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LEMBAR PENGESAHAN

Judul	:	The Potential of Palm Oil Mill Waste As A Source of Energy and Green House Gases Emission Reduction
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SESSION E4

Global warming issues in waste management

9.00 - 9.15
U. Hasanudin, E. Suroso, M. Faisal, H. Kamahara and K. Fujie (ID)
The potential of palm oil mill waste as a source of energy and green house gases emission reduction

9.15 - 9.30
R. Baciocchi, G. Costa, L. Lombardi and D. Zingaretti (IT)
Storage of carbon dioxide captured in a pilot-scale biogas upgrading plant by accelerated carbonation of industrial residues

9.30 - 9.45
A. Massagué, A. Akerman, M. Martín and X. Aldea (ES)
Assessing and reducing the carbon footprint of wastewater treatment plants: Biogas valorisation in boilers and cogeneration engines

9.45 - 10.00
D. Rosso, R. Gori and C. Lubello (IT)
Carbon footprint and energy footprint of activated sludge wastewater treatment plants

10.00 - 10.15
M. Ritzkowski (DE)
New CDM-methodology for Landfill Aeration

10.15 - 10.40 Discussion
10.40 - 11.00 Coffee Break
11.00 - 11.30 Poster presentation

SESSION E5

Role of WTE in global warming

11.30 - 11.45
M. Kranert, D. Clauss, M. Berechet and N. Escalante (DE)
Evaluation of waste management systems regarding the balance of carbon dioxide and costs

11.45 - 12.00
A. W. Larsen and T. Astrup (DK)
Variation of CO_2 emission factors for incineration of household waste

12.00 - 12.15
K. Kuchta and M. Tafel (DE)
Study on the potential of commercial and industrial waste management to contribute to the climate protection goals of the city of Hamburg

12.15 - 12.30
Th. Dorn, M. Nelles, J.M. Cai and S. Flamme (DE)
Burning away - Can waste disposal technology transfer lead to a smaller Chinese Carbon Footprint?

12.30 - 12.45
D. Tonini and T. Astrup (DK)
Global Warming Potential of a waste refinery using enzymatic treatment

12.45 - 13.10 Discussion
13.10 - 14.30 Lunch

THE POTENTIAL OF PALM OIL MILL WASTE AS A SOURCE OF ENERGY AND GREEN HOUSE GASES EMISSION REDUCTION

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SUMMARY: Agro-industries have been selected as an one of the important industries in Indonesia; with it comparative and competitive advantages; therefore Indonesia Government has selected agro-industry as a priority and leading sector. The main products of agro-industry are usually only about 25% or less of raw materials and the rest, in form of wastes, is needed to be treated and handled properly to avoid environmental problems. Large amount of waste and by-products will give high impact on environment but in the other side have high potential to be utilized as an energy sources. The waste water treatment in agro-industries usually uses anaerobic digestion in open deep lagoon. But nowadays, there is a change of environmental paradigms that waste treatment is not only to meet the environmental standard but also to produce benefit from it such as renewable energy. Palm oil mill is one of main agro-industry in Indonesia. The primary product from palm oil mill is crude palm oil which usually not more than 25% of the fresh fruit bunches. Therefore, waste management is very important from the point of view optimization of added value and reduces the environmental risk. Nowadays, several biomass wastes from palm oil mill were utilized for generated energy or other purposes. But, some others palm oil mill biomass waste are not utilized yet. The objectives of this study were to calculate the potential of palm oil mill wastewater utilization as sources of energy and to evaluate their effect on green house gases emission reduction. Palm oil mill waste water released about 10-14.5 m^3 of biogas/ton of FFB (Fresh Fruit Bunches) which has caloric value equivalent to about 5-7.25 liter of diesel oil. If the palm oil mill capacity is 800 ton/day of FFB, it means that the potential energy from the waste water is equivalent to about 4000-5800 liter of diesel oil/day. The utilization of palm oil mill waste water as source of energy also has contribution on

reduction of green house gases (GHGs) emission. The released biogas was equivalent with about 70.26 kg CO_2/ton FFB. Based on total FFB production at 2009 in Indonesia, the utilization of biogas from palm oil mill waste water as an energy source will reduce CO_2 emission more than 6.5 million ton.

1. INTRODUCTION

The world's demand for energy grows rapidly because of increasing population, technology development, and economics growth. International Energy Agency (IEA) at 2007 reported that world energy consumption increased almost twice from 6,128 Million ton of oil equivalent (Mtoe) in 1973 up to 11435 Mtoe in 2005 (Anonym, 2007[a]).

World energy consumption until now mostly is fulfilled by fossil fuels; however, it is decreased in recent years because of many factors. Fossil fuel in 1973 provided around 46 percent of total world energy consumption and in 2005 decreased into around 35 percent (Anonym, 2007[a]). Although share of energy consumption which was fulfilled by fossil fuel decreased, the amount of fossil oil increased. It was shown by increasing almost twice world energy consumption in the last of 30 years. The same condition of energy consumption also took place in Indonesia. Indonesia still depended on fossil oil to fulfill its energy consumption. Fossil oil provided approximately 54 percent of total energy in Indonesia.

To overcome this problem and to anticipate limitation of world fossil oil availability in the world especially in Indonesia, it is time to look for alternative sources of energy, especially renewable energy.

Agro-industries have been selected as a one of the important industries in Indonesia; with it comparative and competitive advantages; therefore Indonesia Government has selected agro-industry as a priority and leading sector. The main products of agro-industry are usually only about 25% or less of raw materials and the rest, in form of wastes, is needed to be treated and handled properly to avoid environmental problems. Large amount of waste and by-products will give high impact on environment but in the other side have high potential to be utilized as an energy sources. The waste water treatment in agro-industries usually uses anaerobic digestion in open deep lagoon. But nowadays, there is a change of environmental paradigms that waste treatment is not only to meet the environmental standard but also to produce benefit from it such as renewable energy.

Palm oil mill was known as surplus energy industry by utilization of solid waste biomass, but liquid waste biomass was not utilized yet for renewable energy production.

Table 1 - Crude palm oil (CPO) production in Indonesia during 5 years.

Year	CPO Production (000 Ton)							
	Small Holders		State Owned Company		Private Company		Total	
	CPO	PKO	CPO	PKO	CPO	PKO	CPO	PKO
2004	3847	731	1618	356	5365	1180	10830	2267
2005	4501	855	1449	319	5911	1300	11861	2474
2006	5789	1156	2313	463	9254	1851	17350	3470
2007	6358	1272	2117	423	9189	1838	17664	3533
2008	6683	1336	2521	425	9282	1856	18486	3618
2009	7209	1442	2962	451	9978	1995	20149	3888

Also, palm oil mill effluent treatment system emitted big amount of green house gases such as methane and carbon dioxide gases. Capturing and utilization of methane as an alternative energy all at once will prevent environmental pollution, reduce green house gases emission and substitute diesel oil consumption in agro-industries. Producing energy from renewable agro-industries biomass wastes can contribute to reduce the consumption of fossil fuel for those industries.

The objectives of this study were to calculate the potential of palm oil mill wastewater utilization as sources of energy and to evaluate their effect on green house gases emission reduction.

2. CPO PRODUCTION

Indonesia is well known as one of the biggest palm oil producer, especially in form of crude palm oil (CPO). CPO production in Indonesia during last 5 years increased almost twice and mainly belonged to private company (Table 1). Palm oil factories and plantation in Indonesia are belonged to State Owned Company and some private companies.

In all of CPO factory, palm fresh fruit bunch (FFB), as raw material, have to be processed as soon as possible, within 24 hr, to prevent a rapid rise in free fatty acids (FFA). High concentration of FFA could greatly affect the quality of the product of CPO.

The palm oil process involves the physical oil extraction of CPO and palm kernel from the FFB as follows:

- Sterilization of the FFB: The fruit bunches are steamed in pressurized vessels at 135-150°C and pressure of 2.5-3 Atm for 90 min, to arrest the formation of free fatty acids, destroy oil-splitting enzymes, remove mucus and prepare the fruits for subsequent sub-processes.
- Threshing in a rotating drum thresher to separate the fruitlets and empty fruit bunches; the empty bunches are then burned in the incinerator and produced ash are sent to the plantation as a fertilizer while the fruitlets are conveyed to the press digester.
- Digestion and pressing: In the digesters, the fruits are heated at 85-95°C and continuously stirred to loosen the oil-bearing mesocarp from the nuts as well as to break open the oil cells present in the mesocarp. ; The digested mash is then pressed using screw press at 50 kg/cm^2 and temperature of 85 – 90°C for about 6 – 10 min to extract the oil. The press cake is then sent to palm kernel processing unit.
- Clarification, purifying and drying: The crude oil from pressing unit (containing palm oil, water, cell debris, fibrous materials and non-oily solids) is then pumped to clarifier tanks to separate the oil from its entrained impurities. The clarified oil is then fed to purifiers to remove dirt and moisture before being dried further in the drying unit (vacuum drier). The clean and dry oil of CPO is ready for storage and dispatch. The sludge from the clarifier is then centrifuged for further oil recovery. The water/sludge mixture coming out of the centrifugation unit is then treated in palm oil mill effluent treatment plant.
- Palm kernel processing: The process begins with separation of fiber and nut in de-pericarper unit. The mixed nut is then fed to drying for water removing. The nuts are cracked and the shell and kernel are separated using winnower and hydro-cyclone. The clean kernels are dried prior to storage or fed to pressing unit to produce kernel oil.

Palm oil industry generates three types of solid waste namely empty fruit bunch (EFB), fiber, kernel shell, and boiler ash. Utilization of biomass waste at present is just to fulfill palm oil processing energy through direct burning of fiber and shell.

3. MATERIAL AND METHODE

This research was conducted in palm oil industries with have capacity 25 and 40 ton FFB/hour. Palm oil mill wastewater samples were taken from inlet and outlet of anaerobic lagoons in palm oil mill wastewater treatment plant. COD concentrations of those samples were analyzed in laboratory. Survey, secondary data collection, and interview were conducted to get information about material balance and energy supply system in palm oil industries. GHGs emitted from anaerobic lagoon was measured using gas trapping devices and gas flow meter (WK-NK-0.5B, Shinagawa Corporation, Japan) as shown in Figure 1. Composition of gas emitted from anaerobic lagoon was analyzed using gas chromatography (Shimadzu GC 2014) with thermal conductivity detector (TCD) and shin-carbon column with 4 meter length. Helium gas was used as carrier gas with flow rate 40 ml/min.

4. RESULTS AND DISCUSSION

4.1 Material Balance And Energy Potential From Solid Waste Palm Oil Industries

Productivity of palm oil varies from company to company due to different factors, such as soil, climate, and processing condition. Companies that have better management resulted higher productivity. For instance, certain company produced in average 23 tons of fresh fruit bunches (FFB)/hectare/year with in average of 24 percent of oil extraction rate (OER). Some company produced less, for instance only in average 13 tons of FFB with 18 percent of OER. Based on this information, about 80% of FFB are biomass waste. The schematic diagram and mass balance of crude palm oil processing in chosen palm oil factories, namely PTPN VII (State Own Company) unit Bekri and unit Rejosari, that are located in Lampung Province, Indonesia are shown in Figure 2 and 3. It was shown that the OER value is about 21.8% from FFB (Anonym. 2007[b,c]). The wastes which were generated from palm oil processing also described in that

a) b)

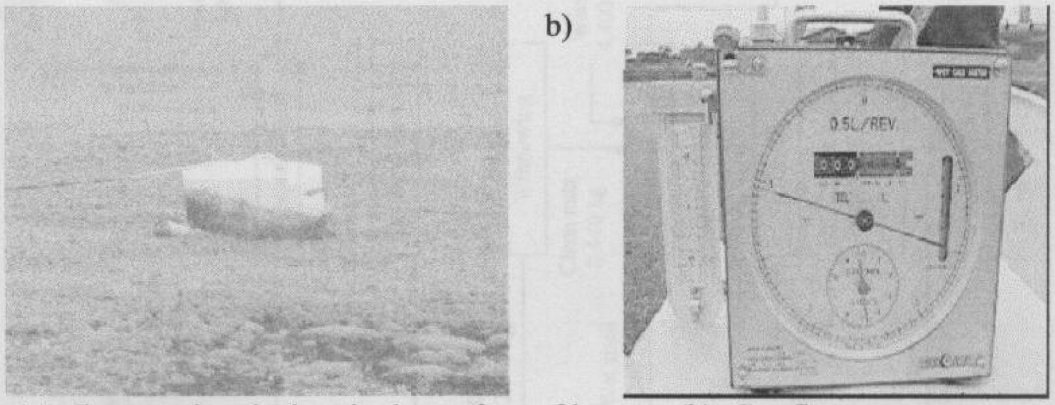

Figure 1. (a). Gas trapping devices in the surface of lagoon, (b). Gas flow meter.

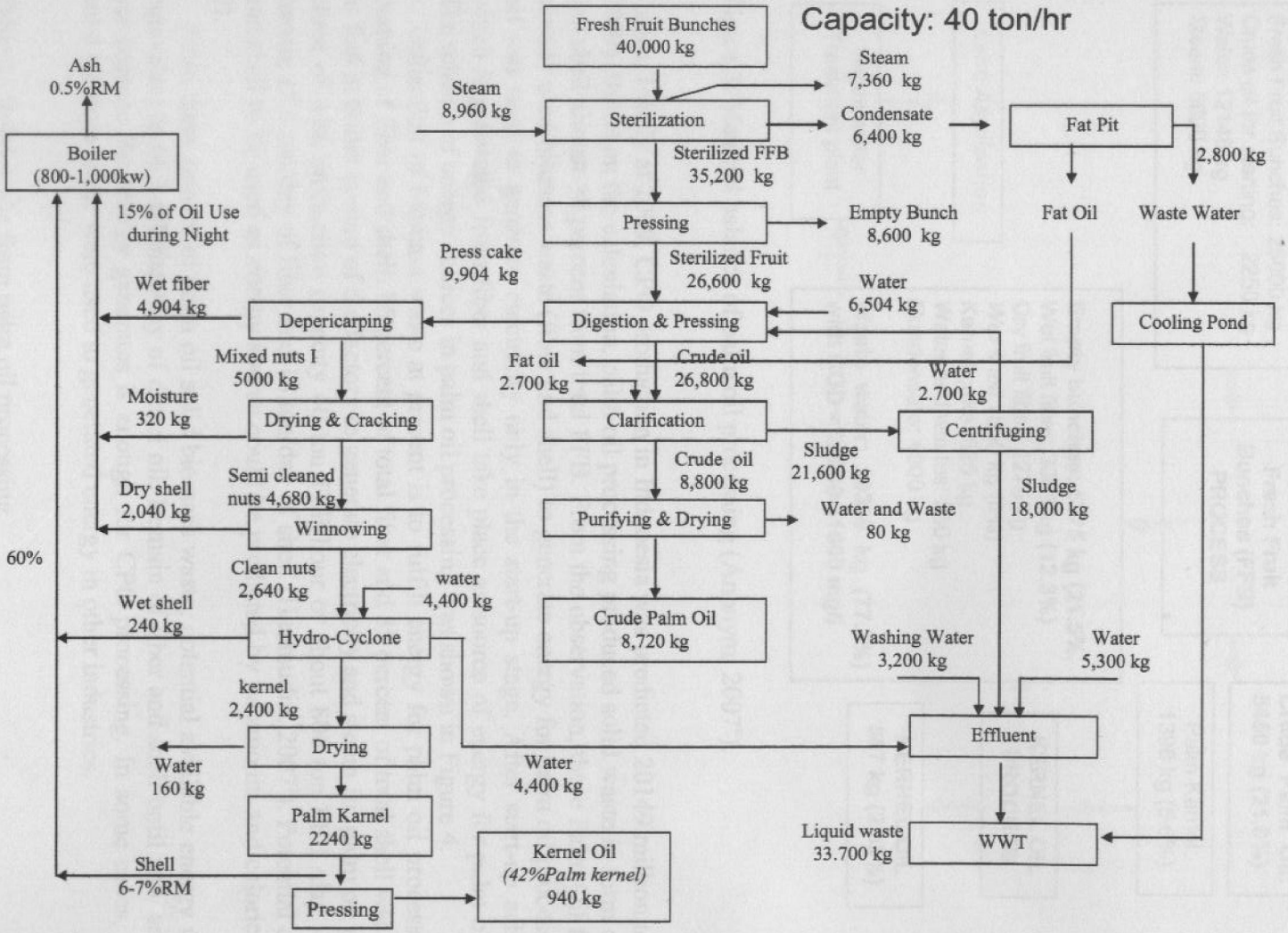

Figure 2. Schematic diagram of palm oil processing (Anonym, 2007[b]).

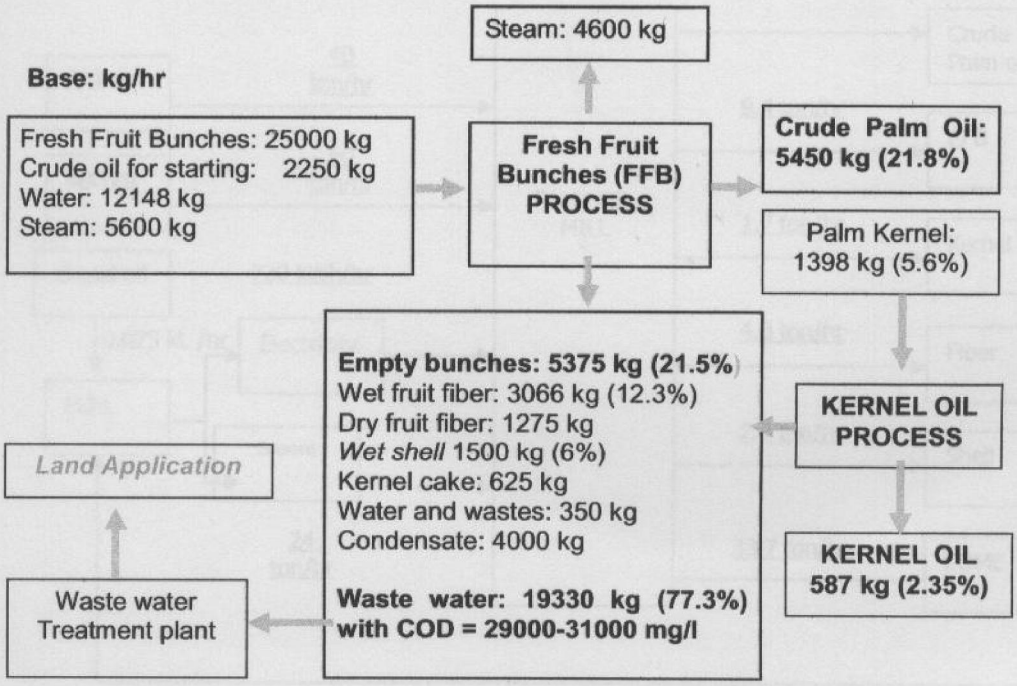

Figure 3. Material balance of palm oil processing (Anonym, 2007[c]).

figure. Totally at 2009, CPO production in Indonesia was predicted 20149 million tons (Daryono, 2009). Based on the calculation, palm oil processing produced solid waste in form of EFB, fiber, and shell almost 40 percent from total FFB. From the observation, these Palm Oil factories have already used biomass waste (fiber and shell) to generate energy for palm oil processing. Diesel oil was used to generate electricity only in the start-up stage. After start-up achieved, steam which is generated from fiber and shell take place as source of energy for palm oil processing. The scheme of energy sources in palm oil processing was shown in Figure 4.

Utilization of biomass waste at present is to fulfill energy for palm oil processing by direct burning of fiber and shell. 85 percent of total fiber and 55 percent of total shell was directly used as fuel in boiler system of the factory to generate electricity and steam for palm oil processing. In chase of with production capacity 40 ton FFB/hour or about 800 ton FFB /day was predicted remain 15.6 ton/day of fiber and 18 ton/day of shell (Hasanudin, 2007[a]). Potential of EFB, fiber, and shell to be used as energy source could be predicted by its amount and caloric value (Table 2).

From these remain of palm oil solid biomass waste, potential available energy was predicted equivalent to 66.3 kiloliter/day of diesel oil. Remain of fiber and shell until now are not utilized yet because the energy generates is enough for CPO processing. In some cases, these remain solid biomass waste were used to generated energy in other industries.

Table 2 - Solid waste from palm oil processing.

Type	Unit	Amount	Caloric value
EFB (wet)	ton/ton FFB	0.20	18795 kJ/kg EFB
Fiber (dry)	ton /ton FFB	0.13	19055 kJ/kg fiber
Shell (dry)	ton /ton FFB	0.05	20093 kJ/kg shell

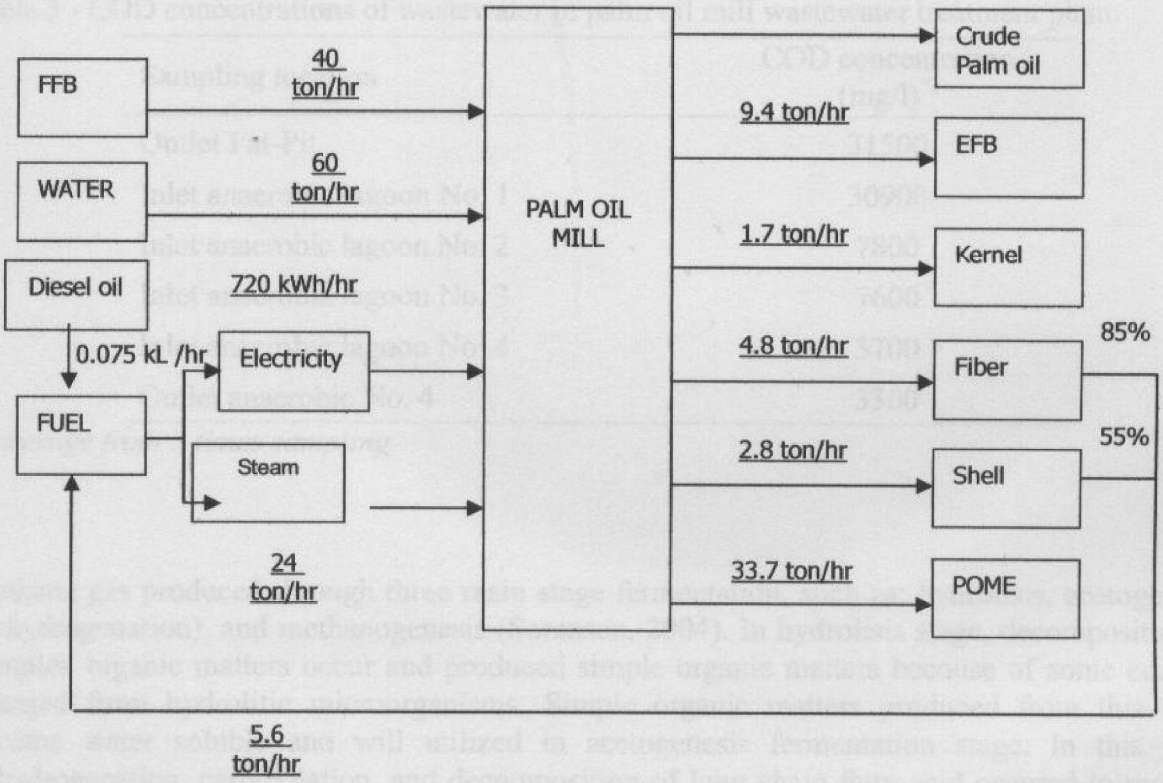

Figure 4. Energy supply system in palm oil processing.

Meanwhile, EFB, and boiler ashes, as residue from boiler system, are directly used as mulching and fertilizer that its return to plantation for reduces consumption of chemicals fertilizer and maintain micro climate condition in nearby oil palm tree. Even though can provide energy by direct burning, EFB is relatively high in water content, so there will be problem and need pre-treatment if use it as fuel like fiber and shell.

4.2 Energy Potential and Green House Gases Emission from Palm Oil Mill Wastewater

Beside solid biomass waste, liquid biomass waste or wastewater produced palm oil industry has high potential as bio-energy resource. The wastewater produced from CPO processing contains high concentration of organic matters which can be use as a raw material for biogas production through anaerobic digestion. Below are COD concentrations of wastewater in palm oil mill wastewater treatment plant (Table 3).

Biogas is product of organic matters decomposition through anaerobic fermentation process with methane producing bacteria. Biogas compositions mainly are methane (CH_4) about 50-70% and carbon dioxide (CO_2) about 30-35%. Methane is flame able gas with heating value 35.9 MJ/m3 (Nakamura, 2006) and also counted as green house gas with green house effect 21 times higher than carbon dioxide (Rodhe, 1990). The utilization of palm oil mill wastewater as a source of energy will give three advantages at once, such as: (1) reducing environmental pollution, (2) reducing fossil fuel consumption, and (3) reducing global warming effect.

Table 3 - COD concentrations of wastewater in palm oil mill wastewater treatment plant.

Sampling location	COD concentration (mg/l)*)
Outlet Fat-Pit	31500
Inlet anaerobic lagoon No. 1	30900
Inlet anaerobic lagoon No. 2	7800
Inlet anaerobic lagoon No. 3	7600
Inlet anaerobic lagoon No. 4	3700
Outlet anaerobic No. 4	3300

*) *average from 3 times sampling*

Methane gas produced through three main stage fermentation, such as: hydrolisis, acetogenesis (dehydrogenation), and methanogenesis (Sorensen, 2004). In hydrolisis stage, decomposition of complex organic matters occur and produced simple organic matters becouse of some enzyme released from hydrolitic microorganisms. Simple organic matters produced from this stage become water soluble and will utilized in acetogenesis fermentation stage. In this stage dehydrogenation, carboxilation, and decomposition of long chain fatty acid occured to produce acetic acid as a final product. Methane gas released at third stage fermentation which converted acetic acid to methane. Methanogenic bacteria is dominant active bacteria groups in methanogenesis stage.

Based on material balance in palm oil processing (Figure 3) known that about 0.8 m^3 wastewater was produced per ton FFB of oil palm with COD concentration 29000 – 31000 mg/l. Using this value, each ton FFB will released about 10-14.5 m^3 of biogas from the wastewater which has caloric value equivalent to about 5-7.25 liter of diesel oil (Hasanudin, 2007[b]). If the palm oil mill capacity is 800 ton/day of FFB, it means that the potential energy from the waste water is equivalent to about 4060-5793 liter of diesel oil/day or about 4900 liter of diesel oil/day in average. Potential energy generated from solid biomass waste and wastewater could be used to fulfill energy required in palm oil mill. For example, the start-up process of palm oil processing that usually uses diesel oil could be replaced by electricity which generated by biogas from the wastewater. The excess energy could be sold to other party like nearby industries or National Electricity Company (PLN). Total potential energy that could be generated from palm oil industry with capacity 800 ton/day of FFB was described in Table 4.

Table 4. Potential of energy generated from remain biomass waste in palm oil mill (production capacity 800 ton/ day of FFB)

Source of potential energy	Equivalent to diesel oil (liter/day)
Remain solid biomass waste (shell and fiber)	66319
Waste water	4900
Total	71219

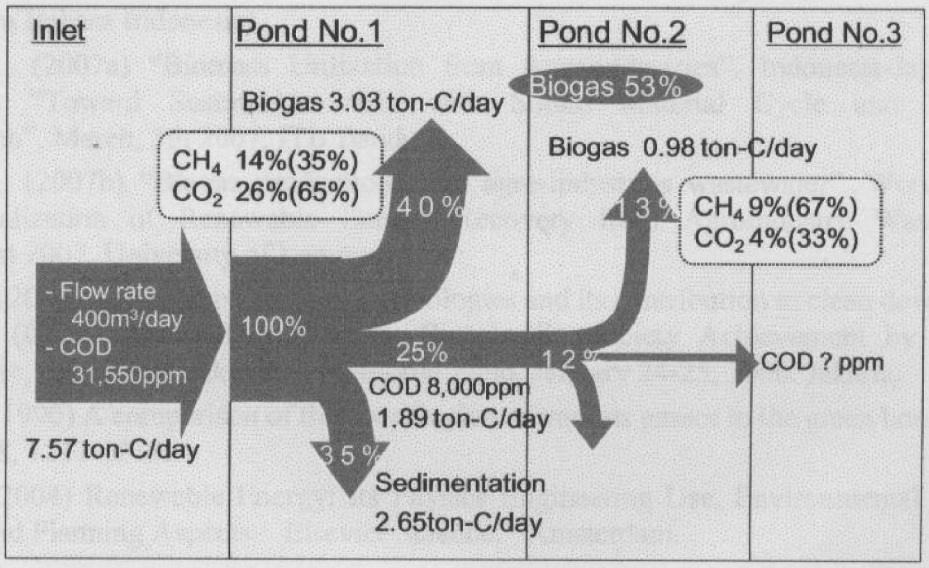

Figure 5. Carbon flow in anaerobic pond of palm oil mill wastewater treatment plant (Hasanudin, 2007b and Fujie et.al., 2009).

The utilization of palm oil mill waste water as source of energy also has contribution on reduction of green house gases (GHGs) emission. Figure 5 show the potential of methane production from palm oil mill waste water treatment plant. Palm oil mill which has capacity 40 ton FFB/hour or about 800 ton FFB/day will release about 4.01 ton C/day of biogas. Based on biogas composition as shown in Figure 5, the released biogas was equivalent with 56.49 ton CO2/day or about 70.61 kg CO_2/ton FFB. Based on prediction of total FFB production at 2009 in Indonesia are about 92.4 million ton of FFB, the utilization of biogas from palm oil mill wastewater as an energy source will reduce CO_2 emission more than 6.5 million ton per year.

5. CONCLUSIONS

The utilization of palm oil mill wastewater as a source of energy has high contribution on renewable energy production without interference on food stock obligation. Through anaerobic decomposition, each ton of FFB processed released about 10-14.5 m^3 of biogas with energy containing equivalent to 5-7.25 liter of diesel oil. Utilization of this biogas as an energy source also reduced green house gas emission. GHGs emission from palm oil mill wastewater treatment plant was about 70.61 kg CO_2/ton FFB. In Indonesia, the utilization of biogas from palm oil mill wastewater as an energy source will reduce CO_2 emission more than 6.5 million ton per year.

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