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Yogyakarta, August 28-29 2013

The International Symposium on Agricultural and Biosystem Engineering

Proceedings

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Fakultas Teknologi Pertanian UGM

Korean Society for Agricultural Machinery

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The International Symposium on Agricultural and Biosystem Enginering 2013

Improving The Role of Agricultural and Biosystem Engineering
Toward Food & Energi Self-Sufficiency and Sustainable Agriculture

AUGUST 28-29 2013
YOGYAKARTA, INDONESIA

PROCEEDINGS

Organized by:

Departement of Agricultural Engineering
Faculty of Agricultural Technology
Universitas Gadjah Mada

Perhimpunan Teknik Pertanian
PERTETA
Cabang Yogyakarta

Supported by:

Korean Society for Agricultural Machinery
사단법인 한국농업기계학회

Sponsored by:

WINGSFOOD

ISBN : 978-602-14315-0-4

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Proceedings
The International Symposium on Agricultural and Biosystem Enginering 2013

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Jurusan Teknik Pertanian, Fakultas Teknologi Pertanian
UNIVERSITAS GADJAH MADA

First Edition: 2013

ISBN : 978-602-14315-0-4

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Message from The Chairperson Of Isabe 2013

It is my honor to welcome you to the International Symposium on Agricultural and Biosystem Engineering 2013. Thank you all for gather here today at the Faculty of Agricultural Technology for attending this important meeting. The ISABE 2013 is held in August 28-29 organized by Department of Agricultural Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada and the Indonesian Society of Agricultural Engineering (PERTETA). The theme of ISABE 2013 is "Improving the role of agricultural and biosystem engineering toward food & energy self-sufficiency and sustainable agriculture". The objectives of the symposium are to disseminate knowledge, to promote research and development, to obtain the latest information, as well as to exchange technical information in agricultural and biosystem engineering innovation. Moreover, the symposium will provide opportunity to strengthen networking among Indonesia and international academia, government and industries. The meeting will feature a series of keynote speech in plenary sessions, presentations in technical sessions, poster sessions, cultural night, as well as excursion.

I am very pleased to welcome all the guest speakers: Prof. Dongil Chang (Chungnam National University, Korea), Dr. Takashi Okayasu (Kyushu University, Japan), Prof. Vinod Jindal (Mahidol University, Thailand), Ir. Patrick van Schijndel (Eindhoven University of Technology, Netherlands), Prof. Kenan Peker (Selcuk University, Turkey), Prof. Fajrettin Korkmaz (Ataturk University, Turkey), as well as Dr. Lilik Sutiarso (Universitas Gadjah Mada, Indonesia). And joining us to deliver a congratulatory speech is Prof. Seung-Je Park (President of Korean Society for Agricultural Machinery, KSAM). Thank you very much for all of you for your contribution in this symposium.

I am also pleased to greet participants of 92 selected papers, among them are 8 papers from Korea, 6 from Japan, 1 from Taiwan, 1 from Austria, 1 from Thailand, and the remaining 75 papers are from Indonesia, as well as 3 posters. For delegates who do not present papers, thank you for your participants. I hope you can enjoy all the agenda.

I would like to express my sincere gratitude to all colleagues, sponsors, organizing committee, steering committee for their support and cooperation for making this event succesfully performed.

Finally, thank you again for your participation and welcome to the ISABE 2013 meeting.

Chairperson of ISABE 2013
Dr. Rudiati Evi Masithoh

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Feasibility Analysis of Palm Oil Mill Effluent Utilization as A Source of Electrical Energy

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Abstract

Palm oil mill effluent (POME) in Indonesia is generally treated with a pond system, where most of the organic materials are decomposed anaerobically. This causes the odor generation and greenhouse gas (GHG) emissions (methane) that contributes to global warming. The organic matter in the wastewater is potentially converted into a green energy in the form of biogas. The biogas can then be converted into electrical energy that can be utilized to supply for energy needed of the plant or the surrounding community. Implementation of this concept can contribute to the improvement of the good practice of palm oil industry by reducing CH_4 emissions, as well as improving added value and the competitiveness of palm oil products (green products) in international market. The purpose of this study was to analyze the feasibility of implementing this concept, in the view points of technical, ecological, and financial aspects. The study was conducted with a case study in the Lampung Province. Results showed that in certain circumstances the use of organic materials as a source of electrical energy is technically, ecologically and financially feasible. Palm oil mills in Lampung Province have the potential to emit about 12,663 t CH_4or equivalent to 310,245 t CO_2e per year. The use of methane gas capture technology can produce approximately 27.171.076 m^3 of biogas that can be converted to 42 – 67 Mio. kWh per year. Based on the conditions in Lampung Province, the most prospective technology seems to be the covered lagoon technology with a total investment of IDR 30 billion. The financial analysis showed that this project could yield an IRR of 29.72%, Net B / C of 1.87; Gross B / C of 1.72; and PBP of 4.06 years.

Keywords: POME, methane capture, emission reduction, covered lagoon, sustainable palm oil industry

Introduction

Currently, Indonesia is the largest palm oil producer in the world. However, the Indonesian palm oil products are still facing various problems related to its environmental management. At the meeting of APEC (Asia-Pacific Economic Cooperation) September 2012, Indonesian CPO (Crude Palm Oil) could not be included in the category of environmental-friendly products.

One of the emerging environmental issues in the oil palm business is the management of palm oil mill effluent. Currently, most of the palm oil effluent is disposed in lagoons to decompose. In such system, most of the organic material degraded anaerobically. It can emit unpleasant odors, harmful air pollutants and greenhouse gases. The air pollutants emitted from the discharged wastewater include volatile organic substances, hydrogen sulfide, and ammonia, many of which can cause odor problems in the surrounding area. Besides polluting the air, organic matter and nutrients of the palm oil effluent can contaminate ground water. Anaerobic decomposition also emits methane, a potent greenhouse gases. Methane has 20-30 times the global warming potential of carbon dioxide (Porteous, 1992). The environmental issue rises in the global market of Indonesian CPO, which leads to a weakening of it bargaining position.

To overcome the problem, methane emissions from the palm oil mill effluent biodegradation can be avoided through application of methane capture technology. Methane (the main component of biogas) may then be utilized as a source of renewable energy for electricity generation. Utilization of this energy source can be considered as a prospective way, because the raw material in form of palm oil mill effluent is available in large quantities. Proven technologies for conversion of the organic material into electricity are also technically available. The remaining question is the feasibility of the recycling organic material method in the view points of technical, environmental, and financial aspects. The purpose of this study was to analyze the feasibility of implementing this concept with a case study of palm oil industry in Lampung Province, Indonesia. This study is expected to contribute to the achieving the target of Government of Indonesia, in which 60% of palm oil mills should have methane capture facilities in 2020 (Indonesian Palm Oil Board, 2012).

Methods

Conceptual Framework

The treatment methods of palm oil mill effluent vary widely in Indonesia, but the highly organic polluted wastewater is generally treated simply by using open-pond system. With such practice, some problems are encountered, such as pollution of water resources, the problem of bad odor, and greenhouse gas emissions (methane gas) from the uncontrolled anaerobic biodegradation of the organic materials (Moletta, 2005). On the other hand, organic matters contained in palm oil mill effluent could potentially be utilized as a source of renewable energy (biogas) that can be used to generate electrical energy. The recycling method is relatively low investment cost, easy in operation, and eco-friendly. The process technologies that convert organic materials of palm oil effluent to methane-rich biogas, and utilize the biogas as an energy source of power generation are well-known process, technically proven and worldwide available commercially. The systems consist of general sub-systems, namely anaerobic treatment unit, methane capture, and unit to convert methane into electrical energy. The technologies offered by each provider are, however, different in characteristics and performances. It should therefore be assessed by comprehensive considering the actual conditions of the intended potential users of the technologies. In this context, a feasibility analysis focusing on technical, environmental, and financial aspects is essential considerations prior to applying the technology in palm oil industry.

Data Collection

This study used primary data and secondary data. Primary data were collected through in-depth interviews with respondents from the oil palm industry practitioners and technology providers of technologies for palm oil mill effluent conversion into electrical energy. Secondary data were obtained through study of literature, such as scientific journals, technical reports from relevant institutions (research institutions, technology providers, or similar institutions). Other secondary data used in this study was the statistical data from the Indonesia Central Statistics Agency as well as plausible data from the website (internet).

Data Analysis

The feasibility analysis was conducted based on the data collected from survey on palm oil mills in Lampung Province. Potential biogas production rate was carried out with the principle of material balance. In this study, the estimation of biogas production rate uses empirical data. Technical aspect analysis was performed by quantification and assessment of the available palm oil mill effluent production rate and it distribution in the study area. Three technologies of methane capture ere compared each other with the main consideration on the parameters of scale, anaerobic bioreactor type, complexity, process time, process temperature, and land requirements, removal of organic materials, biogas production, and electricity generation rate. Environmental aspect was analyzed by comparing the difference between GHG emission rate with and without this project. The emphasis of this analysis lays on emission reduction, fossil fuel substitution, as well as the other relevant environmental impacts. Analysis of the financial aspects was performed using computing cash flow and some investment criteria of some scenarios using procedure as described by Suharto (2002). Investment criteria analysis was performed using the calculation of the value of the net present value (NPV), internal rate of return (IRR), net benefit/cost ratio (Net B / C), gross benefit/cost ratio (Gross B / C), and payback period (PBP).

Results and discussion

Technical Aspects

It was identified that one ton FFB processed produces approximately 0.22 t CPO and 0.83 m^3 of palm oil effluent. The wastewater is highly organic polluted that is characterized by COD contents of 41-50 g / L with an average COD of 44.3 g/L). The wastewater produced from one t FFB produces has a organic load of 37 kg COD. Palm oil mill effluent in Lampung province is currently treated with an open pond system. In the system, the biological degradation of most organic matter takes place anaerobically and produces the final products in the form of methane and carbon dioxide (biogas). One kg of COD can be converted to about 0.4 m^3 CH_4 removed in anaerobic condition (GTZ, 1997; USDA and NSCS, 2007). Assuming removal of 70%, the anaerobic organic substances degradation results in methane production of approximately 7 kg. With a potent greenhouse with about 24.5 times the global warming potential of carbon dioxide, the methane emission was equivalent to 180 kg CO_2e. Table 1 shows the potential GHG emission, emission reduction, and electricity energy generation. Following figures are used for the calculation: methane conversion factor of 400 L CH_4/kg COD eliminated (GTZ, 1997; USDA and NSCS, 2007), COD removal of 70% (typical for pond system), methane content in biogas of 65%, methane density of 0.717 kg/m^3, average methane global warming potential of 24.5 (Porteous, 1992), biogas heating value of 21 BTU/L, and turbine efficiencies of 20-40% (Cuéllar and Webber, 2008).

The wastewater from 1 t FFB processed produces COD load of 37 kg that can be converted into 16 m^3 of biogas. Biogas typically contains about 55-65% methane, 30-35% carbon dioxide, and some hydrogen, nitrogen and other impurities. Its heating value is around 21 BTU per liter or 16,000-20,000 kJ/m^3 or 6 kWh/m^3 (Hutzler, 2004). It is about 60-80 percent of the heating value of natural gas. The energy from biogas can be converted to electricity with a typical efficiency of 34–40% for large turbines and with an efficiency of 25% for smaller generators (Cuéllar and Webber, 2008). Using a range of turbine efficiency from 25–40%, the biogas produced from 1 t FFB can be converted into electrical energy of 25-40 kWh.

Table 1. Potential GHG emission, emission reduction, and electricity energy generation (basis: 1 t FFB processed)

Component	Unit	Value
FFB processed	t FFB	1
CPO produced	t CPO	0.22
Palm oil mill effluent (POME)	m^3	0.83
COD in the POME	kg COD	37
Potential GHG emission:	m^3 CH_4	10.3
	kg CH_4	7
	kg CO_2	180
Specific GHG emission	kg CH_4/t TBS	7
	kg CH_4/t CPO	180
Potential biogas production:	m^3/t TBS	16
	m^3 biogas/m^3 POME	19
Electricity generation	kWh (25% Eff.)	25
	kWh (40% Eff.)	40
Emission due to inefficiencies in the methane capture system	kgCO_2e/t TBS	20
Emission reduction through methane capture	kgCO_2e/t TBS	161

GHG emissions could be from a fugitive emission and emission due to incomplete flaring. Fugitive emissions due to inefficiencies of methane capture in the wastewater treatment system depends on many factors, namely the efficiency of the capture of biogas at the wastewater treatment system, the volume of processed wastewater in the system, conversion factor of waste organic matter to methane (kg CH_4/kg COD), and other non-controllable factors. Flaring emission depends on emissions from waste handling system due to the project activity, the volume of processed wastewater in the handling system, the inlet COD, COD reduction efficiency, and other uncertainties factors (UNFCCC, 2010). In this analysis, the kind of emission in this case was approximated by 20 kg CO_2e per t FFB processed.

Palm oil mill in Lampung Province amounted to 13 factories spread across five districts, covering regencies of the Lampung Selatan, Lampung Tengah, Way Kanan, TulangBawang, and Mesuji. The installed total capacity of the entire palm oil mill in the province was 622 t FFB/hour (2011). The installed processing capacity of each palm oil mills varies widely from 25 to 72 t FFB / hour with an average of nearly 45 t FFB / hour. The actual capacity of the entire palm oil in Lampung Province was 1.7 Mio. T FFB per year, about only 32% of the installed capacity. The average yield of the palm oil mill was approximately 22%. Figure 1 shows schematic representation of the yearly wastewater generation, GHG emission and emission reduction through methane capture in palm oil mills in Lampung Province.

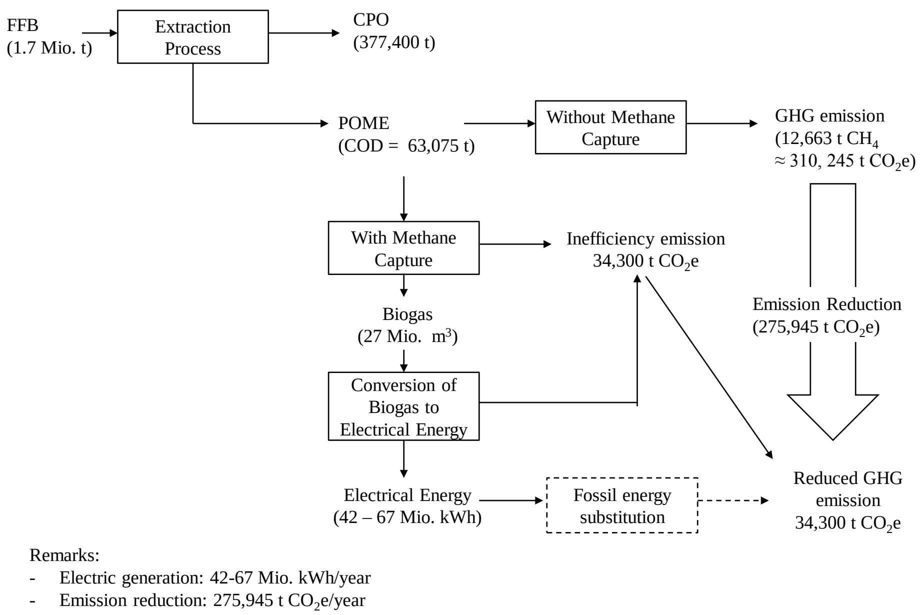

Fig. 1. Schematic representation of yearly wastewater generation, GHG emission and emission reduction through methane capture in palm oil mills in Lampung Province

Assuming anaerobic organic material removal of 70%, it was estimated that palm oil mills in Lampung province could produce approximately 12,663 tons of methane per year. The amount of methane production was equivalent to 310,245 tons of the CO_2e per year. The methane emission was equivalent to about 3 percent of CPO produced, whereas the CO_2 emission counted to about 16 percent of FFB processed.

Processing the entire produced palm oil mill effluent using anaerobic bioreactor system could generate as many as 27 Mio. m^3 of biogas. It was equivalent to 19 m^3 of biogass per m^3 of processed palm oil mill effluent. Using a range of turbine efficiency from 25–40%, the biogas produced can be converted into electrical energy of 42-67 Mio. kWh. It can be used to replace fossil fuel and seen as a new and renewable source of energy.

In yearly basis, total emission from all palm oil mills in Lampung Province was predicted to be 310,245 tons of the CO_2e subtracted by total emission due to inefficiency of 34,000 t CO_2e results in an emission reduction of 275,945 t CO_2e. Reduction of GHG emissions can also be estimated for each palm oil mill using similar procedure described above. The potential GHG emission and the electrical energy generation depend mainly on the amount of palm oil mill effluent that was determined by FFB processing rate. Fig. 2 shows potential electrical energy generation rate and GHG emission reduction as a function of FFB processing rate. With the help of the figure, the possible electrical energy generation rate and the potential GHG emission reduction can be estimated. In the figure the cases of 13 palm oil mills in Lampung Province are also presented.

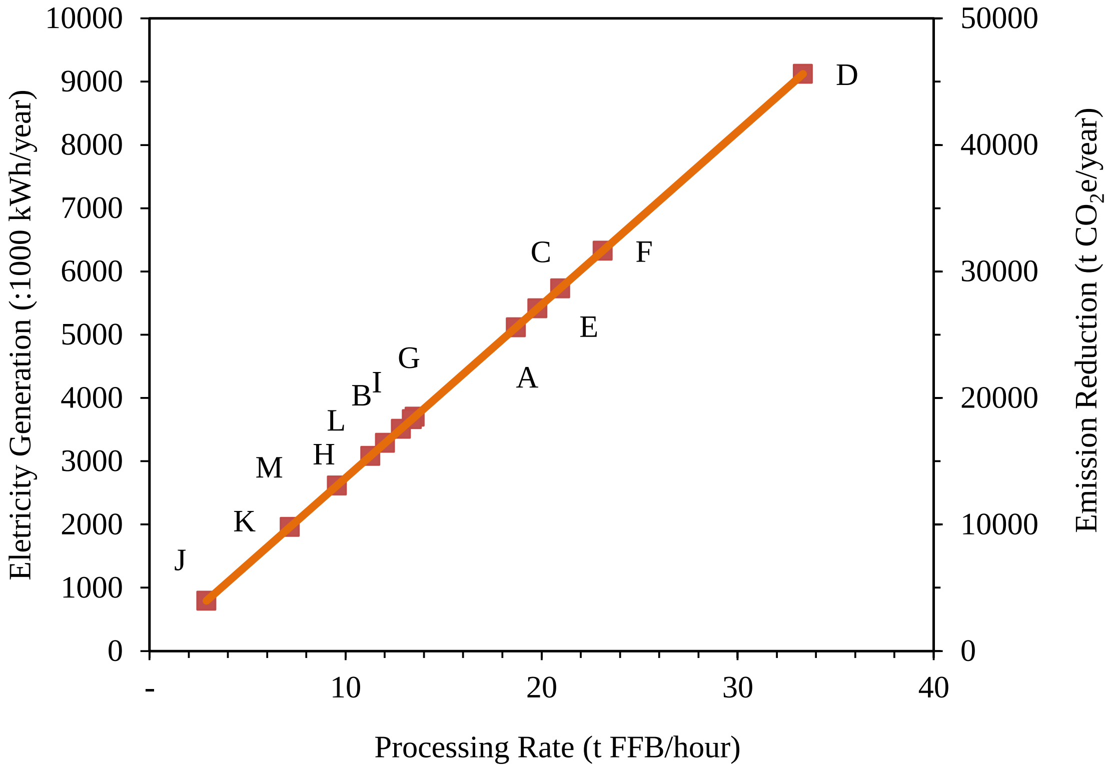

Fig. 2. Potential GHG reduction and electrical energy generation rate as a function of FFB processing rate (A – M: Codes of 13 palm oil mills in Lampung Province)

Currently, technologies for methane capture and for conversion of methane gas (main component of biogas) into electrical energy are available in Indonesia. Three companies were identified as provider for methane capture technology, namely PT A, PT B, and PT C. PT A was a company that uses mainly anaerobic treatment technology CSTR (Continuously Stirred Tank Reactor) for treatment of palm oil mill effluent. The technology package includes pretreatment, anaerobic treatment, secondary treatment and tertiary treatment, biogas upgrading, and sludge handling units. This technology refers to the Indian technology. PT B was a company that provides the technology to capture methane mainly using anaerobic treatment covered lagoon. The principle of this technology is an improvement or modification of existing lagoons. The main components of the system are anaerobic treatment units and biogas handling unit. This technology was originally developed in the United States. PT C uses technology similar to the PT B technology, namely covered lagoon system. It's more complete system as it provides also handling sludge. Table 2 shows the comparison between these technologies. The data were collected from various sources, such as through benchmarking and compiling data from AES Agriverde Ltd. (2006), KIS Group (2012), PT Karya Mas Energy (2012), Soesanto (2012), and Wiryawan (2012).

From the above discussion, it is seen that from the view point of the amount of source material in the form of palm oil mill effluent and the availability of technology, palm oil mill effluent utilization for electricity generation is technically possible to be realized in the palm oil mills in Lampung Province.

Table 2. Technical data of the methane capture technologies

No.	Parameter	Technology provided by PT A	Technology provided by PT B	Technology provided by PT C
1	Capacity of POM	Applicable for POM scale of 30-60< t FFB/h; Dominated by 60 t FFB/h	Applicable for POM scale of 30-60 t FFB/h; Adaptable	Applicable for POM scale of 30-60 t FFB/h; Dominated by 45 t FFB/h
2	Type of implemented bioreactor	CSTR (dominant for POME), UASB	UASB, covered lagoon (dominant for POME)	Covered lagoon
3	Hydraulic retention time	15 – 30 d	30 – 60 d	30 – 60 d
4	Biological process temperature	Mesophylic and thermophylic; 45-60^{o}C; 27-40^{o}C	28-32^{o}C	28-32^{o}C
5	Land area demand	Small	Large	large
6	Facilities installation	New intallaltion	Modification of exiting lagoon	Modification of exiting lagoon
7	Claimed Organic substances removal	≥ 85%	Average 87%	≤ 90%
8	Biogas production (per m^3 LCPKS)	25-30	< 25 - 30<	< 25 - 30
9	CH_4 inbiogas (%)	60-70	60-65	55-65
10	CH_4 production per POME volume	16.8-19.6 m^3/m^3	14.3-20.3 m^3/m^3	12.0-17.5 m^3/m^3
11	Electricity production (MWh): ▪ Potential ▪ Case study	1 – 2 > 1.5 at POM of 60 FFB/h	1 – 2 1-1.5 at POM of 50 FFB/h	1 - 2 < 1 at POM of 45 t FFB/h

Environmental Aspects

Technical aspects of the methane capture technology will have an impact on the environmental aspects. In general, it will reduce the pollution load of wastewater, reduce methane emission, and generate energy. The methane gas conversion to electrical energy can provide additional benefits in the form of reducing GHG emissions, fossil fuel substitution, creating added value and improving sustainability of palm oil industry.

Using methane capture technology and its conversion into electricity will reduce air pollution problem around the factory and wastewater treatment plant (WWTP) as results of avoiding of the odor problem due to uncontrolled generation of hydrogen sulfide (H_2S), ammonia (NH_3), and volatile organic compounds (VOCs). As the system is equipped with geo-membrane for preventing the wastewater percolation, the use of these technologies also reduces the groundwater contamination.

As an illustration of the advantages of methane capture in palm oil industry, the emission reduction by applying methane capture technology in palm oil mills was compared with the ability of plant in CO_2e absorption. When the technology of methane capture and conversion to electrical energy was applied on the entire palm oil mills in Lampung Province, the emission reductions will reach 275.940 t CO_2e per year. Comparing with the ability of Sustainable Forest Management (SFM) that able to absorb carbon dioxide by 9.76 tCO_2/ha/year (Bahruni, 2012), the emission reduction of overall palm oil mills in Lampung

Province would be equivalent to the reduction of carbon dioxide emissions derived from about 18,000 hectares of SFM per year. Further, for the case of palm oil mill with processing rate of 45 t FFB/h, in which an emission reduction of 52,116 t CO_2e per year could be achieved by applying methane capture, the mention emission reduction would be equivalent to the carbon dioxide absorption ability of about 5,340 hectares of SFM per year.Comparing the emission reduction with absorption capability of *Samaneasaman*plant(in Indonesia terminology: “Tanamantrembesi”) that would able to absorb 28,448 kgCO_2/plant/year (Santoso, 2011); approximately 1,830 plants are needed to absorb as much as 52,116 t CO_2e per year.

The environmental aspect of palm oil industry has also consequents on financial aspect. With the better environmental management practices, produced CPO and its derivative products may be more eco-friendly products. Thus, the Indonesian palm oil derivative products may be more acceptable in the international market. Another consequent would be the reduction of duties on CPO exports to APEC member countries up to 0-5% (APEC 2012). As an illustration, Indonesian CPO exports to APEC member countries in 2010 worth USD 1,768,067,000 (Indonesia Central Bureau of Statistics, 2011). When Indonesian CPO does not include environmental-friendly products, imposed customs duty would be USD 238,689,045 (13.5%). On the other hand, if the Indonesian CPO in the category of environmental-friendly products, the savings of about USD 150,285,695 - USD 238,689,045 per year could be earned.

Financial aspects

The first step in conducting a financial analysis was to determine the details of the cost of each technology, and potential financial benefits that can be gained from the project. Some assumptions were made as result of the limited financial data available. Due to the made assumptions, this analysis was intended only to provide a general idea associated with the financial aspects in the application of this concept.

The following financial analysis used the currency of the Indonesian Rupiah (IDR), which the exchange rate was IDR 9,637.00 per U.S. dollar. If the technology provided by PT A was used, project investment costs count IDR 33,888,510,500.00. In addition to the investment cost, operating expenses amount IDR 2,746,550,000.00 per year. In the case of application of the technology provided by PT B, the investment cost (without equipment for the conversion of methane gas into electrical energy) was IDR 4,022,056.854.00. The cost for scrubber was estimated at the price of IDR 18,552,500,000.00. The costs for installation of gas engines and equipment were USD 1,200-1,500 per kW. With the gas engine power of 1250 kW, the investment cost of gas engines and equipment amounted to IDR 14,455,500,000.00. Thus, the total investment cost of this technology reaches IDR 37,030,056,854,00 with an operating cost of IDR 2,013,630,000.00 per year. The investment cost of the technology provided by PT C was estimated by IDR 30,067,440,000.00 (UNFCCC, 2012) with an average operating cost of IDR 1,093,414,984.00 per year. More detailed description of procedure and basis of the cost calculations can be found in Suryanto (2013).

Three scenarios for gaining financially benefits were considered in this study. The first scenario, the financial benefit was from the selling the electricity only. In the second scenario, the financial benefit was derived from the selling of CER (Certified Emission Reduction) only. In the third scenario the financial benefits are obtained from both selling the generated electricity and CERs. Results of the assessment criteria for investments of the scenarios are presented in Table 3. Calculations for the first scenario using the prevailing price of electricity in Indonesia from renewable energy sources, namely biogas was valued at

USD 975/kWh x F, with F value of 1 for Sumatera. The value was set by the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 04 Year 2012. Meanwhile, the CER price used in this calculation was the price prevailing on the date 30 November 2012 amounting to € 0.69 per tCO_2 (European Energy Exchange AG 2012) with rupiah exchange rate against the euro of IDR 12,461.80 per euro, the price of CERs was IDR 8,598.64.

Table 3. Assessment criteria for investments of the three different scenarios

Scenario Revenue	**Technology Provider**	**Investment Criteria**				
		NPV (in Mio. IDR)	**IRR (%)**	**Net B/C**	**Gross B/C**	**PBP (years)**
Electricity selling	PT A	21,004	24.80	1.62	1.42	4.87
	PT B	2,727	13.55	1.07	1.06	6.32
	PT C	25,327	29.23	1.84	1.70	4.13
CER	PT A	-49,007	-	0	0.02	-
	PT B	-45,770	-	0	0.01	-
	PT C	-35,568	-	0	0.02	-
Electricity selling	PT A	21,865	25.27	1.65	1.44	4.78
	PT B	3,387	14.08	1.09	1.07	6.18
	PT C	26,188	29.72	1.87	1.72	4.06

Investment criteria analysis results indicate that the application of methane capture technology at a palm oil mill was feasible only if electricity was sold or used for internal industrial activities. Higher financial benefits could be gained when the electricity selling was combined with the acquisition of incentive CDM project through the sale of CERs. Financial benefit obtained from the sale of CERs only results in an unfeasible financial project.

From the foregoing discussion, it is seen that the utilization of organic materials in the palm oil mill effluent to generate electricity provides not only financial benefits derived from the utilization of biogas energy and incentives through CDM (Clean Development Mechanism) projects, but also environmental benefits from prevention of methane gas emissions and improving the practice of palm oil production. This will in turn lead to create added value that can improve the competitiveness of palm oil products (green products) in the international market. In this regards, conversion of palm oil mill effluent into electrical energy should be considered as feasible in the context of an integrated and sustainable environmental management.

The utilization of biogas anaerobic bioreactor as a substitute for petroleum fuels / fossil could contribute to the environmentally sound production practices of palm oil, so the Indonesian oil palm products would be more acceptable in the international market. However, it should be noted that the accuracy of estimates of emissions and the potential benefits to be gained from the use of biogas as an alternative energy source, as illustrated above, is affected by the accuracy of input data related, especially the specific biogas production, biogas composition, the portion of organic matter degraded anaerobically, the biogas and emission reductions prices. Pilot-scale testing and modifications are still required and the calculation of benefits needs to be adapted to real local condition. This analysis is intended to provide an indication of the high potential for the utilization of industrial waste palm oil as a source of renewable energy (biogas and electricity), in terms of technical, environmental, and financial aspects.

Conclusions

Palm oil mills in Lampung Province have the potential to emit about 12,663 t CH_4or equivalent to 310,245 t CO_2e per year. Under certain circumstances the use of organic materials in palm oil effluent as a source of renewable energy is technically, ecologically and financially feasible. The use of methane gas capture technology and conversion to electrical energy can produce approximately 27.171.076 m^3 that can be converted to 42 – 67 Mio. kWh per year. Considering the general conditions in Lampung province and the complexity of the system, the most suitable technology seems to be the covered lagoon technology with a total investment of IDR 30 billion. The financial analysis showed that this project could yield an IRR of 29.72%, Net B / C of 1.87; Gross B / C of 1.72; and PBP of 4.06 years.

Utilization of organic materials in the palm oil mill effluent for producing electrical energy could provide financial some benefits, such as energy selling, reduction of GHG emissions (and incentives through clean development mechanism project). It could improve palm oil production environmental management practices, which in turn could create added value and improve competitiveness of palm oil products (green products) in the international market.

Acknowledgement

The authors thank the Directorate General for Higher Education, the Ministry of Education and Culture, Government of Indonesia for the financial support through Research Grant Scheme of MP3EI - Master Plan for the Acceleration and Expansion of Indonesian Economic Growth, FY 2012-2013

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