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Biomass Residue from Palm Oil Mills in Aceh Province: A Potential Usage for Sustainable Energy

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***Abstract*— Palm oil is one of the major agro industries in Aceh province. There are 25 crude palm oil (CPO) Mills in Aceh located in 8 districts with 551.12 tons/hour total capacity. The mills are concentrated in five districts along the western and eastern coasts, Aceh Utara, Aceh Timur, Aceh Tamiang, Nagan Raya, and Aceh Singkil (including the newly-established municipality of Subullusalam). As the climatic conditions in the Aceh are suitable for palm trees, the oil palm plantation area has expanded every year. The processing of FFB (Fresh fruit bunches) in palm oil mill produced a biomass residue that mainly consist of EFB (Empty fruit bunches), fiber, shells, and POME (Palm oil mill effluent). This study investigates the potential usage of biomass residue from palm oil mills in Aceh province. Results of the study indicated that the fiber and shells are mainly used as fuel for the mill boilers to generate heat and electricity for the whole plant. The EFB is disposed and spread on the plantation, incinerated or dumped in unmanaged sites. The POME is treated in the anaerobic and aerobic ponds, then normally being discharged into waterways or rivers. In some mills, the treated POME was spread to the plantation for fertilizer. Based on investigation on site, it shows that the load factor of the mill is only about 70% of capacity, thus the mills are inefficient since a lot of energy is lost. The use of EFB is very potential to be implemented in Aceh since this province produce of 724,185 ton EFB per year. With the total capacity of 551.12 tons/hour, palm oil mills in Aceh produce about 426.12 tons/hr of POME that also can be converted into energy. If 3.37 million ton FFB are treated in Aceh CPO mills, biogas energy of about 1.51 millions GJ will be produced.**

***Keywords*— palm solid waste; biomass residue; GHGs emission; sustainable energy.**

I. INTRODUCTION

Oil palm (Elaeis guineensis) is the most important species in Elaeis genus which belongs to the family of Palmae, a tropical species that originated in West Africa. It is indigenous to West Africa but is now planted in all tropical areas of the world, including Southeast Asia and Central America. Moreover, it has become the most important industrial crops especially in certain South East Asia countries such as Indonesia and Malaysia, the highest producer of palm oil. The relatively low priced of the oil has increased its use in various applications. The world demand for palm oil has risen in the last two decades, especially for its use in food and more recently as the raw material for biofuel.

Oil palm is a perennial tree crop, which is cultivated extensively in the humid tropical land. Average planting cycle of a palm tree is about 25 years for efficient productivity. Because of the conversion of solar radiation to plant growth by photosynthesis, the chemical energy content of the harvested palm fruit and biomass exceeds the energy input through the farming system. Thus, oil palm can act as a net source of useful energy [1,2].

The island of Sumatra has long been the largest palm oil production area in Indonesia. The oldest large-scale plantations were first established in 1911 in Aceh and North Sumatra provinces. One of the pioneers is the international company Socfindo, which is currently still very active in Aceh. Since those early days, palm plantation development spread south and to the other areas of Indonesia. The highest producing provinces on Sumatra are North Sumatra and Riau, with 28% and 24% of total production, respectively. Even though the bulk of Indonesia's production remains on Sumatra (about 70-80%), rapid expansion is occurring in Kalimantan, particularly in Central and West Kalimantan [3].

Nowadays, there are 25 crude palm oil (CPO) Mills in Aceh located in 8 districts with 551.12 tons/hour total capacity. In general, CPO Mill is operated for 20 hours/day. However, the mill would be operated for 24 hours/day when a raw materials of fresh fruit bunch (FFB) available abundantly. With the positive economical growth in Aceh, the production of CPO is expected to increase by the coming year. Besides the production of crude palm oil, a large amount of biomass waste is also an output from the palm oil industry. With the increasing of CPO production in Aceh, the amount of biomass residues generated also shows a corresponding increase. One hectare of oil palm plantation can produce about 50–70 tons of biomass residues [3,4]. The type of biomass residue produced from oil palm industry includes empty fruit bunches (EFBs), fiber, shell, wet shell, palm kernel, fronds, trunks, root and palm oil mill effluent (POME). These biomasses have high potential of turning into renewable energy. EFB and mesocarp fiber (MF) is the highest contributor of oil palm biomass. So far these biomasses are not utilized well in many palm oil mills in Aceh. On the other hand, these biomasses have high potential of turning into renewable and sustainable energy considering the calorific value of each component. Only small portion of biomass has been utilized as fuel to produce steam for electricity generation. Moreover, currently, there are already various technologies available to convert oil palm biomass to various types of value added products [3,4].

This paper reports results of field survey of biomass residue from Aceh palm oil mill industry and the possibility of potential usage of the biomass as an energy resource.

II. ACEH PALM OIL MILL INDUSTRY

Despite its pioneering status in Indonesia, Aceh is a relatively minor palm oil producer with less than 3 percent of national production. Table 1 shows the total Palm Oil Plantations in Aceh province. Aceh contained about 261,000 hectares in large private and governmental palm oil estates and smallholder farms, which constitute about 3.8% of the national plantings. This consists of approximately 89,000 hectares of smallholder oil palm producers, 39,000 hectares of government-managed estates (PTP), and 132,000 hectares in private estates.

Table 1 shows Distribution of Aceh's Palm Oil Plantations. The industry is concentrated in five district along the western and eastern coasts, Aceh Utara, Aceh Timur, Aceh Tamiang, Nagan Raya, and Aceh Singkil (including the newly-established municipality of Subullusalam). These six district and municipalities constitute over 84% of the total planted hectares and production, and have been the focus of most proposed new concessions and smallholder expansion schemes. Four district (Aceh Jaya, Aceh Barat, Aceh Barat Daya, and Bireuen) are also considered to be potential candidates for expansion of plantation.

There are 25 Crude palm oil (CPO) milling facilities in Aceh. Three of them are not operated or not operated yet. The location of the CPO mills are mainly near national main road, and thus accessible easily. A few CPO mills are located far from the main road, such as PT. Patisari which is located at about 18 km from the main road of Aceh Tamiang. For those are located far from the main road and not accessible by the National Electric Company (PLN), the factory use their own generator. Table 2 shows the milling facilities in Aceh and their factory capacities.

Almost all of the CPO milling facilities in Aceh does not work at their full capacity, mainly due to less of raw materials. The quality of fresh fruit bunch (FFB) supplied by smallholders to CPO mills is very poor resulting in low processing efficiency at the mill and poor prices paid to farmers. Visit results show that the load factor of the mill is only about 70-75% capacity. Thus the mills are not efficient due to the lost of energy. This apparent excess capacity is in fact not the case in many areas as plantations go unharvested or output is trucked long distances due to logistical issues such as lack of available local mills, manpower, access roads and harvest infrastructure.

TABEL I
DISTRIBUTION OF ACEH'S PALM OIL PLANTATIONS

District (District)	Large Estates Ha	Small holder Ha	Sub totals	Percent age %
Aceh Besar	1,140		1,140	0.44
Aceh Jaya	1,720	5,311	7,031	2.73
Aceh Barat	11,202	3,892	15,094	5.86
Nagan Raya	36,525	13,112	49,637	19.26
Aceh Barat Daya	4,968	1,250	6,218	2.41
Aceh Selatan	3,842	2,410	6,252	2.43
Singkil (Incl. Subulussalam)	24,522	19,046	43,568	16.90
Aceh Tenggara		1,253	1,253	0.49
Pidie	10	81	91	0.04
Bireun	382	3,138	3,520	1.37
Aceh Utara	14,353	14,834	29,187	11.32
Lhokseumawe		90	90	0.03
Bener Meriah		2	2	0.00
Aceh Timur	44,153	4,493	48,646	18.87
Aceh Tamiang	30,128	15,876	46,004	17.85

Source: Dishutbun

TABEL II
PALM OIL MILLS CAPACITY IN ACEH PROVINCE

No	Name of Palm Oil Mills	Capacity (ton FFB /year)
1.	PTPN I Cot Girek	192,300
2.	PT. PPP (PT. Perkasa Subur)	128,400
3.	PTPN I Pulau Tiga	128,400
4.	PTPN I Tj. Seumantoh	256,500
5.	PT. Mapoli Raya	256,500
6.	PT. Parasawita	85,500
7.	PT. Bahari	128,400
8.	PT. PPP	106,800
9.	PT. Sisirau	128,400
10.	PT. Pati Sari	128,400
11.	PT. Socfin (A. Tamiang)	64,200
12.	PT. Karya Tanah Subur	128,400

13.	PT. Mopoli Raya (A. Barat)	128,400
14.	PT. Fajar Baizury	256,500
15.	PT. Kalista Alam	128,400
16.	PT. Socfin (Seunagan)	128,400
17.	PT Socfin (Seumayam)	128,400
18.	PT. Lembah Bakti	256,500
19.	PT. Delima Makmur	171,000
20.	PT. Uber Traco	128,400
21.	PT. Socfin (A. Singkil)	128,400
22.	PT. Lestari Tunggal Pratama	106,800
	Total	3,293,400

III. BIOMASS WASTE GENERATED FROM PALM OIL MILL

The survey data of the process in milling facilities showed no significant different in the detail process. The technology of FFB processing used is similar in every CPO plant visited. Sample taken in the three CPO plant are assumed to be able to represent condition of whole CPO plant located in Aceh. The profile of some CPO Mills in Aceh is presented in Table 3.

TABLE III
PROFILE OF SOME CPO MILLS IN ACEH

	Unit	PT. Patisari	PTPN I Cot Girek	PTPN I Tj. Seumantoh
Full capacity	t/h	20	45	60
Working capacity	% of full cap.	75	75	77
Number of working hour	h/d	18	20	19.11
Number of working day	d/y	300	300	300
Number of EFB	% of FFB	22	22	23
Existing of EFB used: -burned in *incinerator* -other application	t/d	107 (25%) 321 (75%)	128.2 (20%) 512.8 (80%)	171 (20%) 684 (80%)
Source of electricity		Steam turbine (fuel: PKS)	PLN	PLN
Electricity consump.	KWh/t on FFB	n.a.*	13.26	13.26

* Data is not available

The products of oil palm are CPO and kernel Oil. The main process in palm oil milling facilities for producing CPO includes sterilization, pressing, digestion-pressing, clarification, purifying and drying. Observation results indicated that not all factories have a palm kernel shell (PKS) processing facility for producing kernel oil. The FFB from the plantation are transported by truck and weighted at fruit reception prior to introduced to a station loading ramp for fruits selection. The FFBs are sterilized in a horizontal direct contact steam sterilizer at 120°C for 80-90 min to inactivate the lipolytic enzymes and loosen the fruit still attached to the bunches. Generally the enzymes will be inactive at 50oC. Steam (about 450 kg/ton FFB) at a pressure of 2.8 kg/cm2 is used in the sterilization process, and hence, generate waste water. The sterilized bunches are fed by hoisting crane into a rotary drum thresher to separate the fruits from the bunches. The EFBs are conveyed to the dumping ground. The fruits are fed into a digester where water at 90-95°C is added. Digester is used to crush the fruit, separating the flesh with seeds, and facilitate process in pressing unit. The homogenous oil from the digester is pushed through a screw press, and later passes through clarification unit (sand trap tank, vibrating screen, vertical clarifier tank, a hydrocyclone and separators) to separate oil, fine solids and water. Oil purification is then used to remove water from the oil. Vacuum driers, sludge tank, sand cyclone and centrifugal are used to further purify the oil before pumping it to a storage tank. Products from digestion unit are transfer to PKS processing unit includes depericarping, drying, cracking, winnowing, hydrocyclone and drying process. The schematic process diagram and material balance of typical CPO milling process can be seen in Fig.1.

There are various biomasses produced from the CPO mills, i.e. EFB, fiber, shell, POME, kernel cake, sludge cake, POME, fronds, trunks and root. Significant amount of EFB, fiber, shell and POME are considered as biomass residue that could be utilized. The others can be sold for animal feed or fertilizer. The quantity of the biomass residue depends on the quality of the raw material. Table 4 shows the potential biomass generated by palm oil mills in 2012 in Aceh province and their heat value.

TABLE IV
BIOMASS GENERATED BY PALM OIL MILLS IN 2012 IN ACEH PROVINCE

Biomass	Quantity Million tons	*Moisture content (%)	*Oil content (%)	*Heat value (dry) (kcal/kg)
EFB	0.724	62	5	3700
Fiber	0.387	45	5	4420
Shell	0.182	7	1	4950
POME	2.590	95	1	-
Fronds	n.a			
Trunk	n.a			

Note: the biomass amount is calculated based on mill productity or CPO production. * Adapted from Chua [5] and Yusoff [6].

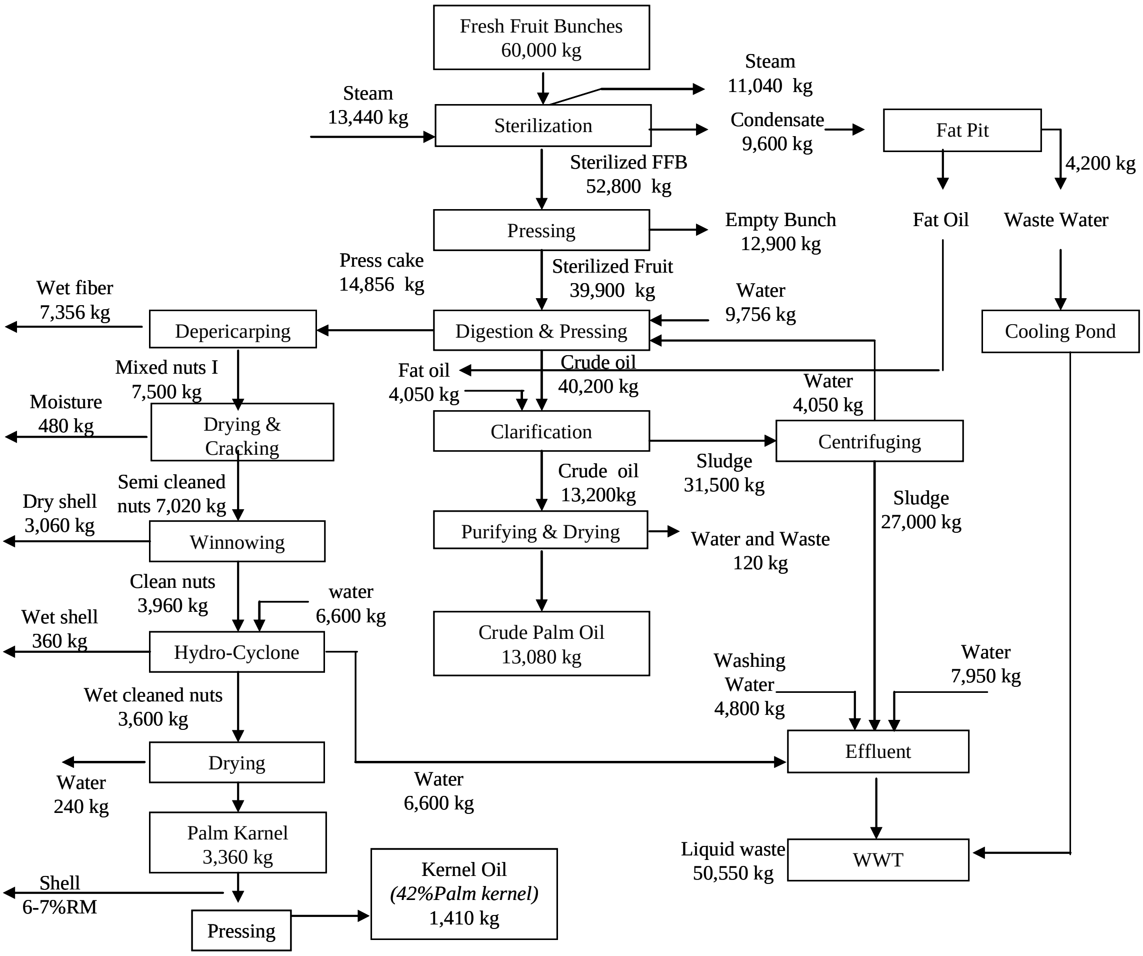

Fig. 1 Palm oil mill process and material balance

IV. POTENTIAL UTILIZATION OF PALM BIOMASS RESIDUE AS SUSTAINABLE ENERGY IN ACEH

A. *Empty fruit bunches (EFB)*

Oil palm biomass such as EFB can be converted into various value added products such as producing of bioplastic of polyhydroxyalkanoat (PHAs) or polylactate. The EFB contain certain macro and micronutrients that are required for plant growth, therefore the EFB can also be incinerated for its ash which serves as a very good fertilizer or soil conditioner. The use of ash from EFB is currently the common practice in many palm oil mills in Aceh. In some plantations, the EFB are left to decompose under the trees. However, the EFB cannot be stacked in more than two layers around the tree as it will attract harmful insects [8]. EFB also can be sold to brick producer near the mill with a very cheap price.

Although oil palm biomass can be converted to various value added products, nevertheless, its potential as a source of renewable energy seems to be more promising, considering current state of energy crisis with the price of crude petroleum hitting record high every other day. Apart from that, its utilization as a source of energy will bring other environmental benefit like reduction in CO2 emissions. [4]. EFB is the major component of all solid wastes. Steam from the sterilization process results in a moisture content in the EFB as high as 60%, which makes it unsuitable as a direct fuel. It was reported that the EFB has 42% C, 0.8% N, 0.06% P, 2.4% K and 0.2% Mg. [8,9].

TABLE V

CHARACTERISTICS OF EFB IN SOME CPO PLANT IN ACEH

Parameters	Unit	Patisari CPO Plant	PTPN I Seumantoh	PTPN I Cot Girek
Calorific Value	kcal/kg	6,098	6,013	5,688.4
Moisture	%	51.07	47.81	47.69
Nitrogen	%	0.48	0.41	0.51
Organic Carbon	%	52.88	51.56	48.97

1 kcal = 4187 Joule = 1.163 Wh

The characteristic of the EFB is very necessary in order to evaluate how much heat will be produced. The characteristics of some EFBs from CPO milling facilities are shown in Table 5.

From the proximate analysis data shown in Table 5, it can be seen that calorific value of EFB are almost similar to calorific value of brown coal (i.e. 5,904 kcal/kg). Thus, the energy obtained from the EFB of those mills is around 6.9 KWh/kg, a significant potency for electricity resources. Moisture of empty bunch of the three CPO plant are relatively low (<55%) comparing to the research report done by Yusoff [1] that is 65%. Carbons contents in those EFB are also not quite different to carbon in brown coal (i.e. 60.65%).

Aceh province produces almost 3,293,400 tons FFB every year from 15 districts/cities with about 261,000 hectare of plantation area. There are 22 CPO plants in all over Aceh which are active until now. Almost all CPO mills do not operated at their design capacity due to the lacking of EFB.

It has been estimated that about 724,285 tons of EFB/year is produced from Aceh CPO Mills. From that amount, 75-80% of empty bunch usually is left near the plant (100-200 meters) and distribute as fertilizer in plantation or people nearby. The rest of 20-25% is combusted on-site incinerator. Although potency of empty bunch in Aceh if 75% of them is used, it will produce energy equal to 936.91 GW(e)h/year in conversion level of efficiency equal to 25%. While the necessity of energy in CPO plant in Aceh every year is only 45.34 GW(e)h. For energy production, EFB should be make more combustible by shredding and dehydrated to a moisture content below 50% [10].

TABLE VI
ENERGY DATABASE FOR THE PALM OIL BIOMASS*

Palm waste	Heat value (kJ/kg)
Empty fruit bunches	18,795
Fiber	19,055
Shell	20,093
Palm kernel cake	18,884
Nut	24,545
Crude palm oil	39,360
Kernel oil	38,025
Liquor from (EFB)	20,748
Palm oil mill effluent (POME)	16,992
Trunk	17,471
Petiole	15,719
Root	15,548

*Adapted from Chuah, et al [5]

B. Presses Fiber (PF)

The oil retained in its cell wall makes the PF a good combustible material. Fiber ash contains 1.7-6.6% P, 17-25% K and 7% Ca. It could therefore be used as source of minerals for plants. Presses fiber contains a higher percentage of fiber and lignin which cannot be digested easily by animals [8]. Although in some factories fiber is considered as waste, in fact, it can be used to produce both steam and electrical power. As can be seen from table 4, the production of fiber in CPO milling facilities in Aceh about 0.387 million tons, while the fiber has heat value of 4420 (dry)(kcal/kg). In addition, the fibers can also be used as fillers in thermoplastics and thermosetting composites for furniture and automobile components.

C. Palm kernel shell (PKS)

Chuah et al [5] reported that the heating value of the shell is 20,093 kJ/kg, as can been seen from Table 6. The shell size is uniform and is not as bulky as the EFB. Thus, the PKS is an energy intensive substance. The CPO plant in Aceh has used the shell for feeding boiler in producing steam and electricity. PKS contains 20.3% of fixed carbon and is physically similar to the coconut shell, which can be used to produce an activated carbon. PKS can be densified into briquettes at high temperature using screw extrusion technology. At present, there are about 0,182 million tons of PKS available annually in Aceh, which means that about 3.6 GJ energy could be produced (based on table 6).

The problems associated with the burning of press fiber and PKS as solid fuels are the emissions of dark smoke and the carry over of partially carbonized fibrous particulates due to incomplete combustion of the fuels. There are many reasons contributing to the incomplete combustion of the fuels. However, these problems have been overcome, to a great extent, through a controlled fuel feeding system and multi-clone dust collectors to trap the particulates. The flue gases from the boiler chimneys are also being used as a heat source for drying of decanter solids [1].

D. Palm oil mill efluent (POME)

Palm oil mills produce large amounts of organic waste It is estimated that for every ton of oil EFB 0, 77 ton of POME. The POME is rich in organic carbon with a biochemical oxygen demand (BOD) value higher than 20 g/L and nitrogen content around 0.2 and 0.5 g/L as ammonia nitrogen and total nitrogen [11]. In many CPO mills in Aceh, POME is treated with a combination of anaerobic and aerobic in a series of ponds. After treating, the use as fertilizer and water supply for the palm trees are the most common methods for the waste water utilization. Based on Table 4, about 2.5 million ton/year of POME are discharged from CPO mills in Aceh. It seems likely that a large part of the carbon input in waste water is converted to methane. In case of open digesting tank systems, the relative composition of emissions is CH4 65% and CO2 35% [12,13]. On the basis of these data, it can be estimated that about 32-48 kg of methane/ha/year (CH4waste) will be emitted from palm oil mill effluent. Using a time horizon of 100 years, the emission of 1 kg CH4 is equivalent to the emission of 24.5 kg CO2. Thus, such CH4 emission is equivalent to 0.16-0.24 ton CO2 equivalent per ton of palm oil. The treatment of other organic wastes from palm oil processing varies, from composting to dumping. In the latter case anaerobic conversion is likely. If it is, for instance, assumed that of the input of organic matter into processing by palm oil mills ~25% will be converted into CH4, per ton of palm oil ~25.5 ton CO2 equivalent will be emitted. [12].

The treating method for current utilization of POME in Aceh is by anaerobic digestion method, since this is an effective method for treatment of wastewater with high organic compounds. During the treatment process, microorganisms hydrolyse fat, oil and carbohydrate (in the form of sugar, starch, pectin and pentosan) to volatile fatty

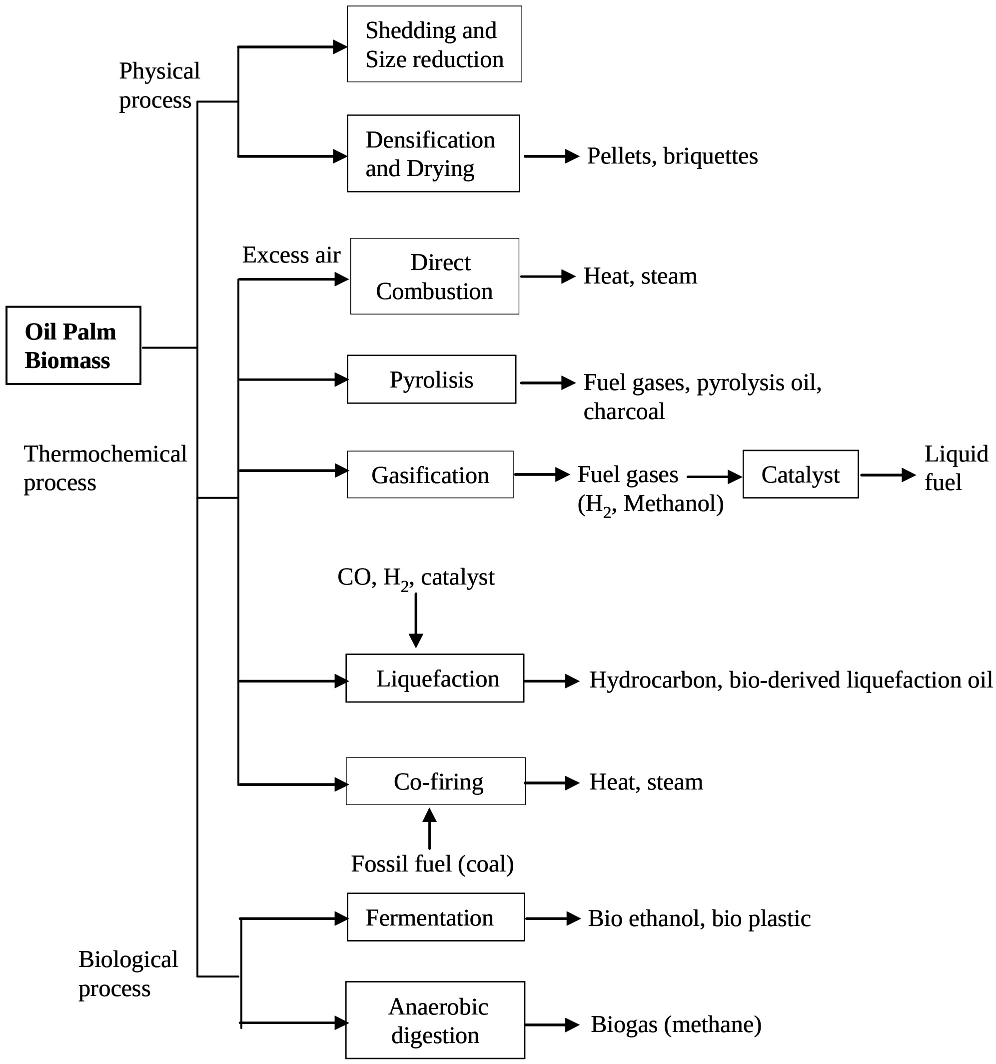

Fig 2. Oil palm biomass conversion technologies [4,14-18]

acids (acetic, butyric, etc.) and isobutyl alcohol [8]. Ammonia, CH_4 and H_2S are also the commons product by this method. These compounds have offensive smells and are regarded as air pollution. Alternatively, the treatment should be carried out in a reactor in which the biogas is obtained. Biogas could be produced from mesophilic anaerobes at a rate of 0.57 m^3/kg COD utilized per day, and contained 60-69% methane gas [8]. The production of biogas has also been conducted on a pilot scale using a thermophilic contact process at a temperature of 45-65°C with an organic loading of 3.0 kg BOD/m3/day. The highest yield of biogas was seen at 65°C and contained less than 10 ppm of hydrogen gas. The treatment efficiency was 96%. With the average output of 40 kg (40,000 ppm) organic matter, the potential production of biogas is 12 m^3/m^3 effluents [8]. In addition, it has been reported by Ma [19] that the biogas generated from 1 ton of FFB is estimated at 19.6 m^3 with a calorific value of 22.9 MJ/m^3. Thus, if all CPO mills in Aceh utilize about 3.37 million ton FFB, total biogas energy produced is about 1.51 millions GJ. The technology for treating biomass into energy and valuable materials are developing currently. Shuit *et al* [3] has summarized some techniques for oil palm biomass conversion from many literatures [14-18]. Fig. 2 shows the possibility of oil palm biomass conversion technologies. The challenge for hydrogen production from POME also have been reported, signifying a cumulative biogas generation of 11.8 L/week (56% H_2) corresponding to chemical oxygen demand (COD) removal of 67% has been reported [20].

V. Conclusions

Sustainable energy issues are increasingly becoming more important in Indonesia and the worldwide. Aceh province, located in the tip of Sumatra Island faces problem with the energy issue within the last few years. One of possible methods to overcome the problem is the use of biomass residue from palm oil industry. The biomass can be converted to various value added materials, nevertheless, its potential as a source of renewable and sustainable energy seems to be more promising. The energy generated is not only for their internal consumption but also sufficient for surrounding remote areas, thus might contributes an appreciable level of economic growth to the people nearby.

The type of biomass residue produced from oil palm industry includes EFB, fiber, shell, wet shell, palm kernel, fronds, trunks, root and POME. These biomasses have high potential of turning into renewable energy. EFB and mesocarp fiber (MF) is the highest contributor of oil palm biomass for fuel. POME on the other hand, gives significant amount of bio energy of H2 and CH4. The technology for treating biomass residue into energy and valuable materials are developing currently. Converting oil palm biomass into energy not only can overcome the petrol crisis but also can help to protect the environment by reducing CO2 emission.

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