Kajian Potensi Produksi Energi Listrik dan Pengurangan Gas Rumah Kaca dari Limbah Cair Pabrik Kelapa Sawit (Studi Kasus di Provinsi Lampung)

by Sarono Sarono

A Study on The Potency of Electrical Energy Production and Greenhouse Gas Reduction from Palm Oil Mill Effluent (Pome) (A Case Study in Lampung Province)

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ABSTRAK

Indonesia merupakan negara penghasil minyak sawit terbesar di seluruh dunia, sekaligus sebagai penghasil limbah cair pabrik kelapa sawit (LCPKS) terbesar di dunia juga. Selama ini LCPKS ditangani secara sederhana dengan sistem kolam. Hal ini menyebabkan pencemaran lingkungan seperti bau tidak sedap, mencemari sumber air, menghasilkan gas rumah kaca. Di sisi lain LCPKS meruapakan sumber energi alternatif yang potensial jika dikonversi menjadi gas methan. Tujuan makalah ini adalah melakukan analisis potensi energi yang dihasilkan dan potensi pengurangan gas rumah kaca di Provinsi Lampung. Metode yang digunakan berdasarkan servey, analisis laboratorium, dan studi pustaka yang relevan. Hasil penelitian menunjukkan bahwa jika semua LCPKS di Provinsi Lampung dikonversi menjadi gas methan akan dihasilkan energi listrik sebesar 5.41 MW dan pengurangan gas rumah kaca sebesar 242.720 ton greenhouse gas emission (CO_2e).

Keywords: LCPKS, GRK, gas metana, biogas.

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Introduction

From 2012 to 2013, National Electric Company of Indonesia (PT. PLN) predicted that Indonesia's electric energy demand will increase 10.1% annually and this is higher than that of the last 10 years electric energy demand increase, namely 9.2% annually. In Lampung Province, the ratio of electricity distribution only covered 45% from 1,575,974 families in 2011 (Statistic Bureau of Lampung Province, 2012). To fulfill national electric energy demands, the government encourage energy diversification by improving renewable energy development; including energy generated from agroindustrial wastes.

According to the Regulation of the Presedent of the Republic of Indonesia number 5 in 2006, Indonesian government determine to reduce oil energy into less than 20% in 2015. To encourage public participation in developing electric energy coming from renewable resources, Indonesian government published a Regulation of Ministry of Energy and Human Resource number 4 in 2012, requiring National Electric Company (PT. PLN) to buy electric energy from small and middle size power plants using renewable energy with capacities up to 10 MW (Ministry of Energy and Human Resources of the Republic of Indonesia, 2012).

In 2011, Indonesia was the biggest palm oil country producer in the world with the production of 22,899,100 tons (*BPS-Statistics Indonesia*, 2012). The process to extract the oil requires significantly large quantities of water for steam sterilizing the palm fruit bunches and clarifying the extracted oil. Oil palm mill plants require a large amount of water for its operation and discharge considerable quantities of liquid waste or palm oil mill effluent (POME).

The production of 1 ton crude palm oil requires 5 tons of fresh fruit bunches (FFB). The average of 1 ton FFB processing in palm oil mills generates 0.23 ton empty fruit bunches (EFB) and 0.65 ton palm oil mill effluent (POME) as residues. These residues cause considerable environmental burdens, particularly greenh ouse gas (GHG) emissions (Stichnothe and Schuchardt, 2011). Tong (2011) stated that in 2009 Indonesia with 19,234 tons CPO production produced 12,61 x 10^6 tons equal to CO_2 greenhouse gas emission. According to Suprihatin (2008), each ton of TBS will produce 184.4 kg equal to CO_2 gas emission. Furthermore, United State government through US Environmental Protection Agency (EPA) published a Notice of Data Ability (NODA) at January the 27th 2012 stating that palm oil derivative products from Indonesia was not environmentally friendly, and one of the problems was that from 608 palm oil mill units only 5.5% possessed methane gas capturing facilities (US Environmental Protection Agency, 2012).

In Lampung Province, the most common POME treatment systems is open ponding. More than 90% of palm oil mills use ponding systems only due to their low costs. Nonetheless, these methods for treatment of POME have several disadvantages such as long hydraulic retention time (HRT), bad odor, large areas of lands or digesters are required and difficulty in collecting and utilizing generated methane which causes a detrimental greenhouse effect to the environment (Kaewmai, *et al*., 2012). Methane is a greenhouse gas (GHG) with global warming potential 20-30 times more powerful than carbon dioxide (Porteous, 1992). On the other hand, methane is flamable gas with high potential to be utilized as the source of renewable energy.

The objectives of this study were to assess the potential energy production from POME and to analyse the potential greenhouse gas reduction from methane capture conducted in Lampung Province.

Methods

Research methodologies are based on theoretical approaches where palm oil mill production process will produce a huge amount of liquid waste (POME), and so far, POME is only drained into open pond systems that cause environmental problems. In this system, the organic materials are partly degraded anaerobically to form methane and release it into the atmosphere and this causes adverse effects for environmentally either locally or globally. One of proposed approaches is processing POME with anaerobic bioreactor or a covered pond system. This system enables capturing and using biogas productions as fuel.

The approach of environmental management with a controlled anaerobic system enables to obtain some benefits. These benefits are analyzed theoretically and quantitatively to give descriptions of methane emission and energy potentials viable to obtain. Analysis is conducted based on primary and secondary data of field survey results conducted in Lampung province palm oil mills. Biogas amounts and compositions, COD/methane productivities degraded in anaerobic conditions are estimated based on the research results of Sarono *et al*. (2013), and then expressed in processed TBS unit of measurement (Figure 1).

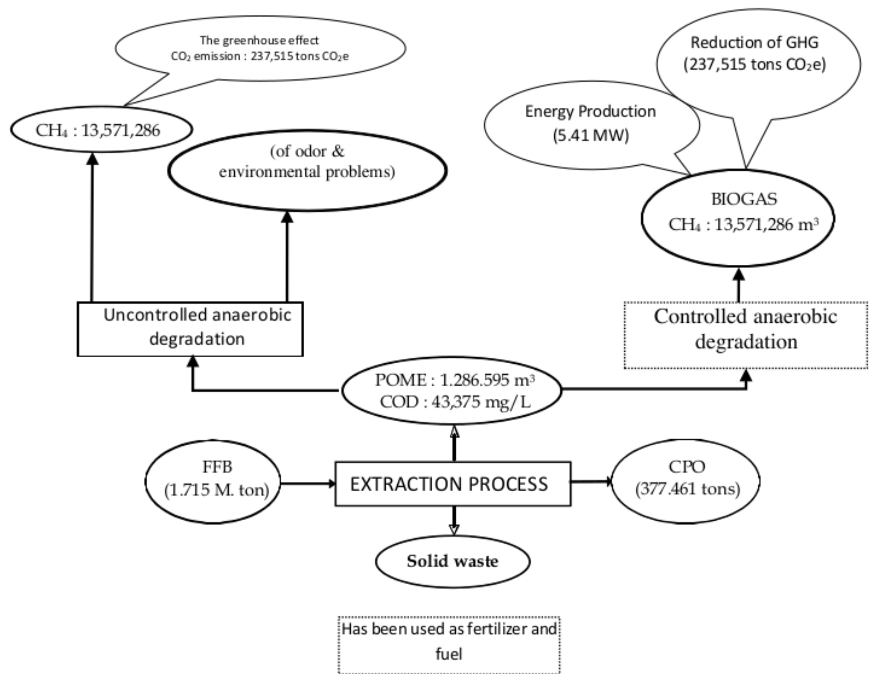

Figure 1. Scheme impacts and potential benefits of POME as a source of energy (a case study in Lampung Province)

Methane emission was converted to greenhouse gas emission in carbon dioxide emission unit by using a value equivalency force greenhouse effect of methane relative to carbon dioxide (Porteous, 1992). To estimate greenhouse emission reduction from using biogas for substituting fossil fuel/oil, the estimation results of methane biogas production was converted into carbon emission form or equivalent to carbon dioxide. By using data of emission reduction US$ 5 per ton C, the compensation value viable to obtain in CDM project was estimated according to obtained emission reduction level. Total benefit would be combination of benefits of biogas as fuel source and environmental benefits trough CDM project expressed in currency unit.

Results and Discussion

The Potency of CPO and POME In Lampung Province

Up to 2011, there were 13 units of POME productions distributed over five districts in South Lampung District (one unit), Central Lampung District (four units), Tulang Bawang District (three units), Mesuji District (three units), and Way Kanan District (two units). In 2011, total installed capacity of palm oil mill in Lampung was 622 tons FFB/hour (Table 1). CPO and POME production development in Lampung Province was shown in Figure 2.

Table 1. The Palm Oil Mills and Their POME Identification In Lampung Province in 2011

Name of Distric	Capacity (Tons/h)	FFB Processed (Tons)	Utility of POM (%)	CPO Yield (%)	Potency of POME (m^3)
South Lampung	25	110.825	72,00	22,94	83.118
Central Lampung	190	461.445	38,13	21,06	346.083
Tulang Bawang	145	442.618	48,44	21,57	331.962
Mesuji	177	467.953	41,06	21,58	350.964
Way Kanan	85	232.612	44,88	14,61	174.458
Lampung Province	622	1.715.453	45,06	22,00	1.286.585

The capacity of palm oil mill in Lampung Province varies from small (25 tons/hour) to large capacity (72 tons/hour). However, in general, utilization degrees were still very low (45.06%). This suggests a very low facility efficiency. The results of discussions and field observations indicate the presence of a very large interest from local investors to set up palm oil mills, but it is not matched with raw material supplies (TBS). On the other hand, the land availability to develop a larger plantation (> 5,000 ha) has been restricted, so that the palm oil mill relies on the raw materials coming from society (Darminto, 2010).

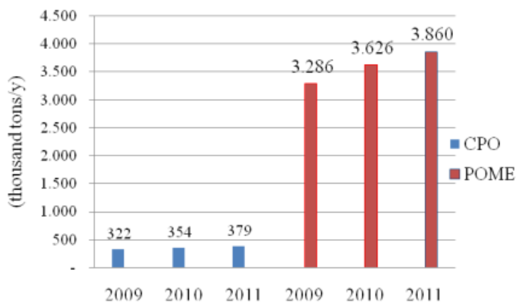

Figure 2. Development of CPO and POME Production in Lampung Province

Palm oil productivity varies amongst companies due to different factors such as soil, climate, and processing condition. Companies with better managements resulted in higher productivities. For instance, a certain company produced an average of 23 tons of fresh fruit bunches (FFB)/hectare/year with an average of 24 percent of oil extraction rate (OER). Some companies produced less, for instance, only an average of 13 tons of FFB with 18 percent of OER. Based on this information, about 80% of FFB are biomass waste (Hasanudin *et al*., 2010).

Table 2. Calculation of Energy Production and GHG Emission Reduction from POME reatment (a case study in Lampung Province)

Description	District					Lampung Province
	South Lampung	Central Lampung	Tulang Bawang	Mesuji Lampung	Way Kanan	
FFB were Processing (tons/year)	110.825	461.447	442.619	467.954	232.613	1.715.459
Flow rate (m^3/year)	83.119	346.086	331.965	350.966	174.460	1.286.595
CH_4 Production (m^3/year)	876.821	3.650.857	3.501.894	3.702.338	1.840.375	13.572.286
Biogas Production (m^3/year)	1.339.885	5.578.938	5.351.306	5.657.607	2.812.310	20.740.046
LHV Biogas (MJ/ m^3)	23	23	23	23	23	23
CH_4 Concentration (%)	65,44	65,44	65,44	65,44	65,44	65,44
Energy generation (MJ/year)	30.817.357	128.315.566	123.080.033	130.124.970	64.683.121	477.021.047
Energy generation (MJ)	0,98	4,07	3,90	4,13	2,05	15,13
Eff. Energy Conversion (%)	35	35	35	35	35	35
Energy Production (MW)	**0,34**	**1,42**	**1,37**	**1,44**	**0,72**	**5,29**
CH_4 Production (kmol CH4/year)	39.144	162.985	156.335	165.283	82.160	605.906
CH_4 Production (kg CH4/year)	626.301	2.607.755	2.501.353	2.644.527	1.314.554	9.694.490
CO_2 emission (kg CO2e/year)	15.344.364	63.889.994	61.283.154	64.790.920	32.206.570	237.515.001
CO_2 emission (kg CO2e/FFB)	138	138	138	138	138	138
CO_2 emission (tons CO2e/year)	**15.344**	**63.890**	**61.283**	**64.791**	**32.207**	**237.515**
Total financial benefits (Rp. million)	**4.498**	**18.727**	**17.963**	**18.991**	**9.440**	**69.618**

This study indicated that the abilities of palm oil mills to extract CPO in this Province was good (22.03% averagely). This showed that the technology used to process fresh fruit bunches is sufficient. More over, some palm oil mills were only able to extract CPO less than 20%. It dues to the use of sand fruits.

The Potency of Electricity Energy Generated from POME In Lampung Province

Calculation of Energy Production and GHG Emission Reduction from POME Treatment (Table 2). Calculation of methane emissions and biogas recovery from POME which on bases 1 t FFB was processed (Table 3). Methane gas from anaerobic decomposition of the organic material has high energy content and can be used as a source of renewable energy. According to Khemkhao *et al*. (2012), POME with organic loading rates (OLR) between 2.2 and 9.5 g COD/L/day can produce 13.2 liters/day of biogas.

Tabel 3. Calculation of methane emissions and biogas recovery from POME (bases 1 t FFB was processed)

Description	Unit	Value
Fresh fruit bunches production	t TBS	1
CPO production	t CPO	0.2203
POME production	m^3	0.75
COD in POME	kg COD	32.81
Potential of GHG Emissions	m^3 CH_4	9.19
	kmol CH_4	0.410
	kg CH_4	6.562
	kg CO_2	160.8
	kg C	43.8
Potential of Biogas Production	m^3	14.0
Fuel savings:		
- Diesel oil equivalent	L diesel oil	7
- In the money	Rp	38,500
Compensation potential CERs through CDM projects	Rp	2,083
Total benefits	Rp	40,583
Input data for calculation:		
Yield (TBS => CPO)	% (Sarono et al. (2013)	22.03
Production of Liquid Waste specific	m^3/t TBS (Morad *et al*., 2008)	0.75
COD	mg/L (Sarono *et al*. (2013)	43,750
Methane productivity	mg methane/L POME (Sarono *et al*. (2013)	0.28
conversion rate	L CH_4/kg COD (GTZ, 1997; USDA and NSCS, 2007)	400
Energy equivalence	L diesel oil/m^3 biogas (Hutzler, 2004)	0.5
Prices of diesel oil	Rp/L	5,500
Afficiency of COD reduction	% (Sarono *et al*. (2013)	86.86
Concentration of methane in the biogas	% vol. (Sarono *et al*. (2013)	65.44
Methana Density (CH_4)	kg/m^3 (http://en.wikipedia.org/wiki/Methane)	0.717
Greenhouse effect of methane	kg CO_2/kg CH_4 (Porteous, 1992)	24.5
The price of carbon credits	USD/t C (Survey results)	5
Currency Exchange	Rp/USD (Survey results)	9.500

Sarono *et al*. (2013) stated that POME processing with CSTR bioreactor in 55^{0}C can reduce COD value 86.86% (COD 43.375 mg/L into 5.700 mg/L) and produce biogas with 65.44% methane concentration. In addition, every one kg COD removal can produce 0.28 m^3 methane gas (methane productivity), or every kg of fresh fruit bunches (FFB) will produce 5.65 kg CH_4.

The results showed that the total potential energy produced from methane captured from POME to electric energy in Lampung Province from the 13 units reached 5.41 MW. Potential energy produced from any plant oil palm in Lampung Province was very different from one manufacturer to another (Figure 3). This was related to the different plant capacity, raw material quality, and efficiency of utility plant use.

Mahendra (2013) reported that the use of biogas produced from POME had been conducted by PTPN V of Tandun Unit in Riau Province since 2011. PTPN V Tandun unit has been using covered lagoon technology to process POME into biogas and the biogas product was used for internal use. The fuel saving from biogas substitution in one year was Rp.3,301,322,000,-

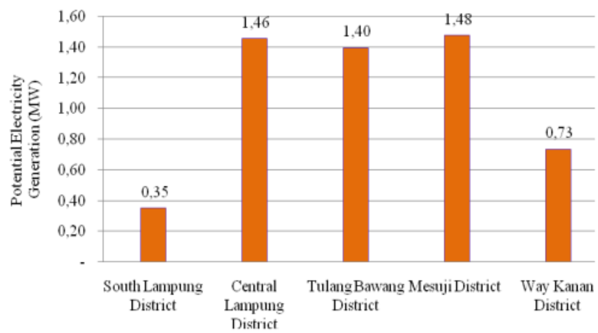

Figure 3. The Potential Electricity Generation from the 13 POMs in Lampung Province

The Estimated GHG Reduction from POME In Lampung Province

Sarono *et al*. (2013) stated that POME processing with CSTR bioreactor in 55^{0}C can reduce COD value 86.86% (COD 43.375 mg/L into 5.700 mg/L) and produce 0.28 m^3 methane gas for each kg COD removal. According to Porteus (1992), methane gas is a greenhouse gas emissions 24.5 times more powerful than carbon dioxide. Based on this data, Lampung province in 2011 with potential POME of 1,286,595 m^3 will be able to reduce greenhouse gas emission of 237,515 tons CO_2e (Figure 4).

Results of a study in Malaysia showed that reduction of GHG emissions from palm oil mill was 225 kg CO2e/ton CPO by using methane capture and was 987 kg CO2e/ton CPO without methane capture (Vijaya et al., 2010). In Thailand, the reduction was 750 kg CO2e/ton CPO with methane capture and it was 1,087 kg CO2e/ton CPO without methane capture (Kaewmai at al., 2012). According to Tan *et al*. (2012), every ton of CPO resulted in greenhouse gas emission reduction by 971 kg CO2e without methane capture and 506 kg CO2e with methane capture. This suggests that one of greenhouse gas main sources is biogas from POME.

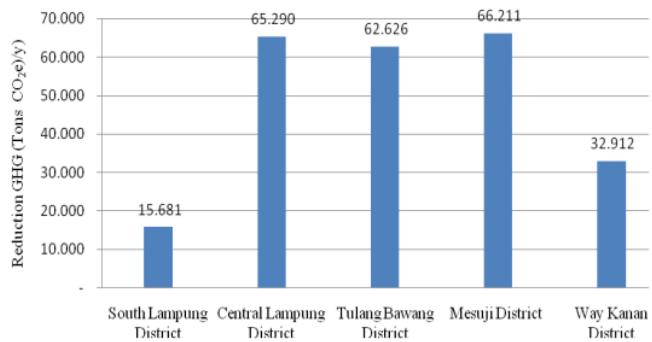

Figure 4. Potential Estimated Greenhouse Gas Emission Reduction of POMs in Lampung Province

On the other hand, methane gas from anaerobic organic material decomposition has high energy content and can be used as a source of renewable energy. Khemkhao et al. (2012) reported that POME with organic loading rates (OLR) between 2.2 and 9.5 g COD/L/day can produce 13.2 liters/day of biogas.

Conclusions

CSTR technology application in 55^0C fermentation temperature to process POME in 13 palm oil mills in Lampung province in 2011 was able to produce energy potency of 5.41 MW and reduce greenhouse gas emission of 242,720 tons CO_2e. Processing liquid waste with controlled system may contribute improvements of environmentally friendly palm oil production practices and produce additional values and competitiveness of palm oil product (*green product*).

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