

## REJECT WASTE PELLETS OF PAPER MILLS AS FUEL AND THEIR CONTRIBUTION TO GREENHOUSE GAS (GHG)

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### ABSTRACT

The paper-recycling process of paper mills generates reject waste in the region of 5–25% of its raw material, depending on the recovered fiber quality and process used in the mill. We carried out an assessment of the paper industry's reject waste pellets (RWP) as a boiler fuel. Reject waste was identified by means of sorting. The pelletizing of paper mills' reject waste is a solidification process, as it is easier to store, handle, and transport solid waste. We analyzed the approximate calorific value and the sulphur content of reject waste pellets. The results showed that the components of reject waste are largely comprised of 51% fibers and 49% plastic. The plastic components of are dominated by the high density poly ethylene (HDPE) plastic type. RWP contains a lot of organic matter and has a high calorific value and low sulphur content, which gives it the potential of being used as fuel. Utilization of 10% RWP mixed with 90% coal as boiler fuel could reduce CO<sub>2</sub> gas as greenhouse gas (GHG) emissions by about 9%.

*Keywords:* Coal; CO<sub>2</sub>; Greenhouse gas; Pellet; Reject waste

### 1. INTRODUCTION

Currently in Indonesia there are 75 paper industries producing various types of paper such as newsprint, fluting, craft liner, board, and wrapping and tissue papers. Generally, their paper mills utilize waste paper as raw material (IPPA, 2011). In the production process, besides producing paper, the industry also produces reject waste amounting to 5–25% of raw material used (Gavrilescu, 2008; Thacker, 2000). IPPA reported that the consumption of waste paper for paper production is in the amount of 6,598,464 tons per year (IPPA, 2011). Most Indonesian paper industries generate reject waste in the amount of 5–10% of waste paper used, or 329,923 to 659,846 tons of air dried reject waste per year. In order to manage this waste, it is generally disposed of outside the factory through third party services, or the amount of waste is reduced by burning it in an incinerator. The waste is largely comprised of bundles of fibers, foils, and plastic pieces, their number depending on the quality of the waste paper used as raw material. Reject waste generally has a high calorific value, with low ash and sulphur contents, which gives it the potential to be used as fuel (Gavrilescu, 2008; Oudi et al., 2012; Thacker, 2000).

The use of paper mills' reject waste pellets as fuel to produce energy has been applied in Japan and many European countries (Takenaka, 2009). The industry that produces pellets as fuel developed rapidly, because it is seen as the fuel of the future (Nobuyuki & Hiroyuki, 2011). Takenaka reported that the use of refuse paper and plastic fuel (RPF) as fuel could reduce the CO<sub>2</sub> emissions rate by 35% (Takenaka, 2009). This demonstrates that the use of reject waste pellets (RWP) as fuel, instead of coal, could contribute to the reduction of CO<sub>2</sub> emissions

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as a greenhouse gas (GHG). However, this strategy has not yet been applied in Indonesia.

The solidification method can be used to change the shape of reject waste from bulk to pellet form, through shredding, iron separation, drying, pelletizing, and cooling processes (Nichol & Flanders, 1994; Onno, 2006; Takenaka, 2009). The advantages of having reject waste in the form of pellets include uniformity of size, reduction in the amount of dust, and ease of storage and transport (Samson et al., 2000; Thacker, 2000).

This paper presents a study of the potential of reject waste pellets as a boiler fuel, including identification of the components of reject waste, the manufacturing process of RWP, and the characterization of RWP. We also present the amount by which greenhouse gases (GHG) can be reduced through the substitution of RWP for coal as a boiler fuel.

## 2. METHODOLOGY

### 2.1. Material

Reject waste with a moisture content of 40–50% (Figure 1) was taken from a paper mill's production process of corrugating medium and kraft liner paper made from recycled paper. The reject waste was dried in the sun to heat it up, resulting in a moisture content of less than 10%. Coal, used as a boiler fuel by the paper mill, was used as a mixing material for the RWP, and it was also used as a comparison. In order to learn the mixture quality of RWP and coal, the mixture was made in the ratio of 5–50% RWP and 50–95% coal.



Figure 1 Reject waste of hydra pulper

### 2.2. Identification of Reject Waste Components

The reject waste was manually sorted based on its component types such as plastic, fiber, and metal. Plastic types were identified by using the water test and isopropyl alcohol test. The copper wire test was also conducted in order to identify the flame color. A flow diagram of the plastic type identification of the reject waste is shown in Figure 2 (Exler, 2008).

### 2.3. RWP Preparation

The dried reject waste was shredded by a shredding machine with a knife, with a holes screen of around 4 mm for the output of the shredding results. The shredded waste was then moulded into pellets in a pellet machine, with a pellet mold hole size of 10 mm. The pellets formed had a diameter of 10 mm and a length of about 10–15 mm; they were then cooled.

### 2.4. Calculation of GHG Emissions

Estimation of the CO<sub>2</sub> emissions generated by coal and RWP combustions was based on the calculation method for estimating GHG emissions from pulp and paper mills (NCASI, 2005;

CGIEA, 2011). The total GHG emission from fossil fuel combustion was the sum of the CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions. Each gas's emissions were calculated based on the amount of energy consumed and the emission factor of the fossil fuel burned (NCASI, 2005; CGIEA, 2011). The equation for calculating CO<sub>2</sub> emissions is as follows.

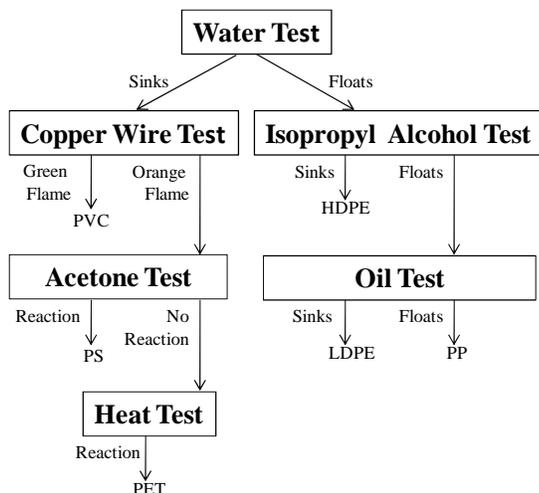


Figure 2 Flow diagram of plastic type identification of reject waste (Exler, 2008)

$$\text{CO}_2 \text{ emission (ton CO}_2\text{/yr)} = E_k \times \text{FE}_{\text{CO}_2} = m \times \text{NCV}_{\text{fuel}} \times \text{FE}_{\text{CO}_2} \quad (1)$$

where :

- $E_k$  : amount of energy consumed (TJ/yr)
- $\text{FE}_{\text{CO}_2}$  : emission factor of CO<sub>2</sub>
- $m$  : amount of fuel burned (kg/yr)
- $\text{NCV}_{\text{fuel}}$  : net calorific value of fuel (TJ/kiloton)
- $\text{NCV}$  : 0.95 gross calorific value (GCV)

While calculation of CH<sub>4</sub> and N<sub>2</sub>O emissions was based on the amount of energy consumed which is multiplied by the emission factor of CH<sub>4</sub>, emission factor of N<sub>2</sub>O, and global warming potential (GWP) of CH<sub>4</sub> and N<sub>2</sub>O gasses, respectively. The GWP for CH<sub>4</sub> and N<sub>2</sub>O gasses is 21 CO<sub>2</sub> equivalent and 310 CO<sub>2</sub> equivalent, respectively (NCASI, 2005; CGIEA, 2011). The equation for calculating CH<sub>4</sub> and N<sub>2</sub>O emissions is as follows.

$$\text{CH}_4 \text{ emission (ton CO}_2\text{-eq/yr)} = m \times \text{NCV} \times \text{FE}_{\text{CH}_4} \times \text{GWP}_{\text{CH}_4} \quad (2)$$

$$\text{N}_2\text{O emission (ton CO}_2\text{-eq /yr)} = m \times \text{NCV} \times \text{FE}_{\text{N}_2\text{O}} \times \text{GWP}_{\text{N}_2\text{O}} \quad (3)$$

$$\text{Total GHG emissions (ton CO}_2\text{-eq/yr)} = \text{CO}_2 \text{ emission (ton CO}_2\text{/yr)} + \text{CH}_4 \text{ emission (ton CO}_2\text{-eq/yr)} + \text{N}_2\text{O emission (ton CO}_2\text{-eq /yr)} \quad (4)$$

## 2.5. Analysis

In order to determine the RWP's quality, the mixture of 5–50% RWP and 50–95% coal, and coal, were analyzed for an approximate analysis (moisture, ash, volatile matter, and fixed carbon), calorific value, sulphur content, ash mineral content, and ash fusion temperature (AFT). Analysis of these materials used the American Standard of Testing Material (ASTM) and the gravimetric and atomic absorption spectrum (AAS) of analysis.

### 3. RESULTS AND DISCUSSION

#### 3.1. Reject Waste Components

Based on our results, reject waste is mostly composed of fiber (pieces of paper) in the amount of 50.75%, and plastic (packaging tape and wrapping plastic types) in the amount of 49.25%. This study demonstrated that these components are found in almost identical amounts. From plastic type identification through the water test, the amount of material in reject waste that floats or sinks comprises 82.33% and 17.67%, respectively. The material that floats is probably high density poly ethylene (HDPE), low density poly ethylene (LDPE), or poly propylene (PP). In order to identify the plastic's type and quantity, it was then tested in isopropyl alcohol solution. It was observed that the sinking material in isopropyl alcohol was higher than 99% w/w, and the floating material was lower than 1%. Based on Figure 3, the sinking material in the isopropyl alcohol test was the high density poly ethylene (HDPE) plastic type, while the plastic that floated in this test was low density poly ethylene (LDPE) and/or poly propylene (PP). The material that sank in water was then tested using copper wire to identify the flame color when it burnt. It was observed that the material was difficult to attach to the hot copper wire. Therefore, this material was pressed to attach to the copper wire. It was observed that the flame had an orange color, which indicates that this material was not poly vinyl chloride (PVC); however, further analysis of the content of PVC plastic in reject waste is required in order to be sure. We can say that if present, it would be in a very low concentration. Due to this reject waste containing adhesive from plastic tape, there is a possibility that it would attach to other plastic that has a lower specific gravity in water, causing it to float.



Figure 3 Reject waste pellets

#### 3.2. Preparation and Quality of RWP

During pellet molding, the temperature of pellet machine can reach up to 80–90°C. This temperature causes plastic to soften and function as an adhesive, assisting the solidification process. Reject waste which has a moisture content of less than 15% can form compact pellets (Figure 3) which are not easily broken down again. A moisture content of over 15% would cause the pellets to easily break down again. In this case, the evaporation of water is a more dominant force than plastic softening; therefore, it does not form the adhesiveness of the pellets produced.

RWP, and mixtures of RWP and coal, were analyzed using similar parameters as those for coal analysis, including approximate analysis (moisture, ash, volatile matter content, and carbon content of solid), calorific value, and ash content, in order to determine the quality of the biomass fuel (Gavrilescu, 2008). The results of the proximate analysis of RWP, coal, and the mixture are shown in Table 1, Which demonstrates that coal used as boiler fuel in the paper industry was included in medium calorific value (5,100 to 6,100 cal/g) and low sulfur content (< 0.5) (Tekmira, 2006). The ash content of coal used as boiler fuel in paper mills was higher than that of the RWP or the mixture. This shows that the addition of RWP to coal can reduce

the combustion ash content of the boiler. The volatile matter content of coal was much lower than that of RWP or the mixture. In this case, RWP had the highest volatile matter content, which increased the volatile matter content of the mixtures. The fixed carbon content of RWP and the mixture was lower than that of coal.

The high and low contents of fixed carbon, and the volatile matter contents of the fuel, are very influential for the characteristics of ignition during fuel combustion and the amount of burned carbon. The ratio of fixed carbon content to volatile matter content is called the fuel ratio; a fuel ratio value of  $< 1.2$  will produce a good fuel combustion ignition when increasing the burning speed. Conversely, a fuel ratio of  $> 1.2$  would cause a lot of unburned carbon (Tekmira, 2006; Budiraharjo, 2009). The fuel ratio of fuel pellets made from RWP and the mixture is smaller than that of coal. This would cause the ignition and combustion speed to be faster than that of coal. The fuel ratio of RWP, the mixtures, and coal is  $< 1.2$ , which shows a good process of fuel combustion ignition. As such, the addition of RWP to the coal would be very useful, especially during the initial combustion where the ignition coal boilers will work faster (Tekmira, 2006; Budiraharjo, 2009). The calorific value of RWP is higher than that of coal when used as boiler fuel in paper mills. However, RWP's sulphur content is lower than coal's. It is advantageous that the addition of RWP to coal would increase the calorific value of the fuel boiler, while the sulfur content of the fuel boiler would decrease. This would lead to a decrease in the  $\text{SO}_2$  concentration of boiler emissions.

Table 1 Results of proximate analysis of calorific value and sulphur content of RWP, coal, and the mixture

Material	Moisture (%)	Ash (%)	Volatile matter (%)	Fixed carbon (%)	Fuel ratio	Calorific value (Cal/g)	Sulphur (%)
RWP*	2.47	6.70	86.32	4.51	0.08	7,002	0.15
Coal	10.69	12.94	37.89	38.48	1.02	5,240	0.80
95% coal + 5% RWP	10.18	13.60	39.61	36.61	0.92	5,314	0.74
90% coal+ 10% RWP	9.87	12.35	41.70	35.49	0.85	5,435	0.68
70% coal+ 30% RWP	8.42	11.10	52.49	28.92	0.55	5,748	0.60
50% coal + 50% RWP	6.68	9.28	62.05	21.59	0.35	6,095	0.48

\*RWP: Reject waste pellet

We also analyzed the parameters of the ash mineral content and ash fusion temperature (AFT) in order to determine the possibility of slagging and fouling problems in the boiler (Hare et al., 2010). Analysis results of the ash mineral content of RWP, coal, and the mixtures are shown in Table 2.

Knowing the ash mineral content of the fuel is very useful for evaluating the possibility of slagging and fouling problems in the boiler during the fuel combustion process. It is known that slagging and fouling are sticking phenomena, caused by accumulation of fuel ash melt in the heat exchanger tube or walls of the boiler. These phenomena are very serious as they can have a major impact on boiler operations in terms of heat conduction problems, decreases in boiler efficiency, and clogging of pipes. The phenomenon of ash attachment is mainly caused by the ash mineral content such as  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{Fe}_2\text{O}_3$ , and  $\text{CaO}$ , and the ash fusion temperature (AFT). The presence of  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$  compounds in ash will form a compound with a low melting point when bonded with other elements (Hare et al., 2010).

Table 2 Ash mineral content of RWP, coal, and the mixtures

No	Material	Fe <sub>2</sub> O <sub>3</sub> (%)	CaO (%)	MgO (%)	Na <sub>2</sub> O (%)	K <sub>2</sub> O (%)	SiO <sub>2</sub> (%)	Al <sub>2</sub> O <sub>3</sub> (%)	TiO <sub>2</sub> (%)
1	RWP*	33.4	21.5	1.43	0.72	0.57	21.0	14.2	4.06
2	Coal	8.01	2.25	0.87	0.97	1.62	60.3	23.6	1.07
3	95% coal + 5% RWP	8.96	2.74	0.94	0.56	2.01	55.1	26.1	1.25
4	90% coal+ 10% RWP	10.49	3.91	1.00	0.70	2.18	53.5	25.5	1.50
5	70% coal+ 30% RWP	9.18	6.75	0.31	0.35	0.38	51.5	23.7	1.51
6	50% coal + 50% RWP	8.75	11.03	0.85	0.49	0.67	47.9	20.6	1.59

\*RWP: Reject waste pellets

The increase in the slagging tendency will be followed by an increase in the fouling tendency, depending on the alkali content in the ash. Quality standards of coal used in Japan and by boiler makers in Europe and the U.S. require an Na<sub>2</sub>O content of < 3%, a total alkali content of Na<sub>2</sub>O and K<sub>2</sub>O of < 3%, a CaO content of < 20%, and an Fe<sub>2</sub>O<sub>3</sub> content of < 15% (Roderick, 1990; Tshifhiwa, 2008; Parthiban, 2011; Hiltunen et al., 2010).

When referring to the above requirements of the ash mineral content of coal, coal used as boiler fuel in paper mills should contain an Na<sub>2</sub>O content of 0.97%, a total alkali (Na<sub>2</sub>O and K<sub>2</sub>O) content of 2.59%, a CaO content of 2.25%, and an Fe<sub>2</sub>O<sub>3</sub> content of 8.01%. The RWP should contain an Na<sub>2</sub>O content of 0.72%, a total alkali (Na<sub>2</sub>O and K<sub>2</sub>O) content of 1.29%, a CaO content of 21.5%, and an Fe<sub>2</sub>O<sub>3</sub> content of 33.34% to comply with the requirements. However, the parameters of CaO and Fe<sub>2</sub>O<sub>3</sub> do not comply with the requirements. The mixture of 50-95% coal and 5-50% RWP contains an Na<sub>2</sub>O content of 0.49-0.56%, a total alkali (Na<sub>2</sub>O and K<sub>2</sub>O) content of 1.16-2.57%, a CaO content of 2.25-11.03%, and an Fe<sub>2</sub>O<sub>3</sub> content of 8.75-8.96%, where all parameters already comply with the requirements. This data shows that the addition of RWP by up to 50% to coal is still possible with low slagging and fouling during the combustion process (Roderick, 1990; Parthiban, 2011; Hiltunen et al., 2010; Hare et al., 2010).

Apart from the mineral ash content, the potential for slagging and fouling was also predicted using the AFT (ash fusion temperature) test. The analysis results of the AFT test for RWP, coal, and the mixtures is shown in Table 3.

Table 3 Ash fusion temperature (AFT) of RWP, coal, and the mixtures

No	Material	Reducing atmosphere				Oxidizing atmosphere			
		DT** (°C)	ST** (°C)	HT** (°C)	FT** (°C)	DT** (°C)	ST** (°C)	HT** (°C)	FT** (°C)
1	RWP	1,193	1,243	1,258	1,300	1,203	1,253	1,273	1,325
2	Coal	1,415	1,460	1,470	1,495	1,465	1,495	>1,500	>1,500
3	95% coal + 5% RWP	1,360	1,420	1,430	1,450	1,430	1,450	1,460	1,470
4	90% coal+ 10% RWP	1,315	1,325	1,338	1,398	1,333	1,343	1,353	1,400
5	70% coal+ 30% RWP	1,270	1,290	1,310	1,350	1,380	1,390	1,400	1,420
6	50% coal + 50% RWP	1,230	1,270	1,290	1,330	1,320	1,330	1,340	1,360

\*\*DT: Deformation temperature; ST: Softening temperature; HT: Hemisphere temperature; FT: Flow temperature

Based on the AFT test, RWP has a softening temperature (ST) which is quite high ( $> 1,200^{\circ}\text{C}$ ). The addition of RWP of 5-50% to coal slightly decreases the ST, but it is still high at  $>1,250^{\circ}\text{C}$ . Based on the results of the field survey and literature review, the furnace temperature of a circulating fluidized bed (CFB) boiler during the combustion process in the paper industry is generally around  $900^{\circ}\text{C}$ . Compared to the initial deformation temperature (DT) and ST of RWP, it indicates that the initial DT and ST of RWP are still above the operating temperature of boilers in the paper industry. This means that when RWP is added by as much as 5-50% to coal, when used in a fuel boiler operating at a temperature of  $900^{\circ}\text{C}$ , the ST of the ash mineral of RWP is not achieved. Therefore, the phenomena of slagging and fouling do not occur in the boiler (Hare et al., 2010; Miles et al., 1995; Lu & Do, 1991).

### 3.3. GHG Emissions of RWP

Based on Tekmira's finding that the amount of coal used as boiler fuel in the paper industry in 2005 was about 2,272,443 tons (Tekmira, 2006), we can calculate the NCV of coal, the emission factors of the gases  $\text{CO}_2$ ,  $\text{CH}_4$ , and  $\text{N}_2\text{O}$ , and the total GHG emissions of coal burning as the follows:

$$\text{CO}_2 \text{ emissions (ton CO}_2\text{/yr)} = m \times \text{NCV}_{\text{fuel}} \times \text{FE}_{\text{CO}_2} = (2,272,443 \text{ tons/yr}) \{(0.95) (5,240 \text{ kcal/kg}) (4.186 \times 10^{-9} \text{ TJ/1 kcal})\} (96,100 \text{ kg CO}_2\text{/TJ}) = 4,550,619$$

$$\text{CH}_4 \text{ emissions (ton CO}_2\text{-eq/yr)} = m \times \text{NCV} \times \text{FE}_{\text{CH}_4} \times \text{GWP}_{\text{CH}_4} = (2,272,443 \text{ tons/yr}) \{(0.95) (5,240 \text{ kcal/kg}) (4.186 \times 10^{-9} \text{ TJ/1 kcal})\} (30 \text{ kg CH}_4\text{/TJ}) (21) = 29,832$$

$$\text{N}_2\text{O emissions (ton CO}_2\text{-eq/yr)} = m \times \text{NCV} \times \text{FE}_{\text{N}_2\text{O}} \times \text{GWP}_{\text{N}_2\text{O}} = (2,272,443 \text{ tons/yr}) \{(0.95) (5,240 \text{ kcal/kg}) (4.186 \times 10^{-9} \text{ TJ/1 kcal})\} (5 \text{ kg N}_2\text{O/TJ}) (310) = 73,397$$

$$\text{Total GHG emissions (ton CO}_2\text{-eq/yr)} = \text{CO}_2 \text{ emissions (ton CO}_2\text{/yr)} + \text{CH}_4 \text{ emissions (ton CO}_2\text{-eq/yr)} + \text{N}_2\text{O emissions (ton CO}_2\text{-eq/yr)} = 4,550,619 + 29,832 + 73,397 = 4,653,848.$$

IPPA reported that the amount of air dried waste paper consumption in paper production is in the realm of 6,598,464 tons (IPPA, 2011). Based on the results of the field survey, the maximum reject waste generated from the decomposition of waste paper fibers in the paper industry is about 10% of the amount of waste paper used, or as much as 659,846 tons that could be produced as RWP for fuel. When 10% RWP is mixed with 90% coal in an amount of 2,045,199 tons, total GHG emissions will be as follows:

Emissions from coal:

$$\text{CO}_2 \text{ emissions (ton CO}_2\text{/yr)} = m \times \text{NCV}_{\text{fuel}} \times \text{FE}_{\text{CO}_2} = (2,045,199 \text{ tons/yr}) \{(0.95) (5,240 \text{ kcal/kg}) (4.186 \times 10^{-9} \text{ TJ/1 kcal})\} (96,100 \text{ kg CO}_2\text{/TJ}) = 4,095,558$$

$$\text{CH}_4 \text{ emissions (ton CO}_2\text{-eq/yr)} = m \times \text{NCV} \times \text{FE}_{\text{CH}_4} \times \text{GWP}_{\text{CH}_4} = (2,045,199 \text{ tons/yr}) \{(0.95) (5,240 \text{ kcal/kg}) (4.186 \times 10^{-9} \text{ TJ/1 kcal})\} (30 \text{ kg CH}_4\text{/TJ}) (21) = 26,849$$

$$\text{N}_2\text{O emissions (ton CO}_2\text{-eq/yr)} = m \times \text{NCV} \times \text{FE}_{\text{N}_2\text{O}} \times \text{GWP}_{\text{N}_2\text{O}} = (2,045,199 \text{ tons/yr}) \{(0.95) (5,240 \text{ kcal/kg}) (4.186 \times 10^{-9} \text{ TJ/1 kcal})\} (5 \text{ kg N}_2\text{O/TJ}) (310) = 66,057$$

$$\text{GHG emissions from fossil fuel} = 4,095,558 + 26,849 + 66,057 = 4,188,464 \text{ ton CO}_2\text{-eq/yr}$$

Emissions from biomass:

$$\text{CH}_4 \text{ emission (ton CO}_2\text{-eq/yr)} = m \times \text{NCV} \times \text{FE}_{\text{CH}_4} \times \text{GWP}_{\text{CH}_4} = (659,846 \text{ tons/yr}) \{(0.95) (7,002 \text{ kcal/kg}) (4.186 \times 10^{-9} \text{ TJ/1 kcal})\} (30 \text{ kg CH}_4\text{/TJ}) (21) = 11,575$$

$$\text{N}_2\text{O emissions (ton CO}_2\text{-eq/yr)} = m \times \text{NCV} \times \text{FE}_{\text{N}_2\text{O}} \times \text{GWP}_{\text{N}_2\text{O}} = (659,846 \text{ tons/yr}) \{(0.95) (7,002 \text{ kcal/kg}) (4.186 \times 10^{-9} \text{ TJ/1 kcal})\} (5 \text{ kg N}_2\text{O/TJ}) (310) = 28,479$$

$$\text{GHG emissions from biomass} = 11,575 + 28,479 = 40,054 \text{ ton CO}_2\text{-eq/yr}$$

Total GHG emissions of 10% RWP + 90% coal = emissions from fossil fuel + emissions from biomass = 4,188,464 + 40,054 = 4,228,518 ton CO<sub>2</sub>-eq/yr.

This calculation shows that the use of 10% RWP mixed with 90% coal as boiler fuel can reduce GHG emissions to the tune of 425,330 ton CO<sub>2</sub>-eq/yr, or about 9%.

#### 4. CONCLUSION

Reject waste is comprised mostly of fiber (50.75%) and plastic (49.25%), which is dominated by the HDPE plastic type (> 99%). RWP has a high calorific value and low ash and sulphur contents. A mixture of RWP in the amount of 5-50% with coal can be used as boiler fuel without causing slagging and fouling problems. Utilization of 10% RWP as a coal substitute can contribute to the reduction of CO<sub>2</sub> emissions as greenhouse gases (GHG) by 9%.

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