for mill is referred to typical power consumption of 60 tonnes of FFB/ hour production capacity with 2 operational lines (Parinduri, 2018). On the other hand, electricity demand for house is identified by interviewing staff who works and lives close to palm oil mill.

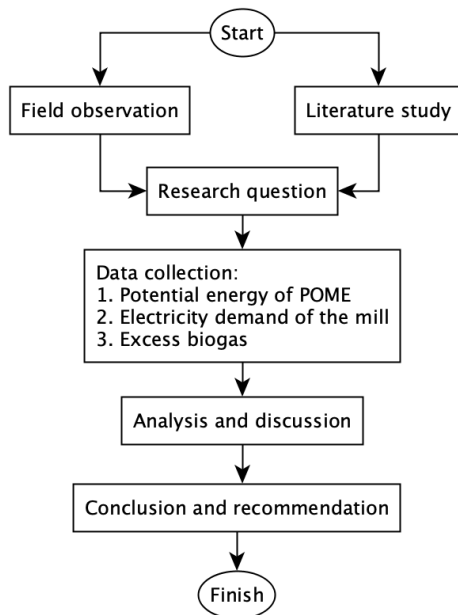


Figure 2. Research flowchart

2.2. Methods

Recorded biogas data is mainly used for analysis and scenario development. Each scenario is measured based in the excess amount of biogas (m³). The electricity generation is calculated by using conversion factor, 3.4 kW/m³ CH₄, based on Key Performance Indicator (KPI) of the mill. In general, biogas engines for electricity generation from 100 kWel and 1 MWel have efficiency range between 34% and

Table 2. Operational hours in a day in palm oil mill. Source: author's documentation

No.	Day	Operational hours in a day	
		Processing hours	Non-processing hours
1	Monday	12.9	9.1
2	Tuesday	14.51	9.49
3	Wednesday	11.77	12.23
4	Thursday	15.1	8.9
5	Friday	8.95	15.05
6	Saturday	7.05	14.95

40% (Benato et al., 2017). In this study, 40% is used as efficiency number for calculation in each scenario.

Electricity demand per day is estimated by using typical usage of power consumption in palm oil mill, both for non-processing and processing hours (see Table 3). Similar approach is also implemented for household electricity of staff houses near the mill.

Power consumption of staff houses is obtained by interviewing staff who lives close to the mill. Standard electronic appliances are available in the house. The period of usage is assumed by typical work and stay-at-home hours of mill staffs (Table 4).

3. RESULTS AND DISCUSSION

The calculated average potential energy of POME in the mill is 43,380 kWh per day. The clean fuel product was firstly delivered to KCP which required around 19,540 kWh/day or equivalent with 45% of total potential energy of POME (Equation 1). The average excess amount of biogas and its power generation from January until April 2018 are summarised in Table 5. The calculated electricity from excess biogas is then allocated to different scenarios to see alternative ways of utilising the renewable fuel besides flaring.

Power demand for KCP(%) = $\frac{\text{average biogas consumption}}{\text{average } E_p \text{ of POME}} \times 100\%$

$$\text{Power demand for KCP}(\%) = \frac{19,540 \frac{\text{kWh}}{\text{day}}}{43,380 \frac{\text{kWh}}{\text{day}}} \times 100 \%$$

$$\text{Power demand for KCP}(\%) = 45\%$$

3.1. 1st Scenario: Excess biogas for non-processing and/ or processing hours

First scenario is to allocate excess biogas for non-processing and/ or processing hours activities in CPO station production. According to Table 5, excess biogas is equivalent with around 11,000 kWh per day. The total measured electricity for each day of non-processing hours is summarised in Table 6.

Electricity demand for non-processing hours is around 2,900 kWh until 5,000 kWh per day. If the excess biogas is only allocated for non-processing hours, there will be between 55% and 74% of total excess biogas left to be

Table 3. Typical usage of electricity consumption in palm oil mill CPO capacity production 60 tonnes of FFB/ hour with 2 operational lines. Source: (Parinduri, 2018)

No	Station	Actual Power per hour	
		Processing hour kW	Non-processing hour kW
1	Reception & steriliser	13	13
2	Thresher	50	-
3	Pressing line 1	68	-
4	Pressing line 2	74	-
5	Clarification	105	-
6	Oil storage	6	-
7	Kernel line 1	158	-
8	Kernel line 2	118	-
9	Boiler control	158	158
10	Water Treatment Plant	66	66
11	Boiler demineralisation	29	29
12	Effluent treatment	21	21
13	Factory lighting	26	26
14	Domestic lighting	21	21
TOTAL (kW per hour)		913	334

flared. In another case, if excess biogas is only delivered to fulfil operational activities of processing hours, it is quite in risk because some operational days will require more power supply (Table 6). Another alternative is to use all excess biogas for both non-processing and processing hours, with first priority to fulfil processing hours then the remaining biogas is used to support non-processing hours. Based on electricity demand calculation for both processes, total demand will be varying between 10,000 kWh and 16,000 kWh per day. All excess biogas will not be enough to support both processes. Additional power supply is required (Figure 3). This issue could alternatively be tackled by supplying electricity from boiler. Therefore, flaring will not be needed because all biogas has been utilised.

3.2. 2nd Scenario: Excess biogas for staff households

Second scenario is to distribute excess biogas to electrify staff houses near palm oil mill. According to Table 4, a

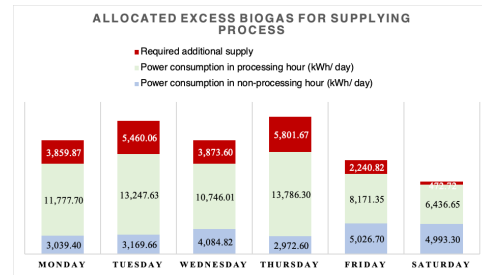


Figure 3. Power consumption in non-processing and processing hours and amount of additional power supply

staff house needs around 20 kWh per day. The excess biogas on daily basis is around 11,000 kWh. Therefore, if all electricity generation from excess biogas is delivered to staff houses, there will be about 557 houses are electrified. This alternative scenario is considered because the mill actually has surplus biomass supply to generate power. As mentioned earlier, during CPO production, palm oil mill also produces solid waste, such as palm kernel shell and fibre. These biomass then are used as fuel in boiler to generate electricity (Figure 1). Thus, rather than using all biomass for only internal usage in the mill, some of them could also alternatively be used to electrify surrounded house communities.

Typical power consumption for a day in a staff house is in Figure 4. It can be seen that peak hours rise between 05:00 and 06:00 also 16:00 and 17:00. These hours are representative as staffs are going to mill in the morning and back to their house in the evening. Refrigerator and AC 1/2 pk have highest percentage of power demand, consuming 37% and 35% of total supplied power, respectively. Each of the remaining electrical appliances only consumes less than 10% of total supplied power.

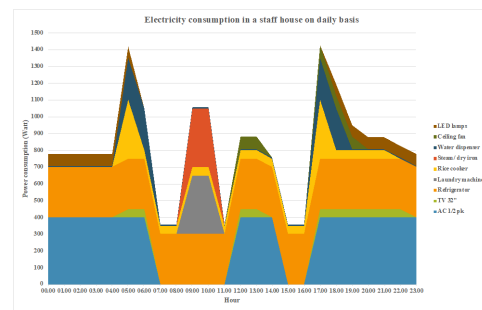


Figure 4. Typical power usage in a staff house

4. CONCLUSIONS

Instead of flaring, there are some alternative ways to optimise the usage of excess biogas. Biogas is considered as clean fuel that can substitute fossil fuel combustion, which then lead to less carbon emission. Excess biogas in the palm oil mill is equivalent with around 11,000 kWh per day.

Table 4. Power usage of standard electronic appliances in staff house between 00.00 – 12.00 and 13.00 – 23.00 hours.
Source: author's documentation

No	Power (Watt)	USAGE PERIOD											
		0	1	2	3	4	5	6	7	8	9	10	11
1	AC 1/2 pk	400	400	400	400	400	400	400					
2	TV 32"						50	50					
3	Refrigerator	300	300	300	300	300	300	300	300	300	300	300	300
4	Laundry machine										350	350	
5	Rice cooker						350	50	50	50	50	50	50
6	Steam/dry iron										350	350	
7	Water dispenser	6	6	6	6	6	250	250	6	6	6	6	6
8	Ceiling fan												
9	LED lamps	70	70	70	70	70	70						
	Total power (W/hour)	776	776	776	776	776	1420	1050	356	356	1056	1056	356

No	Power (Watt)	USAGE PERIOD											
		12	13	14	15	16	17	18	19	20	21	22	23
1	AC 1/2 pk	400	400	400			400	400	400	400	400	400	400
2	TV 32"	50	50				50	50	50	50	50	50	50
3	Refrigerator	300	300	300	300	300	300	300	300	300	300	300	300
4	Laundry machine												
5	Rice cooker	50	50	50	50	50	350	50	50	50	50		
6	Steam/dry iron												
7	Water dispenser	6	6	6	6	6	250	250	6	6	6	6	6
8	Ceiling fan	75	75				75	75	75				
9	LED lamps							70	70	70	70	70	70
	Total power (W/hour)	881	881	756	356	356	1425	1195	951	876	876	826	776
	Total power per day (kWh/ day)							20					
	Total power for 30 days (kWh)							591					

Table 5. Excess amount of biogas and its power generation. Source: author's documentation

Month	Average feeding POME (m ³ / day)	Average excess biogas to flare (m ³ / day)	Potential flare to electricity generation* (kW/m ³ CH ₄ / day)	Calculated electricity** (kW/day)
Jan-18	396	7,921	26,931	10,773
Feb-18	342	7,897	26,851	10,740
Mar-18	349	8,412	28,601	11,440
Apr-18	342	7,997	27,189	10,876
AVERAGE	357	8,057	27,393	10,957

Table 6. Power consumption of process

Operational day	Power consumption in non-processing hour (kWh/ day)	Power consumption in processing hour (kWh/ day)
Monday	3,039.40	11,777.70
Tuesday	3,169.66	13,247.63
Wednesday	4,084.82	10,746.01
Thursday	2,972.60	13,786.30
Friday	5,026.70	8,171.35
Saturday	4,993.30	6,436.65

There are 2 alternative scenarios to minimise biogas flaring. First scenario is to distribute excess biogas as biofuel for electricity generation in non-processing and/ or processing hours in the mill. If power generation from excess biogas is only allocated for non-processing hours, then up to 5,000 kWh per day is required, leaving 55% to be flared. If power generation is only distributed for processing hours, all excess biogas could potentially be used. However, further observation is required as there will be some operational days that need additional power supply. If excess biogas is intended to be allocated for both non-processing and processing hours, extra power generation such as from boiler is definitely needed. Alternatively, in the second scenario, excess biogas could also be used to electrify staff houses who live near the mill. Around 557 houses are electrified.

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