Eco. Env. & Cons. 26 (2) : 2020; pp. (699-709)
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ISSN 0971–765X

Renewable energy from palm oil agroindustry in Indonesia: availability, quantity, distribution and potential

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(Received 10 November, 2019; accepted 5 January, 2020)

ABSTRACT

Biomass from Palm Oil agro-industry has great potential to be used as renewable energy because of its abundant supply, cheaper material and flexibility. This is suitable for the provision of sustainable raw materials to produce renewable energy in Indonesia. The sources of biomass comes from plantation area, and palm oil mill. The biomass waste from harvesting, pruning, and replanting activities in plantations area in the form of frond, leaves and palm tree trunks. From the palm oil mill produced liquid waste as Palm Oil Mill Effluent (POME), and produced solid waste in the form of Palm Kernel Shells (PKS), Mesocarp Fibers (MF), and Empty Fruit Bunches (EFB). Biomass potential in Indonesia can be calculated from the productivity of oil palm. The paper is to give an overview of the availability, and distribution of the oil palm biomass wastes in Indonesia and the potential for utilization. The volume of biomass is PKS 5-7%, EFB 20-23%, MF 11-14% from 1 ton of Fresh Fruit Bunches (FFB). The results showed that the entire potential of oil palm solid waste biomass in Indonesia 2017 is 90.34 million tons and POME is 92.96 million tons. The five largest of distribution biomass is in Riau, North Sumatra, South Sumatra, Middle Kalimantan, and West Kalimantan province. It can supply of around 10% of Indonesia's national energy demand and grow even greater if combined with other types of biomass.

Key words: *Availability, Biomass, Palm oil, Potential, Renewable energy*

Introduction

The needed global energy is predicted to increase significantly, including in Indonesia, which is dominantly depending on the fossil energy sector as its energy source. Based on the primary energy supply data in Indonesia for the period of 2000-2015 (Figure 1), the energy use is dominated by fossil fuel energy. The highest energy used is the energy from oil that is 41.74% in 2000. The number decreased to 31.49% in 2015. The decline in the use of fuel oil is in line with the larger use of coal as an energy source, from 9.42% in 2000 to 24.82% in 2015. Both energy sources are classified as non-renewable fossil fuels. Meanwhile the percentage of biomass energy is quite large (18.64%-28.80%), however there is no data on the specific type of biomass used. The intended biomass includes firewood and charcoal, which is the result of the biomass burning process (Ministry of Energy and Mineral Resources 2016). According to the data, in 2000, Indonesia uses atotal of 59.64% of fossil fuels. This number then decreased to be 39.86% in 2015. Whereas the use of renewable energy from pure biofuel only began in

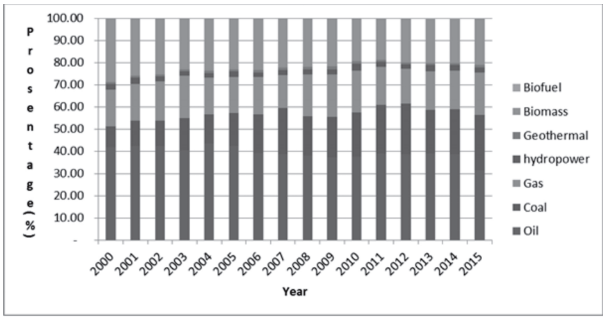


Fig. 1. Primary Energy Supply In Indonesia Period 2000-2015

2005 at 0.1% and became 0.16% in 2015 and from hydropower only around 2.98% in 2015.

Fossil energy sources such as petroleum, natural gas and coal have gradually decreased throughout the world. So that renewable energy is the best alternative and is a solution to overcome this problem. Indonesia, which is geographically located in the equatorial region, has abundant renewable energy sources such as solar, hydro, wind and the most practical is a source of biomass. Energy derived from biomass can be planned to be developed properly considering that Indonesia is very rich in the amount and variation of its biomass sources. Biomass is the fourth largest source of energy after coal, petroleum and natural gas (Chen *et al.*, 2009). The biomass can be converted into various biofuels, chemical products and also power generation. (Rizky Fauzianto, 2014). Along with technological developments, biomass has become one of the mainstay energies sources for various needs. Biomass energy sources have several advantages, including renewable energy sources that can provide a sustainable source of energy. There are several sectors that can be utilized for these choices, namely forestry crops and residues, agricultural, and residues, industrial residues, municipal solid waste, animal residues, recycling of nutrition from wastewater treatment facilities, seaweeds, and algae (Pande and Bhaskarwar, 2012); (Tajalli, 2015).

The increase of energy demand and concern for waste management motivate agricultural producers to consider the decentralization of conversion by agricultural products for energy and high value-added products such as biochar, biofuels, etc. One of the most biomass potential sources in Indonesia is the one from the oil palm agro-industry sector. Production activities in palm oil agro-industry besides producing Palm Kernell Oil (PKO), and Crude Palm Oil (CPO), also produce solid waste from the plantation, and palm oil mill. From the palm oil mill produced liquid as Palm Oil Mill Effluent (POME), and solid waste in the form of PKS, MF and EFB. The solid waste of oil palm agro-industry from plantations areas is frond, leaves and palm tree trunks. (Abnisa *et al.*, 2013; Azri *et al.*, 2017; Suzuki *et al.*, 2017; Tajalli, 2015; Kong *et al.*, 2014).

Researchers have a high interest in using biomass as feedstock in generating renewable energy alternatives for fossil fuels because of its flexibility, abundantly and a cheaper raw material (Go *et al.*, 2019; Awalludin *et al*., 2015); (Abdulrazik *et al.*, 2017). Many countries had utilized biomass by converting them to produce many useful multi-products such as bioenergy, biofuel, biochar, chemical, which are used for various needs including generating electricity, heating homes, fueling vehicles and providing process heat for industrial facilities (Toklu, 2017). Like in Sweden in 2010, about 14% of the energy supply comes from biomass. In Finland, 21% of its total energy consumption comes from the forestry sector, and the United States produces 9-million-watt electricity from biomass (Karhunen *et al.*, 2012). While in Germany, biomass contributes about 68.9% of the total energy as renewable energy (Andreas, 2011). In Indonesia, the potential source of biomass waste is very large, especially from the palm oil agro-industry sector which also has a large plantation area. Both conditions above, namely the use of fossil energy sources into main energy and the availability of energy sources from biomass shows a very contrasting condition. Because the abundance of biomass sources, especially from palm oil agroindustry sources, can be utilized optimally to reduce dependence on the fossil energy sector while making biomass a promising renewable energy sources. The study on the availability of biomass from palm oil waste besomes very crucial and urgently needed as an early stage of mapping its potential. Energy consumption has been increased rapidly, and continuously. So, it is necessary to research the possibility of using renewable energy sources as alternative energy to substitute fossil fuel energy. The purpose of this research is to give an overview regarding the availability, quantity and distribution of the oil palm biomass wastes, and the potential to utilize the wastes as renewable energy.

Materials and Method

Data Collection

Data were collected from an official publications suchas Tree Crop Estate Statistics of Indonesia 2015-2017 Palm Oil (Perkebunan, 2016) and Handbook of Energy and Economic Statistics of Indonesia Final Edition 2016 (Ministry of Energy and Mineral Resources 2016). Among the potential biomass, the collected data include all part of palm oil residues such as EFB, PKS, MF, OPT, OPF, and leaf. Data on palm oil crop in 34 provinces were collected from Tree Crop Estate Statistics of Indonesia 2015-2017 Palm Oil.

Data Analysis and Calculation

In Palm Oil Mill, the process of oil extraction from dry FFB, various products such as crude oil, MF, PKS, EFB and dirt are made. Among such products, EFB, MF, and PKS are regarded as a potential for biomass energy. While the sources of biomass from plantations are Oc4PT, and OPF. The OPT data used are those based on OPT tons/ha and are not based on the percentage of FFB production, with the consideration that the pest is only obtained from the area of replanted land. Data released by the Directorate General of Plantation (Perkebunan, 2016) in the form of CPO data generated by each area. Therefore, FFB data is obtained based on mass balance data which shows that FFB produces 24% CPO (Hambali and Rivai, 2017), so each biomass is calculated as follows in Table 1. The water content of each biomassisthe water content of EFB 65%, PKS 17%, MF 42%, OPF 71%, and OPT 76%. This data is used as a basis for calculating biomass in a dry basis and its energy potentia l(Loh 2017). Meawhile, the energy potential of POME is calculated based on the resulting biogas which is 28m^3 biogas/m^3 POME with a caloric value of 20 MJ/m^3.

FFB and biomass estimation data produced in 2020, 2025, 2030, 2035 and 2040 were obtained using time-series data analysis obtained from (Perkebunan, 2016) and biomass estimates generated from the estimation results according to Table 1. The time-series data analysis is then analyzed using trend techniques for quantitative data forecasting analysis. Trend patterns are analyzed by trial on linear, quadratic, S curve, or exponential patterns. After that, the appropriate model is used to estimate the data in the following year. Suitability of the trend pattern model used is based on the smallest Mean Absolute Deviation (MAD), Mean Absolute Percentage Error (MAPE), and Mean Squared Deviation (MSD).

Results and Discussion

Background History of Palm Oil Crop in Indonesia

Palm oil was imported to Indonesia by the Dutch East Indies government in 1848 from West Africa

Table 1. Estimating Data by Sources and Type Palm Oil Biomass

Residues Sources	Type Residues	Unit	Value						
FFB	PKS	% weight	5,50	5,50	7	5-7	5,5-7	5-7	6.05
	EFB		22,00	22,00	23	20-23	22-23	20-23	22
	MF		13,50	13,50		11-12	13.5-15	11-14	12.94
Oil Palm	OPT	% weight	70,00	74,50	50		75	74.48*	6074.66
(from	OPF	Ton/ha							
harvesting)		% weight	20,50	14,5	20		15	14.47	20.25
	Leaf	Ton/ha	6,53						14.66
	Etc		2,97						
Pruning	OPF	Ton/ha	10.4*	12*				10.4*	10.93
POME		M3			67	50-60		67	59
Refference			(Abnisa *et al.*, 2013)	(Azri *et al.*, 2017)	(Suzuki *et al.*, 2017)	(Tajalli, 2015)	(Kong *et al.*, 2014)	(Loh, 2017)	Average (this study)

*Dry basis

In 74.48 tons per ha is assumed 142 oil palm tree and only 50% are removed from the plantation, in 10.40 tons per ha only 50% are removed from the plantation (from pruning), and in 14.47 tons per ha only 50% are removed from the plantation (from replanting).

which was then planted in the Bogor Botanical Garden. When there was an increase in the demand for vegetable oils due to the industrial revolution in the mid-19th century, then came the idea of making oil palm plantations. In 1911, palm oil began to be cultivated and cultivated commercially with its pioneer in the Dutch East Indies Adrien Hallet followed by K. Schadt. The first palm oil plantations are located on the East Coast of Sumatra (Deli) and Aceh covering an area of 5,123 hectares which later increased to 32,000 Ha in 1925 and 3,400 ha in Malaysia. But in West Africa alone large-scale oil palm planting began in 1910 (Corley and Tinker, 2016).

Statistics data on oil palm crops showed that in the 1970s, Indonesia had only 133,298 ha of oil palm plantation and then the oil palm crops area are has increased significantly as shown in Figure 2. Based on data from the Indonesian Oil Palm Plantation Association (GAPKI) in 2017, oil palm crops area estimated 11,312 million hectares and produced 38.17 million ton CPO. The status of exploiting oil palm plantations in Indonesia is divided into three, namely the smallholder Plantation (*Perkebunan Rakyat* or PR), the State Plantation (*Perkebunan Besar Negara or* PBN), and the Private Plantation (*Perkebunan Besar Swasta*or PBS). At the beginning of the development of oil palm plantations, there were only PBS and PBN. Only around 1978, Private Plantation (PR) started to appearand increased significantly every year. However, oil palm plantations in Indonesia are currently still dominated by PBS. The estimated percentage of mastery in each plantation is PBS 55.24% (6.798.820 Ha), PR 38.64% (4.756.272 Ha), and PBN only 6.11% (752.585Ha) of Indonesia's oil palm area in 2017 (Perkebunan 2016). In its development, the PBS plantation area is more dominant than PBN and PR, but the development of the PR area has increased quite significantly. Figure 2 shows the development of the total area of oil palm plantations and the percentage of ownership of oil palm plantations in the period of 1970-2016. With the total area of these plantations, Indonesia has become the number one oil palm producing country in the world.

Palm Oil Biomass Residues as Renewable Energy Resources

Based on the United Nations Framework Convention on Climate Change (UNFCCC, 2005), biomass is non-fossil and biodegradable organic material originating from plants, animals, and microorganisms. This shall also include products, by-products, residues and waste from agriculture, forestry, and related industries as well as the non-fossilized and biodegradable organic fractions of industrial and municipal waste (Basu, 2010). Refer to the definition, all of the waste from oil palm agro-industry is classified as biomass residue that can be utilized.

Biomass waste can contribute to the greatest potential for the supply of renewable and sustainable energy sources with abundant quantities (Hosseini *et al.,* 2015) (Hossain *et al.,* 2016). Nevertheless, to

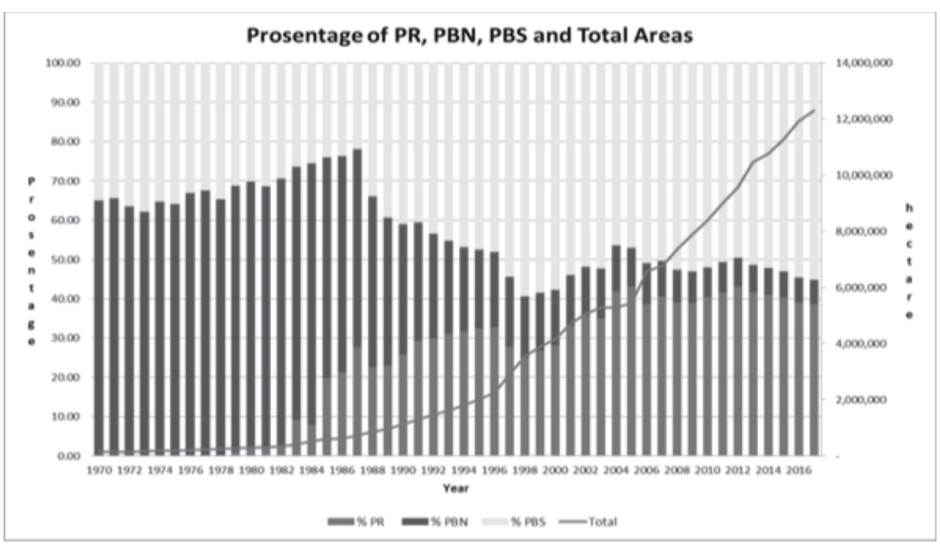


Fig. 2. The development of the total area and the percentage of oil palm plantations in the period of 1970-2016 (source (Perkebunan 2016))

utilize the available biomass around us as the raw material of energy sources requires various considerations. Characteristics of an ideal source of energy raw material from plantation sources are high yield (maximum dry matter production per ha), low energy for production, low cost, the least amount of contaminants and low required nutrients (Mckendry, 2002). In addition, the appropriate biomass requirements to be used as raw material of energy are biomass with low economic value, in the form of waste biomass that has been taken from its primary product. Referring to the statement of these criteria, EFB fulfills the requirements as an ideal renewable energy raw material. But the HSL still needs further study and mapping related to the magnitude and distribution of the biomass potential.

Source and Type Oil Palm Biomass Residue

The process of harvesting and processing plants in plantation agroindustry must be related to the organic residue produced. This organic material can be divided into two sources, namely primary residue available in the field after harvesting the main product and secondary residue available after processing in the industry (Rios and Kaltschmitt, 2013). In an oil palm plantation agro-industry, the primary residuesare biomass from plantation areas such as fronds, leaves which are pruned as routine maintenance along with harvesting fresh fruit bunches. Besides, it is also in the form of oil palm trees which are cut down when the plants are no longer productive causing replanting to be done. Whereas, secondary residue originates from by-products processing FFB into CPO, and PKO in the form of EFB, PKS, and MF (Figure 3).

Characteristic of Oil Palm Biomass Residue

Residues from agricultural area are generally divided according to the stage a mature crop has undergone. Biomass residues left in the field during the harvesting stage are referred to as agricultural residues. But residues produced after the harvesting crop has undergone treatment or process to produce a product commodity, are collectively taken as agro-industrial residues. Furthermore, biodegradable residues generated in the subsequent processing of agricultural products may be classified as derivative agro-industrial residues (Go *et al.*, 2019). The generated residues may vary from one crop to another, depending on the crop processed and component of crop recovered. The crops produced in large quantities of harvest may not always be assumed to generate equivalently large amounts of residues.

In accordance with the type of biomass, the components of each palm oil biomass waste namely EFB, PKS, MF, OPT, OPF, and leaves have characteristics of hemicellulose, cellulose and lignin content as shown in Table 2.

These characteristics are used as the basic consideration in determining the appropriate technology to convert biomass into products with more added value such as bioenergy. The conversion of biomass to energy is carried out through three main processes namely biochemical, thermochemical and physically mechanical. The biological process is an

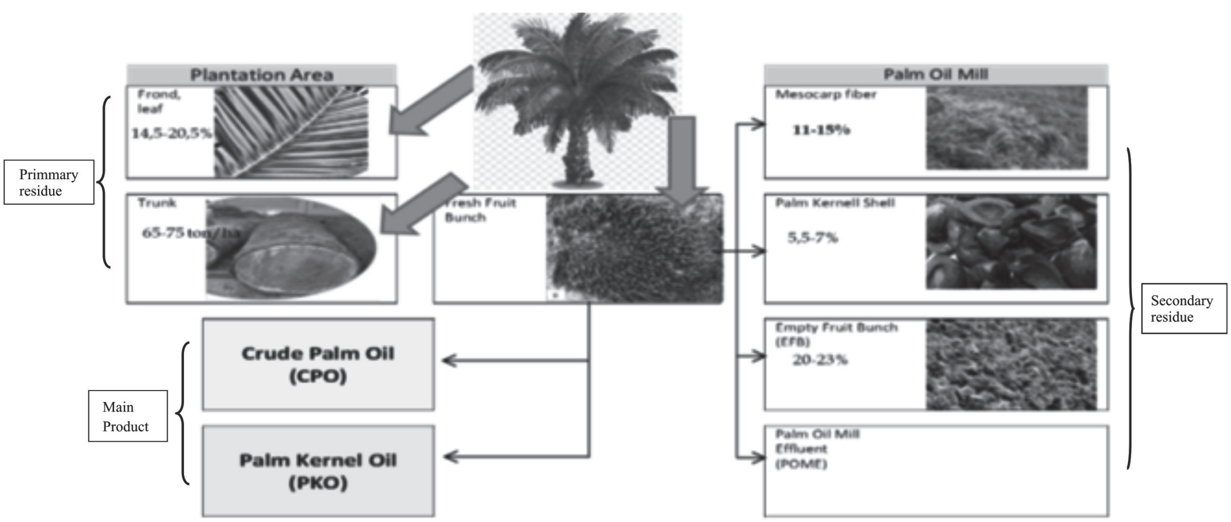


Fig. 3. Product and Biomass Residue From Palm Oil Industry

Table 2. Chemical Components of Palm Oil Biomass Waste

Biomass type	Chemical component (% dry weight)		
	Hemicellulose	Cellulose	Lignin
MF	26.1	33.9	27.7
EFB	35.3	38.3	22.1
	38.46 ± 0.83	24.23 ± 1.28	37.32 ± 1.14
PKS	22.7	20.8	50.7
	14.20 ± 0.44	27.51 ± 0.39	58.30 ± 0.5*
	27.06	14.64	58.30
	21.4±1.3**	30.1±1.8**	47.3±0.3**
OPT	23.94	34.44	35.89
OPF	23.18	50.33	21.7
Palm oil leaves	22.97	32.49	26.00
Palm leaf bone	23.17	46.1	29.31

(Kong *et al.,* 2014); (Abnisa *et al.,* 2013) (Jiat *et al.,* 2017) (Marrugo *et al.,* 2017)**(Choi *et al.,* 2015)

anaerobic digestion, hydrolysis and fermentation process. Whereas, heating involves combustion, pyrolysis, liquefaction, torrefaction and gasification methods (Mohan *et al.,* 2014; Basu, 2010).

Availability Biomass from Oil Palm Agro-industry: Quantity, Distribution

Biomass-derived from the plantation area in the form of OPF and leaves-is generated together with the FFB harvesting process as a routine maintenance process for oil palm plants. While the palm tree trunks are produced at the time of replanting plants that have decreased productivity at the age of 25-30 years (Abnisa *et al.*, 2013). While from the palm oil mill, each part of biomass will have a composition by weight of the FFB produced (Abnisa *et al.*, 2013); (Azri *et al.*, 2017); (Suzuki *et al.*, 2017); (Tajalli, 2015); (Kong *et al.*, 2014) as shown in Figure 4.

Estimates of biomass that is generated from palm oil agro-industry can be calculated based on these data and publications related to Indonesian palm oil statistics that contain the extent and productivity of plantation land in Indonesia. The largest palm oil solid waste biomass is in the form of EFB with an estimated total of more than 34 million tones, OPT with volumes of more than 47 million tons in 2017. The total potential of solid waste biomass generated by palm oil plantations in Indonesia is more than 250 million tons of biomass material, and has the potential to increase every year (Table 3).

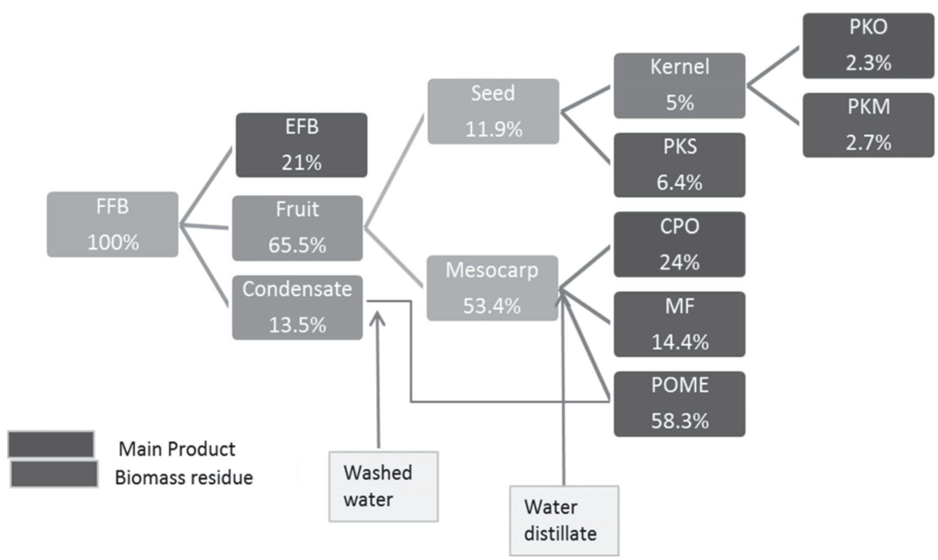


Fig. 4. Mass Balance of Oil Palm Processing (Hambali & Rivai 2017)

Table 3. The Potential of Biomas from Agro-industy Oil Palm in Indonesia

Description	Unit	2014	2015	2016	2017	2018
Total Area Plantation	Ha	10,754,801.00	11,260,276.00	11,201,465.00	14,030,574.00	14,309,256.00
Product FFB	Ton	121,992,458.33	129,458,395.83	132,212,337.50	157,552,616.67	173,612,587.50
PKS wet basis	Ton	7,380,543.73	7,832,232.95	7,998,846.42	9,531,933.31	10,503,561.54
PKS dry basis	Ton	6,125,851.30	6,500,753.35	6,639,042.53	7,911,504.65	8,717,956.08
EFB wet basis	Ton	26,838,340.83	28,480,847.08	29,086,714.25	34,661,575.67	38,194,769.25
EFB dry basis	Ton	9,393,419.29	9,968,296.48	10,180,349.99	12,131,551.48	13,368,169.24
MF wet basis	Ton	15,785,824.11	16,751,916.42	17,108,276.47	20,387,308.60	22,465,468.82
MF dry basis	Ton	9,155,777.98	9,716,111.52	9,922,800.35	11,824,638.99	13,029,971.92
OPT wet basis	Ton	36,132,904.92	37,831,149.28	37,633,561.96	47,138,519.47	48,074,807.38
OPT dry basis	Ton	8,671,897.18	9,079,475.83	9,032,054.87	11,313,244.67	11,537,953.77
OPF replant wet basis	Ton	7,094,942.22	7,428,404.08	7,389,606.46	9,255,969.67	9,439,816.18
OPF replant dry basis	Ton	2,057,533.24	2,154,237.18	2,142,985.87	2,684,231.20	2,737,546.69
OPF pruning wet basis	Ton	117,549,974.93	123,074,816.68	122,432,012.45	153,354,173.82	156,400,168.08
OPF pruning dry basis	Ton	34,089,492.73	35,691,696.84	35,505,283.61	44,472,710.41	45,356,048.74
POME (liquid biomass)	m^3	71,975,550.42	76,380,453.54	78,005,279.13	92,956,043.83	102,431,426.63
Total biomass wet basis	Ton	210,782,530.74	221,399,366.49	221,649,018.01	274,329,480.53	285,078,591.26
Total biomass dry basis	Ton	69,493,971.72	73,110,571.20	73,422,517.22	90,337,881.40	94,747,646.44

However, the moratorium policy to increase the area of oil palm plantations through the Presidential Instruction (Inpres) number 8 year 2018 concerning moratorium on new palm oil development and review of existing plantations as well as boost the productivity of palm oil plantations. Inpres signed on September 19, 2018 ordered all central and provincial governments, including governors, mayors and district heads to re-evaluate the permits. The moratorium will take place three years after it took effect. The regulation does not allow for an increase in plantation area or there is still an increase in a relatively small amount. This addition is possible from the area of private plantations that have obtained their permits. However, not all of the area has been planted. This is usually done because companies generally do not plant at the same time to maintain continuity supply of FFB production.

Distribution by province

Data on estimated biomass produced in each province is shown in the table (Appendix 1). The distribution of biomass volumes is not evenly distributed. In some provinces such as Central have no oil palm plantations. On the other side, Indonesia's main palm oil producers come from six provinces which contribute as much as 73.69% of the total palm oil production in Indonesia. The first and second ranks are Riau and North Sumatra Provinces with a contribution of 23.75% and 16.24% of the total Indonesian palm oil products. Subsequent ranks of Central Kalimantan, South Sumatra, Jambi, and West Kalimantan respectively contributed 10.96%, 9.76%, 6.39%, and 6.60%.

Projection of the availability and energy potential

Based on these data, it can be estimated the potential energy generated from palm oil waste biomass in Indonesia. The estimation is based on the LHV value of each palm oil waste biomass (Table 4) refer to (Chin *et al.*, 2008).

Based on the above data calculation, it represents the potential energy from oil palm biomass residue is very large, which is around 6,851.65 million GJ in 2018 and has the potential to increase with increasing FFB production. The greatest potential of biomass from industrial sources comes from the EFB biomass residue while from the plantation area comes from the OPT which is obtained when replanting unproductive plants are no longer productive. The biomass projections produced in the period of 2020 to 2040 are as shown in the Table 5. This projection assumes that there is no moratorium on additional plantation land. FFB estimation is based on the methodology reference then follows a quadratic pattern while the area of land follows the pattern (according to the smallest MAD, MAPE, and MSD).

A total maximum of the energy potential is based on the assumption that all biomass of solid waste OPT and OPF can be utilized, while it is assumed only 50% can be taken from the plantation area to be utilized as the minimum potential (Table 1).

Table 4. Potential Energy Generated From Oil Palm Agro-Industry in Indonesia 2015-2018

Product Oil Palm	Type Residues	Production (kton)	Fraction*	Quantity of biomass	LHV [a] (MJ/kg)a	Potential Energy (million GJ)
		129,458.40				
	EFB		22	28,480.85	18.795	535.30
	MF		12.94	16,751.92	19.055	319.21
FFB production 2015	PKS		6.05	7,832.23	20.093	157.37
	Frond		25.59	64,833.85	15.719	1,019.12
	Trunk		74.66	189,155.75	17.471	3,304.74
		Total Potential Energy			5,335.74	
		132,212.34				
	EFB		22	29,086.71	18.795	546.68
	MF		12.94	17,108.28	19.055	326.00
FFB Production 2016	PKS		6.05	7,998.85	20.093	160.72
	Frond		25.59	64,495.24	15.719	1,013.80
	Trunk		74.66	188,167.81	17.471	3,287.48
		Total Potential Energy			5,334.68	
		157,552.62				
	EFB		22	34,661.58	18.795	651.46
	MF		12.94	20,387.31	19.055	388.48
FFB Production 2017	PKS		6.05	9,531.93	20.093	191.53
	Frond		25.59	80,784.54	15.719	1,269.85
	Trunk		74.66	235,692.60	17.471	4,117.79
		Total Potential Energy			6,619.11	
		173,612.59				
	EFB		22	38,194.77	18.795	717.87
	MF		12.94	22,465.47	19.055	428.08
FFB Production 2018	PKS		6.05	10,503.56	20.093	211.05
	Frond		25.59	82,389.12	15.719	1,295.07
	Trunk		74.66	240,374.04	17.471	4,199.57
			Total Potential Energy			6,851.65

*Based Table 1
*Based 4.5% replanting/years
[a](Chin *et al.,* 2008)

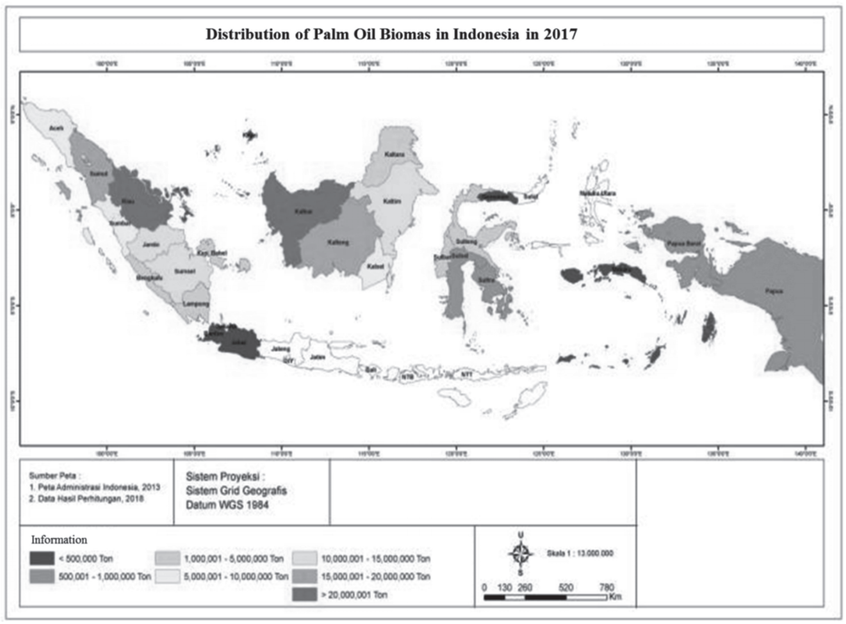
Table 5. The Projection of Potential Biomass and Energy Generated From Oil Palm Agro-industry

	Value	2020	2025	2030	2035	2040
FFB	Ton	187,355,155.00	239,099,392.00	281,613,787.00	311,931,972.00	331,436,496.00
Plantation area	Ha	15,191,278.00	19,249,426.00	23,798,327.00	28,837,980.00	34,368,385.00
EFB	Ton	41,218,134.10	52,601,866.24	61,955,033.14	68,625,033.84	72,916,029.12
PKS	Ton	11,334,986.88	14,465,513.22	17,037,634.11	18,871,884.31	20,051,908.01
MF	Ton	24,243,757.06	30,939,461.32	36,440,824.04	40,363,997.18	42,887,882.58
OPT	Ton	6,124,576.40	7,760,675.58	9,594,628.71	11,626,435.37	13,856,095.57
OPF replanting	Ton	1,453,144.48	1,841,332.72	2,276,464.67	2,758,540.23	3,287,559.42
OPF pruning	Ton	24,075,896.94	30,507,452.80	37,716,778.55	45,703,872.60	54,468,734.97
POME	m3	110,539,541.45	141,068,641.28	166,152,134.33	184,039,863.48	195,547,532.64
Total Biomass Residue	Ton	108,450,495.86	138,116,301.88	165,021,363.21	187,949,763.53	207,468,209.67
Potential Energy	GJ	1,129,516,503.66	1,437,838,317.82	1,723,257,319.02	1,974,245,282.32	2,196,175,209.10
Potensi POME	GJ	61,902,143.21	78,998,439.12	93,045,195.22	103,062,323.55	109,506,618.28
Total potensi Energy	GJ	1,191,418,646.87	1,516,836,756.94	1,816,302,514.24	2,077,307,605.87	2,305,681,827.38
Potential Energy Max	GJ	1,533,046,416.74	1,946,328,877.32	2,351,911,109.07	2,736,025,949.70	3,104,046,400.57
Total Potential Energy Max	GJ	1,594,948,559.95	2,025,327,316.44	2,444,956,304.30	2,839,088,273.25	3,213,553,018.85

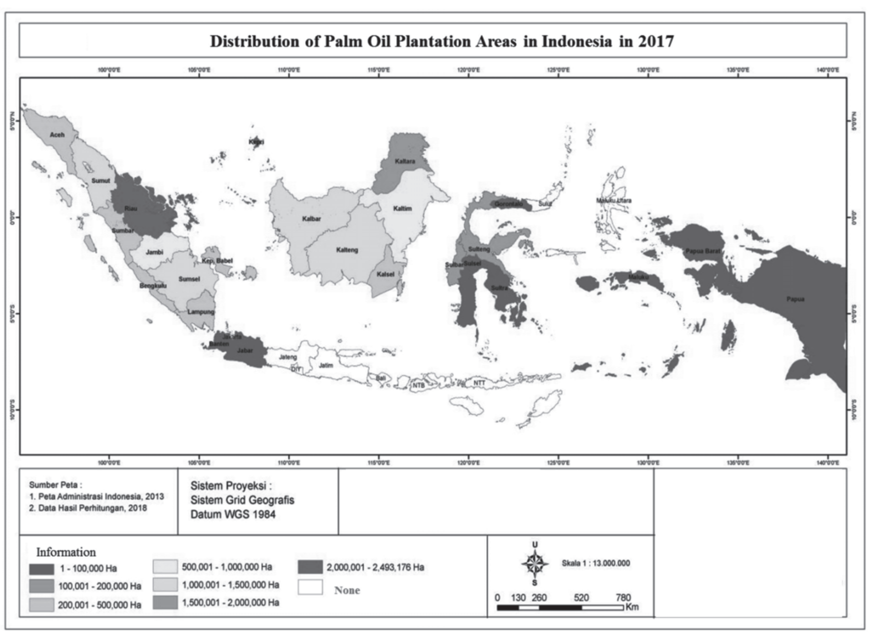
Potential displacement of fossil fuels and renewable energy scenario

Conventional Utilization

Conventionally, the biomass waste is used directly as a boiler fuel in the palm oil industry without a prior conversion process (Kong *et al.,* 2014). The most utilized part of palm oil biomass is shell and fiber which has high calorific value as fuel for steam in the palm oil processing industry and electricity. But the energy requirements for the industry are much lower than the available biomass sources. So, this will cause an increase in the volume of available biomass each year (Elmer and Nygaard, 2014). However, EFB characteristics which are high moisture content, transportation-cost and disposal costs



(a)



(b)

Fig. 5. (a). Distribution of Oil Palm Biomass by Province (b) Distribution of Palm Oil Plantation Areas by Province

are things that cause less utilization of EFB. However, conventional utilization activities through the combustion process and empty bunch disposal have a negative impact on the environment (Saswattecha *et al.*, 2015). With the results, conventional use is not recommended.

Competitive uses

Renewable energy materials in the form of biofuels commonly used plants that are well known and can grow well in Indonesia. Based on the availability and efficiency of land use, it is estimated that oil palm and cassava can become the most potential sources of biofuel raw materials in Indonesia. However, the constraint is that both types of plants are used more for the needs of the food industry. So the development of these plants as biofuel raw materials is a challenge and is expected to require land development and further research.

Biomass from palm oil agro-industry waste that has not been maximally used can fill the gap between the use of these plants as plants for energy or food security. However, the use of biomass waste still requires in-depth studies covering various aspects such as aspects of the supply chain of raw materials, economic, environmental and social aspects to be applied as a commercial industry.

Energy Recoverable Potential

Indonesia National energy demand will increase every year in all sectors be it industrial, household, transportation, commercial, etc. Figure 6 shows estimates of national energy needs in various sectors from 2015 to 2040. To meet these needs, energy supply sources that are used come from coal, petroleum, renewable energy sources such as water, wind, solar and including biomass. From the biomass sector, the energy potential of the palm oil agroindustry is quite large (Figure 6).

The contribution of oil palm biomass is quite large reaching an average of 9.45-18.70% of the total national energy demand. The minimum condition is achieved with the assumption that only about 50% of the OPT and OPF biomass is utilized and the maximum condition is achieved with the assumption of maximum biomass utilization. This contribution only comes from one source of biomass, namely oil palm agro-industry. While in Indonesia, there are still many sources of plantations and agriculture that produce biomass residues. So that the potential of this biomass in the future is worth considering as

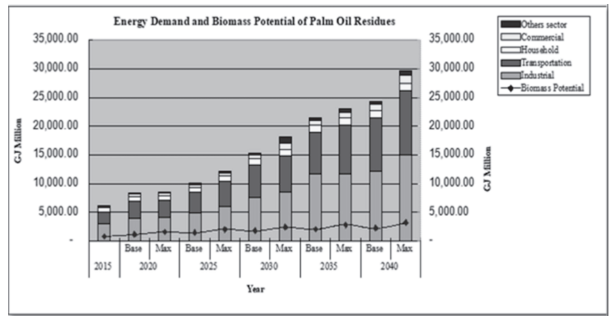


Fig. 6. Indonesia's National Energy Demand and Potential Contribution from Palm Oil Biomass

a potential renewable energy source that is sustainable.

Conclusion

Biomass from Palm Oil Agroindustry is very abundant (more than 100 million tons of biomass) and is estimated to increase every year. When compared with the national energy needs, the biomass from palm oil can supply of around 10%. This amount will grow even greater if it is combined with other types of biomass which are also abundant in Indonesia. It is necessary to map all the potential biomass so that further efforts can be made to optimize utilization and reduce GHG impacts due to accumulated of unutilized biomass.

Acknowledgement

The authors gracefully acknowledge *Direktorat Risetdan Pengabdian Masyarakat* (DRPM) and *Kementrian Riset Dikti* for the finansial support through the "Penelitian Disertasi Doctor" program.

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