A Review of Biomass Cofiring as An Effort for Maintaining Steam Power Plant Performance in Indonesia

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Abstract. Nowadays, fossil fuels like coal, oil, and natural gas represent primary energy resources in the world. However, the depletion of fossil fuel reserves and human population growth contrast with human energy needs. It also created more environmental problems such as global warming and high carbon emissions. It can be converted into any other form of fuel but needs special treatment. Co-firing biomass with coal can provide a range of opportunities, such as reducing fuel costs for some companies and minimizing greenhouse gas emissions to protect the environment. In this review, several aspects which are associated with cofiring biomass in boilers have been investigated such as the effect after using biomass to equipment performance, exhaust gas emissions, and any other problem like slagging or fouling in boiler caused by biomass, what we can do to improve biomass quality in the future to implemented high percentage cofiring. From this review, we want to show what the best way Biomass cofiring for maintaining Steam Power Plant performance in biomass cofiring in Indonesia such as Pellet Biomass. There are more than 85 million ton / year pellet potential in Indonesia with some power plant already using biomass to cofired with coal more than 29 thousand ton per year in East Indonesia Region power plant. The future of biomass in Indonesia depends upon the development of the markets for fossil fuels and on policy decisions regarding the biomass including the premium price of biomass, the ability to establish stable feedstock supply chains, and a range of technical challenges.

Keywords: *Biomass, Cofiring, Power Plant, Boiler.*

1. Introduction

The depletion of fossil fuel reserves and human population growth contrast with human energy needs. Over the last five years, Indonesia has experienced a decline in national energy production caused by reduced fossil fuel reserves in mining areas or production wells. This contrasts with energy consumption which continues to increase every year.

Co-firing biomass with coal can provide a range of opportunities, such as reducing fuel costs for some companies and minimizing greenhouse gas emissions to protect the environment. Co-firing creates many opportunities and possible new employment. It encourages wood or agricultural industries to

Received _____, revised _____, Accepted for publication _____

manage combustible agricultural and wood wastes better. Additionally, the cost to modified an existing coal power plant to co-firing biomass is lower than the cost of building new biomass power plant. Other limitations of generating power solely from biomass are the low heating values and the fuel's low bulk densities, which create problems in transporting large quantities of biomass [1]. The main obstacle for large-scale biomass plants is the problem of the availability of material supply and the initial design of the power plant which is not for biomass.

Here we want to review Biomass use in Boiler Co-Firing or any other power plant that has already been implemented it. And we want to show the effect after using biomass to equipment performance, exhaust gas emissions, and any other problem like slagging or fouling in boiler caused by biomass. Last, we want to show what we can do to improve biomass quality in the future to implement high percentage cofiring. From this review, we want to show the best way Biomass cofiring for maintaining Steam Power Plant performance in biomass cofiring.

In this review, we are using method by paper or journal selection. First, we select paper using keyword Biomass, Cofiring, Power Plant, and Boiler from the selected database. Second, we read the articles and study them; if we can use them as references then we review it.

2. BIOMASS USAGE IN BOILER COFIRING

Review about biomass use in co-firing worldwide, any studies or experimental test and effect in performance or financial.

2.1. Biomass types / categories

There are some Biomass that can be used in Steam Power Plant Cofiring. Some power plants can use bagasse, wood and coconut shell. It can be stored during respective season [2]. Some of the Biomass that is commonly used in power plants are shown in table 1.

2.2. Slagging and Fouling because Cofiring

As Coal fired boilers in Indonesia are converted to high biomass co-firing or pure biomass boilers, there will be issues with fouling by alkali salts. In (converted) coal-fired boilers, the flue gas temperature is high so that a slag phase can form that allows for gaseous alkali dissolution. Different condition happens in dedicated biomass boilers, flue gas temperatures are lower, and slag formation is limited so more alkalis will remain gaseous, and aerosols will form when the flue gasses cool down.

Table 1. List of biomass and waste fuels potentially useful to utilities [1], [3].

Biomass Category		Name of Fuels	Key Fuel Properties
Agricultural Product	Processing residues	Rice husks	Size Distribution
		Sugarcane bagasse	Moisture
		Olive residues	Ash
		Palm oil residues	Heat Content
		citrus fruit residues	Volatile matter
	Harvesting residues	Cereal straws	Sulfur (S)
		Oil seed, rape, linseed oil straws	Nitrogen (N)
		flax straw	Potassium (K)
		Coen stalks	Chlorine (Cl)
	Animal wastes	poultry litter	Ultimate Analysis
		tallow	Proximate Analysis
		Meat/bone	Trace Element Analysis
Domestic/ Municipal wastes	domestic/ Industrial	Municipal solid wastes (MSW)	Sieve Tray Analysis
		Refuse-derived fuels (RDF)	Base/Acid Ratio
		Construction and demolition wood wastes	Ash Fusion Temperature
		scrap tires	Slagging Index
		waste pallets	Grindability Index
	Urban green wastes	leaves	
		grass and hedge cuttings	
Energy crops	wood	willow	
		poplar	
		cottonwood	
	grasses and other crops	switchgrass	
		reed canary grass	
		miscanthus	
forestry products	processing residues	sawdust	
		Bark	
		Offcuts	

Table 2. The slagging and fouling behavior of mixed ashes at high cofiring ratios [5] .

	SA export coal	**Wood Pellets**	**50% blend**	**Olive Residues**	**50% blend**	**Distiller grain**	**50% blend**
Ash Content, %	14.6	2	7.1	2.9	7.6	4.2	8.6
Slagging Index	0.83 (med)	1.09 (high)	1.01 (med/high)	N/A (severe)	1.43 (high)	N/A (severe)	1.63 (high)
Fouling Index 1	0.08 (low)	2.3 (severe)	0.5 (low/med)	5.1 (severe)	1.2 (high/severe)	5.9 (severe)	1.6 (severe)
Fouling Index 2	0.028 (low)	0.157 (med/high)	0.102 (med)	0.515 (severe)	0.288 (high)	0.804 (severe)	0.418 (severe)

2.3. Boiler Emission after cofiring

Biomass co-firing is a technique that utility companies can use to reduce carbon dioxide emissions from fossil fuels and other emissions like sulfur oxides (Sox) and nitrogen oxides (NOx) [6].. This technique can help meet the environmental goals of the voluntary global climate challenge program. Biomass co-firing can significantly reduce Sox and NOx emissions because biomass usually contains less sulfur and nitrogen than coal [7].

Biomass Cofiring can have impact in decrease the emission of Boiler. Wood Cofiring emitted less CO, NOx, SO2, and PM than willow, switchgrass, miscanthus, and red canary grass also Pelletized Biomass fuels have lower CO, CH4 and PM compared to chopped products [8]. SO2 in emission gas is dependent on the chlorine content of the biomass. The higher the chlorine composition, the lower the SO2 emitted. Sulphur observed in the solid phase, forming sulphates. NOx emissions are barely affected by the chlorine. NOx is much more sensitive to the oxygen Excess [9].

3. BIOMASS PRE-TREATMENT / RE-SHAPING

Pretreatment methods such as pelletization or briquettes can significantly improve and reduce the cost of handling process and also improve combustion efficiency in boiler. It also can minimize the investment cost of plant and reduce total cost of operation and maintenance [10].

3.1. Briquettes

Biomass can convert to solid fuel like briquette and is more flexible in terms of biomass species and moisture content, but to extend it to large scale industrial production there are some problems commonly occurring for any other biomass resources. One of the biggest problems is storage need to produce briquette. [11][13]. Kumar produced biomass briquetted in an undeveloped area like applicated in coal yard or coal stockpile. Unsecured area or outdoor area does not need additional building, so it become more economically than indoor storage. But it also creates problems because biomass has different properties than coal. Biomass that stores outdoor can creates spores and fungus that creates diseases [14]. Keeping biomass briquette in unsecured areas can also degrade briquette's quality because physical and chemical properties degradation. [15].

Binder material also influences briquette quality, suitable material can improve its quality. A stable hydrophobic binder material can reduce the physical and chemical properties degradation in the storage. It protects the briquette from moisture sorption and physical degradation [16]. Weather-resistant briquettes can also be made from using thermoplastic material. Thermoplastic material can

make a stable briquette, increases the calorific value, and make briquette reach a 100% survival rate [17]. Thermoplastic is made from hydrocarbon fuel so it can give briquette high calorific value. But it also can create the slagging problem during the combustion of solid fuel contains plastic [18].

3.1.1. Pelletization

The pelleting process is usually including the following stages (Fig. 1) but also adapted to the specific biomass feedstock, it depends on reception of raw material, drying, grinding, pelleting, cooling, and screening [25]. Roundwood usually chipped and waste wood sorted into different grades. After that, its tub-ground and screened against plastics and metal then bales shredded. Initial comminution is always done before drying. After drying, the material is ground into fine particles using a cutting mill. Milled feed enters a mixing chamber where steam and additives are added. The pellet mill consists of a circular die that perforated with holes that the biomass forced through via the action of rollers. The biomass continuously fed into the pellet mill where it compressed into the pellet channels.

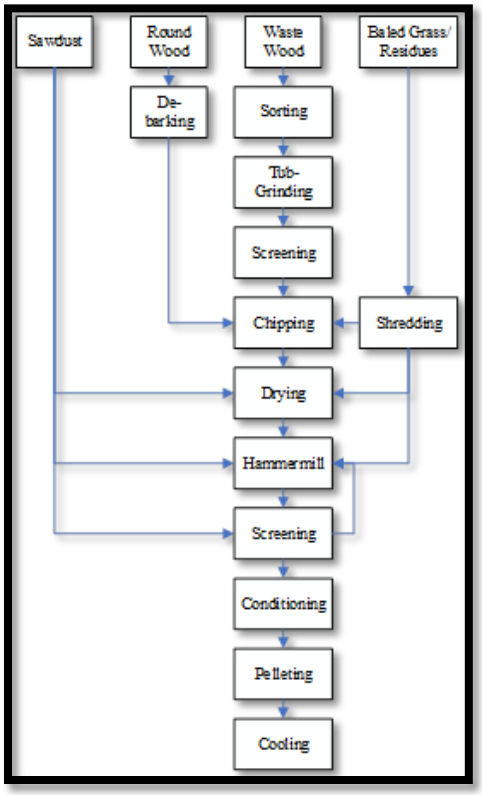

Figure 1. Typical pelleting process flow for wood [13]

3.1.2. Torrefaction

Dry torrefaction is biomass process using partial decomposition in temperature at 200 –300 ◦C and ramp rate under 50 ◦C/min under an oxygen lean condition with time processing around 5–90 min [29], [30]. The result is torrefied biomass that have altered polymeric structure and ash [31]. Torrefaction removing primarily light volatiles and degrades hemicellulose and cellulose structures [32]. Its product gives a densified biomass with a mass yield of about 70% but with a much higher energy yield of 90%. The loss is from 30% condensable and non-condensable gases [33]. The temperature maintained at under 300 ◦C to get high energy efficiency [34]. Its commonly high solid yield using short residence time and slow ramping rate [35]. Condition in torrefaction process such as temperature, residence time, and particle size may affect the properties of biomass such as yield, chemical composition, calorific value, and grindability [36], [37]. Temperature and resident time are dominant factors that affect biomass properties. Particle size also affects the kinetics of the torrefaction with small particles require less retention time and increase energy efficiency.

4. COFIRING IN INDONESIA

4.1. Trend Analysis

In the world of trade, standards are used as mutually agreed specifications between sellers and buyers or as market access openers. The standard agreement in Indonesia is called the Indonesian National Standard (SNI). In international trade, there are international standards. By meeting international standards, Indonesian products can enter the world market. SNI related to bio pellets that are already available include SNI 8675:2018 Biomass pellets for energy, SNI 8021:2020 Wood pellets, SNI 8951:2020 Biomass pellets for power plants, SNI 8966:2021 Solid encounter materials for power plants.

It shows that the government already made a guidance in creating pellet to meet power plant condition. It can support the pellet potential in Indonesia as shown in the table below. In the last few years, the government has always set up the total oil production of approximately 900 MBOPD. By utilizing the whole potential of seven types of biomasses given, almost two thirds of oil production can be substituted already shown in table 4.

Table 3. Standard Biomass Pellet for Power Plants in Indonesia [51]

No	Test Parameter	Unit	Quality		
		min/max	Premium	Standard	Utility
1	Density	g/cm3, min	0.5	0.5	0.5
2	Ash Content	% wt, max	1.5	3	4
3	Moisture	% wt, max	9.5	10	12
4	Volatile Matter	%, max	72	71	70
5	Fixed Carbon Content	%, min	17	16	14
6	Net Calorific Value	kkal/kg, min	4300	4300	4040
7	Chlorine Content	%, max	0.02	0.03	0.05
8	Kalium Content (As K2O)	%, max	5	10	20
9	Natrium Content (As Na2O)	%, max	2.5	2.5	5
10	Sulfur Content	%, max	0.05	0.05	0.1
11	Hardgrove Grindability Index	HGI, min	32	32	32
12	Ash Fusion Temperature	^{o}C, min	1200	1180	1150

Table 4. Biomass Pellet Potential in Indonesia [52]

Biomass	Biomass waste production (million ton/year)	HHV (MJ/kg)	Biomass pellet production (million ton/year)	Bio-energy potential (million GJ/year)	Barrel of crude oil equal (10^6 BOE / year)
Rice Straw	49	13.23	44.1	583.63	99.11
Rice Husk	13.5	13.49	12.15	163.86	27.83
Kamper Wood	8.3	16.87	7.47	126.03	21.4
Rubber Wood	2.8	16.85	2.52	42.46	7.21
Coconut Fiber	6.7	17.48	6.03	105.38	17.9
EFB	12.9	16.66	7.74	128.93	21.89
Bagasse	8.5	17.34	5.1	88.42	15.02
	Total		85.11	1238.71	210.36

4.2. Biomass Usage Realization in Indonesia

Table 5 showed biomass realization supply of seven power plants that operates in East Indonesia until November 2023, where woodchip has the highest supply between all of biomass. This is because another biomass like Pecan shell and corncob depends on the agricultural season. Indonesia also has high area of tropical forest; it contributes too to high supply of woodchip to Power Plant.

Table 5. Biomass Usage Realization in East Region Indonesia Power Plant in 2023

POWER PLANT	BIOMASS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	TOTAL (MT)
A	Woodchip	580	1,191	1,037	1,200	1,653	1,602	1,636	1,371	2,080	1,135	2,530	16,015
B	Oil Palm Bunches	-	-	-	-	-	-	-	-	-	-	-	-
C	Pellet toss and Pecan shell	11	14	14	10	7	7	-	5	-	-	-	68
D	Corncob	118	139	504	752	1	119	393	432	332	241	57	3,088
E	Woodchip	96	49	29	-	41	218	345	346	307	232	435	2,098
F	Sawdust	-	358	-	290	869	753	833	963	1,327	1,323	445	7,161
G	Wood Chip	-	-	-	-	-	372	118	299	191	-	313	1,293
	SUBTOTAL (MT)	**805**	**1,751**	**1,584**	**2,252**	**2,571**	**3,071**	**3,325**	**3,416**	**4,237**	**2,931**	**3,780**	**29,723**

4.3. Prospect in Indonesia

Indonesia has a plan to make the co-firing of biomass in power plants mandatory as part of its effort to phase out coal-powered plants. Coal powered plants themselves account for more than 60% of the country's electricity supplies. The plan focuses on leveraging existing 18 gigawatts (GW) of coal-fired power plant capacity from PLN. Its plan is slowly increasing biomass power generation by co-firing that potentially extends the Life of older and under-utilized coal power plants while at the same time claiming credit for increasing the renewable energy mix.

Indonesia is endowed with a variety of energy resources, both fossil and renewable. Biomass is one of the renewable energy sources that has an advantage in terms of being clean and environmentally sustainable [53]. According to a report by the Economic Research Institute for ASEAN and East Asia (ERIA), Indonesia produces approximately 146.7 million tons of biomass per year, which is equivalent to about 470 GJ/y. The biggest biomass energy potential in concentrated scale can be found in the Island of Kalimantan, Sumatera, Irian Jaya, and Sulawesi.

However, the utilization of biomass for electricity generation is still very small due to non-economic energy prices [53]. Biomass and its application for energy generation could play a significant role in Indonesia's renewable energy leadership strategy.

5. CONCLUSION

Biomass is a very promising source of energy in power plants. It is a carbon neutral source of energy and regarded as renewable energy resource and can play an important role in future fuel supply trends. In this review, several aspects of biomass have been investigated such as biomass pretreatment, looking for

optimum compositions of using biomass, and realization and prospect of biomass in Indonesia.

In this paper, it has been found that biomass can be converted to fuel using several processes. The choice of a process will depend on the type of available biomass, economic conditions, available technology and other factors. Some of these processes are briquette, pelletization, and torrefaction.

Pellet Biomass has a low emission production and has moderate to high slagging probability than any other biomass fuel combinations. Indonesia also has standardized pellet in SNI, so biomass supplier has a guidance to meets biomass power plant requirements. Indonesia also has high pellet potential. So, for now pellet biomass has the best reference point to implemented in Indonesia Power Plant Cofiring. But power plants or biomass suppliers need to install new equipment to convert woodchip to pellet.

From this paper there are some aspects need improvement, like exploring more of biomass pretreatment and its effect to combustion also in the future we need more reference of modelling and tuning data from Indonesian power plant.

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Acknowledgement

This research is supported by collaboration of PLN and Institut Teknologi Bandung.