Oil Palm Plantations - A Plausible Renewable Source of Energy

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ABSTRACT

The paper begins by outlining the cultivation of oil palm trees in Malaysia. This is followed by a section that briefly discusses the products and practices of the oil palm plantations as well as the processes that occur in palm oil mills. The yield of the above ground production of lignocellulosic biomass is then estimated. A value of approximately 20 336 kg per 10 000 m² per year was estimated. If these biomass were to be used for energy purposes, they would be equivalent to 62.45 boe per 10 000 m² per year. Of these 16.01 boe are currently being used by the oil palm mills in their oil extraction processes. The energy potential of liquid wastes arising from the above processes is estimated, as these wastes can be used for the production of biogas. The environmental benefits arising from this practice are also briefly mentioned. Currently the oil produced is used for a variety of purposes. However if the oil were to be used for energy purposes then 10 000 m² will produce 25 boe per year. Attempts to use the oil as a motor fuel are then briefly described. The final section of the paper is devoted to a discussion of oil palm trees as an energy crop vis-a-vis the fossil fuel reserves in the country.

1. INTRODUCTION

In 1994 Malaysia produced 51% of the world production of palm oil, thus making her the world's largest producer [1]. It has been estimated that in 1996, 8040 million kg of crude palm oil and 1130 million kg of palm kernel oil were produced from an estimated planted area of 25 700 million m². Of these it was estimated that 2326 million m² have mature oil palm trees [1].

Oil palms *(Elaeis guineensis)* were first introduced into Malaysia from West Africa for planting through the botanical gardens in Singapore in 1870. Commercial cultivation however was not initiated until 1917. The first two estates to venture into oil palm plantations were the Tennamaran and Elmina Estates in Kuala Selangor [2]. Since then the area under oil palm cultivation has been increasing over the years as depicted in Table 1.

Research laboratories have also been set up by the larger plantations to look into factors that can maximize yield and minimize cost. In addition the Malaysian Government has also set up a research center, the Palm Oil Researh Institute of Malaysia (PORIM), to undertake research projects that are related to the utilization of the oil.

Table 1. Area under oil palm cultivation in Malaysia [3].

Year	Area cultivated (x 10 000 m²)
1920	404
1925	3237
1930	20 639
1935	25 900
1940	31 566
1950	38 850
1955	44 921
1960	54 674
1965	93 990
1970	308 515
1975	604 551
1980	1 048 237
1985	1 482 000
1990	1 984 000
1995	2 507 000

2. PRODUCT OF THE OIL PALM PLANTATION

In Malaysia, the oil palm tree (Fig. 1) is cultivated for its oil. Oil extracted from the pericarp/mesocarp of ripe fruits is called palm oil while oil extracted from the kernels of the nuts of the fruit is called palm kernel oil. These oils are presently used by the world community for a variety of purposes as depicted in Fig. 2 [4].

Fig. 1. The oil palm tree.

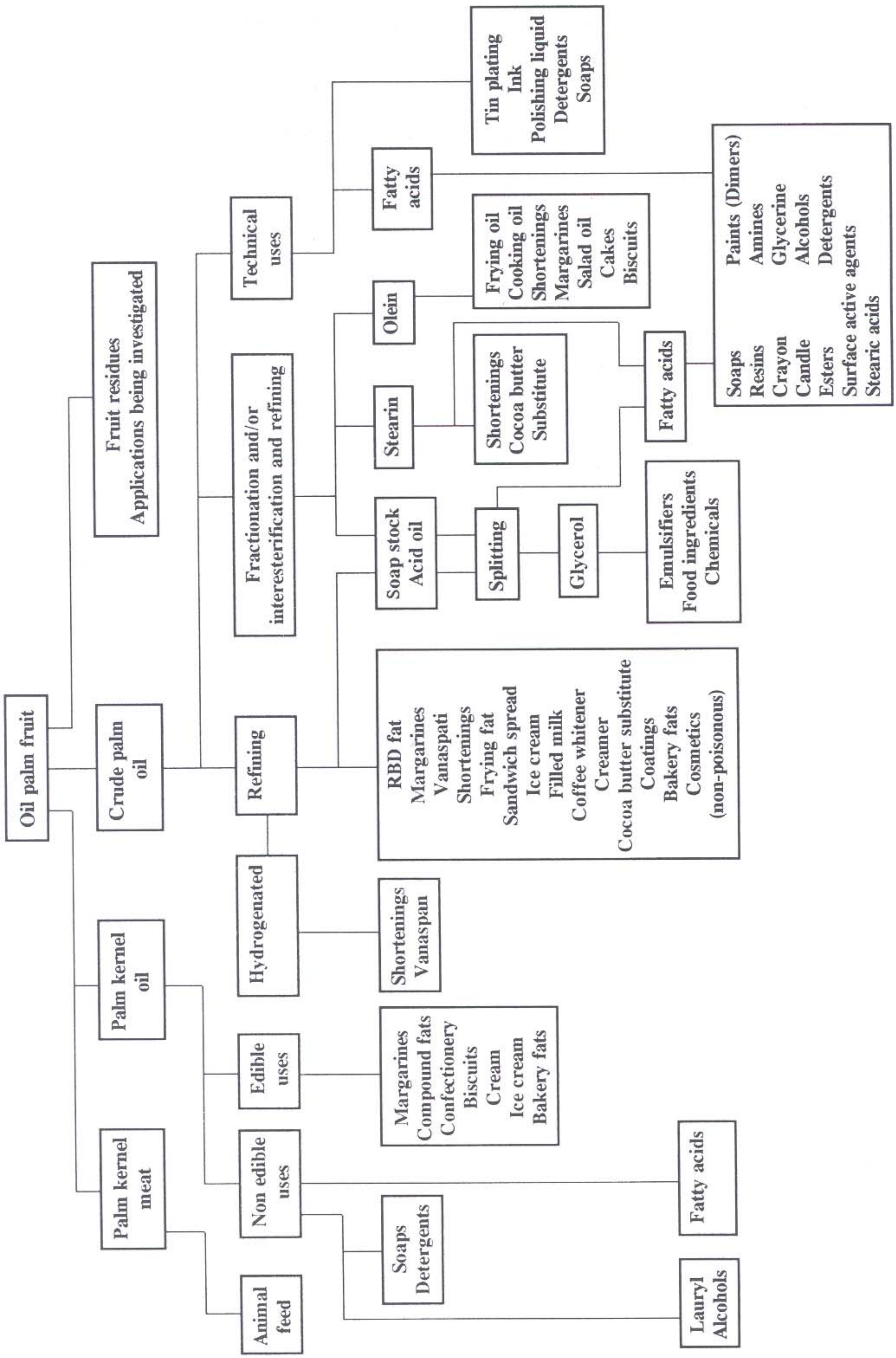

Fig. 2. Palm oil utilization chart.

The oils produced in Malaysia are consumed locally as well as exported. In 1996, the estimated export earning from palm oil and palm kernel oil were respectively, RM 8.18×10^9 and RM 0.91×10^9 [1] [US$ 1 = RM 3.8].

Figure 3 is a picture of the oil palm fruits. The fruits are produced in bunches. To get to the ripe fruit bunches so that they can be harvested, palm fronds may have to be cut. This is called pruning. Pruning can also be done on a periodic basis and not necessarily at the time of fruit harvesting. This practice generates large quantities of lignocellulosic biomass. Besides easier harvesting, other beneficial effects of pruning include easier visual assessment of fruit ripeness and easier access for pollination [5].

Fig. 3. Ripe bunches of oil palm fruits.

The harvested fruit bunches called fresh fruit bunches (FFB) are then gathered and transported to palm oil mills where oil extraction takes place. Figure 4 is a diagrammatic description of the process that happens in the palm oil mills.

From Fig. 4, the author finds that the process of oil extraction results in the production of both solid and liquid wastes (Some like to call them coproducts). The solid wastes which are mostly lignocellulose are in the form of empty fruit bunches (EFB), fibers from the pericarp/ mesocarp of the fruits, and shells from the nuts of the fruit. The liquid waste produced is the result of the extraction process which requires large quantities of water. The liquid waste is called palm oil mill effluents (POME).

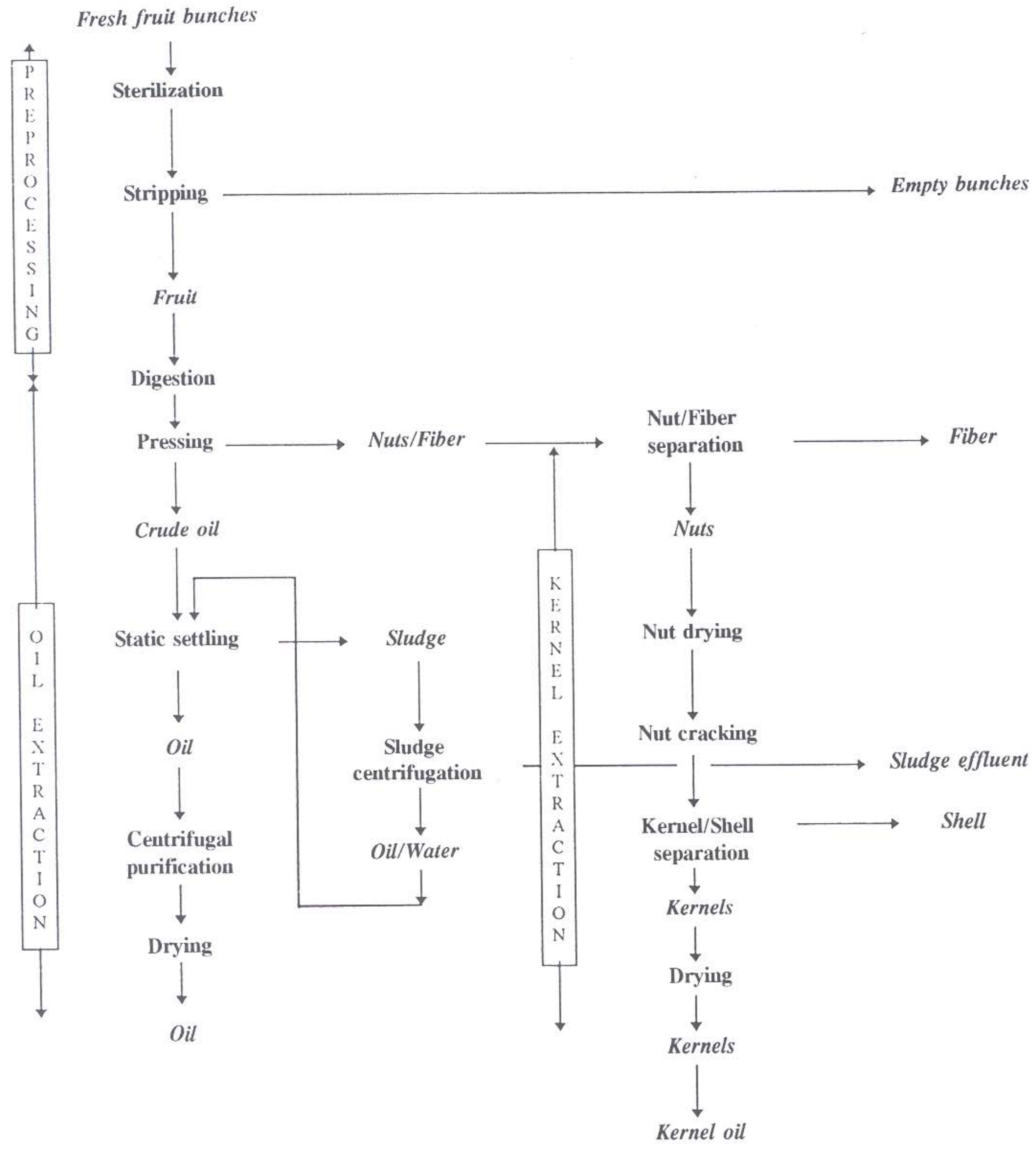

Fig. 4. Flow chart of palm oil and palm kernel oil extraction process.

Because of declining yields, palm trees are replanted after 25 to 30 years. The replanting activity if carried out on a large scale will also result in the generation of large quantities of biomass in the form of felled tree trunks and fronds.

3. ENERGY POTENTIAL OF THE SOLID BIOWASTES

Lim [6] reported that the dry matter yields of shells, fruit fibers and empty fruit bunches are, respectively, 2780 kg; 1853 kg and 1483 kg per 10 000 m^2 per year. The energy amounts potentially available from biomass are, respectively, 10.15, 5.86 and 4.92 barrels of oil equivalent (boe) per 10 000 m^2 per year.

Mohammad Husin, et al. [7] on the other hand reported that roughly 11 000 kg of dry fronds are annually pruned from 10 000 m^2 of land. The energy content of these works out to be 33.39 boe per 10 000 m^2 per year, as the calorific value of fronds is 18.73 x 10^6 J/kg oven dry weight [6].

Lim (6) also estimated that, at the time of replanting of 10 000 m^2 of land, 66 000 kg of dry palm trunks and 14 400 kg of dry fronds are generated. Assuming that replanting is after 25 years, the average annual amount of biomass available as a result of replanting works out to be 2640 kg of dry trunks and 580 kg of dry fronds. The barrels of oil equivalents of these are 6.37 and 1.76, respectively.

From the above figures it can be concluded that the dry lignocellulose biomass yield from oil palm plantations is 20 336 kg per 10 000 m^2 per year with an energy content of 62.45 boe per 10 000 m^2 per year.

The extraction of oil from FFB requires energy in the form of electricity and steam. Currently the energy requirements of all palm oil mills in Malaysia are met by the use of fibers and shells where cogeneration is widely practised. In fact in some mills, there is an excess of shell, which are then sold to other mills that further refine the crude palm oil [6]. This situation has been going on since the inception of palm oil mills in the 1960's. As such, of the 62.45 boe that are available per 10 000 m^2 per year, roughly 16.01 boe are currently being put to use as a source of energy.

4. ENERGY POTENTIAL OF LIQUID WASTES - BIOGAS FROM POME

Large quantities of water are required for sterilizing the fruits and for oil clarification when palm oil is extracted from the FFB. As a result large quantities of liquid wastes called palm oil effluents (POME) are produced. The characteristics of raw POME, which is a brownish colloidal suspension, as reported by Chong and Zaharuddin [8] are shown in Table 2.

From the data provided by two palm oil mills [9, 10] the author estimates that 3.54 m^3 of POME are generated for each 10 000 m^2 of crude palm oil produced. Since in 1996 Malaysia produced 8040 million kg of crude palm oil, the total amount of POME produced works out to be 28.46 million m^3.

The BOD, suspended solids, oil and grease and total Kjeldah nitrogen values of the POME are way above the values permitted by the Department of Environment, which are respectively, 100 mg l^{-1}, 400 mg l^{-1}, 50 mg l^{-1} and 200 mg l^{-1}. As such, if raw POME are discharged into waterways without treatment, they are an environmental hazard. Presently what most oil palm mills do is to allow the POME to degrade in open ponds that are 3 m to 4 m deep until the BOD values drop to less than 50 mgl^{-1}, a value acceptable by the Department of Environment, before

Table 2. Characteristics of raw POME.

Biochemical oxygen demand (BOD)	25 000 mg l^{-1}
Chemical oxygen demand (COD)	53 600 mg l^{-1}
Total solids	43 600 mg l^{-1}
Suspended soilds	19 000 mg l^{-1}
Volatile solids	36 500 mg l^{-1}
Oil and grease	8400 mg l^{-1}
Ammoniacal nitrogen	35 mg l^{-1}
Total Kjeldahl nitrogen	770 mg l^{-1}
pH	4
Temperature	80 °C to 90 °C

they are discharged [11]. For this to occur the POME are held for 40 days in the ponds. Ponding is practised as it is a relatively cheap system to adopt. In this process CH_4 is produced and allowed to escape into the atmosphere. From the global warming point of view this practice should be deplored.

Since allowing POME to degrade anaerobically produces CH_4, attempts have therefore been initiated in a couple of palm oil mills to utilize the POME for biogas production. As far as the author knows only two mills are doing this. The experience from one mill indicates that with their production of 680 m³ of POME per day, 19 000 m³ of biogas per day can be produced in digester tanks [10]. The biogas produced is found to have the following characteristics:

54% to 80% CH_4
20% to 46% CO_2
560 ppm to 2580 ppm of H_2S
Calorific value of 4740 kcal/m³ to 6150 kcal/m³

Assuming an average calorific value of 5445 kcal/m³, the energy potentially available from the anaerobic digestion of 680 m³ of POME is 434.5 GJ/day, which is equivalent to about 70.4 barrels of oil equivalent per day.

As mentioned, in 1996 Malaysia produced 28.46 million m³ of POME. This amount of effluent, if digested to produce biogas, will result in an energy production of 2.95×10^6 boe and this comes from an area of 23 260 million m² of mature oil palm trees. Thus, considering 10 000 m² basis of mature trees, the energy potentially available from POME is roughly 1.27 boe per year.

The data that the author gathered from reports show that in one mill, which produces about 13 000 m³ of biogas per day, all the gas are utilized [11], while in a second mill only about 17% of the biogas produced is used in a gas engine after H_2S removal while the remainder is flared [10]. Thus the current total amount of biogas utilized is about 1600 m³ per day, i.e., 59.3 boe per day or 2.16×10^4 boe per year. This is less than 1% of the 2.95×10^6 boe that were available in 1996. As such the potential of harnessing POME for fuel is still great indeed. Not only will this contribute to the energy supply of the country, it will also have a positive effect on the environment. The practice of harnessing POME for biogas has another advantage in that the products of the digestion process can be used as an organic fertilizer in the oil palm plantation itself, thus reducing the demand for artificial fertilizers. The discharge of the digester from one mill has the following properties [10] as shown in Table 3.

Table 3. Properties of digester discharge.

pH	7.3
BOD	3000 ppm
Total nitrogen	900 ppm
Phosphorus	120 ppm
Potassium	1800 ppm
Total volatile solids (TVS)	13 000 ppm

5. PRODUCTION OF OIL

The 1996/97 Economic Report estimated that for 1996, 8040 million kg of crude palm oil and 1130 million kg of palm kernel oil will be produced from an average of 23 260 million m² of mature oil palm trees. Thus on an average a total of 3940 kg of oil per year can be harvested from 10 000 m² of land. Abd. Halim Shamsuddin [12] reported that the calorific value of palm oil is 39 357 kJ/kg. Since the calorific value of palm kernel oil is comparable to that of crude palm oil [13] the energy content of 3940 kg of oil works out to be roughly 25 boe. Thus 10 000 m² of land will produce an energy equivalent of 25 boe per year if all the oil produced are used for energy purposes.

6. PALM OIL AS LIQUID FUEL

A project to investigate the feasibility of using the crude palm oil (CPO) as a liquid fuel was initiated in 1984 [11]. This project was jointly undertaken by the Palm Oil Research Institute of Malaysia (PORIM), Mitsui of Japan, and Elsbett Konstruktion of Germany. CPO was tested on the German Elsbett engine which can also run using petroleum derived diesel and other vegetable oils. To date trials done on commercial vehicles such as buses have been completed and the results are encouraging. When compared to using diesel, CPO results in lower emissions and less wear and tear on the engines. Trials on passenger car such as the Mercedez Benz are still in progress though preliminary results show that CPO gives about 14.3 km to the liter while diesel gives about 10.9 km to the liter [14]. At traded prices in the early part of 1997, the cost of using CPO is a little over 100 sen per liter while diesel cost is 65.5 sen per liter (RM 1.00 equals 100 sen = US$ 0.26). This therefore translates to a cost of around 7.5 sen per km when CPO is used and 6.0 sen per km when diesel is used. Thus at current prices and from a purely economic consideration it appears that using CPO instead of diesel is not an attractive proposition. However, if the effects on the environment are factored in, the use of CPO then becomes attractive especially in a scenario where CPO prices drop while that of diesel increases. CPO is not toxic flammable or explosive. It does not emit much SO_2 when burned or result in a net increase in atmospheric CO_2 concentration. These are pluses which should be given due recognition.

Prior to the above study that uses CPO directly as an engine fuel, studies have also been made to convert CPO into its methylester which can then be used in conventional diesel engines. [12, 15]. The palm oil diesel produced has the same burning qualities, chemical stability and ignition properties as petroleum diesel. PORIM has set up a pilot plant to demonstrate the viability of producing palm diesel [15]. However, as far as the author is aware, this technology has not been taken up for commercial implementation as the additional process for conversion to methylester has made the palm diesel more expensive.

7. DISCUSSION AND CONCLUSIONS

The above data indicate that the total energy that can potentially be harnessed from the above ground lignocellulosic biomass and oil of the oil palm plantations is roughly 88.7 boe per 10 000 m^2 per year. Even if one were to argue that 16.01 boe have been used for the extraction of oil and therefore not really available for use by others, the balance of 72.7 boe per 10 000 m^2 per year is still a respectable amount.

If the above energy potential be compared to the various plant species such as poplars, willows and Miscanthus that are currently being field tested as potential energy crops in Europe, oil palm stands out as a much superior energy crop. For example, willows cultivated in Sweden [16] give a biomass yield of about 12 000 kg of dry matter per 10 000 m^2 per year. This translates into an energy potential of roughly 38.3 boe per 10 000 m^2 per year assuming that the calorific value of the biomass produced is 19.7 GJ per dry 1000 kg. Similar figures can be calculated for the other plant species.

Since modern economies depend very much on the availability of electric power and liquid transportation fuel, the cultivation of oil palms for energy purposes is indeed attractive in that all three forms of fuels, solid, liquid and gas can be produced. In addition Malaysia's experiences with the palm oil mills indicate that producing electric power from the lignocellulosic biomass is not a problem though it is admitted that conversion efficiencies can be further improved. Furthermore the field tests done with CPO as a motor fuel are also very encouraging.

Looking at the implications of the above data from a more local perspective, though Malaysia is currently a net exporter of oil and gas, it has been estimated that her fossil fuel reserves will last for another 40 or so years. In this scenario it is envisaged that there is no net export of her fossil fuel reserves [17]. This however is not the case. As such it is prudent for the country to start considering for the future, alternative sources of energy. Local experience in producing and using biomass makes bioenergy a feasible option to be given serious attention. The discussion above on oil palm indicates that the crop presents an attractive consideration. After all some 80 years of experience in cultivating the crop on a large scale is acquired and in addition, oil palm can grow in virtually every part of the country. Currently Malaysia's per capita energy consumption is around 12 boe per year [17]. Thus 10 000 m^2 of land cultivated with oil palm is sufficient to meet all the energy requirements of 7.4 persons. With a present population of around 20 million, it is needed to cultivate 27 000 million m^2 of oil palms [18]. Since the total land area of Malaysia is about 33 000 million m^2, the 27 000 million m^2 above constitute just under 8% of our land area. Thus with that area cultivated with oil palms Malaysia will be able to meet all our current energy needs. Incidentally the 27 000 million m^2 mentioned above happen to be also close to the 25 700 million m^2 that in 1996 were planted with oil palms. As such it can be conluded that Malaysia can be self-sufficient in energy if the biomass option is selected as an alternative source of energy.

8. REFERENCES

1. Ministry of Finance. *Economic Reports (1986/1987, 1991/92, 1994/95, 1995/97).* Kuala

Lumpur: Government of Malaysia.
2. Khozirah Shaari, and Khoo, K.C. 1991. Introduction. In *Oil Palm Stem Utilisation- Review of Research*. Research Phamplet No. 107. Kuala Lumpur: FRIM.
3. Lim, K.O. 1986. The future energy potential of replanting wastes in Malaysia. *Renewable Energy Review Journal* 8: 76-85.
4. Ong, A.S.H. (unpublished and undated).
5. Corley, R.H.V.; Hardon, J.J.; and Wood, B.J. 1982. *Developments in Crop Science 1. Oil Palm Research*. Amsterdam: Elservier Scientific Publishing.
6. Lim, K.O. 1986. The energy potential and current utilisation of agriculture and logging wastes in Malaysia. *Renewable Energy Review Journal* 8: 57-75.
7. Mohamad B. Husin; Abd Halim b Hj. Hassan; and Ahmad Tarmizi B. Mohammed. 1986. *Availability and Potential Utilization of Oil Palm Trunks and Fronds up to the year 2000*. PORIM occasional paper. Kuala Lumpur: PORIM.
8. Chong, C.N., and A. Zaharudin Idrus. 1988. Biomass energy potential in Malaysia. *ASEAN Journal of Science and Technology Development* 5(2): 15-27.
9. Chua, E.H. 1996. Malpom Industries, Nibong Tebal, Penang (personal communication).
10. Tan, H.J. 1996. Tennamaram Palm Oil Mill, Batang Berjuntai Selangor (personal communication).
11. See, Y.A. 1996. *STAR Publications*. July 16, 1996.
12. Adb. Halim Shamsuddin. 1989. Palm oil products and wastes as alternative energy sources. *RERIC International Energy Journal* 11 (2): 25-33.
13. Boey, P.L. 1997. Personal communication.
14. Tan, C.L. 1991. *STAR Publications*. Dec. 22, 1991.
15. Choo, Y.M.; Ma A.N.; and Yusof Basiron. 1993. Palm oil methylesters as fuel: Palm diesel. *PORIM Information Series*. Oct. 1993.
16. Nutek Info. 1996. *Renewable Energy Technologies in Sweden*. Stockholm: Nutek Info.
17. Lim, K.O. 1996. Our energy situation - More positive actions needed. *The Malaysian Technologist* 1: 17-27.
18. N. Shashi Kala. 1990. *STAR Publications*. July 31, 1990.