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Environmental Analyses of Waste Cooking Oil Recycling and Complete Use Practices in Bogor, Indonesia

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***Abstract*— An estimation of GHG emission of waste cooking oil recycling producing bio diesel fuel, was undertaken in comparison with a complete use of cooking oil, the former is currently promoted in Bogor City, Indonesia, while the latter is commonly practiced by the street food stalls in the region. The functional unit covers, cooking oil production from crude palm oil, cooking use, waste cooking oil collection at a 0.2 recovery ratio in case of recycling, bio diesel fuel or regular diesel fuel production for a 8.865 MJ output, and lightweight vehicle transportation for waste cooking oil collection and diesel fuel delivery. A total GHG emission of 1.25L cooking oil production and a residual 0.25L waste cooking oil recycling for bio diesel fuel production, was estimated as 1.28kg CO_2e including materials, energy, wastes and transportation for collection/delivery, where an estimation of 1L cooking oil production for the complete use was 1.53kg CO_2e including GHG output from regular diesel fuel production, compensating the bio diesel fuel produced by the recycling. The result showed a theoretical 0.256kg CO_2e emission reduction by the 0.25L waste cooking oil recycling, compared with the complete use. However, the estimation was relevant to deep-frying cooking and not stir-frying. It also did not take other oil reduction factors, such as, vapouring, spitting, residual loss in cooking equipment and oil container into consideration, which might not be negligible at small quantity household uses. Further improvement on oil reduction model is necessary.**

Keywords- GHG emission, waste cooking oil recycling, LCA, biodiesel, residual ratio

I. INTRODUCTION

Climate change caused by greenhouse gas (GHG) emission to atmosphere has become a global issue. Indonesia's GHG emission is expected to grow by 2% per year, reaching 2.8 milliard tons in 2020 and 3.6 milliard tons of CO_2 equivalent (CO_2e) in 2030. Studies on mitigation technologies by Agency for Assessment and Application of Technology Indonesia in 2010-2011 showed that the main sources of Indonesia's GHG emissions come from forestry including land clearing for oil palm plantation (2.563 milliard tons of CO_2e), waste and energy sectors, especially from industries, power generation and transportation.

The development and implementation of low-carbon emission practices in Indonesia requires life cycle assessment (LCA) on common daily use products and their recycling to identify GHG emission derived of input materials, energy use and waste in recycling processes, in comparison with non-recycling option. Based on LCA, the best scenario for low carbon option can be obtained.

Bogor City has been encouraging waste cooking oil (hereafter WCO) collection and recycling to produce bio diesel fuel (hereafter BDF) since 2008, being regionally promoted under the Environmental Partnership Program of Bogor City[1], collaborated with local school communities and approximately 600 food shops/restaurants, a recycling company and a public transportation company using diesel buses.

The aim of this report is to elaborate the environmental impacts of the current practices in Bogor, focusing on the recycling and the complete use practices in GHG emission.

II. SYSTEM BOUNDARIES OF LCA ANALYSES OF RECYCLING AND COMPLETE USE

The Figure 1 and 2 show the system boundaries of the WCO recycling and the complete use respectively. Cooking oil production from crude palm oil is the first input in the system boundary both cases, followed by the cooking use. An oil reduction modeling was conducted, with an initial oil quantity of 1.25L, at 0.9 residual ratio by each deep frying. After 15.28 times cooking, 0.25L used oil was recovered resulting a 10L cumulative cooking oil quantity, and transported to produce BDF.

Meanwhile for the complete use, an initial oil quantity of 1L was calculated, under an infinite cooking modeling at 0.9 residual ratio, to match the same 10L cumulative cooking oil quantity.

The calorific value of bio diesel produced from 0.25L waste cooking oil recycling was estimated as 8.865 MJ quoting Bajpai et al. (2006) [2]. A GHG emission of regular diesel fuel (hereafter RDF) production to cover the same calorific value of BDF, was added to GHG emission of the complete use.

III. GHG EMISSION IN COOKING OIL PRODUCTION

Table 1 shows GHG emission to produce 1.25L NBD palm oil, by Schmidt (2007) [4] except for the crude palm oil shown as a material.

To reflect GHG emission of crude palm oil production in Indonesia, the value of 1.18kg CO_2e was calculated by using environmental load data provided by Mr. Siregar, based on the environmental data shown in Siregar et al. (2012) [3], as the data in the report includes some extra LCA factors not included in the system boundary.

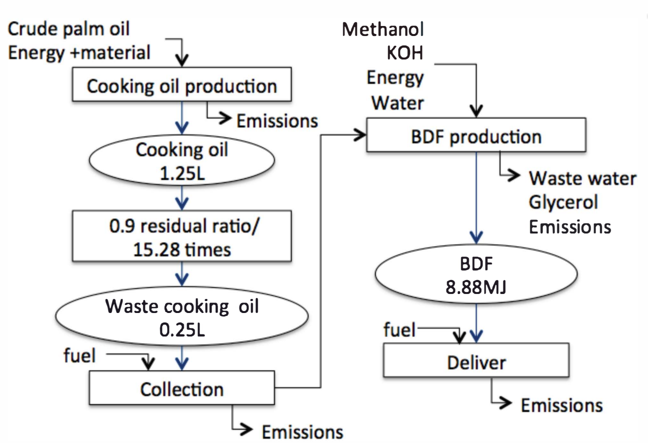

Figure 1. System boundary of waste cooking oil recycling to BDF

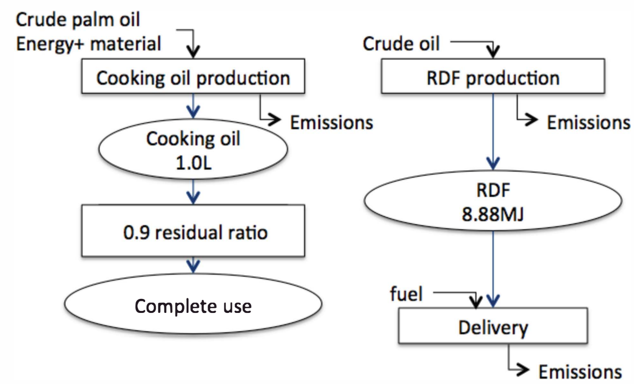

Figure 2. System boundary of complete cooking oil use

TABLE1. GHG emission of cooking oil production, recycling

Input	Material	Crude palm oil	1.18E+00	kg
		Phosphoric acid	2.81E-04	kg
		NaOH	3.26E-03	kg
		Bleaching earth	5.06E-03	kg
		Water	7.88E-01	kg
	Energy	Electricity	1.42E-01	MJ
		Heat (steam)	3.69E-01	MJ
	Waste treatment	Water treatment	7.88E-01	kg
		Landfill of bleaching ea	5.06E-03	kg
Output		NBD palm oil	1.25E+00	L

IV. GHG EMISSION IN WASTE COOKING OIL RECYCLING

GHG emission in BDF production is shown in Table 2, where data of materials, energy use and waste were provided by the Earth Energy Equatorial, a company who undertakes the sole BDF processing from WCO collected in Bogor City. Energies used during the catalysis processes were 0.0133kWh electricity and 0.0167kg LPG.

The biochemical oxygen demand (BOD) and the chemical oxygen demand (COD) in the sampled waste water of the BDF factory were 9748 mg/L and 11495 mg/L respectively. The methane generation was estimated using the IPCC 2006 guidelines by Doorn et al. (2006) [5], setting the methane correction factor as 0.5, because the water treatment was considered as a septic system. GHG emission was estimated as 0.833kg CO_2e.

GHG emission by light-weight truck to collect waste cooking oil and deliver BDF were estimated as 0.0105 and 0.0103kg CO_2e at a 20km running distance respectively. Table 4 shows a total GHG emission of 1.28kg CO_2e in the WCO recycling.

TABLE2. GHG emission in BDF production

Input	Material	Used-Cooking Palm Oil	2.50E-01	L
		Methanol	3.30E-02	kg
		KOH	4.17E-03	kg
		Water	8.33E-01	kg
	Energy	Electricity	1.33E-02	kWh
		LPG	1.67E-02	kg
Output		Bio-diesel	2.50E-01	L
		Glycerol	3.33E-02	kg
		Water treatment	8.33E-01	kg

V. GHG EMISSION IN COMPETE COOKING USE

Table 3 shows GHG emission in the cooking oil production of 1L for the complete use. As previously noted, the initial cooking oil amount was calculated to match the same cumulative cooking oil quantity of 10L both in the complete use and the collection at 0.25L after 15.28 times cooking, at 0.9 residual ratio. A total GHG emission of 0.835kg CO_2e was obtained by Table 3. To match an equal BDF calorific value of 8.865 MJ by the recycling, a compensating GHG emission of 0.688kg CO2e producing the same calorific value of RDF was added. GHG for RDF relivery was assumed as 0.0103kg CO_2e same as recycling, and the result shows a total GHG emission of 1.53kg CO_2e in the complete use, shown in Table 4.

TABLE3. GHG emission of cooking oil production, complete use

Input	Material	Crude palm oil	9.41E-01	kg
		Phosphoric acid	2.25E-04	kg
		NaOH	2.61E-03	kg
		Bleaching earth	4.05E-03	kg
		Water	6.30E-01	kg
	Energy	Electricity	1.13E-01	MJ
		Heat (steam)	2.95E-01	MJ
	Waste treatment	Water treatment	6.30E-01	kg
		Landfill of bleaching ea	4.05E-03	kg
Output		NBD palm oil	1.00E+00	L

TABLE4. GHG emission of cooking oil recycling and complete use in Bogor City

[kg-CO_2e/FU]

	Cooking oil	Collection	BDF production	Delivery	RDF production	Methane	Total	Dif
WCO recycling	1.04E+00	1.05E-02	1.56E-01	1.03E-02	0.00E+00	6.09E-02	1.28E+00	
Complete use	8.35E-01	0.00E+00	0.00E+00	1.03E-02	6.88E-01	0.00E+00	1.53E+00	2.56E-01

VI. COMPARISON BEWEEN RECYCLING AND COMPLETE USE

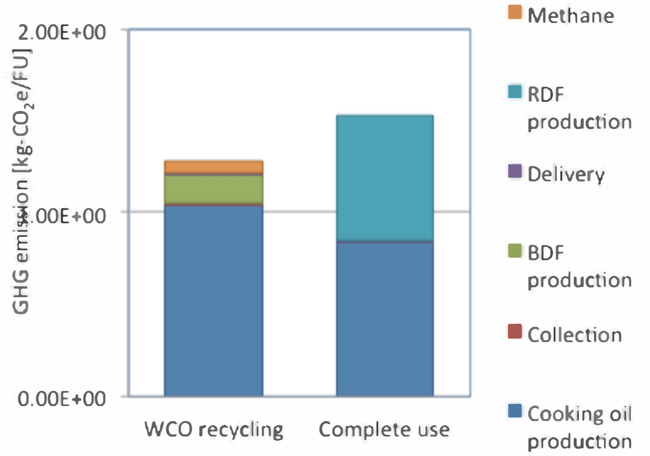

Figure 3. Comparison in GHG emission between WCO recycling and complete use

Figure 3 and Table 4 shows a comparison of GHG in the WCO recycling and the complete use. The result shows a theoretical 0.256kg CO2e reduction by WCO recycling if compared with the complete use, under the same 10L cumulative cooking oil quantity. As the initial cooking oil quantities are 1.25L and 1L respectively, the 25% GHG emission difference exists. The large GHG emission in RDF production contributed 45% in a total GHG emission, resulted a substantial increase in GHG compared with WCO recycling. This implies the benefit of WCO, even additional GHG derived from BDF production, collection and methane generation in waste water, where these increases in GHG can be easily compensated by much large GHG emission to produce RDF.

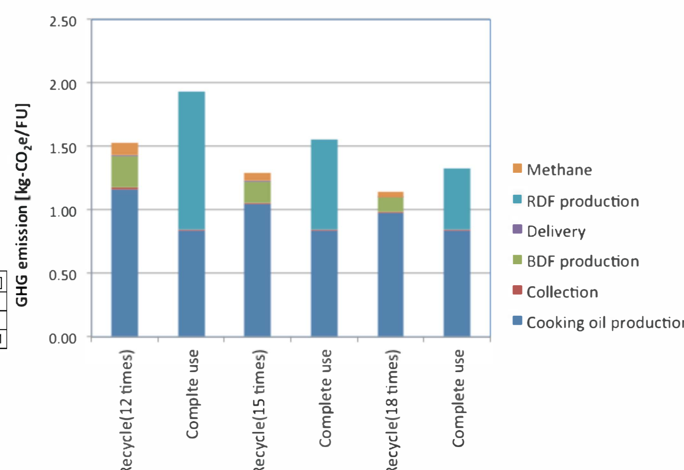

Figure 4. Effects of cooking times on GHG emission

VII. EFFECTS OF COOKING TIMES ON GHG EMISSON

Figure 4 shows the effects of number of cooking times on GHG emission in the WCO recycling and the complete use under the 10L cumulative cooking oil quantity. As cooking time increases to 18 times, GHG emission decreases both in the recycling and the complete use, due to the decreasing quantity of initial cooking oil. The difference of GHG emission in the WCO recycling and the complete use, increases as cooking time decreases to 12 times. Figure 4 also illustrates as cooking time decreases, GHG emission in both BDF and RDF production increases, however, the increase ratio in RDF production was much larger than that of BDF production.

VIII. COOKING OIL USE AND POTENTIAL RECYCLING QUANTITY IN BOGOR CITY

According to a citation of WCO collecting company in Bogor, 3L of new cooking oil monthly consumption is estimated each family, e.g., 36L annual consumption. There was an estimation of approximately 225,000 families in Bogor city, summing 8,100k liters per year. It was also cited that about 25% of household consumption of cooking oil is currently being consumed at food shops and restaurants in Bogor area. Therefore, an estimation of 10,125k liter cooking oil being currently consumed in Bogor. An estimation was made that 2,025k liter of oil seems to be potential amount for recycling if the recovery ratio of 20% was applied.

Table 5 shows annual WCO collection and BDF production in those years from 2008 to 2011. An assumption was made that 0.79% of potential WCO was currently being collected in the year of 2011, and it was considered that a substantial increase of WCO collection could be achieved, if the whole society moves to the recycling activities.

TABLE5. Annual WCO collection and BDF production in Bogor City (source BPLH Kota Bogor, 2011)

Year	2008	2009	2010	2011
WCO collection	3120	5984	10950	16090
BDF production	2496	4787	8760	12050

IX. LIMITATION OF MODELING AND FURTHER STUDY NEEDED

The estimation was relevant to deep-frying cooking without adding new cooking oil. The model does not handle usual adding oil cooking which is common in households. Cooking oil use for stir-frying was also not taken into consideration. The cooking model also did not take other oil reduction factors, such as, vapouring, spitting, residual loss in cooking equipment and oil container into consideration, which might not be negligible at small oil quantity uses in ordinary households. Moreover the residual ratio varies by foods being cooked, oil temperature and other factors. Further improvement on oil reduction modeling is necessary.

X. CONCOUSION

An estimation of GHG emission of the waste cooking oil recycling producing bio diesel fuel, was undertaken in comparison with a complete use of cooking oil, applying the data of Bogor City, Indonesia. The result showed a theoretical 0.256kg CO_2e emission reduction by the 0.25L waste cooking oil recycling, compared with the complete use, under a limitation of the modeling.

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