GREENHOUSE GAS EMISSIONS FOR THE PRODUCTION OF CRUDE PALM KERNEL OIL – A GATE-TO-GATE CASE STUDY

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ABSTRACT

Currently, carbon footprint, also known as greenhouse gas (GHG) emissions, is such a catchphrase in the world that it has become a must for responsible producers to quantify the carbon footprint of their products. The Malaysian oil palm industry is an export-orientated industry which relies heavily on the world market. Export earnings of oil palm products in 2010 alone reached RM 59.77 billion, while palm kernel oil exports increased to 1.16 million tonnes. However, the oil palm industry is under constant attack for its performance from the perspective of the environment, especially with regard to its GHG emissions. Being an export-orientated industry, this issue has to be tackled head-on to quantify the GHG emissions of the oil palm industry. The objectives of this study were to quantify the GHG emissions from the production of 1 t of crude palm kernel oil (CPKO) at the kernel-crushing plant, and to compare the GHG emissions of 1 t CPKO with and without biogas capture at the palm oil mill for a kernel-crushing plant located near the ports compared to a kernel-crushing plant located near the palm oil mill. The scope of this study is limited to the palm oil mill and the kernel-crushing plant. It starts at the palm oil mill where the fresh fruit bunches (FFB) are received, to the production of palm kernel at the mill, to the transportation of the palm kernel to the kernel-crushing plant, right up till the production of CPKO at the kernel-crushing plant. GHG emission was calculated using the global warming potential and emissions factors. Within the system boundary, the main contributor to GHG emission comes from the biogas at the palm oil mill, followed by the electricity from the grid for processing the palm kernel into CPKO. Capturing the biogas at the palm oil mill where the palm kernel is produced and using the biogas as a renewable energy source, reduces the main GHG emissions in this study. By integrating the kernel-crushing plant with the palm oil mill, GHG emissions from both the electricity to process the palm kernel into CPKO and transportation of the palm kernel to the kernel-crushing plant are reduced significantly. The best scenario will be to integrate the kernel-crushing plant with a palm oil mill that captures its biogas to obtain the best carbon footprint for the production of CPKO.

Keywords: greenhouse gas emissions, carbon footprint, crude palm oil, crude palm kernel oil, palm oil mill.

Date received: 24 June 2011; **Sent for revision:** 5 July 2011; **Received in final form:** 5 December 2011; **Accepted:** 24 July 2012.

INTRODUCTION

Currently, carbon footprint, also known as greenhouse gas (GHG) emissions, is such a catchphrase in the world that it has become a must for responsible producers to quantify the carbon footprint of their products.

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GHG are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself and by clouds. This property causes a greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary GHG in the Earth's atmosphere. Moreover, there are a number of entirely human-made GHG in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol also deals with the GHG sulphur hexafluoride (SF_6), hydrofluorocarbons (HFC) and perfluorocarbons (PFC) (IPCC Fourth Assessment Report, 2007). GHG emissions from all these sources are summed up and changed into units of CO_2 equivalent (CO_2 eq) which is used to standardise GHG emissions (Altuslumen, 2009).

GHG greatly affect the temperature of the earth; without them, the earth's surface would be on average about 33°C colder than at present. The sharp acceleration in CO_2 emissions since the year 2000 to more than a 3% increase per year (more than 2 ppm per year) from 1.1% per year during the 1990s is attributable to the lapse of formerly declining trends in carbon intensity of both developing and developed nations (Wikipedia, 2010).

The oil palm's fresh fruit bunches (FFB) is a unique crop product. Two types of oil can be obtained from FFB. A palm fruit is a drupe, oval in shape, and contains a kernel which is the seed. The kernel is surrounded by the fruit wall made up of a hard shell (endocarp), fibrous fruit pulp or oil-bearing tissue (mesocarp) and the skin as shown in *Figure 1* (Hamdan *et al*., 2000). Within the nut is the kernel. As shown in the cross-section of an oil palm fruitlet in *Figure 1*, crude palm oil (CPO) is obtained from the mesocarp while crude palm kernel oil (CPKO) is obtained from the kernel within the nut.

The Malaysian oil palm industry is an export-orientated industry which relies heavily on the world market. Export earnings of oil palm products in 2010 alone reached RM 59.77 billion (Choo, 2011), while palm kernel oil exports increased to 1.16 million tonnes. USA was the major export market for palm kernel oil at 0.26 million tonnes (or 22.8% of total palm kernel oil exports), followed by China, PR at 0.21 million tonnes (17.7%), the European Union at 0.12 million tonnes (10.1%) and Japan at 0.09 million tonnes (8.0%) (Choo, 2011).

The oil palm industry is under constant attack over its performance from the perspective of the environment, especially with regard to its GHG emissions. Being an export-orientated industry, this issue has to be tackled head-on to quantify the GHG emissions of the oil palm industry. In view of this, the GHG emissions from the production of CPKO will be highlighted in this article.

OBJECTIVES

The objectives of this study were:

a) To quantify the GHG emissions from the production of 1 t CPKO at a kernel-crushing plant; and
b) To compare the GHG emissions of 1 t CPKO:
   - with and without biogas capture at the palm oil mill for a kernel-crushing plant located near a port with allocation, and
   - with and without biogas capture at the palm oil mill for a kernel-crushing plant located near the palm oil mill with allocation.

METHODOLOGY

System Boundary

The scope of this study is limited to the palm oil mill and the kernel-crushing plant. It starts at the palm oil mill where the FFB are received, proceeding to the production of palm kernel at the palm oil mill, to the transportation of the palm

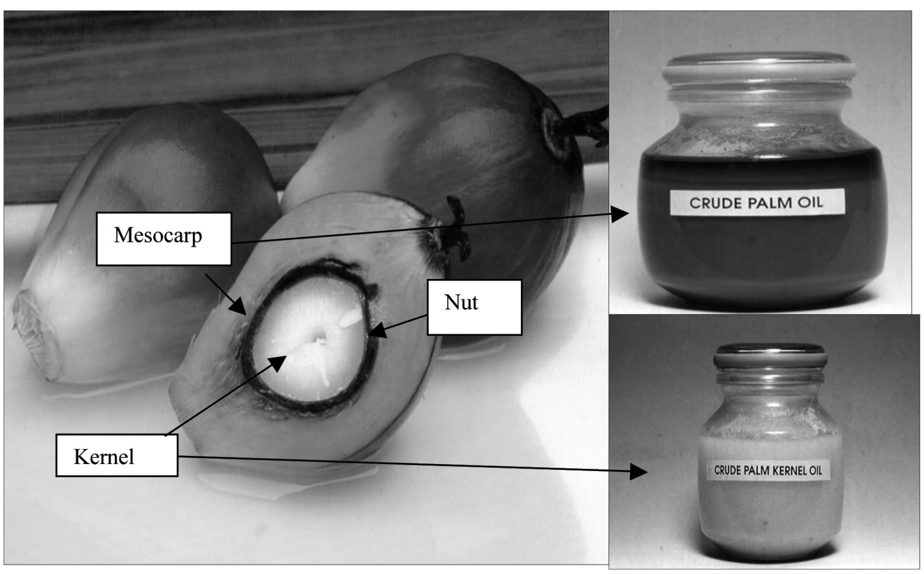

Figure 1. Cross-section of an oil palm fruitlet.

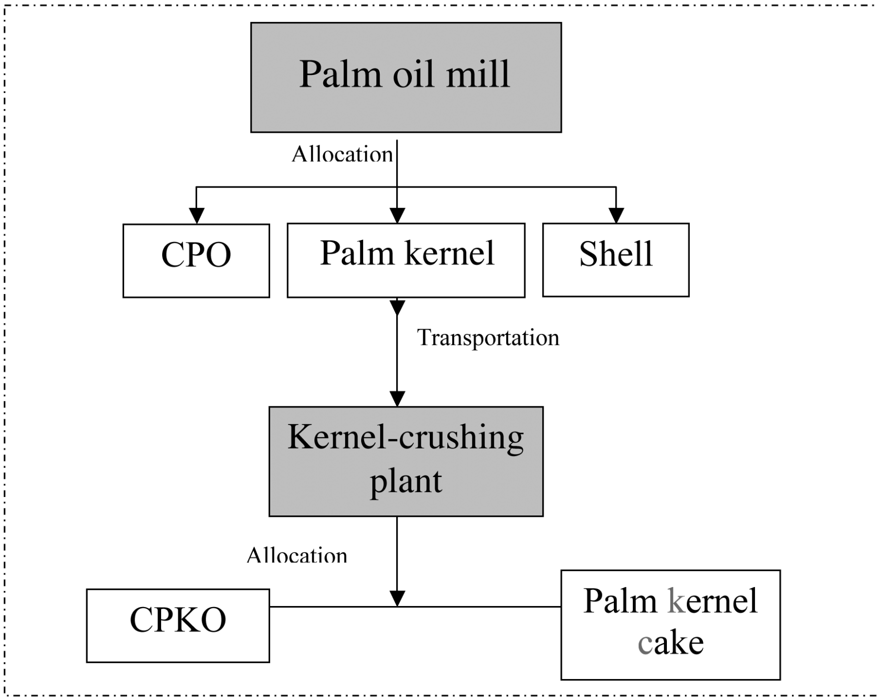

Figure 2. System boundary of the study – gate-to-gate.

kernel to the kernel-crushing plant, right up till the production of CPKO at the kernel-crushing plant. The system boundary is shown in *Figure 2*.

There are several zones in Malaysia with a high number of palm oil mills clustered together. These clusters mainly follow the areas that have oil palm plantations nearby. The plantations are located in areas where the soils, such as inland soil and coastal soil, are suitable for growing oil palm.

For this study, 40 palm oil mills were chosen from the main clusters which contain a high density of palm oil mills within them. The palm oil mills were chosen from these clusters to ensure that the mills were representative and covered the main areas that have palm oil mills in Malaysia. Within each cluster itself, the palm oil mills were chosen based on their age, type of mill, FFB-processing capacity, location and also other variables such as grid connection and oil extraction rate. The reason for this is to ensure that the chosen mills had all the different variations existing among the palm oil mills in Malaysia.

Kernel-crushing plants are normally located near the ports to ensure easy access to export facilities, for both CPKO and the resulting palm kernel cake. Inventory data were collected directly from the kernel-crushing plants through questionnaires which were developed specifically for data collection and also through actual on-site measurements and quantification. Compliance with geographical coverage for data collection was adhered to by collecting data from different regions in Malaysia. For this study, six kernel-crushing plants were chosen which were located all over Peninsular Malaysia. Five kernel-crushing plants were located near ports, which are the Klang Port in the mid-region, the Pasir Gudang Port in the south and the Kuantan Port in Pahang, on the east coast of Peninsular Malaysia. One kernel-crushing plant was located right beside a palm oil mill. These were specifically selected to examine the different scenarios that exist in Malaysia, and also to be representative of the various scenarios of kernel-crushing plants in the country.

The five chosen kernel-crushing plants which are located near the ports use electricity directly from the national grid supply for processing, while the kernel-crushing plant which is located beside a palm oil mill uses electricity generated at a neighbouring palm oil mill. Inventory data which consist of the inputs and outputs of the system boundary were collected for a duration of five years from the palm oil mills and the kernel-crushing plants. These consisted of data on raw materials, energy consumption, wastes and emissions.

Functional Unit

This study quantified the input and output for 1 t of CPKO produced at a kernel-crushing plant.

Allocation with By-products

More often than not, a system will yield more than one product. In such cases, allocation must be made for the respective input and output flows. Within the palm oil milling sub-system, a number of processes takes place in addition to the main process, *i.e.* the extraction of CPO from the mesocarp of sterilised palm fruits. One of the by-products from the milling process is palm kernel. Besides the main products, comprising CPO and palm kernel, other outflows include the production of sludge or palm oil mill effluent (POME) during the clarification step, empty fruit bunches (EFB) during the stripping of FFB, pressed mesocarp fibre from mechanical pressing of the palm fruits, nuts from the depericarping stage, and, lastly, shell after nut-cracking to release the palm kernel. This kernel is then shipped by trucks to nearby kernel-crushing plants that process it into CPKO.

In this study, the method selected for partitioning the by-products was allocation based on weight. Palm kernel and palm shell are considered as by-products at the palm oil mill. The pressed mesocarp fibre and shell are burnt as fuel in the palm oil mill boiler while the excess shell is sold out to other biomass boilers. However, the credits for the use of shell elsewhere are not included in this study as it is out of the system boundary, and so allocation is carried out for shell. Palm kernel cake is also considered a by-product at the kernel-crushing plant, and allocation is carried out between CPKO and palm kernel cake. The allocation at the palm oil mill between CPO, palm kernel and palm shell was 61%, 25% and 14%, respectively, while the allocation at the kernel-crushing plant between CPKO and palm kernel cake was 47% and 53%, respectively.

Global Warming Potential

The concept of global warming potential (GWP) was developed to compare the ability of each GHG to trap heat in the atmosphere relative to another gas. The definition of GWP for a particular GHG is the ratio of heat trapped by one unit mass of the GHG to that of one unit mass of CO_2 over a specified time period (US EPA, 2010). GWP of selected GHG is shown in *Table 1*. GHG emissions were calculated using GWP and emission factors. The emission factors used for diesel and electricity are shown in *Table 2*.

TABLE 1. GLOBAL WARMING POTENTIAL (GWP) FOR SELECTED GREENHOUSE GASES (GHG)

GHG	GWP for 100 years
CO_2	1
CH_4	23
N_2O	296
HFC - 23	12 000
HFC – 134a	1 300
SF_6	22 200

Source: *IPCC Third Assessment Report* (2001).

TABLE 2. EMISSION FACTORS

Energy	Emission factors
Diesel	0.00268 t CO_2 eq litre^{-1}
Electricity	0.000594 t CO_2 eq kWhr^{-1}

Source: Wisions (2009).

RESULTS AND DISCUSSION

Life Cycle Inventory

Table 3 shows the life cycle inventory (LCI) data for 1 t palm kernel produced at a palm oil mill which had been allocated.

Table 4 shows the LCI data for 1 t CPKO produced at a kernel-crushing plant located nearer to a port, while *Table 5* shows the LCI data for 1 t CPKO for a kernel-crushing plant that is located just beside a palm oil mill but is far away from any port.

Almost all the kernel-crushing plants in Malaysia use the mechanical method of crushing, which is basically the direct crushing and pressing of the kernel to squeeze out the kernel oil. The waste from this process is palm kernel cake which is the crushed kernel after the oil has been pressed out. The selected crushing plants all have identical processing methods and conditions. These crushing plants are typical of the majority of the plants in Malaysia. All these kernel-crushing plants use the double squeezing method to press out as much CPKO as possible.

The kernel-crushing plant which is located beside the palm oil mill is also identical in its processing method to the other crushing plants, but it has one big difference – which is its source of energy. The other kernel-crushing plants use only one energy source for processing, which is electricity from the national grid supply. However, the kernel-crushing plant located beside a palm oil mill uses the electricity supply from the neighbouring palm oil mill. The palm oil mill generates electricity for its own milling process as well as for the kernel-crushing plant nearby. In the palm oil mills, pressed mesocarp fibre and shell are used as fuel in the boiler and are burnt to produce heat to convert water into steam. This steam is then used to run a turbine which generates electricity for the milling process and the whole mill compound. The pressed mesocarp fibre and shell are actually wastes from FFB which are then recycled as boiler fuel. The pressed mesocarp fibre is the waste after oil has been pressed out of the mesocarp of the fruit. The shell is the outer layer of the nut which when cracked produces kernel and shell. However, this kernel-crushing plant still consumes some electricity from the national grid supply when the palm oil mill is not in operation. However, it should be noted that the amount is very low.

TABLE 3. LIFE CYCLE INVENTORY FOR THE PRODUCTION OF 1 t PALM KERNEL AT A PALM OIL MILL (allocated from crude palm oil)

Parameter	Amount	Range (no allocation)
Fresh fruit bunches (t)	3.10	4.67-5.48
Power consumption from turbine (MJ)	224.08	336.28-394.45
Power consumption from grid (MJ)	1.76	0-10.62
Diesel consumption for mill	100.33 MJ	0-4.47 litre
Transportation of diesel to mill	250 km	200-300 km
Fuel used in boiler:		
Mesocarp fibre (t)	0.36	0.52
Shell (t)	0.09	0.15
Boiler water consumption (t)	1.57	2.10-3.64
Water for processing (t)	2.17	2.95-3.79
Kernel (t)	0.41	0.37-0.44
Mesocarp fibre (t)	0.00	0.00 -0.01
Shell (t)	0.23	0.09-0.31
Empty fruit bunches, EFB (t)	0.71	1.07- 1.26
Palm oil mill effluent, POME (t)	1.86	2.80-3.29
Methane gas (kg)	22.21	-
CO_2 from POME pond (kg)	36.04	-
Boiler ash (t)	0.01	0.01-0.02
Steam input to turbine (t)	1.62	2.10-3.64
Steam input for sterilisation (t)	1.56	2.10- 3.29
Flue gas from stack:		
Particulate matter (kg)	0.12	0.07-0.56
CO (kg)	0.04	0.02-0.14
CO_2 (kg)	41.28	13.74-161.20
SO_x (kg)	0.0006	0.0005-0.003
NO_x (kg)	0.07	0.07-0.20
Wastes		
EFB	Mulching	
POME	Treated as fertiliser	
Excess mesocarp fibre and shell	Sold as fuel	
Boiler ash	Land application	

TABLE 4. LIFE CYCLE INVENTORY FOR THE PRODUCTION OF 1 t CRUDE PALM KERNEL OIL (CPKO) FOR FIVE KERNEL-CRUSHING PLANTS LOCATED NEAR THE PORTS (allocated)

Parameter	Amount	Range (no allocation)
Palm kernel (t)	1.07	2.20-2.35
Electricity from grid (MJ)	448.6	846.6-1 062.6
Transportation of kernel (km)	149.40	120-160
Palm kernel cake (t)	1.12	1.00-1.19

TABLE 5. LIFE CYCLE INVENTORY FOR THE PRODUCTION OF 1 t CRUDE PALM KERNEL OIL (CPKO) FOR A KERNEL-CRUSHING PLANT LOCATED BESIDE A PALM OIL MILL FAR FROM THE PORTS (allocated)

Parameter	Amount
Palm kernel (t)	1.07
Electricity from grid (MJ)	44.0
Electricity generated at palm oil mill (MJ)	421.30
Transportation of kernel (km)	2.24
Palm kernel cake (t)	1.12

Greenhouse Gas Emissions

The GHG emissions from the production of 1 t CPKO in kernel-crushing plants located near the ports are shown in *Table 6*. The GHG values are the sum total from the palm oil mill and kernel-crushing plant with allocation.

The largest GHG contribution comes from the biogas which amounts to 583.20 kg CO_2 eq t^{-1} CPKO from the production of palm kernel at the mill, followed by the consumption of electricity from the grid for processing CPKO (which emits 74.33 kg CO_2 eq t^{-1} CPKO). When biogas is captured, the total GHG emissions are reduced to 183.01

kg CO_2 eq t^{-1} CPKO compared with 678.73 kg CO_2 eq t^{-1} CPKO without biogas capture. This is a significant reduction in GHG emissions when biogas is captured. The GHG emissions when the kernel-crushing plant is located near a palm oil mill are shown in *Table 7*.

When the kernel-crushing plant is located near the mill, the consumption of electricity from the grid is reduced from 74.33 kg CO_2 eq t^{-1} CPKO to only 7.59 kg CO_2 eq t^{-1} CPKO. GHG emission from the transportation of palm kernel from the mill is also reduced from 6.53 kg CO_2 eq t^{-1} CPKO to 0.24 kg CO_2 eq t^{-1} CPKO. These results are further illustrated in *Figures 3* and *4* which show the GHG emissions in a graphical form comparing both the scenarios.

Based on the results, within the system boundary, the main contributor to the GHG emissions comes from the biogas emissions from the palm oil mill, which is followed in turn by the electricity from the grid for processing the palm kernel into CPKO. Capturing the biogas at the palm oil mill where the palm kernel is produced, and using the biogas as a renewable energy source reduces the main GHG emission in this study. By integrating the kernel-crushing plant with the palm oil mill, GHG emissions from using both the electricity to process the palm kernel into CPKO and transportation of palm kernel to the kernel-crushing plant are reduced significantly. The best scenario will be to integrate the kernel-crushing plant with a palm oil mill that captures its biogas to obtain the best carbon footprint for the production of CPKO.

TABLE 6. GREENHOUSE GAS (GHG) EMISSIONS FOR 1 t CRUDE PALM KERNEL OIL (CPKO) FROM KERNEL-CRUSHING PLANTS LOCATED NEAR THE PORTS (palm oil mill and kernel-crushing plant with allocation)

Output	GHG emissions for 1 t CPKO kg CO_2 eq
Electricity from grid	74.33
Diesel:	
Mill consumption	7.24
Transportation of diesel to mill	7.43
Transportation of palm kernel	6.53
Biogas	583.20
Biogas captured (85%)	87.48
Total with biogas	678.73
Total with biogas captured	183.01

TABLE 7. GREENHOUSE GAS (GHG) EMISSIONS FOR 1 t CRUDE PALM KERNEL OIL (CPKO) FROM A KERNEL-CRUSHING PLANT LOCATED NEAR A PALM OIL MILL (palm oil mill and kernel-crushing plant with allocation)

Output	GHG emissions for 1 t CPKO (with allocation from CPO) kg CO_2 eq
Electricity from grid	7.59
Boiler emissions	46.16
Diesel:	
Mill consumption	7.24
Transportation of diesel to mill	7.43
Transportation of palm kernel	0.24
Biogas	583.20
Biogas captured (85%)	87.48
Total with biogas	651.86
Total with biogas captured	148.71

CONCLUSION

For years past, environmental management was categorised more for image-building purposes. However, in recent developments with the shift towards wanting a greener earth, environmental demands are becoming marketing tools. It is becoming a determining factor in the selection

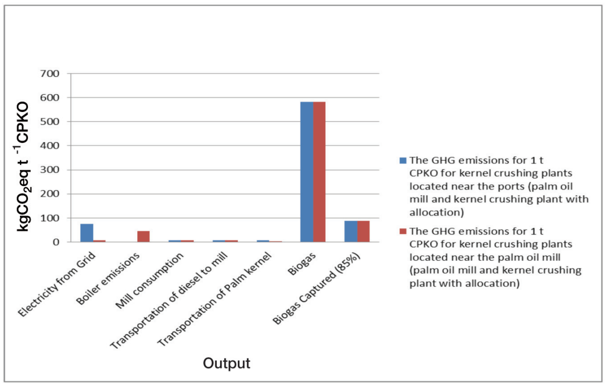

Figure 3. Comparison of greenhouse gas (GHG) emissions for 1 t crude palm kernel oil (CPKO) for two scenarios.

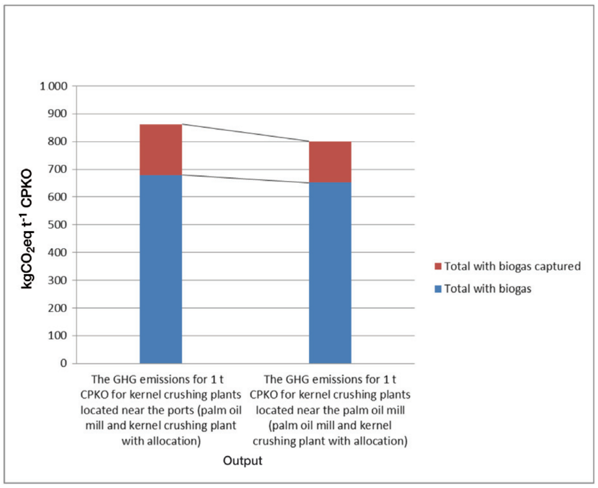

Figure 4. Comparison of the total greenhouse gas (GHG) emissions for 1 t crude palm kernel oil (CPKO) for two scenarios.

and for use of products by the consumer. In view of the current shift towards higher environmental demands from customers as well as the emergence of eco labels, there is an unavoidable need for the oil palm industry to also shift with the current trend. This shift is vital for the oil palm industry as it has to be sustainable and competitive to increase its long-term profitability and sustainability.

Within the system boundary, the main contributor to the GHG emissions comes from the biogas, which is followed by the electricity from the grid for processing the palm kernel into CPKO. The best scenario will be to integrate the kernel-crushing plant with a palm oil mill that captures its biogas to obtain the best carbon footprint for the production of CPKO.

ACKNOWLEDGEMENT

The authors would like to thank the owners/ operators of the palm oil mills and kernel-crushing plants for allowing them to conduct the study in their premises.

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