RENEWABLE ENERGY FROM THE PALM OIL INDUSTRY*

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Palm oil mills produce crude palm oil and palm kernel or crude palm kernel oil as their main products. Considerable amounts of co-products, such as fibre (from the mesocarp), shell (from around the kernel), empty fruit bunches and palm oil mill effluent are also generated by the milling process.

Fibre and shell are the main energy sources for the palm oil mills. In 1992, fibre and shell generated about 650 million kWh to meet the energy demand of 265 palm oil mills in the country. This amounted to 2%–3% of the national energy consumption.

Other co-products like empty fruit bunches and biogas are very much under-utilized as energy resources. They have the potential of generating 1131 million kWh of electricity which is about 5% of the national energy demand.

Palm oil methyl esters and crude palm oil are being evaluated as diesel substitutes. The palm oil methyl ester mixture (palm diesel) is being run in unmodified diesel engines. So far it has passed all the tests as a diesel substitute in exhaustive field trials. Very positive results have been obtained in terms of engine wear and tear, and reduction in dark smoke, CO, CO_2 and SO_2 in the exhaust emission. Crude palm oil is run in modified diesel (Elsbett) engines. Its performance is being evaluated.

This paper discusses the potential energy available from the above-mentioned products and co-products from palm oil mills.

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INTRODUCTION

Malaysia is fortunate in having plentiful supplies of petroleum and natural gas. These two sources of energy are expected to contribute the major share of the commercial energy requirements of the nation. However, the rapid diminution of energy reserves, greater environmental awareness and increasing energy consumption as a result of rapid industrialization make it necessary to examine alternative energy resources.

Alternative energy resources such as solar and wind power appear to be promising in regard to environmental protection and renewability. However, in the Malaysian context there are several technical and socio-economic uncertainties involved in their utilization. Their long run feasibility, nevertheless, is an important aspect of the nation's research and development efforts, but their immediate application on a commercial scale is limited. What is needed is a renewable energy resource whose utilization system is already proven and operational as well as amenable to expansion without much difficulty.

This paper critically examines the potential for utilizing the products and co-products readily available from the palm oil industry as renewable energy resources.

ENERGY FROM FIBRE, SHELL AND EMPTY FRUIT BUNCHES

Elaeis guineensis is grown for its oils. Palm oil and palm kernel oil are extracted from the mesocarp and kernels of the fruits respectively. In general the fresh fruit bunches contain (by weight) about 27% palm oil, 6%–7% palm kernel, 14%–15% fibre and 6%–7% shell, and 23% empty fruit bunch material (EFB).

In Malaysia there are at present more than 2.1 million hectares of land under oil palm cultivation, and in 1992 the country produced 6.37 million tonnes of crude palm oil. In other words, a total of 31.35 million tonnes of FFB were processed (assuming a 20% palm oil extraction rate). The amounts of biomass generated are shown in *Table 1*. The heat value of each type of biomass is also indicated.

Fibre and shell

All the palm oil mills in Malaysia use fibre and shell as boiler fuel to produce steam for electricity generation for the processes of palm oil and kernel production and for other purposes within the mill complex. The fibre and shell alone can supply more

TABLE 1. BIOMASS GENERATED BY PALM OIL MILLS IN 1992

Type of Biomass	Quantity (million tonnes)	Moisture Content (%)	Oil Content (%)	Heat Value (dry) (kcal/kg)
EFB	7.3	65	5	3 700
Fibre	4.5	42	5	4 420
Shell	1.9	7	1	4 950
POME	15.9	95	1	–

EFB – Empty fruit bunch,
POME – Palm oil mill effluent,
Source: Chua (1991).

than enough electricity to meet the energy demand of a palm oil mill. It is estimated that 20 kWh of electrical energy is required to process one tonne of FFB. The energy requirement per tonne is lower in a high-capacity mill. Thus in 1992 about 627 million kWh of electricity were generated and consumed by the palm oil mills. Assuming that each mill operates on the average 400 hours per month, then together they will have a generating capacity of 132.7 MW. This constitutes about 2%–3% of the energy demand of the country. It must be mentioned here that the palm oil mills generally have excess fibre and shell which are not used and have to be disposed of separately.

It is estimated that a diesel power generator consumes 0.34 litre of diesel for every kWh of electricity output. Thus the palm oil industry saved the country about 217 million litres of diesel in 1992, valued at about RM141 million (pricing diesel at RM0.65 per litre). The energy requirement for palm oil mills is mounting as palm oil production is expected to reach 8 million tonnes in the year 2000. The fuel cost would have been very much more if diesel fuel oil was used as boiler fuel to generate steam separately for the milling processes.

The palm oil industry is indeed very fortunate in the sense that the fibre and shell can be conveniently used without further treatment as boiler fuel, provided combustion is properly controlled to avoid the production of black smoke. Another less obvious advantage of using fibre and shell as boiler fuel is that it helps to dispose of these bulky materials which would otherwise contribute to environmental pollution.

Unless and until these materials can be utilized more beneficially, it is envisaged that they will continue to be used as boiler fuel. It has commonly been taken for granted that energy is free in the palm oil mills and this has undoubtedly contributed greatly to the success of the industry.

Empty fruit bunches

Apart from fibre and shell, empty fruit bunches (EFB) are another valuable biomass co-product which can be readily converted into energy. However this material has only been utilized to a very limited extent. This is partly because there is already enough energy available from fibre and shell. Also, because of its physical nature and high moisture content (50%–65%), the EFB has to be pretreated to reduce its bulkiness and bring its moisture content to below 50%, in order to render it more easily combustible (Jorgensen, 1985; Chua, 1991). The EFB has a heat value of 3700 kcal/kg on a dry weight basis. Thus the total heat energy obtainable from the EFB in 1992 would have been 9.45×10^{12} kcalories. This is sufficient to generate about 9.9 million tonnes of steam (at 65% boiler efficiency and 620 kcal per kg of steam) and 330 million kWh of electricity. This would have saved the country 112 million litres of diesel of RM71.5 million. The above calculations assume a standard non-condensing turbo-alternator working against a back pressure of 3 bars gauge. More than double the energy could be obtained if condensing turbines working at a vacuum of 0.25 bar (absolute) were used for power generation (Chua, 1991).

The above estimate represents the total energy obtainable from the 265 palm oil mills distributed all over the country. The energy generated from a single palm oil mill will not be significant in amount and it may not be practicable for commercial use or to supply the electricity to the national grid. However, the EFB, unlike fibre, can be easily collected and transported. The production of electricity at a central power generating plant may be a viable proposition. Such central power plants could be sited at locations where there are high concentrations of palm oil mills so that the EFB and the surplus fibre and shell from the mills could be transported over a reasonable distance and at a reasonable cost to the power plants. Also, since the power plants could be independent entities, they could be operated throughout the year.

Biogas from POME

Apart from fibre, shell and EFB, palm oil mills also generate large amounts of POME which has to be treated to the level prescribed by the

Department of Environment's stringent regulations before it is allowed to be discharged into a watercourse. In a conventional palm oil mill, about 2.5m^3 of POME is generated for every tonne of palm oil produced. Hence in 1992, about 15.9 million m^3 of POME were generated. An anaerobic process is adopted by the palm oil mills to treat their POME. Biogas is the unavoidable but valuable gaseous product of such a process. The biogas from POME contains 60%–70% methane, 30%–40% carbon dioxide and a trace amount of hydrogen sulphide. Its fuel properties are shown in *Table 2* together with those of some other gaseous fuels.

About 28 m^3 of biogas are generated for every m^3 of POME treated. Thus in 1992 about 445 million m^3 of biogas were generated by all the palm oil mills together. However most of the biogas was not (and is not) recovered. It is either flared off or released into the atmosphere, in either case contributing to the greenhouse effect. So far only a few palm oil mills harness the biogas for heat and electricity generation (Quah *et al.*, 1982; Gillies and Quah, 1984; Chua, 1991). In a gas engine it was reported that about 1.8 kWh of electricity could be generated from one m^3 of biogas (Quah *et al.*, 1982). The potential energy from biogas generated by POME is shown in *Table 3*. Again, as all the palm oil mills have enough energy from fibre and shell, there is no outlet for this surplus energy. Considering the costs of storage and transportation of the biogas, perhaps the most practicable proposition would be to encourage the setting up of industries in the vicinity of the palm oil mills where the biogas energy could be directly utilized. This could result in substantial savings in energy bills (Chua, 1991).

It is estimated that one cubic metre of biogas is equivalent to 0.65 litres of diesel for electricity generation. Hence the total biogas energy could in principle, have replaced 289 million litres of diesel in 1992, worth RM188 million. Again the amount of biogas generated by individual palm oil mills is not significant for commercial exploitation. However, the economics may be feasible for mills using all the fibre, shell and EFB, as well as the biogas, to generate steam and electricity.

The total potential energy from biogas (*Table 3*) may be compared with Tenaga Nasional's estimate of Malaysian's total electricity requirement of 25 255 kWh in 1990.

TABLE 2. SOME PROPERTIES OF GASEOUS FUELS

	Biogas	**Natural Gas**	**Liquefied Petroleum Gas**
Gross calorific value (Kcal/Nm^3)	4 740– 6150	9070	24 000
Specific gravity	0.847–1.002	0.584	1.5
Ignition temperature (ºC)	650–750	650–750	450–500
Inflammable limits (%)	7.5–21	5–15	2–10
Combustion air required (m^3/m^3)	9.6	9.6	13.8

All gases evaluated at 15.5ºC, atmosphere pressure and saturated with water vapour.
Source: Quah and Gillies (1981).

TABLE 3. POTENTIAL ENERGY FROM BIOGAS

Year	Palm oil production (million tonnes)	POME (million m^3)	Biogas (million m^3)	Electricity (million kWh)
1992	6.37	15.9	445	801
2000[a]	8.0	20	560	1 008

[a]Forecast figures

PALM OIL METHYL ESTERS AS DIESEL SUBSTITUTE

Crude palm oil, crude palm stearin and crude palm kernel oil can be readily converted to mixtures of methyl esters of fatty acids. The production by PORIM/PETRONAS patented technology (Choo *et al.*, 1988, 1989; Ong *et al.*, 1989) has been adequately described recently (Ma *et al.*, 1993).

Methyl esters from crude palm oil and crude palm stearin produced by PORIM/PETRONAS technology have very similar fuel properties to those of petroleum diesel (*Table 4*). The mixture of esters from CPO has a higher cetane number than diesel (*Table 5*). It can be used directly as fuel in unmodified diesel engines, and obviously it can be used as a diesel improver. Compared to crude palm oil, the methyl ester mixture has very much improved viscosity and volatility properties. It has a pour point of 16°C. It does not contain gummy substances. However, the high pour point of the methyl ester mixture allows it to be used only in tropical countries. In testing unmixed salad oil, salad oil blended with diesel, and methyl esters of the vegetable oil in a diesel engine with a pre-combustion chamber, Volkswagen of Brazil strongly supported the choice of methyl esters as the best diesel fuel alternative (cited in Peterson *et al.,* 1983).

Over the past few years, palm oil methyl esters have been extensively tested as a diesel substitute in a wide range of engines (stationary engines, taxis, trucks, *etc.*). Very promising results have been obtained. Fuel consumption by volume is comparable to that with petroleum diesel, and the differences in engine performance are so small that an operator would not be able to detect them. The exhaust gas was found to be much cleaner: it contained comparable NOx, but less CO and CO_2. The very obvious advantage was the absence of black smoke and sulphur dioxide from the exhaust. This is truly an environmentally benign fuel substitute.

Another more scientifically designed trial involving 30 engines from a well-known manufacturer of diesel engines is near completion. The engines are mounted on buses running on long and short distance routes. A third of the engines are running on 100% methyl esters, a third on 100% petroleum diesel, and a third on a 50:50 blend of the two fuels. The engines will be thoroughly examined at the end of the trial when the vehicles have covered 300 000 km each. The vehicles are closely monitored by a team of engine experts from the manufacturer, at the normal recommended intervals. So far there have been no complaints concerning the performance or maintenance of the engines. In fact some of them were inspected at 200 000 km and it was found that they were normal, without noticeable wear and tear. Some of the engines have already travelled the required distance and have been removed for thorough inspection.

The storage properties of the palm oil methyl esters are very good. After more than six months in a 50m^3 storage tank, it was found that there was little deterioration in the quality parameters of the fuel, except that the colour had changed from orange to light yellow. This was due to the breakdown of the strongly coloured carotene compounds originally present: these are valuable, and the process of preparing the methyl esters could be modified to recover them separately.

Considering the fact that the transportation sector is one of the largest consumers of energy in the country, and also that diesel constitutes about 40% of the fuel consumption, the use of a

TABLE 4. FUEL CHARACTERISTICS OF MALAYSIAN DIESEL, METHYL ESTERS FROM CRUDE PALM OIL (CPO) AND METHYL ESTERS FROM CRUDE PALM STEARIN (CPS)

Property	Malaysian Diesel	Methyl Esters from CPO	Methyl Esters from CPS
Specific gravity ASTM D 1298 (°F)	0.8330 at 60.0°	0.8700 at 74.5°	0.871 at 78.0°
Sulphur content (%Wt) IP 242	0.10	0.04	0.002
Viscosity at 40°C (cST) ASTM D 445	4.0	4.5	4.6
Pour point (°C) ASTM D 97	15.0°	16.0°	17.0°
Distillation D 86(°C)			
I.B.P.	228.0	324.0	320.0
10%	258.0	330.0	331.0
20%	270.0	331.0	332.0
50%	298.0	334.0	335.0
90%	376.0	343.0	343.0
F.B.P.	400.0	363.0	349.0
Final recovery (%)		98.0	98.5
Cetane Index ASTM D 976	53	50	52
Gross heat of combustion (kJ/kg) ASTM D 2382	45 800	40 135	39 826
Flash point (°C) ASTM D 93	98	174	165
Conradson carbon residue (% wt) ASTM D 189	0.14	0.02	0.05

TABLE 5. CETANE NUMBERS OF CRUDE PALM OIL METHYL ESTERS, PETROLEUM DIESEL AND THEIR BLENDS

Blends		
CPO Methyl Esters (%)	**Petroleum Diesel** (%)	**Cetane Number ASTM d 613**
100	0	62.4
0	100	37.7
5	95	39.2
10	90	40.3
15	85	42.3
20	80	44.3
30	70	47.4
40	60	50.0
50	50	52.0
70	30	57.1

renewable and environmentally friendly palm oil methyl esters as a diesel substitute merits serious consideration. Perhaps for a start, heavy vehicles like buses, trucks and taxis in the high polluted areas like the Klang Valley, Johor Baharu and Prai should be encouraged to use palm oil methyl esters. Such a measure would certainly reduce the air pollution very much, especially the emission of dark smoke. In this matter government's assistance and commitment are very necessary.

CRUDE PALM OIL AS A DIESEL SUBSTITUTE

Many researchers have investigated the possibility of using vegetable oils (unmixed or blended) as diesel substitutes. A good account of their attempts was given in the 1983 JAOCS Symposium on Vegetable Oils as Diesel Fuels (Adams *et al.*, 1983; Klopfenstein and Walker, 1983; Pryde 1983; Strayer *et al.*, 1983; Ziejewski and Kaufman, 1983). The symposium revealed that vegetable oils would have good potential as alternative fuels if certain problems could be overcome satisfactorily. These include high viscosity, low volatility, and the reactivity (and consequent polymerization) of the unsaturated hydrocarbon chains if the oil is highly unsaturated. These factors will give rise to coking on the injectors, carbon deposits, sticking of oil rings and thickening and gelling of the lubricating oil as a result of contamination with the vegetable oil.

It is possible to reduce the viscosity of the vegetable oil by incorporating a heating device in the diesel engine, as has been successfully demonstrated by the manufacturer of the Elsbett engine (Yusof Basiron and Ahmad Hitam, 1992). Other factors that may have long term effects on the engine are free fatty acids and gummy substances which are found in crude vegetable oils. Incomplete combustion may contribute to undesirable deposits on the engine components. The gummy substances may cause plugging of filters. This will call for more regular and frequent services and maintenance of the engine. Currently, there are about twenty cars fitted with Elsbett engines running on unmixed crude palm oil. The long-term effects of the oil on the engine are being monitored.

CONCLUSION

The progressive escalation of energy shortages and fuel prices in recent times has led to an intensified search for viable alternative sources of energy world-wide.

The palm oil industry is fortunate in giving rise to a plentiful supply of co-products that can be readily used as energy resources. The production and application technologies have been fully demonstrated.

Energy is considered free for palm oil mills. Fibre and shell together can supply more than enough energy to meet their requirements. The electricity generated indirectly from fibre and shell represents 2-3% of the national electricity demand. Energy from biogas and empty fruit bunches has so far been largely ignored though it represents a significant 5% of the national energy demand in terms of electricity.

Palm oil methyl esters have been fully evaluated as a diesel substitute. The economic viability of the material will have to be looked into together with the environmental aspects.

With the rapid depletion of fossil fuel reserves, it is time to review critically the potential of these renewable and environment-friendly materials for energy production, and the economic opportunities for their use.

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