Environmental Performance of the Production of Crude Palm Kernel Oil Using the Life Cycle Assessment Approach

Vijaya Subramaniam*; Ma Ah Ngan* and Choo Yuen May*

INTRODUCTION

The world is demanding for economic growth but yet this growth must be achieved through environmental conservation while enhancing the quality of human life. Sustainability is about preserving the health of the biosphere and the efficient use of natural resources such as air, water, land, flora and fauna (Chan, 2004). Sustainable development has been popularly defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (UNCED, 2002). This clarion call has resulted in the enormously increased recognition of environmental issues from the last decade, and which is gaining momentum each year. The public is increasingly more aware that the consumption of manufactured products and services offered may contribute to adverse effects on resources and the quality of the environment, and that these effects can occur at all stages of the life cycle and not just during manufacturing.

Since the late 1990s there is a widespread emergence of eco-labelling criteria and Environmental Management System which have extended to the agriculture products and processing sectors. Eco-labelling is slowly evolving to become a market-based voluntary mechanism in the greening of the agriculture products supply chain. Eco-label Type I is a voluntary third party programme that awards a license that authorizes the use of environmental labels on a product indicating its better environmental performance. Eco-label Type II is a self-declaration label on environmental performance, while Eco-label Type III specifically requires a life cycle assessment (LCA) study to be conducted on the product before certification.

LCA is a tool for evaluating the environmental impact of a product or process throughout its entire life cycle (SETAC, 1993). It was first developed as a method for evaluating the impact of a product over its entire life cycle, the so-called 'cradle-to-grave approach', but it has since grown for use in evaluating the environmental impact of business activities, and finally of all the economic activities of a nation as well. Over the last decade there has been a rapid expansion in the demand for LCA studies to chart the environmental performance of products. LCAs have thus become a common environmental management tool and a good analytical method for assessing and optimizing the environmental quality of a system over its whole life cycle (Stalmans *et al.*, 1995).

THE OIL PALM INDUSTRY IN MALAYSIA

The oil palm is a unique oil crop in that it yields two commercially important vegetable oils, namely, crude palm oil (CPO) from the mesocarp, and crude palm kernel oil (CPKO) from the palm kernel embedded in the palm nut (*Figure 1*).

The oil palm industry contributes immensely towards the economy

* Malaysian Palm Oil Board,
P. O. Box 10620,
50720 Kuala Lumpur, Malaysia.
E-mail: vijaya@mpob.gov.my

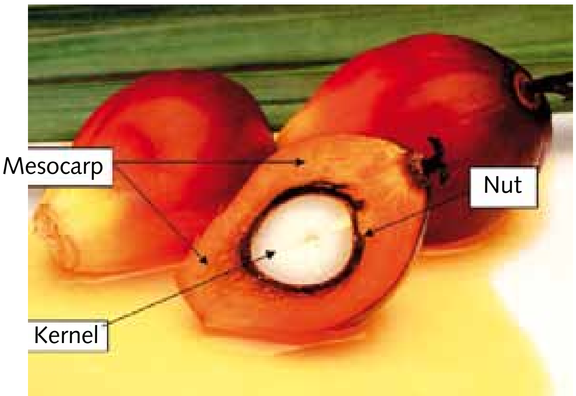

Figure 1. Cross-section of an oil palm fruitlet.

of Malaysia. In 2007 alone, the total exports of oil palm products such as palm oil, palm kernel oil, palm kernel cake, oleochemicals and finished products reached 19.6 million tonnes, contributing to an enormous earning of RM 45.1 billion (Basri, 2008).

Exports of palm kernel oil increased by 14.1% to 1.06 million tonnes in 2007 with the USA as the major importer at a volume of 0.24 million tonnes, followed by China P R, the European Union (EU) and Japan. However, exports of palm kernel cake declined by 1.9% to 2.09 million tonnes from 2.13 million tonnes in 2006. The major palm kernel cake export markets were the EU, South Korea and Australia (Basri, 2008).

Extraction of Palm Kernel Oil

Crude palm oil is extracted from the oil palm fresh fruit bunches at the palm oil mills, and in the process, palm kernels are obtained as a by-product. These kernels are then transported by trucks to nearby kernel-crushing plants that process them into CPKO. This is carried out by a continuous screw press.

The screw press consists basically of a perforated cylindrical cage in which runs a worm or screw. The discharge end of the cage is fitted with an adjustable cone which restricts the discharge opening of the cage. The rotation of the worm transports the kernel meal towards the outlet end of the perforated cage, and as the outlet is restricted by the cone, pressure is built up in the cage thus causing the oil to be squeezed out of the meal. The internal pressure in the cage is regulated by adjustments to the outlet cone. The extracted oil flows through the perforations in the cage whilst the solid matter, or cake, is discharged from the opening around the cone. When efficiently operated, the residual oil in the cake is around 5%-6% (Ma, 1994).

POTENTIAL ENVIRONMENTAL IMPACT FROM CRUDE PALM KERNEL OIL (CPKO) PRODUCTION

Studies were conducted at six kernel-crushing plants. Five of them used electricity directly from the national grid supply for processing, while only one used electricity generated at a neighbouring palm oil mill. The inventory data which consisted of raw materials, energy consumption, wastes and emissions were collected over a period of one year from each kernel-crushing plant. A life cycle inventory (LCI) for every tonne of CPKO produced was computed for each of the plants, and the SimaPro Software Version 7.1 was used to carry out the life cycle impact assessment (LCIA).

System Boundary and Functional Unit

This study had a gate-to-gate system boundary which started at the palm oil mills where the palm kernels were collected, up till the production of CPKO at the kernel-crushing plants. *Figure 2* shows the various stages included in the system boundary. The functional unit for this study is 1 t of CPKO produced at the kernel-crushing plant.

Limitations/constraints

The Simapro software used was developed in Europe, and is based on European data. However, the software is generic, and Malaysian data were input into the database, wherever possible, to conduct this study. However, the background data had been adopted from the Simapro database itself, for example, those regarding the usage of diesel, as the corresponding Malaysian data are lacking.

LIFE CYCLE INVENTORY (LCI) OF CPKO

Using the inventory data collected over a period of one year from each of the kernel-crushing plants, an LCI was created for every tonne

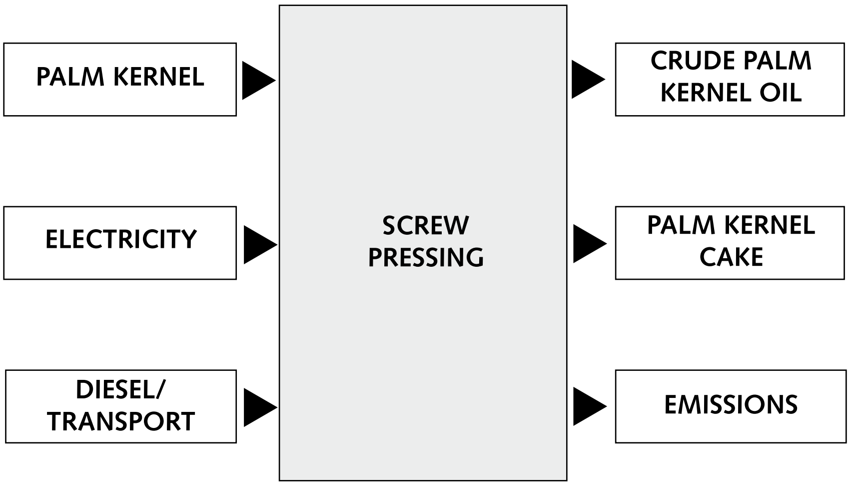

Figure 2. System boundary of the mechanical extraction of crude palm kernel oil.

of CPKO produced at the plants as shown in *Table 1*.

LCIA was conducted on the five kernel-crushing plants (A to E) which used electricity from the national grid and were all located at a distance from the palm oil mills, as shown in *Figures 3* and *4*. *Figure 5* shows the LCIA for the kernel-crushing plant F which used renewable energy and was located within 3 km of the palm oil mill.

ENVIRONMENTAL INPUTS

Almost all the kernel-crushing plants in Malaysia use mechanical extraction which is basically a direct crushing process, followed by a two-stage pressing of the kernels to squeeze out the oil, leaving behind a residual by-product called palm kernel cake. The selected crushing plants all had identical processing methods and conditions, and were typical of the majority of the crushing plants in Malaysia. The process conditions were chosen to optimize the oil recovery while maintaining the quality of the palm kernel cake.

Table 1 shows that the major environmental input is the energy consumption for the whole process of crushing palm kernels into CPKO and palm kernel cake. For the five crushers (A to E), this energy source was the electricity supply from the national grid, which was the biggest input within this system boundary, with an average consumption of about 265.13 kWhr for every 1 t of CPKO produced.

Kernel-crushing plant F was different. Though it had a processing method identical to the other five crushing plants, it used another source of electrical energy which was supplied by a neighbouring palm oil mill. This palm oil mill, like all other mills in Malaysia, generated electricity by burning biomass, mainly pressed mesocarp fibre and palm shells, in the boiler furnace to produce steam for running a turbine which generated electricity for

TABLE 1. LIFE CYCLE INVENTORY FOR THE PRODUCTION OF 1 t OF CRUDE PALM KERNEL OIL (CPKO)

Crushing Plant	A	B	C	D	E	Average	Std Dev.	F
Environment inputs								
Palm kernel (t)	2.35	2.30	2.20	2.27	2.20	2.27	0.06	2.38
Electricity form grid (kWhr)	275.02	238.19	283.47	234.62	294.36	265.13	27.14	26.02
Electricity generated at POM (kWhr)	-	-	-	-	-	-	-	249.00
Distance (km)	62.50	80.00	77.50	90.00	85.00	79.00	10.40	3.00
Diesel consumption (l)	11.25	14.40	13.95	16.20	15.30	14.22	1.87	0.90
Environment outputs								
Palm kernel cake (t)	1.13	1.19	1.00	1.18	1.10	1.12	0.10	1.22

its own milling process as well as for the kernel-crushing plant nearby. The pressed mesocarp fibre and palm shells are actually wastes from the processing of oil palm fresh fruit bunches which are then recycled as boiler fuel. However, kernel-crushing plant F still consumed a small amount of electricity from the national grid supply when the palm oil mill was not operating. It should be noted that the electricity required from the national grid was only 26.02 kWhr t^{-1} of CPKO.

Another environmental input was diesel consumption, mainly arising from the trucks or lorries that transported the palm kernels from the palm oil mills to the kernel-crushing plants. The distance varied from mill to mill but the average in our study was 79 km. However, in the case of plant F, which was situated right beside the palm oil mill, the distance was only about 3 km. This explains the low figure of 0.9 litre of diesel per tonne CPKO produced for this plant compared to 14.22 litres for the other five.

The other environmental input is, of course, the palm kernels which ranged from about 2.20-2.35 t to produce each tonne of CPKO. This range was computed based on the oil extraction rate of each plant which directly reflected its pressing efficiency.

ENVIRONMENTAL OUTPUTS

The main environmental outputs are emissions from the trucks and the palm kernel cake. In the mechanical pressing process, there was a small amount of oil retained in the residue, the palm kernel cake, which is a good ingredient for animal feeds. Palm kernel cake is mainly exported, with less than 10% used locally in animal feeds.

LIFE CYCLE IMPACT ASSESSMENT (LCIA) FOR 1 t OF CRUDE PALM KERNEL OIL (CPKO)

The LCIA results are shown in *Figures 3*, *4* and *5*. The damage assessment in SimaPro 7.1 shows the impact which is divided into three main damage categories, namely, impact to human health, ecosystem quality and to resources. This damage assessment actually clusters all the 11 impact categories into three main damage categories to directly show which parameter causes what impact to which category as shown in *Table 2*.

Energy Derived from Fossil Fuels

Figure 3 shows that there were two major parameters causing the potential impact in all the impact categories in this LCA study, namely, transportation of the palm kernels from the palm oil mills to

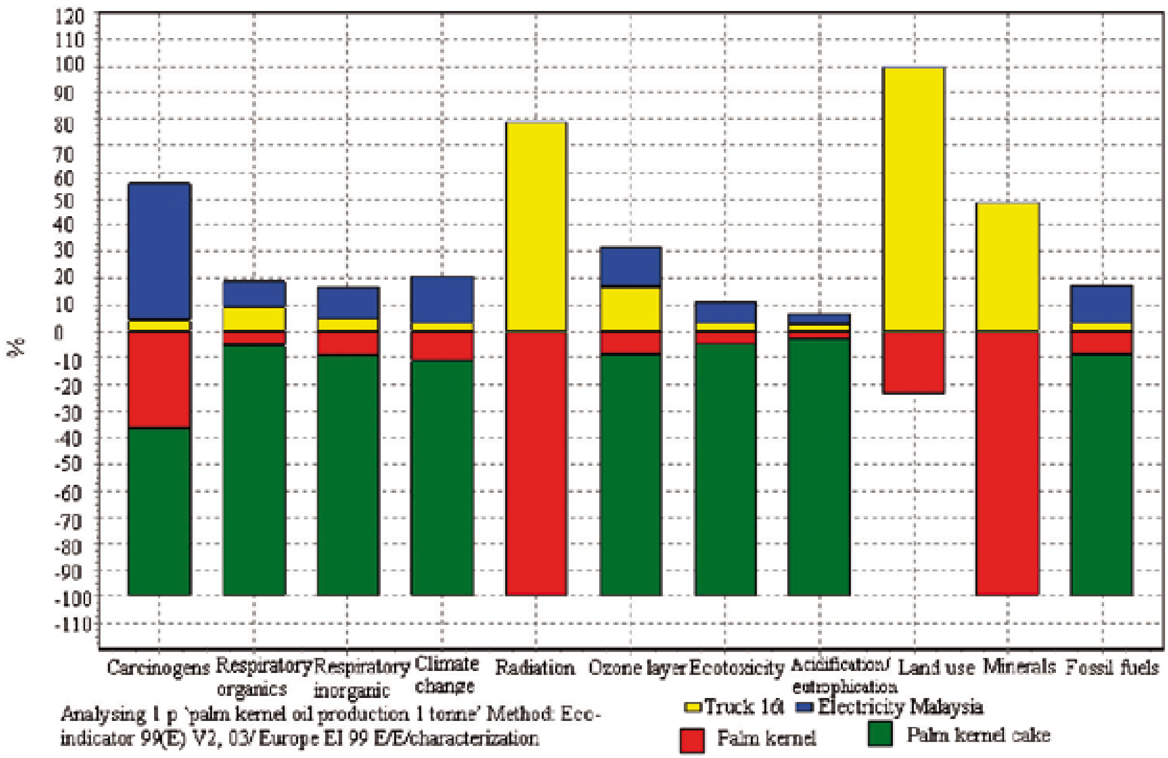

Figure 3. Characterization of the life cycle impact assessment (LCIA) for 1 t of crude palm kernel oil (CPKO) produced.

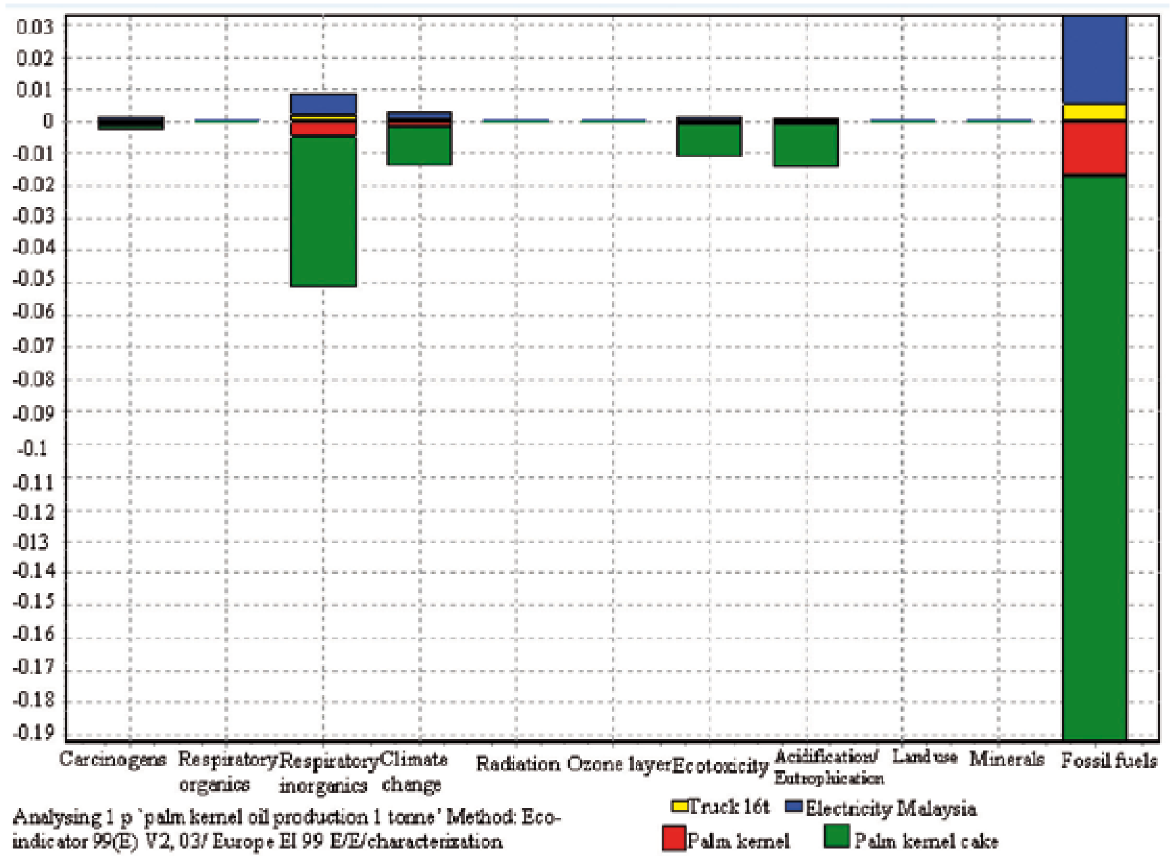

Figure 4. Normalization of the life cycle impact assessment (LCIA) for 1 t of crude palm kernel oil (CPKO) produced.

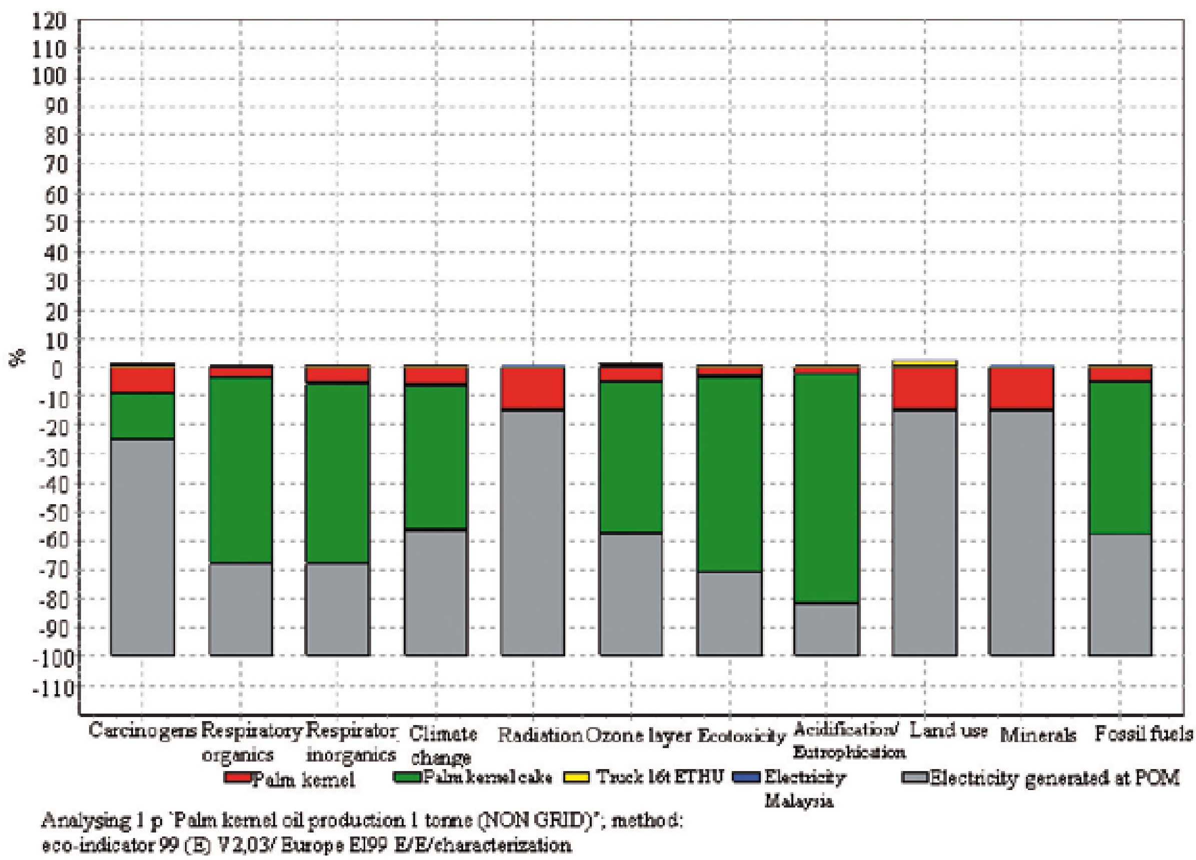

Figure 5. Characterization of the life cycle impact assessment (LCIA) for 1 t of crude palm kernel oil (CPKO) produced (non-grid energy supply).

TABLE 2. IMPACT CATEGORIES IN ECO-INDICATOR 99

Impact category	Damage category	Emissions to	Examples
Carcinogens	Human health	Air, water and soil	Chlorinated compounds, heavy metals
Respiratory organics	Human health	Air	Organic particulates
Respiratory inorganics	Human health	Air	Particles from combustion processes
Climate change	Human health	Air	CO_2 from combustion, CH_4 from anaerobic digestion
Radiation	Human health	Air, water and soil	Cobalt, hydrogen, radon, plutonium, *etc*.
Ozone layer	Human health	Air	CFC 11, HCFC 22
Ecotoxicity	Ecosystem quality	Air, water and soil	Pesticides, Heavy metals
Acidification	Ecosystem quality	Air	SOx, NOx
Eutrophication		Water	NO_3 from fertilizers, nitrogen and phosphate compounds
Land use	Ecosystem quality	-	Emissions from raw materials, traffic
Minerals	Resources	-	Al, Fe, Cu, Pb
Fossil fuels	Resources	-	Coal, oil, gas

Source*:* Goedkoop and Spriensma (1999).

the kernel-crushing plants, and the electricity consumption from the national grid for processing CPKO. The potential impact from transportation was mainly derived from the diesel consumption by the lorries. Due to the distance between the palm oil mills and the kernel-crushing plants, transporting the kernels which used fossil fuel caused a potential impact under all the impact categories. The kernel-crushing plants in Malaysia are situated near to the ports for easy access to bulking terminals when exporting their CPKO. This explains the long distance between the palm oil mills and the kernel-crushing plants, as the palm oil mills are normally located nearer to the oil palm plantations. The other parameter causing potential impact was the electricity consumption from the national grid. Again being a fossil fuel-based energy source, this also contributed a potential impact under all the impact categories.

Palm kernel cake is the residue left after extraction of the palm kernel oil. This cake becomes a savings as it is sold as an ingredient in animal feeds. As both electricity and transportation seemed to cause a potential impact in all impact categories, normalization was carried out to examine which impact was more significant or harmful. The normalization results are shown in *Figure 4*.

When normalized, the potential impact from electricity seemed to be more prominent than from transportation. This can be attributed to the use of fossil fuels such as coal, oil and natural gas for producing this energy, whereas in the case of transportation, only diesel was used. Furthermore, the quantity of the diesel consumed for transporting the kernels from the palm oil mills was much less than the electricity consumed to process the palm kernels into CPKO.

Energy Derived from Non-Fossil Fuels

Most kernel-crushing plants in Malaysia predominantly use electricity from the national grid for their processing. However, there are some kernel-crushing plants, especially those owned by plantation companies, which use alternative sources of energy. Kernel-crushing plant F was such a plant that was located within the boundaries of a palm oil mill. This plant made use of the electricity generated at the palm oil mill which used biomass as boiler fuel. Only when there was a shortage of energy, or during the shut down of the palm oil mill, was electricity from national grid used as back-up.

In order to compare the differences between the crushing plants in these two scenarios (electricity from the national grid against that from biomass as fuel), an LCIA for crushing plant F was conducted. *Figure 5* shows clearly that when the plant was located either within the compound of the palm oil mill or nearby, the impact from the diesel consumption was very little. The same applied to the potential impact from the electricity consumption from the grid, as this plant used the electricity which was generated from biomass at the palm oil mill instead of fossil fuels.

CONCLUSION

The palm oil industry now faces the challenge of having to deal with environmental issues. Mitigation using the LCA concept must be viewed as an investment for our future generation, if not for ourselves, because these efforts will translate into a concerted effort to combat the many environmental impacts resulting from mismanagement of natural resources and energy. LCA is the tool that puts the development of products, materials and their associated processing steps in the context of the most important issue of the moment, *i.e.*, sustainability.

On the whole, the production of CPKO has only two major environmental impacts within the system boundary, and both are attributed to the use of fossil fuels. The above study reveals that the use of biomass to generate energy for a kernel-crushing plant integrated in the palm oil mill facility offers the best approach to overcome the potential impact to the environment. In view of this, more kernel-crushing plants integrated with the palm oil mills should be encouraged.

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