Converting Waste Oil Palm Trees into a Resource

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Acknowledgement

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Compiled by

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List of Acronyms

ASTM	American Society for Testing and Materials
BCR	Benefit Cost Ratio
C	Carbon
Ca	Calcium
CDM	Clean Development Mechanism
CERs	Carbon Emission Reduction
CHONS	Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur
CO_2	Carbon dioxide
CO	Carbon Monoxide
CPO	Crude palm oil
CV	Calorific Value
DOE	Department of the Environment
EFB	Empty fruit bunches
EST	Environmentally Sound Technology
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FELDA	Federal Land Development Agency
FFB	Fresh fruit bunches
FFPRI	Forestry and Forest Products Research Institute
FRIM	Forest Research Institute Malaysia
GEF	Global Environment Facility
GHG	Green house gases
GNI	Gross National Income
H	Hydrogen
HC	Hydrocarbon
HPLC	High-Performance Liquid Chromatography
IPPC	Intergovernmental Panel on Climate Change
IRR	Internal rate of Return
JAS	Japanese Agricultural Standard
JIRCAS	Japan International Research Centre for Agricultural Sciences
K	Potassium
KLK	Kuala Lumpur Kepong Berhad
KPPK	Ministry of Plantation Industries and Commodity
LKPP	Lembaga Kemajuan Perusahaan Pertanian
LVL	Laminated Veneer Lumber
Mg	Magnesium
MARDI	Malaysian Agriculture and Development Institute

MDF	Medium Density Fibreboard
MEAs	Multilateral Environmental Agreements
MOA	Ministry of Agriculture
MPOB	Malaysian Palm Oil Board
MTDC	Malaysian Technology Development Corporation
MW	Mega Watt
N	Nitrogen
NKEA	National Key Economic Areas
NPV	Net Present Value
O_2	Oxygen
OPF	Oil Palm Frond
OPT	Oil Palm Trunk
P	Phosphorus
PKO	Palm kernel oil
PKS	Palm Kernel Shell
POIC	Palm Oil Industry Cluster, Sabah
POME	Palm Oil Mill Effluent
R&D	Research and Development
RE	Renewable Energy
RISDA	Rubber Industry Smallholders Development Authority
RM	Ringgit Malaysia
ROA	Return on Assets
ROI	Return on Investments
S	Sulphur
SEDA	Sustainable Energy Development Authority
SIRIM	Standards Industrial Research Institute Malaysia
SREP	Small Renewable Energy Project
SSR	Sap squeezed residues
UMP	Universiti Malaysia Pahang
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UPM	Universiti Putra Malaysia
USM	Universiti Sains Malaysia
USD	US Dollar
UTP	Universiti Teknologi Petronas
WPT	Waste oil palm trees

Executive Summary

Oil palm trees are the most important plantation crop in Malaysia and Indonesia. The plantations cover an area of roughly 4.7 million hectares in Malaysia and 5 million hectares in Indonesia with about 100-130 trees per hectare. The oil palm tree, which bears fruit at the age of approximately two to three years, has an economic life of approximately 25-30 years, upon which the tree is felled for replanting. As the first plantations started in the mid-1980s, felling of trees has already begun, with several million trees scheduled to be felled every year for the foreseeable future. In the coming years, a large quantity of biomass waste will therefore be generated in Indonesia and Malaysia.

Currently, the resource is under-utilized. The felled trees are not used productively with any consistency, and are often shredded, filled in trenches and left to decompose naturally. In order to explore potential uses for this biomass, a study was carried out in Malaysia to determine the feasibility of converting waste oil palm trees (WPT) into a resource, either as raw material for various industrial applications or for utilization in energy generation.

A baseline study on the quantity, characteristics and current uses of WPT was carried out. The baseline study projected that WPT availability within the next 20 years would be promising, with a maximum availability of 18,561,060 trees in the year 2022.This would in turn generate dried biomass material of about 15.2 million tons. WPT biomass represents approximately 18.6% of the total biomass generated annually in Malaysia.

Being lignocellulosic in nature and thus similar to wood, WPT biomass presents the possibility of being utilized in similar value added products. However, differing characteristics from wood, such as high moisture content and a fibrous nature, make it difficult for established wood based industries in Malaysia to exploit WPT's potential. Although various options for its utilization have emerged from R&D, very few products manufactured from WPT are currently being commercialized. In general, products from WPT that have potential to be developed but are still in the R&D stage include: panel products, sugar, chemical derivatives, bioethanol, pulp and paper and dietary supplements. Products being developed by industries at the pilot scale stage and prepared for commercial production include: plywood, lumber, flooring, micro-crystalline cellulose and animal feed pellets.

Products developed from WPT are able to sequester carbon dioxide directly and indirectly for a better environment. The calculation of GHG emissions showed that the average amount of CO_2 emitted from the decomposition of WPT annually, available in years 2011-2032, would be equivalent to 14.19 million tons of CO_2.

The amount of CO_2 that could be sequestered from the manufacture of potential products was also calculated. Assuming that 50% of the annual availability of WPT in Malaysia from years 2011-2032 would be converted, it was estimated that GHG emissions would be reduced by 8.11% through plywood and flooring manufacture, 20.50% through lumber manufacture, 1.95% through bioethanol production from sap, and 21.35% through animal feed and microcrystalline cellulose production.

Giving additional consideration to current and future market demand, it was concluded that a combination of bioethanol and fuel pellets produced from WPT, when used as a replacement for fossil fuel, gave the best carbon offsets, at a total of 39.87%. Therefore, the most environmentally sound technologies (ESTs) for converting WPT into an energy resource were found to be:

- fermentation to produce bioethanol from oil palm trunk sap
- briquetting to produce fuel pellets from the sap squeezed residues

A techno-economic feasibility study was carried out to provide a cash flow analysis and determine the financial viability of setting up an integrated bioethanol and fuel pellet plant. The plant was projected to operate at a production capacity of 100 tons of bioethanol and 700 tons of fuel pellets per day. The required fixed investment was estimated to be RM79 million (USD26 million), with an estimated annual operating cost of RM1,473 million (USD486 million). The financial analysis projected a net present value (NPV) obtained of RM211 million (USD 70.3 million), with a 39% internal rate of return (IRR), a cost benefit ratio (BCR) of 1.28 and a payback period of four years.

A break-even analysis showed that the plant needed to produce 95,984 tons of bioethanol and 936,210 tons of fuel pellets, which would generate revenues of RM266 million (USD89 million) for bioethanol and RM300 million (USD100 million) for fuel pellets. Any production over and above these levels could be expected to begin generating net profits.

In conclusion, the business proposal for converting WPT into renewable energy looks promising, given the demand for green products globally. The ideal potential business partners would be plantation owners who own the raw material source (WPT), and organizations such as the POIC (Palm Oil Industry Cluster) which can provide the infrastructure needed for the production line.

The financial analysis demonstrates that combining the production of bioethanol with fuel pellets in a single production facility is a sound business investment. Applying the principles outlined in the study can result in substantial benefits, both in terms of boosting the economy and preserving the environment of Malaysia for generations to come.

1. Chapter 1: Characterization and quantification of waste oil palm trees in Malaysia

1.1 Introduction

1.1.1 Background

The oil palm tree (Elaeis guineensis) originated from the tropical rain forests of West Africa. It was introduced into Malaysia in 1870 through the Singapore Botanic Gardens as an ornamental tree. Once its commercial value was recognized, the tree was grown in plantations on a large scale. The oil palm tree bears fruit at the age of about two to three years. The fruit takes about five to six months to develop before it is ready for harvest. Its economic life is approximately 25-30 years, at which point the tree is felled for replanting. The fruits are developed in large condensed infructescence and are usually called fresh fruit bunches (FFB). The size and weight of each bunch varies considerably depending on the age and growing conditions. The weight ranges from 8-16 kg per bunch. Palm oil from the fruit is an important export commodity for Malaysia. The commodity is exported in the form of crude palm oil (CPO) and palm kernel oil (PKO). Palm oil is the second Gross National Income (GNI) product of Malaysia after electronics, with a total contribution of RM52.7 billion annually. There are 4.7 million hectares of oil palm trees in Malaysia, representing 14% of the total land area. One hectare of land constitutes an average of 140 palm trees. The oil from one tree constitutes only 10% of the total biomass, leaving 90% available during felling for replanting or further land development activities. Currently, these felled palm trees are being shredded and left in the field for mulching/soil regeneration purposes.

The impact from management of the end life of palm trees is one of the major challenges at the local, national and international levels. Malaysia is party to a number of Multilateral Environmental Agreements (MEAs), including the Rio Conventions on biological diversity, climate change and desertification. Although considerable past and on-going capacity initiatives have been or are being undertaken, there is still much room for improvement at the individual, institutional and systemic levels to implement these conventions. Malaysia signed the UNFCCC on 9 June 1993 and subsequently became a party to the Convention by ratification on 13 July 1994. Malaysia is a Non-Annex 1 Party to the UNFCCC. Therefore, it has no special obligations with regard to reducing emissions of greenhouse gases (GHG) under the Kyoto Protocol. Following the ratification of the Convention, efforts were strengthened to address climate change in Malaysia, with climate change considerations being included in various sectors under the heading of sustainable development.

In this regard one of the important focus areas is waste agricultural biomass, where waste oil palm trees contribute significantly. There is a high potential for converting waste oil palm trees into a resource such as providing energy or other value added products. This would reduce greenhouse gas emissions in two ways:

- GHG emissions from rotten waste biomass would be avoided
- GHG emissions would be reduced when replacing fossil fuel with waste biomass as an energy source.

1.1.2 Scope and objectives

The scope of this report is to establish baseline data on characterization and quantification of the potential waste oil palm trees (WPT) that will be available in Malaysia after their productive life cycle. Future projections of availability will be presented for the purposes of exploiting WPT as a resource material. The biomass reported here includes only that which is derived from the plantation activities of the palm oil industry in Malaysia.

The objectives of this report are to present the physical and chemical characteristics of the palm trees after their productive life i.e. at the age of 25 years and above. The annual availability of these waste oil palm trees will be determined based on projections from the annual hectare data of planted palm trees in Malaysia. Further quantification of the nutrient values of the material will also be reported.

1.2 Characterization of waste oil palm trees (WPT)

1.2.1 Characterization of waste oil palm trees

The characterization of waste oil palm trees was obtained from published research and development reports and annual data from various agencies in Malaysia. Additional quantification of the chemical characteristics was calculated to establish the amounts of chemicals available from these waste oil palm trees that could be beneficial as a resource material for other industries.

WPT at 25 years of age is composed of various physical parts (figure 1.2.1). Table 1.2.1.1 shows the physical components of the tree that will be obtained during felling with an estimated oven dried weight. The major component by fresh weight is the trunk (70%), followed by rachis (20.5%) and leaflets (6.53%). The moisture contents (based on O.D. weight) of the various components varies between 95% and 78%. Since one hectare of an oil palm plantation consists of between 136-140 trees, the total amount of dry matter (tons/ha) of the various components available during felling on a per hectare basis can also be estimated.

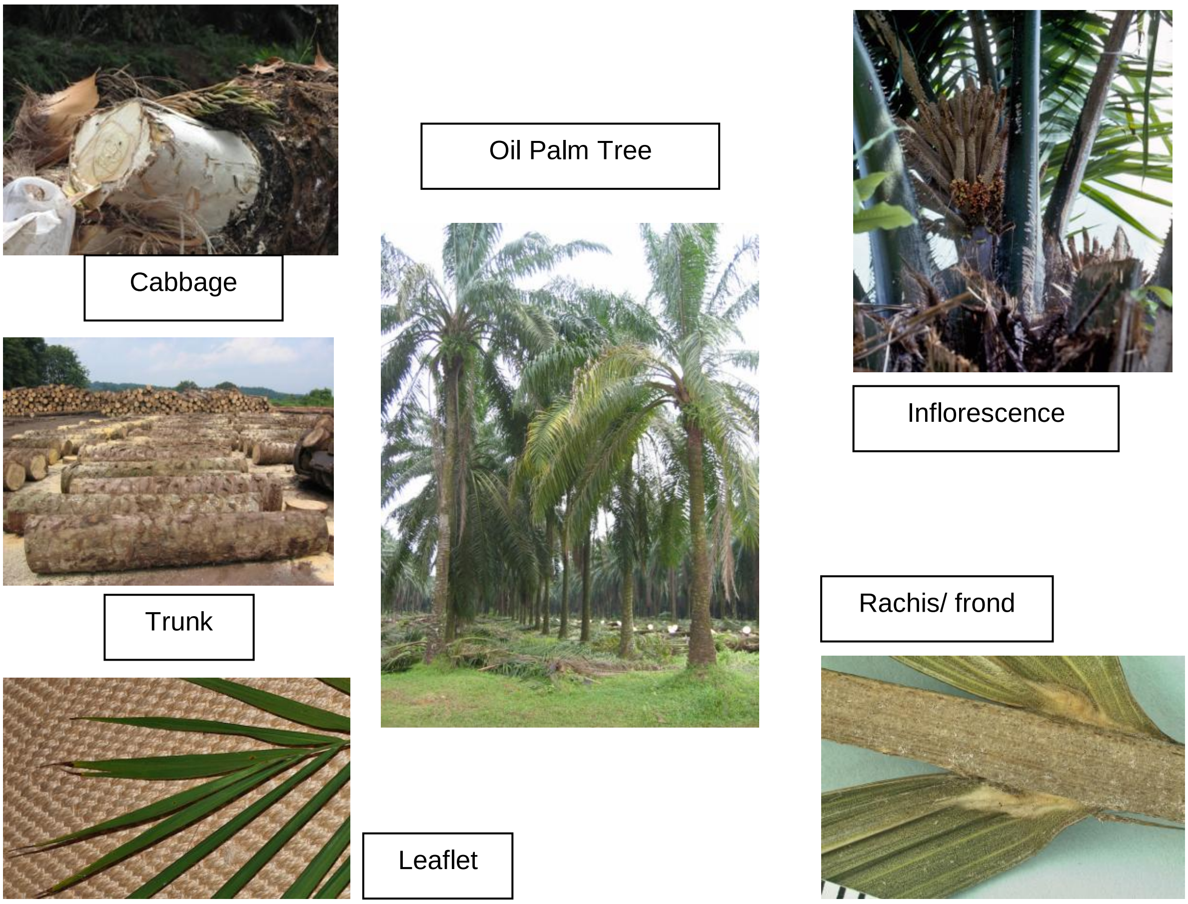

Figure 1.2.1

Components of an oil palm tree

Table 1.2.1.1

Composition of one palm tree at felling

WPT component	*Average fresh weight (kg)*	*Weight percentage (%)*	*Estimated oven dried (OD) weight (kg/tree)*	*Oven dried weight (ton/ha)*
Trunk	1507.50	70.0	301.50	41.07
Leaflets	145.00	6.53	58.00	7.69
Rachis	452.50	20.5	117.70	16.00
Spears	42.75	1.92	9.40	1.28
Cabbage	44.50	2.00	4.50	0.60
Inflorescence	134.50	1.11	6.30	17.56
Total weight	2217.50	100.00	497.30	0.86

Source: Khalid et al. (1999)

The palm oil industry in Malaysia includes plantation (upstream) and mill (downstream) activities. These activities generate various types of residues that are also reported as the residues from the palm oil industries. The type and quantity of the biomass and residues generated in 1998 from these activities and their level of utilization are shown in table 1.2.1.2. Most of these biomass and residues are used within the system for mulching/fertilizer and for energy production at the mill. From these, the biomass residues generated from replanting activities are only the trunks and fronds at replanting. Pruned fronds are available all year round during fruit harvesting.

Table 1.2.1.2

Level of utilization of oil palm biomass residues in Malaysia (1998)

Biomass	*Quantity produced (mil tons)*	*Quantity utilized (mil tons)*	*Utilized (%)*	*Method of utilization*
Pruned fronds	27.20	25.83	95	Inter-row mulching in plantations
Trunks and fronds at replanting	1.38	1.10	80	Left to degrade in the fields as mulch to newly planted palms
Mesocarp Fibre	3.56	3.20	90	Fuel
Palm Kernel Shell	2.41	2.17	90	Fuel
Palm Oil Mill Effluent (POME)	1.43	0.50	35	Nutrient source & organic fertilizer
Empty Fruit Bunch (EFB)	3.38	2.20	65	Left to degrade in the fields as mulch and bunch ash
Crude Palm oil (CPO)	39.36	35.00	-	-

Source: Elbersen, 2004

Although major portions of the felled trunks and fronds are reported being used as mulch, there have been no reports on the quantity actually required by young palm trees, since fertilizers are still being applied at the same rate for mulched and un-mulched trees. Mulching has been reported as a means of soil surface moisture retention, and is also being carried out in oil palm plantations by means of cover crops. The other 20% of the WPT is probably being wasted away when poisoning methods are used to dispose of old palm trees. WPT is also used by local communities for temporary structural use such as small bridges and for road maintenance around the village and plantations.

1.2.2 Chemical composition from proximate analysis of WPT

The chemical composition of the palm trunks, fronds and bark from proximate analysis taken from two sources is shown in table 1.2.2.1. The lignin, holo-cellulose and alpha-cellulose content of each were reported to be 18.1%, 76.3%, and 45.9% for the oil palm trunk, and 18.3%, 80.5% and 46.6% for oil palm fronds respectively. The highest amount of lignin was found in the bark (21.85%), followed by fronds (18.3%) and trunk (18.1%). The highest amount of extractives was also found in the bark (10.0%).

Table 1.2.2.1

Chemical composition of oil palm biomass (% of dry weight)

Component	*Oil palm trunk*	*Oil palm fronds*	**Bark*
Lignin	18.10	18.30	21.85
Hemi-cellulose	25.30	33.90	58.95
Alfa cellulose	45.90	46.60	18.87
Holo-cellulose	76.30	80.50	77.82
Ash	1.10	2.50	-
Alcohol-benzene solubility	1.80	5.00	-
*Extractives	5.35	1.40	10.00

Source: Oil palm biomass (www.bfdic.com) & Hashim et al. 2011

Table 1.2.2.2

Starch and sugar contents of different parts of the oil palm

Part of Oil Palm	*Starch*	*Glucose (mg/ml)*	*Xylose (mg/ml)*	*Arabinose (mg/ml)*	*Fructose (mg/ml*	*Total sugar (mg/ml)*
Bark	4.14	3.53	6.55	1.15	0.22	11.42
Leaves	2.53	2.17	3.79	1.70	-	7.66
Fronds	3.10	5.31	6.50	1.33	-	13.14
Mid-part of trunk	12.19	5.97	6.61	1.09	-	13.67
Core-part of trunk	17.17	6.55	6.20	1.31	0.04	14.06
* Sap extracted from trunk (volume per trunk – 200 L)						
Core (24% wt. of trunk)	-	85.2	0.7	6.5	4.1	96.5
Middle (56.7% wt. of trunk)	-	52.2	0.8	3.0	3.1	59.1
Outer (19% wt. of trunk)	-	13.1	1.4	1.9	2.1	18.5

*Source: Hashim et al. 2011 & * Kosugi et al.2010*

The starch and sugar contents of the palm tree components are shown in table 1.2.2.2. The highest starch and total sugar contents are found in the core of the trunk. Total sugars were composed of glucose, xylose, arabinose and fructose with high values found in the core trunk (6.55 mg/ml), bark (6.55 mg/ml), leaves (1.70 mg/ml) and bark (0.22 mg/ml) respectively. From these values it can be concluded that the trunk would be a valuable resource material for sugars and starch. The oil palm trunk sap can also be extracted. The sugar compositions of the sap are listed in table 1.2.2.2, the major component being glucose. This glucose can be a potential feedstock for bioethanol production through fermentation. Saps from parts of the trunk have different concentrations of sugar with higher values in the inner portion. Approximately 200 litres of sap can be extracted from one oil palm trunk with an average length of 27 feet, producing a total sugar content of 106 kg. This sap can be converted through a fermentation process to produce about 68.6 litres of bioethanol. Therefore, a total of 9,604 L can be produced from one ha of WPT, demonstrating that bioethanol has considerable potential as a by-product of WPT.

1.2.3 Macro nutrient contents

Different parts of WPT have different nutrient value contents. The composition of nutrients enables the WPT to be valued for various applications, namely for fertilizers and animal feed. The percentage of nutrient contents for different parts of WPT and the weight of nutrients per palm that will be available at time of felling are presented in table 1.2.3.1. An estimation of the nutrient availability from one hectare of WPT was also estimated based on the dried matter available per hectare of WPT as shown in table 1.2.3.2.

Table 1.2.3.1

Mean concentration of macro nutrients (N, P, K, Mg and Ca) based on dry matter of oil palm for different parts of WPT

Component	*N (%) (kg/palm)*	*P (%) (kg/palm)*	*K (%) (kg/palm)*	*Mg (%) (kg/palm)*	*Ca (%) (kg/palm)*
Trunk	0.56	0.054	1.62	0.15	0.31
	1.691	0.163	4.892	0.453	0.936
Leaflets	2.18	0.116	0.98	0.21	0.52
	1.264	0.067	0.568	0.122	0.302
Rachis	0.45	0.049	1.52	0.11	0.43
	0.529	0.058	1.788	0.129	0.506
Spears	2.14	0.152	1.72	0.23	0.42
	0.201	0.014	0.162	0.022	0.039
Cabbage	3.12	0.387	3.45	0.51	0.38
	0.140	0.017	0.153	0.023	0.017
Inflorescence	1.94	0.254	2.24	0.43	0.55
	0.122	0.016	0.141	0.027	0.035

Source: Khalid et al. (1999)

Table 1.2.3.2

Potential biomass and macro nutrient contents of oil palm biomass available from one hectare of WPT at felling

Oil palm biomass	*Dry Matter (ton/ha)*	*Nutrient (kg/ha)*				
		N	P	K	Mg	Ca
Trunks	48.17	26.98	2.60	78.04	7.23	14.93
Leaflets	9.25	20.17	1.07	9.07	1.94	4.81
Rachis	18.77	8.45	0.92	28.53	2.06	8.07
Spears	1.50	3.21	0.23	2.58	0.35	0.63
Cabbage	0.70	2.18	0.27	2.42	0.36	0.27
Inflorescence	20.60	39.96	10.15	22.74	9.78	5.38
Total	98.99	100.95	15.24	143.38	21.72	34.09

Source: Khalid et al. (1999)

1.2.4 Elemental analysis of carbon, hydrogen, oxygen, nitrogen and sulphur

Elemental contents for carbon, hydrogen, oxygen, nitrogen and sulphur (C, H, O, N, S) is shown in table 1.2.4. CHONS are valuable indicators related to energy processes and gases emissions during combustion of the resource material. The values from WPT showed higher value of C (52.28%) for fronds compared to that of the trunk (40.64%). Comparisons were also made with the elemental composition of the empty fruit bunches (EFB), a palm oil mill residue currently being utilized as fuel in the palm oil mill. The calorific values for trunk and EFB were found to be similar.

Table 1.2.4

C, H, O, N, S and calorific values of parts of oil palm trees

Element	*EFB (%)*	*Trunk*	*Fronds*
C	53.78	40.64	52.28
H	4.37	5.09	-
O	41.5	53.12	-
N	0.35	2.15	0.75
S	-	-	-
CV (MJ/kg)	17.08	17.27	-

Source: Mohd Azri Sukiran et.al, 2009, American Journal of Applied Sciences

1.3 Quantification of waste oil palm trees

1.3.1 Total oil palm plantation area

Malaysia consists of Peninsular Malaysia (West Malaysia) and the States of Sabah and Sarawak (East Malaysia). Sabah and Sarawak are located on the Borneo Island. Establishment of oil palm plantations began in Peninsular Malaysia in 1917 and the plantation area has now reached near total capacity (2.5 million ha in 2010). In Sabah (1.4 million ha in 2010) and Sarawak (839,748 ha in 2010) the area planted with oil palms is still increasing, due to the availability of larger potential areas. The distribution of oil palm plantation hectares in Peninsular Malaysia, Sabah and Sarawak from 1975-2008 is shown in figure 1.3.1.1.

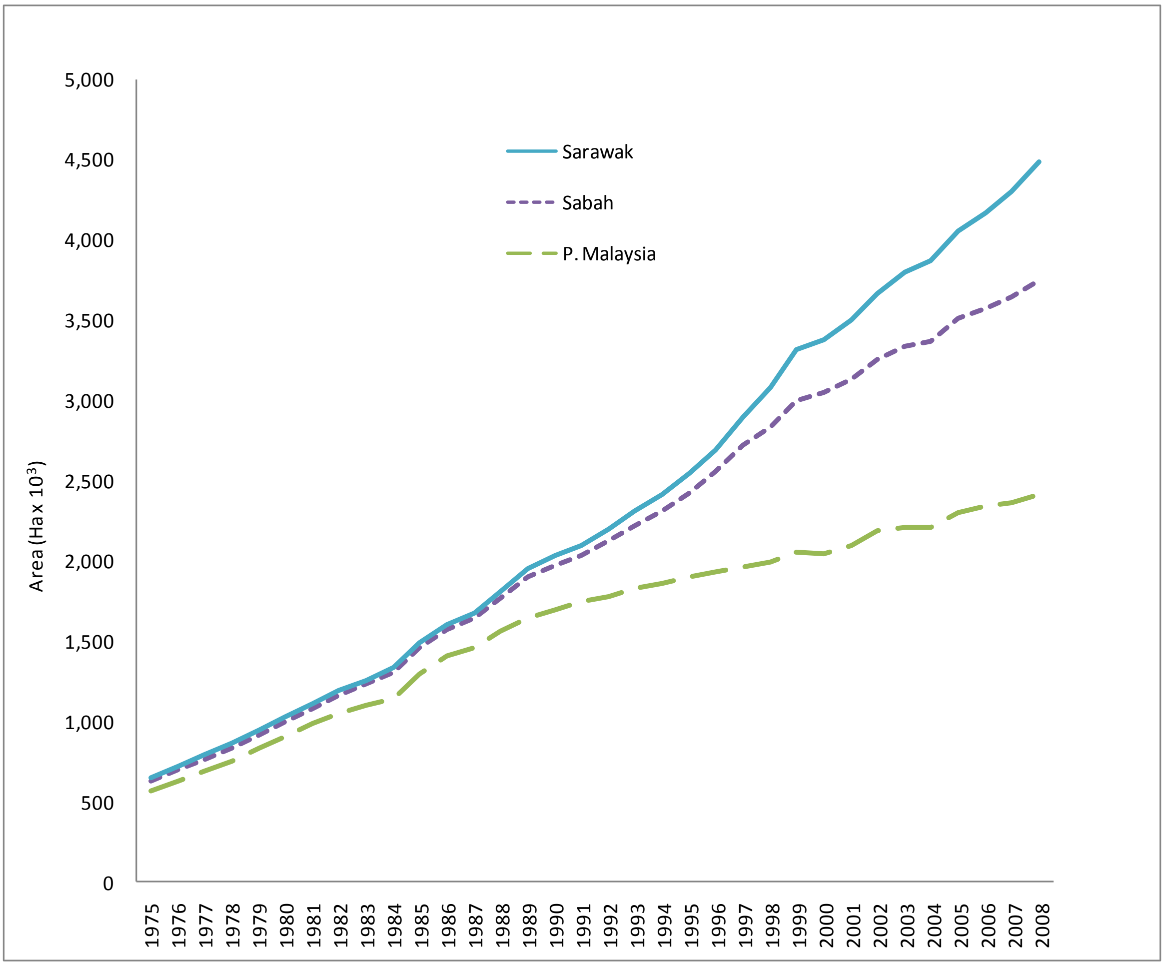

Figure 1.3.1.1

Distribution of oil palm plantation area based on year planted (1975-2008)

The oil palm plantations in Malaysia are owned by various types of companies. Plantation ownership is grouped into various categories: private estates, government owned agencies/schemes such as Federal Land Development Agency (FELDA), Federal Land Consolidation and Rehabilitation Authority (FELCRA), and Rubber Industry Smallholders Development Authority (RISDA), state schemes and smallholders.

Table 1.3.1.1

Distribution of oil palm planted areas by ownership category for years 2006 to 2008

Category	*2006 (Hectares)*	*(%)*	*2007 (Hectares)*	*(%)*	*2008 (Hectares)*	*(%)*
Private estates	2,476,135	59.45	2,598,859	60.37	2,706,876	60.31
Govt. Schemes						
FELDA	669,715	16.08	676,977	15.73	675,167	15.04
FELCRA	159,780	3.83	163,891	3.81	163,511	3.65
RISDA	81,169	1.95	81,486	1.89	80,262	1.79
State schemes	323,520	7.77	313,545	7.28	321,947	7.17
Smallholders	454,896	10.92	470,155	10.92	540,194	12.04
TOTAL	4,165,215	100.00	4,304,913	100.00	4,487,957	100.00

Distribution of oil palm planted areas based on ownership category is shown in table 1.3.1.1. The highest area of oil palm plantations belongs to private estates. These include companies such as Sime Darby, KLK, IOI, Tabung Haji and others. From the year 2006 to 2008 private ownership plantations showed an increasing hectare pattern unlike the government agencies and smallholders, which remained constant.

Figure 1.3.1.2 shows the oil palm trees that are available for replanting from years 2011 to 2032. The maximum availability of WPT will be in year 2024 with about 235,277 ha due for replanting with the largest area owned by the private estates (142,037 ha). Figure 1.4 shows the area under oil palm plantations in P. Malaysia, Sabah and Sarawak based on age. The graph shows that the older trees i.e. potential WPT, would be available in P. Malaysia compared to Sabah and Sarawak. The distribution of oil plantation area by states and ownership category in 2007 is shown in table 3.3. Sabah has the largest area followed by Sarawak, Johor and Pahang.

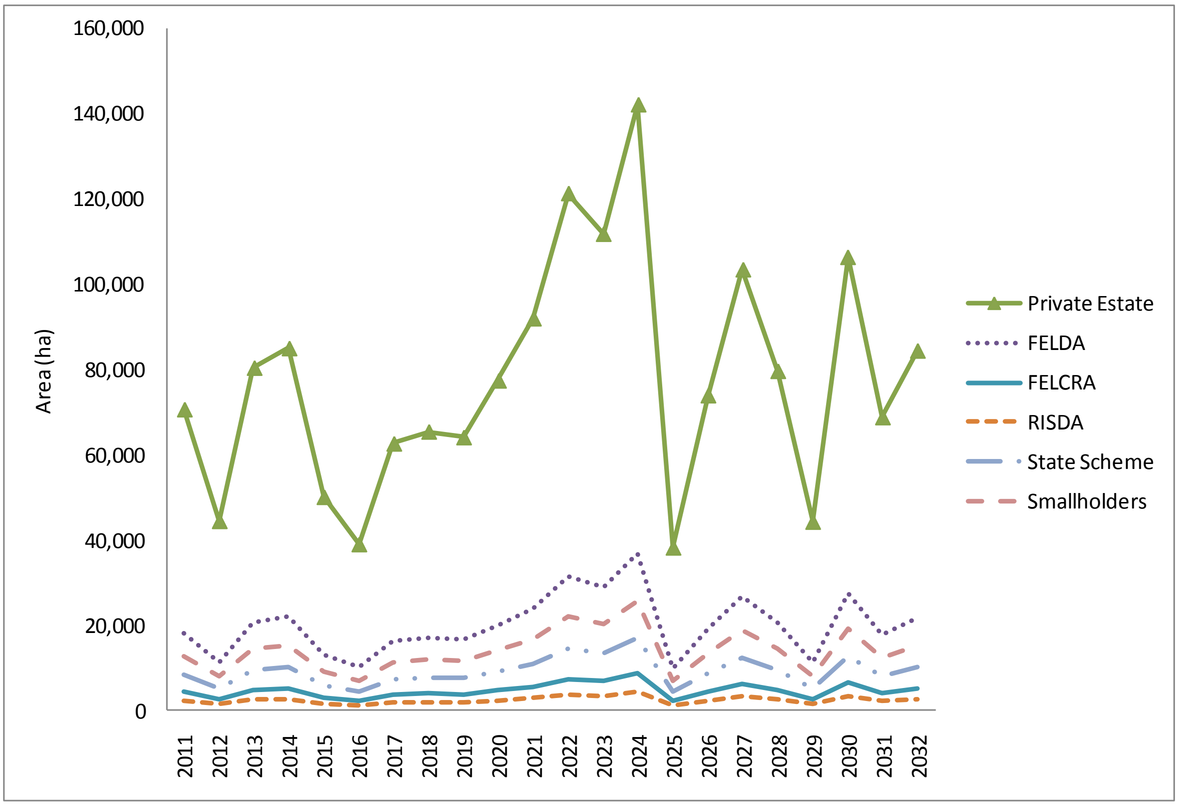

Figure 1.3.1.2

Oil palm area available based on ownership category (ha)

The dips in years 2012, 2016, 2025 and 2029 are due to a reduction in replanting activities 25 years back i.e. in years 1987, 1991, 2000 and 2004. Replanting activities are almost always influenced by global CPO prices. Although during these years the CPO prices were low (figure 1.3.1.3), planting was also reduced tremendously. Planting and replanting exercises by plantation owners are not only influenced by CPO market prices but also by other internal factors including governmental land use policies, labour availability and cost, environmental/climatic changes (e.g. El Nino), plant epidemic attacks on mono-crops and the introduction of high yielding plants. MPOA reported a high labour cost in 1987. The Malaysian Government announced that the targeted area for oil palm plantations for the

Seventh Malaysian Plan would be met by the year 2000. Furthermore, increased production of CPO could have been met through planting of high yielding trees, reducing the replanting cycle. Hence during these years the planting of new trees was reduced.

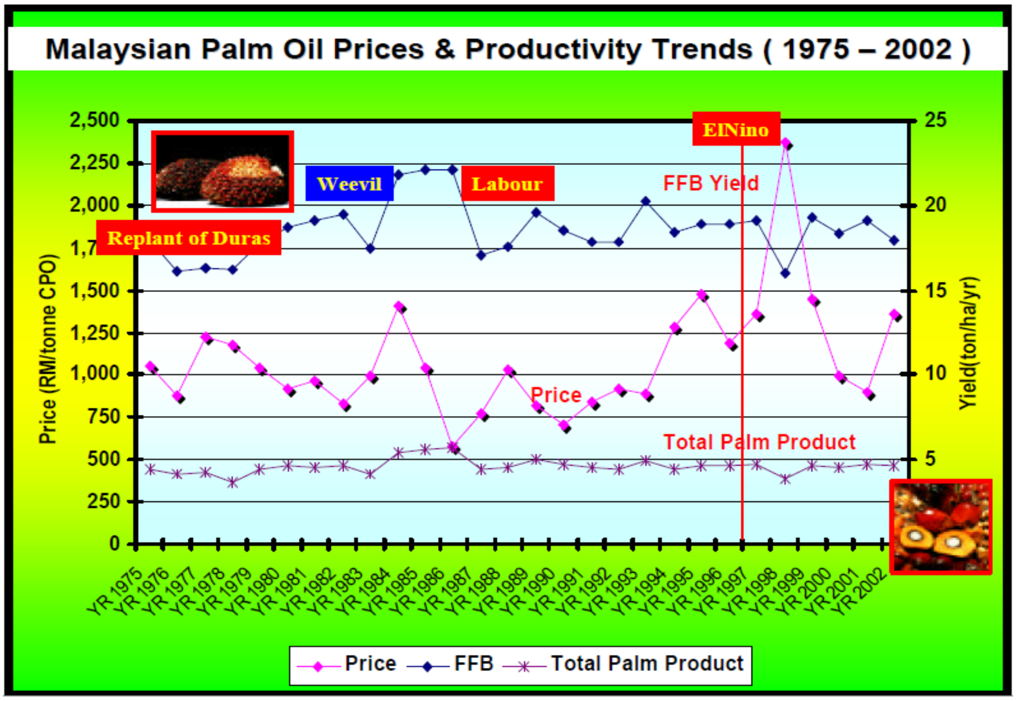

Figure 1.3.1.3

Malaysian palm oil prices and productivity trends (1975-2002)

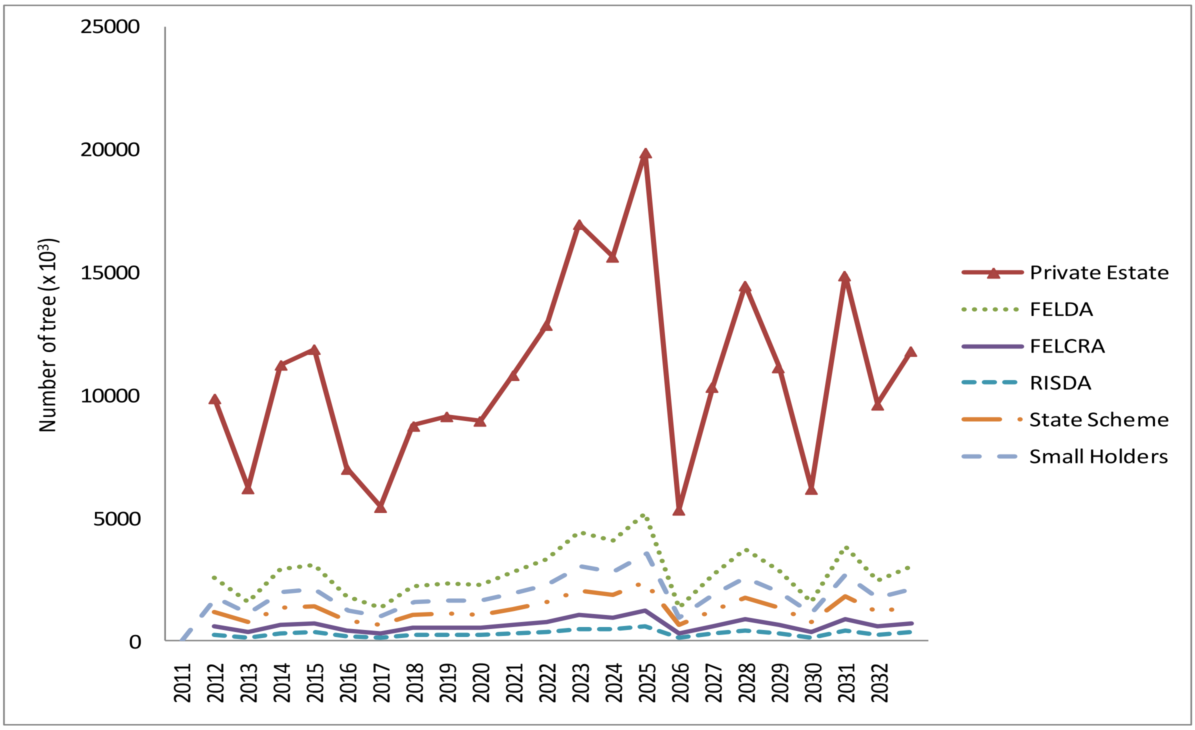

Figure 1.3.1.4

Number of palm trees available based on ownership category

Table 1.3.1.2 shows the distribution of cumulated oil palm planted area by State and category in the year 2007. Figures 1.3.1.4 and 1.3.1.5 show the number of trees available based on category and total area of oil palm based on State (hectares) respectively.

Table 1.3.1.2

Distribution of oil palm planted areas by State (hectares, 2007)

State	*S/Holders (Licensed)*	*FELDA*	*FELCRA*	*RISDA*	*State Schemes/ Govt. Agencies*	*Private Estates*	*Total*	*% Total*
Johor	151,025	119,740	22,070	5,134	43,921	328,751	670,641	15.6
Kedah	15,484	510	1,124	1,252	1,916	54,810	75,096	1.7
Kelantan	1,873	38,230	5,314	767	8,878	44,701	99,763	2.3
Melaka	6,419	2,848	2,411	1,966	-	35,469	49,113	1.1
N. Sembilan	15,229	46,125	7,644	10,523	3,003	88,319	170,843	4.0
Pahang	29,213	284,228	31,283	22,112	55,956	218,660	641,452	14.9
P. Pinang	7,054	-	511	56	-	5,683	13,304	0.3
Perak	72,292	20,252	31,548	19,779	13,717	193,395	350,983	8.2
Perlis	61	-	199	-	-	-	260	0.0
Selangor	30,685	4,989	4,297	342	1,126	87,876	129,315	3.0
Terengganu	5,435	38,500	19,962	19,555	12,732	65,103	161,287	3.7
P. Malaysia	334,770	555,422	126,363	81,486	141,249	1,122,767	2,362,057	
Sabah	106,186	113,874	14,690	-	94,087	949,407	1,278,244	29.7
Sarawak	29,199	7,681	22,838	-	78,209	526,685	664,612	15.4
Sabah/ Sarawak	135,385	121,555	37,528	-	172,296	1,476,092	1,942,856	
MALAYSIA	**470,155**	**676,977**	**163,891**	**81,486**	**313,545**	**2,598,859**	**4,304,913**	**100.0**

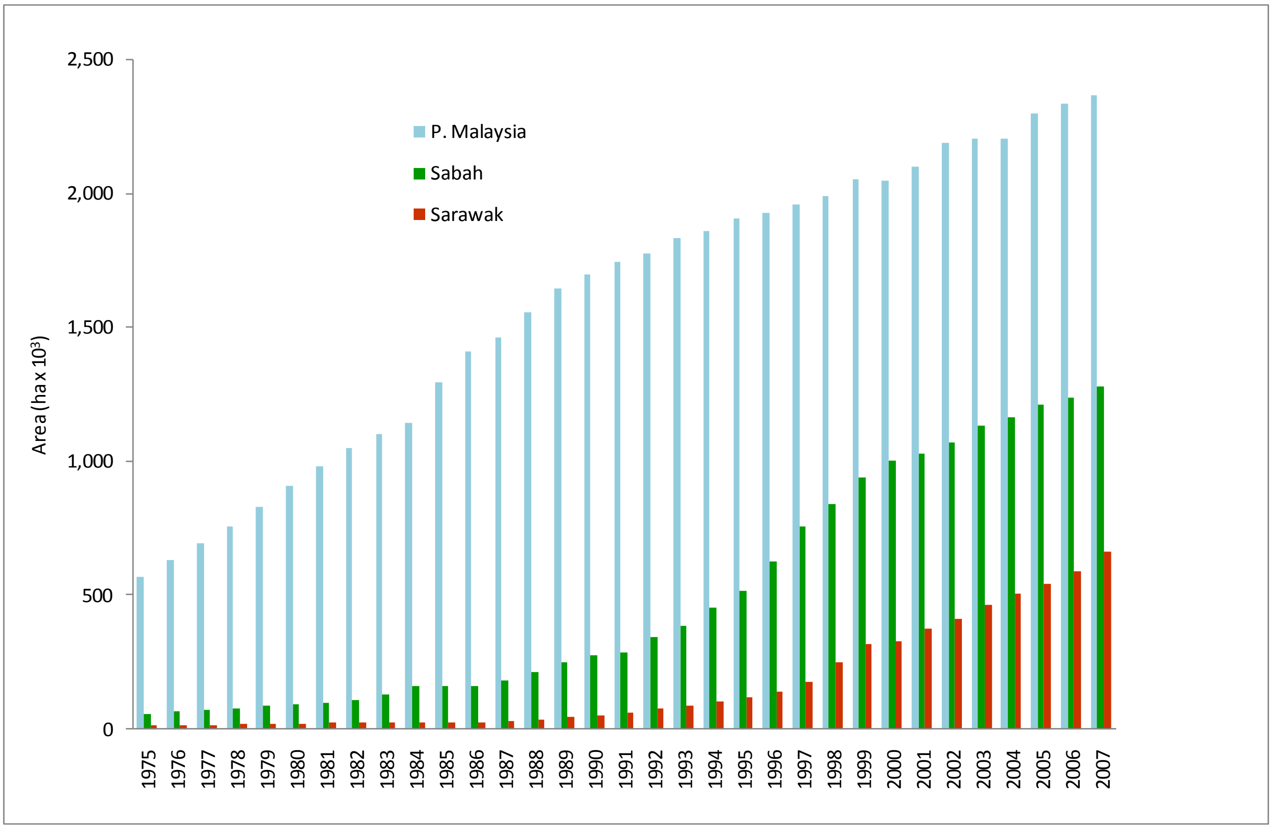

Figure 1.3.1.5

Total area of oil palm plantations in Peninsular Malaysia, Sabah and Sarawak in years 1975-2007

1.3.2 Area of potential WPT available in years 2011 – 2032

The area of oil palm plantation data published annually by the Malaysian Palm Oil Board enables the computation of palm trees that have reached replanting age i.e. 25 years. These are the trees that were planted from 1986 through 2007, and will be referred to as potential WPT. The potential WPT area from years 2011 – 2032 is shown in figure 1.3.2.1. The dry matter weight of the WPT biomass available yearly is shown in figure 1.3.2.2. The area of potential WPT available annually in Peninsular Malaysia, Sabah and Sarawak is shown in figure 1.3.2.3.

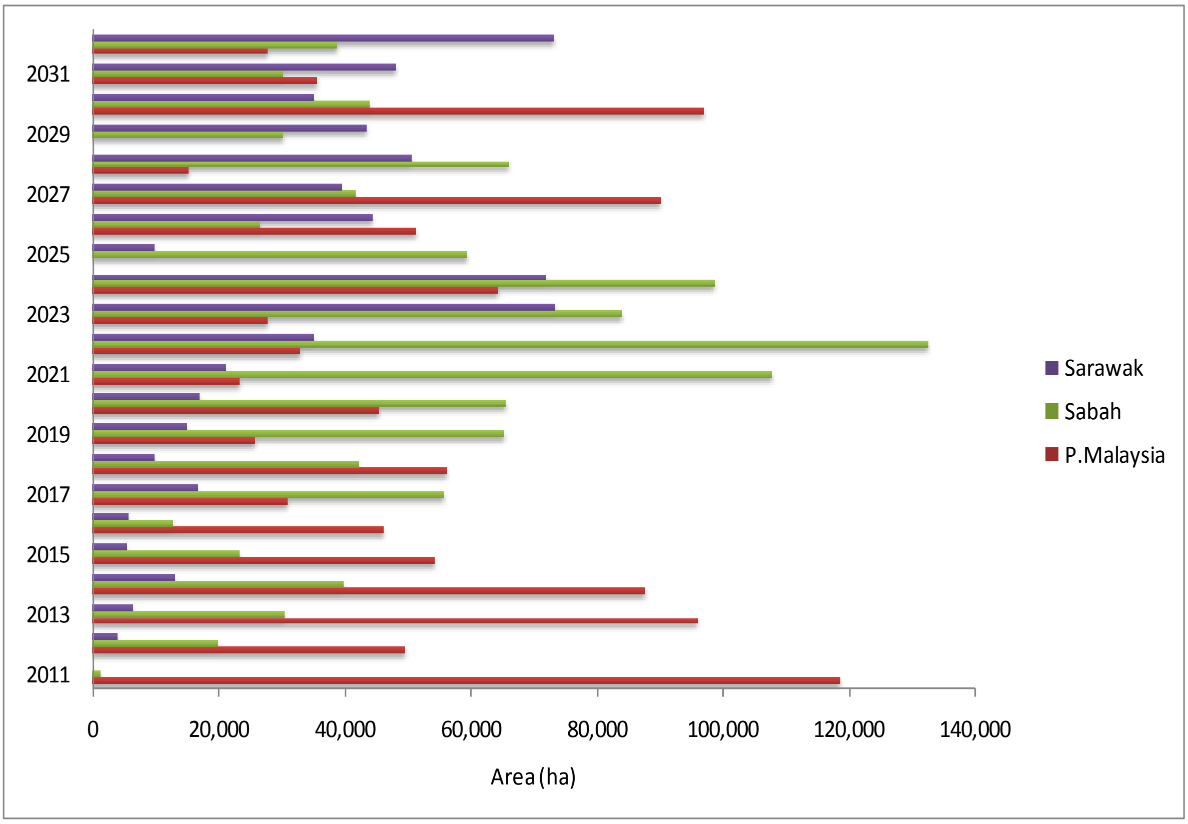

Figure 1.3.2.1

Potential area of WPT in Malaysia in years 2011-2035

Based on the fact that one hectare of plantation area consists of an average of 140 trees, it is possible to compute the number of WPT available within the country, and hence the total available dry biomass. Figure 1.3.2.4 shows the number of potential WPT available annually in Peninsular Malaysia, Sabah and Sarawak. The highest number of WPT will be available in Sabah (18,561,060 trees in year 2022) followed by P. Malaysia (16,593,360 and 13,580,280 trees in years 2011 and 2030 respectively). The trunks from these WPT would then generate dried biomass weight tonnage in the same order (figure 1.3.2.5).

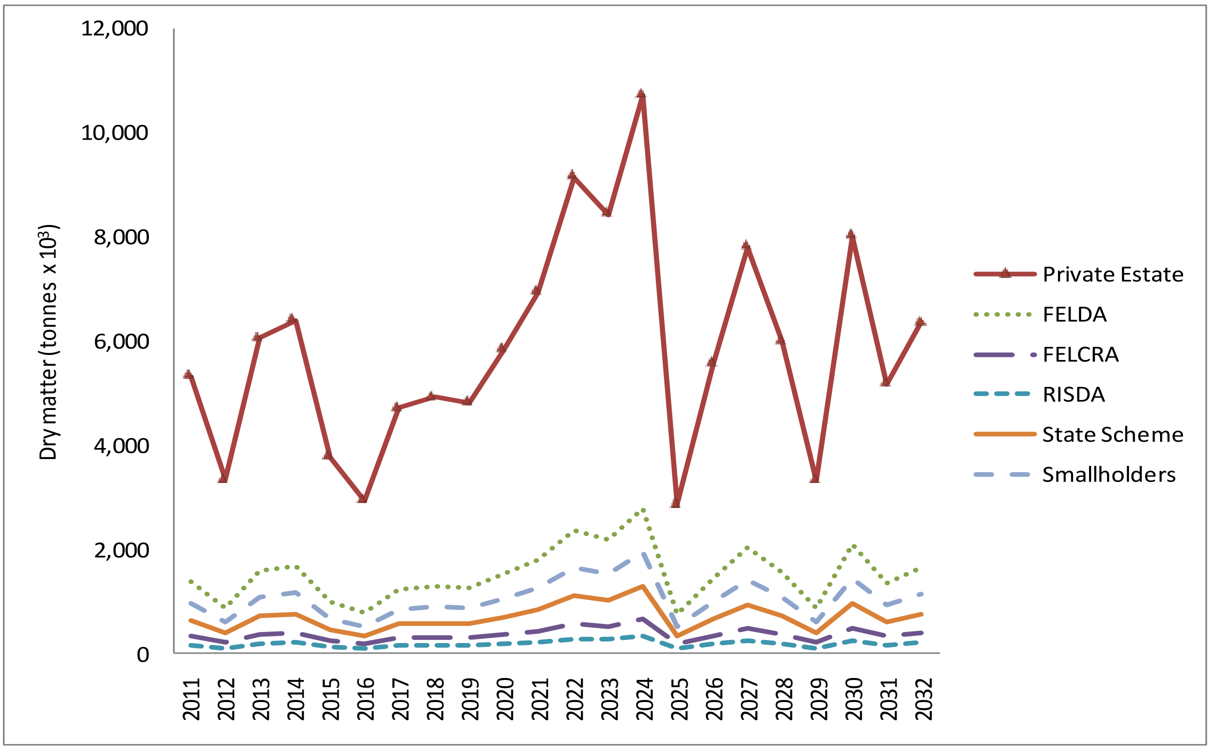

Figure 1.3.2.2
Potential dry matter weight of WPT based on ownership category

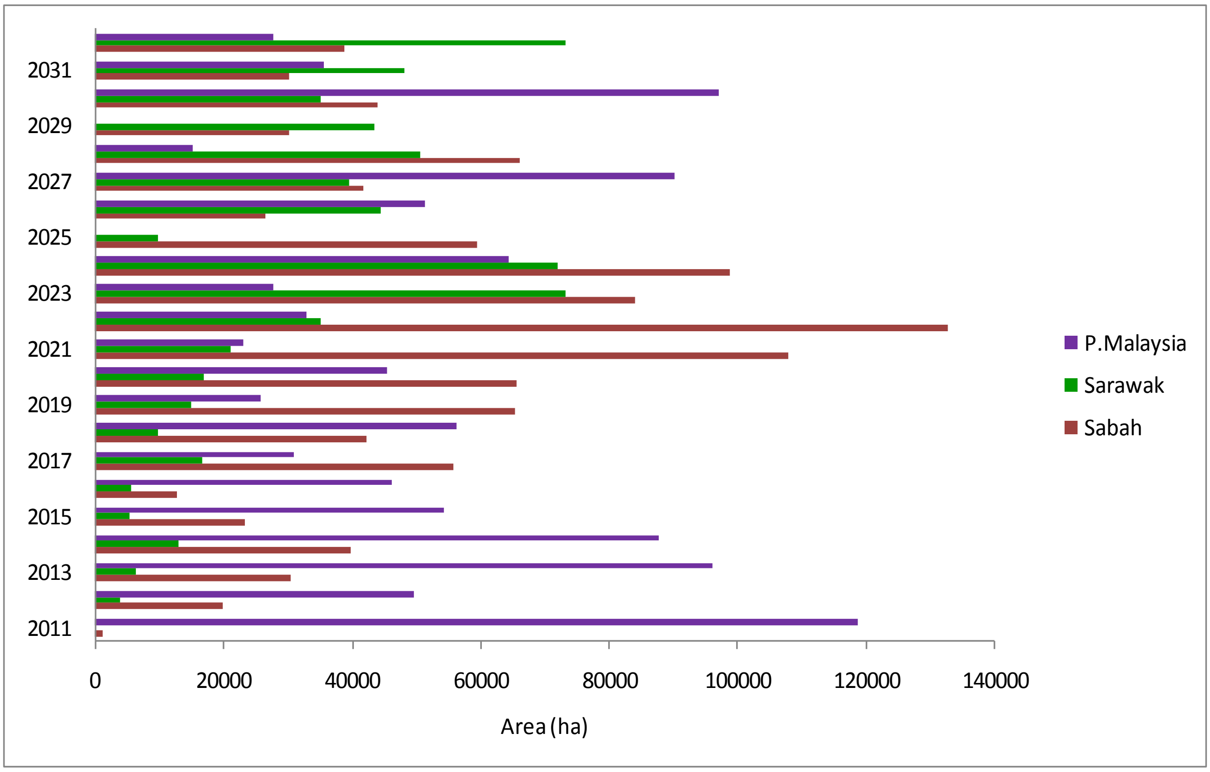

Figure 1.3.2.3
Area of potential WPT in years 2011- 2032 for Peninsular Malaysia, Sabah and Sarawak

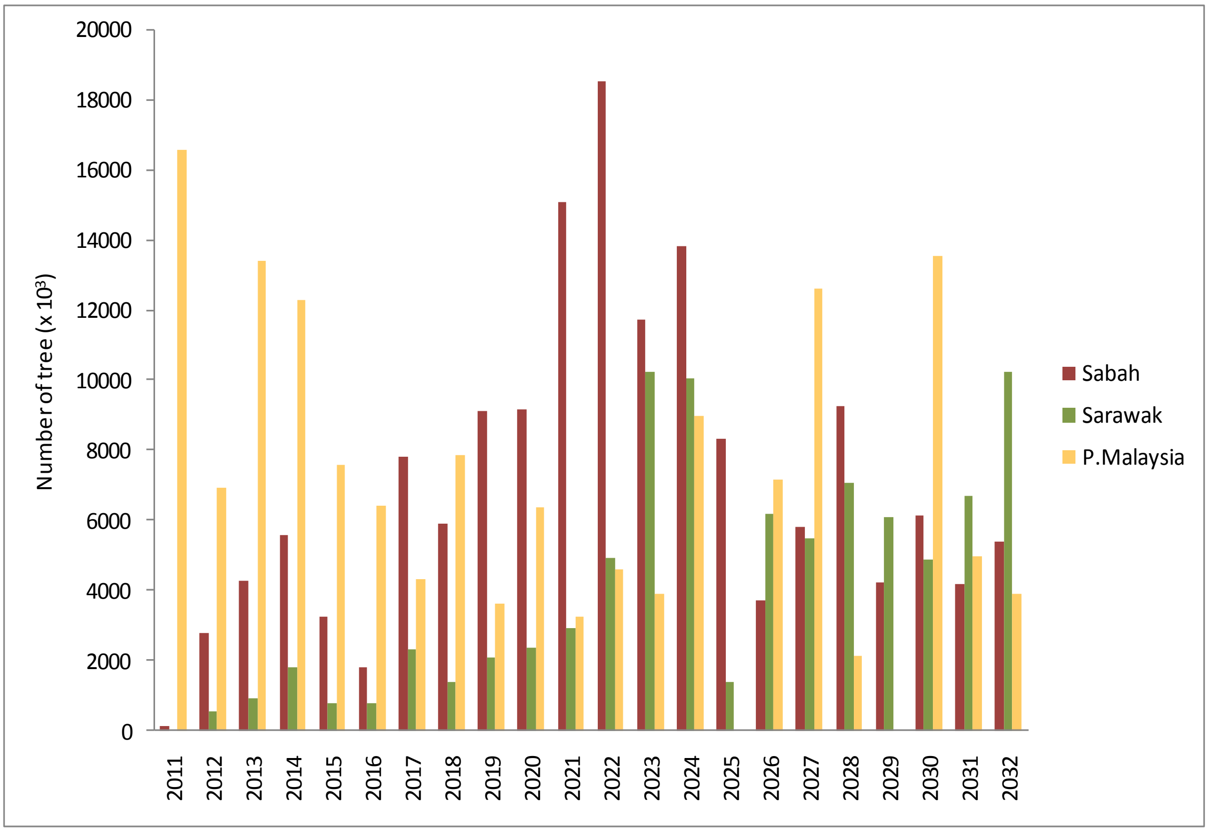

Figure 1.3.2.4

Number of potential WPT in Peninsular Malaysia, Sabah and Sarawak in years 2011- 2032

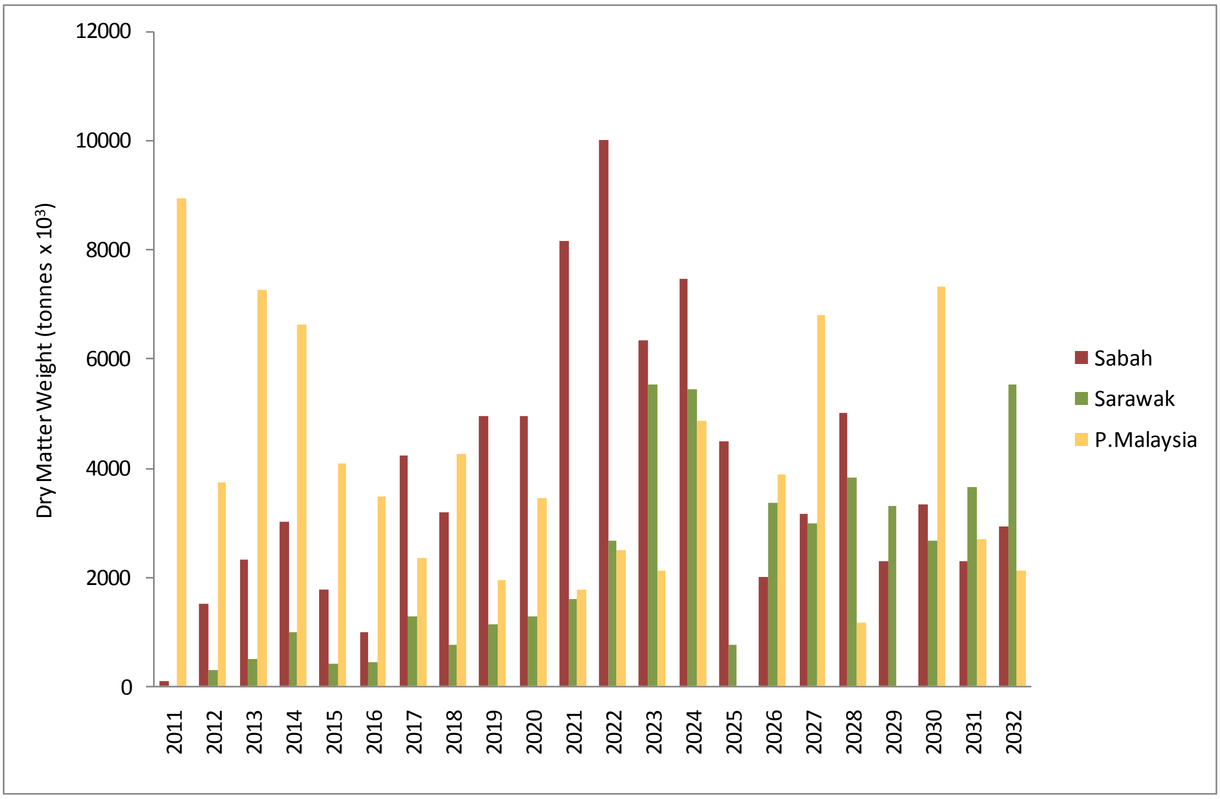

Figure 1.3.2.5:

Dry matter weight of trunks from potential WPT

1.3.3 Frond availability from WPT

From these potential WPT, fronds also contribute to biomass generation during felling. Fronds are generated as well during harvesting of the fresh fruit bunches (harvesting). This type of frond is called fronds generated during pruning. However, this is not under the scope of the present study and thus will not be discussed here. The amount of dry matter weight of the fronds that will be generated from the WPT at time of felling is presented in table 1.3.3.

The total amount of fronds generated was calculated based on 14.4 ton/ha (dry matter). The amount of fronds available during felling of WPT is shown in figure 1.3.3, ranging from 9,297-33,880 tons throughout years 2011-2032. Frond amounts available annually in terms of States and ownership category will exhibit a similar trend in terms of maximum availability to that of the trunks, as reported previously.

Table 1.3.3

Amount of dry matter weight of fronds available annually from potential WPT based on ownership category

Year	*Private Estate*	*FELDA*	*FELCRA*	*RISDA*	*State Scheme*	*Smallholders*	*Total Malaysia*
2011	10,163*	2,648	641	318	1,226	1,838	16,835
2012	6,395	1,666	404	200	771	1,157	10,593
2013	11,566	3,014	730	362	1,395	2,092	19,159
2014	12,226	3,186	772	383	1,474	2,211	20,252
2015	7,207	1,878	455	226	869	1,304	11,938
2016	5,613	1,462	354	176	677	1,015	9,297
2017	9,009	2,347	569	282	1,086	1,630	14,923
2018	9,412	2,452	594	295	1,135	1,702	15,590
2019	9,221	2,403	582	289	1,112	1,668	15,275
2020	11,135	2,901	703	349	1,343	2,014	18,445
2021	13,231	3,447	835	414	1,596	2,393	21,917
2022	17,456	4,548	1,102	547	2,105	3,158	28,916
2023	16,085	4,191	1,015	504	1,940	2,910	26,644
2024	20,453	5,329	1,291	640	2,466	3,700	33,880
2025	5,500	1,433	347	172	663	995	9,111
2026	10,636	2,771	671	333	1,283	1,924	17,618
2027	14,886	3,879	939	466	1,795	2,693	24,657
2028	11,457	2,985	723	359	1,382	2,072	18,979
2029	6,371	1,660	402	199	768	1,152	10,553
2030	15,304	3,988	966	479	1,846	2,768	25,351
2031	9,897	2,579	625	310	1,193	1,790	16,393
2032	12,144	3,164	766	380	1,464	2,197	20,117

*Total amount of fronds was calculated based on 14.4 ton/ha (dry matter)

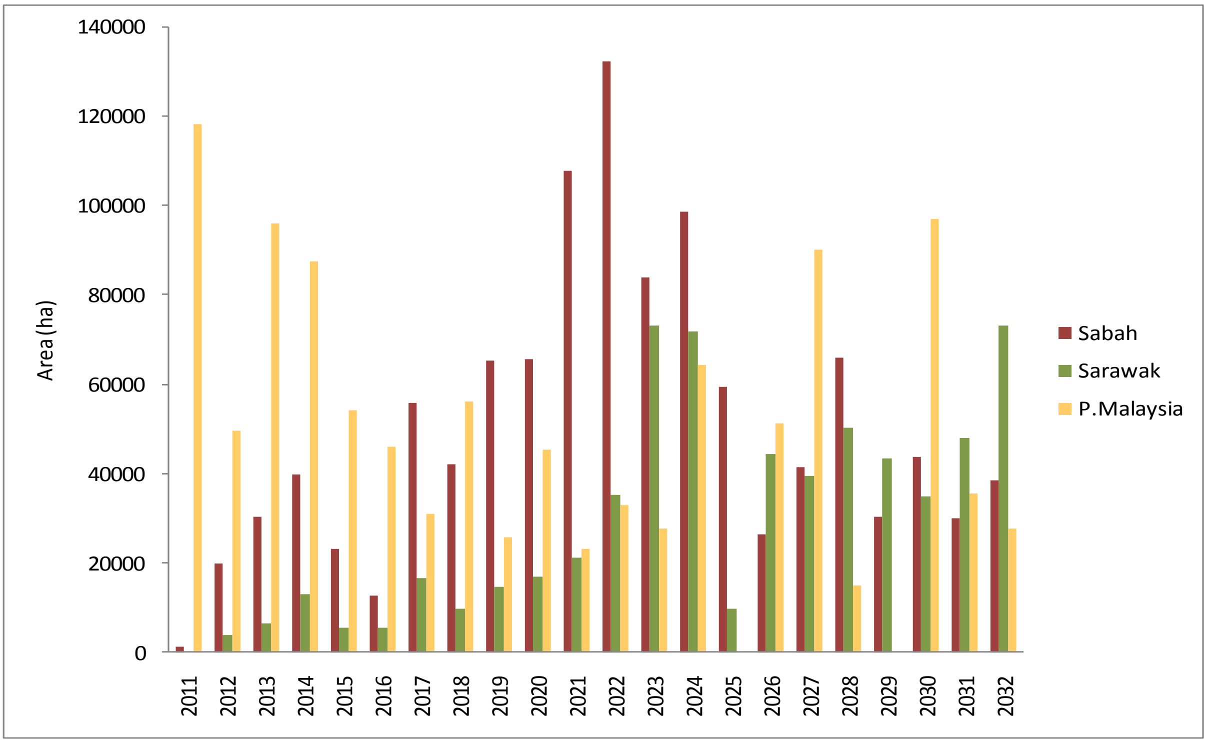

Figure 1.3.3

Amount of dry matter weight of fronds available annually from potential WPT in Peninsular Malaysia, Sabah and Sarawak

1.3.4 Potential chemical and macro nutrients available in WPT

The amount of chemicals that will be available in the WPT at time of felling was calculated based on the chemical analysis reported in the previous chapter. At time of felling the chemical composition and nutrients available in the palm trunk is presented in tables 1.3.4.1 and 1.3.4.2. The total amounts of lignin hemi-cellulose, alpha-cellulose and holo-cellulose, ash and alcohol-benzene solubility in years 2011 to 2032 range from 2.6 to 9.7 million tons. These chemicals are potential material and resources for various industries.

Table 1.3.4.1

Amount of chemicals available from WPT trunks (tons)

Year	*Lignin*	*Hemi-cellulose*	*Alpha-cellulose*	*Holo-cellulose*	*Ash*	*AB* solubility*	*Total Malaysia (ha)*	*Total Tons Malaysia*
2011	867,604	1,212,728	2,200,167	3,657,358	52,727	86,281	116,912	4,793,392
2012	545,918	763,079	1,384,401	2,301,303	33,177	54,290	73,564	3,016,124
2013	987,349	1,380,107	2,503,830	4,162,141	60,005	98,189	133,048	5,454,968
2014	1,043,660	1,458,817	2,646,629	4,399,516	63,427	103,789	140,636	5,766,076
2015	615,238	859,974	1,560,189	2,593,517	37,390	61,184	82,905	3,399,105
2016	479,129	669,722	1,215,030	2,019,756	29,118	47,648	64,564	2,647,124
2017	769,053	1,074,975	1,950,251	3,241,920	46,738	76,480	103,632	4,248,912
2018	803,435	1,123,033	2,037,439	3,386,854	48,828	79,900	108,265	4,438,865
2019	787,175	1,100,306	1,996,207	3,318,313	47,839	78,283	106,074	4,349,034

2020	950,541	1,328,657	2,410,488	4,006,977	57,768	94,529	128,088	5,251,608
2021	1,129,469	1,578,760	2,864,233	4,761,241	68,642	112,323	152,199	6,240,159
2022	1,490,159	2,082,930	3,778,912	6,281,720	90,562	148,193	200,803	8,232,923
2023	1,373,085	1,919,285	3,482,023	5,788,200	83,447	136,550	185,027	7,586,107
2024	1,745,991	2,440,528	4,427,678	7,360,170	106,110	173,634	235,277	9,646,357
2025	469,534	656,310	1,190,697	1,979,307	28,535	46,694	63,271	2,594,111
2026	907,945	1,269,116	2,302,467	3,827,412	55,179	90,293	122,348	5,016,268
2027	1,270,705	1,776,179	3,222,396	5,356,619	77,225	126,368	171,231	7,020,471
2028	978,066	1,367,130	2,480,288	4,123,006	59,440	97,266	131,797	5,403,677
2029	543,863	760,206	1,379,188	2,292,637	33,052	54,086	73,287	3,004,767
2030	1,306,445	1,826,136	3,313,028	5,507,278	79,397	129,923	176,047	7,217,927
2031	844,814	1,180,873	2,142,374	3,561,288	51,342	84,015	113,841	4,667,481
2032	1,036,699	1,449,087	2,628,977	4,370,173	63,004	103,097	139,698	5,727,618

* alcohol-benzene

Table 1.3.4.2

Amount of macro nutrients available from WPT trunks (tons)

Year	*Total Malaysia (ha)*	*Total Ton*	*N (Ton)*	*P (Ton)*	*K (Ton)*	*Mg (Ton)*	*Ca (Ton)*
2011	116,912	4,793,392	8,106	781	23,449	2,171	4,487
2012	73,564	3,016,124	5,100	492	14,755	1,366	2,823
2013	133,048	5,454,968	9,224	889	26,686	2,471	5,106
2014	140,636	5,766,076	9,750	940	28,208	2,612	5,397
2015	82,905	3,399,105	5,748	554	16,628	1,540	3,182
2016	64,564	2,647,124	4,476	431	12,950	1,199	2,478
2017	103,632	4,248,912	7,185	693	20,786	1,925	3,977
2018	108,265	4,438,865	7,506	724	21,715	2,011	4,155
2019	106,074	4,349,034	7,354	709	21,275	1,970	4,071
2020	128,088	5,251,608	8,880	856	25,691	2,379	4,916
2021	152,199	6,240,159	10,552	1,017	30,527	2,827	5,841
2022	200,803	8,232,923	13,922	1,342	40,275	3,730	7,706
2023	185,027	7,586,107	12,828	1,237	37,111	3,437	7,101
2024	235,277	9,646,357	16,312	1,572	47,190	4,370	9,029
2025	63,271	2,594,111	4,387	423	12,690	1,175	2,428
2026	122,348	5,016,268	8,483	818	24,540	2,272	4,695
2027	171,231	7,020,471	11,872	1,144	34,344	3,180	6,571
2028	131,797	5,403,677	9,138	881	26,435	2,448	5,058
2029	73,287	3,004,767	5,081	490	14,699	1,361	2,812
2030	176,047	7,217,927	12,206	1,177	35,310	3,270	6,756
2031	113,841	4,667,481	7,893	761	22,833	2,114	4,369
2032	139,698	5,727,618	9,685	934	28,020	2,595	5,361

The total amounts of macro nutrients N, P, K, Mg and Ca that will be available from the WPT in 2011 to 2032 are in the range of 2.7–9.7 tons. These chemicals are potential fertilizing agents for plants. This can be seen also as a benefit to the soil when mulching the plantation with WPT after felling has been carried out.

1.3.5 Case study on actual locality and quantification of WPT

The Malaysian palm oil industry has experienced a tremendous growth over the years and has contributed to the achievements of the Malaysia economy today. Oil palm planted areas have increased from 1.02 million hectares in 1980 to 4.48 million hectares in 2008. In 2007, Malaysia export earnings from palm oil products amounted to RM45.1 billion. The rapid growth in this industry has benefited many, and also increased the number of people involved in palm oil activities.

1.3.6 Feedback from oil palm plantation companies

A survey was carried out by dividing all States into two categories which are Peninsular and East Malaysia. Peninsular Malaysia consisted of 13 states and East Malaysia of two states. A survey was carried out based on 50% of the total of oil palm plantations in Malaysia. The total number of oil palm plantation companies as of the year 2008 was 4,273. Details on the number of oil palm plantation companies are contained in table 1.3.6.

Table 1.3.6

Number of oil palm plantation companies in Malaysia

Category	*No. of estates*	
	Overall	*Survey*
Peninsular Malaysia	2505	1259
Sabah	1478	739
Sarawak	290	145
Total	4273	2143

A total of approximately 2,143 questionnaires were submitted to oil palm plantations and approximately 33.5% of the total sent in responses. Based on an analysis of the feedback received, data was compiled to include criteria such as the size of plantations, age of palm trees, replanting programme for the next 25 years, and the number of plantations willing to sell their oil palm trunks after felling.

1.3.7 Size of oil palm plantations

The total area of the oil palm plantations in Malaysia surveyed is about 1,414,449 hectares based on feedback received. Figure 1.3.7 shows the total area of oil palm plantations for each State in Malaysia. Sabah has the largest plantation area (491,120.68 ha) followed by Sarawak (244,676.42 ha) and Pahang (198,652.66 ha).

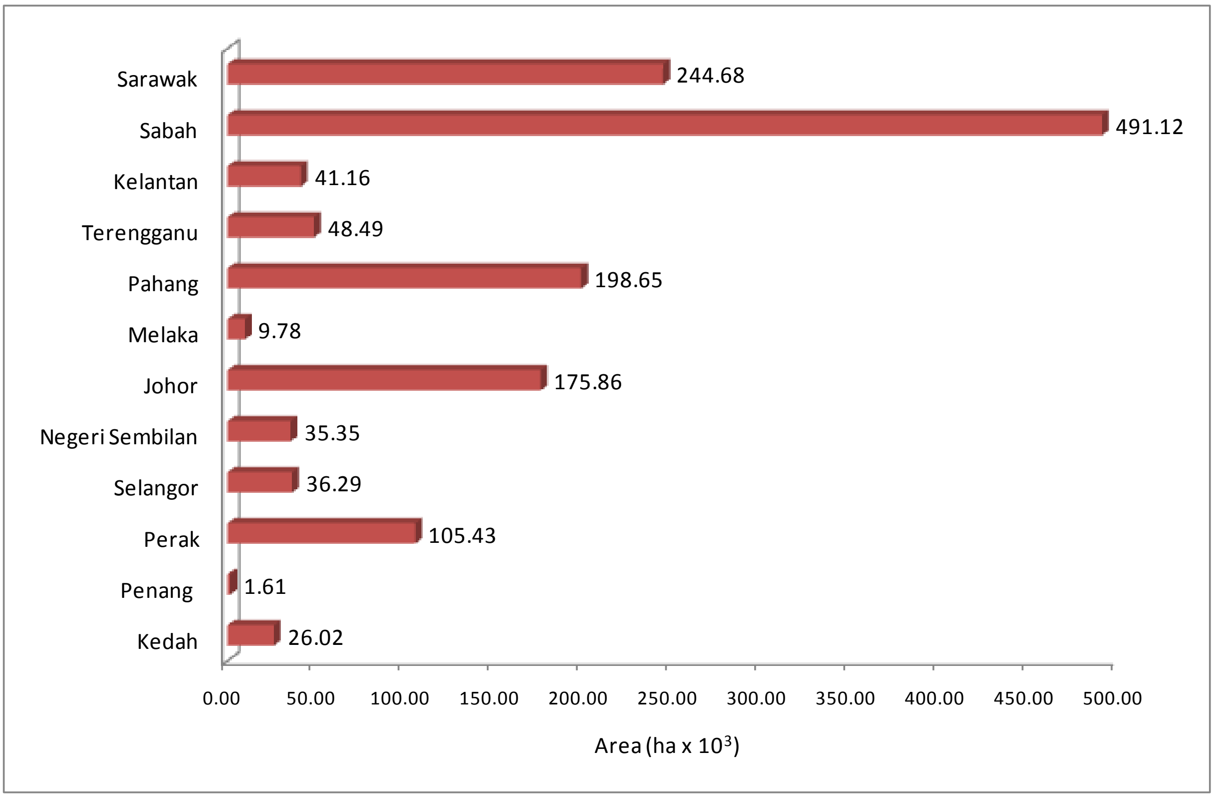

Figure 1.3.7
Total area of oil palm plantations for each State in Malaysia

1.3.8 Age category of oil palm trees

The age of oil palm trees for each State was reported based on the following four categories:

- Below 5 years
- 5 years to 15 years
- 16 years to 25 years
- More than 25 years

Figure 1.3.8 shows the age of oil palm trees for each State. Most oil palm trees have ages between either 5-15 years or 16-25 years. Table 1.3.8 shows the details of number of oil palm trees planted for each category. About 1,403,758 ha of oil palm trees have been planted overall. The amount of area planted with an age distribution of 5-15 years is the highest with 611,795 ha. Second highest is the age distribution of 16-25 years, with the amount of area planted at 456,810 ha.

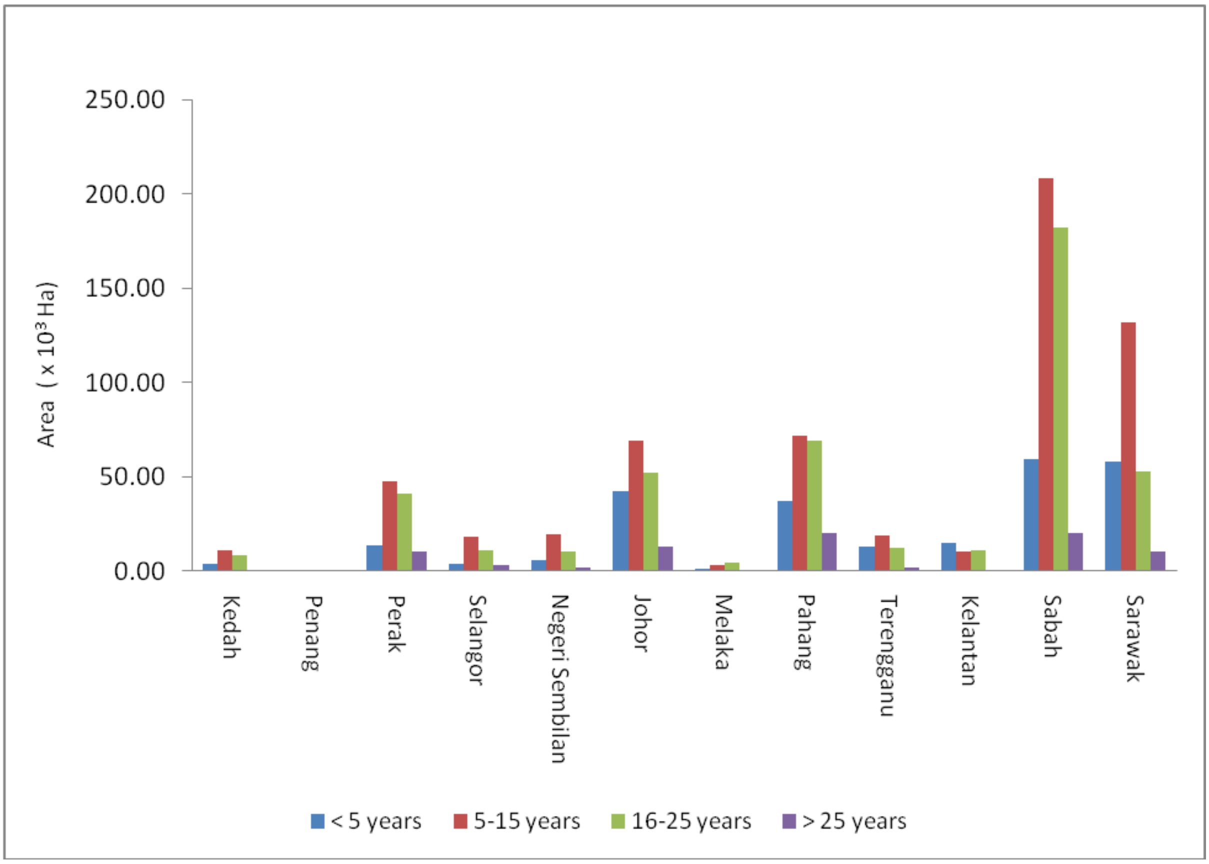

Figure 1.3.8
Age distribution of palm trees and area of plantation in each State in Malaysia

Table 1.3.8
Area planted based on various ages of oil palm trees

State	*< 5 years*	*5-15 years*	*16-25 years*	*> 25 years*
Kedah	3601.80	11318.33	8810.67	308.86
Penang	330.61	648.92	720.87	173.64
Perak	13501.37	47949.56	41145.76	10878.13
Selangor	3386.23	17981.87	10933.38	3412.42
Negeri Sembilan	5596.42	19818.33	10363.03	2206.64
Johor	41999.89	69447.49	52116.46	12935.70
Melaka	1000.64	3162.73	4563.51	878.96
Pahang	36706.11	71825.71	69474.63	20477.64
Terengganu	12715.68	19045.24	12628.28	2097.82
Kelantan	14894.32	10658.23	11157.61	621.07
Sabah	58940.01	207948.73	181870.75	20359.08
Sarawak	57735.68	131989.94	53025.78	10394.27
Total	250408.76	611795.07	456810.73	84744.23

1.3.9 Number of trees per hectare

Total number of trees planted per hectare varies for each oil palm plantation company. A survey was taken based on several ranges of total numbers of trees. Figure 1.3.9 shows the number of trees for each State based on various ranges, whereas Table 1.3.9 shows the number of trees per ha for different ranges of trees. The range of 131–140 trees planted per hectare was the most utilized, based on feedback given by 305 oil palm plantation companies.

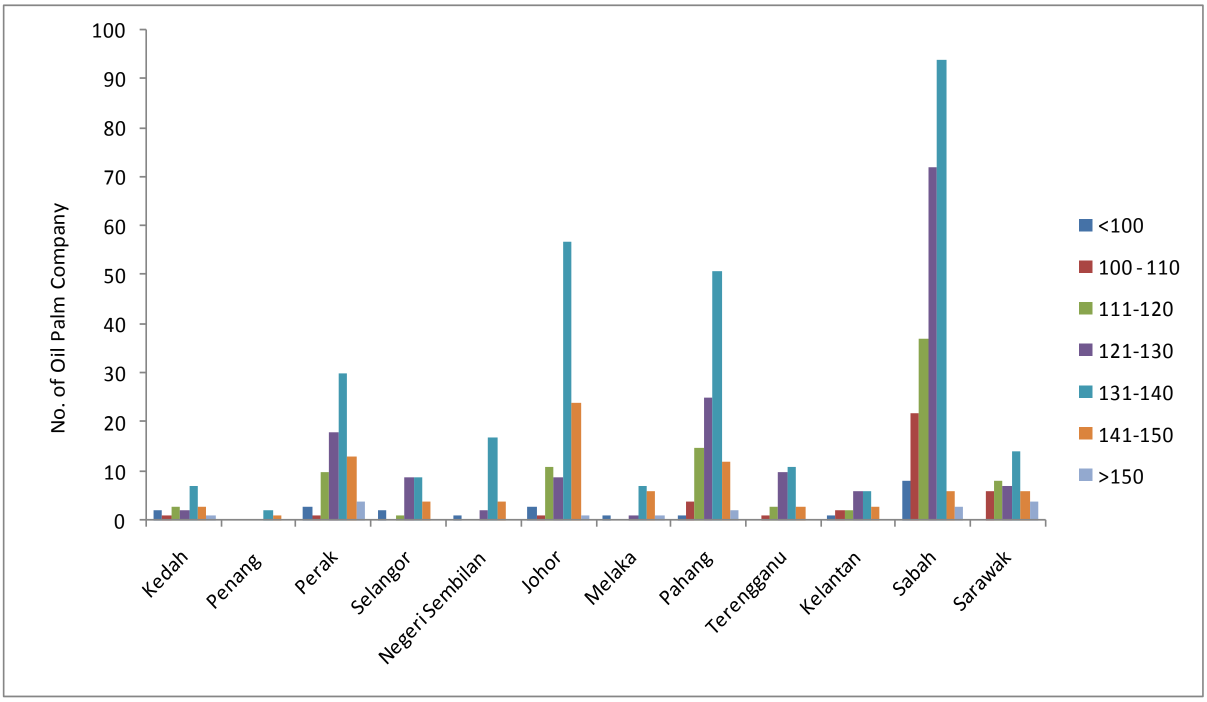

Figure 1.3.9

Number of oil palm trees planted per hectare for each State

Table 1.3.9

Number of trees planted per hectare

Range of numbers of trees planted per ha.	*<100*	*100 - 110*	*111-120*	*121-130*	*131-140*	*141-150*	*>150*
Number of oil palm companies	22	38	90	161	305	85	16

1.3.10 Area of actual felling programmes from years 2010 to 2031

The data for total area of potential replanting programmes for years 2010 to 2031 was obtained from the survey conducted. Figure 1.3.10.1 below shows the total areas per year that have replanting potential.

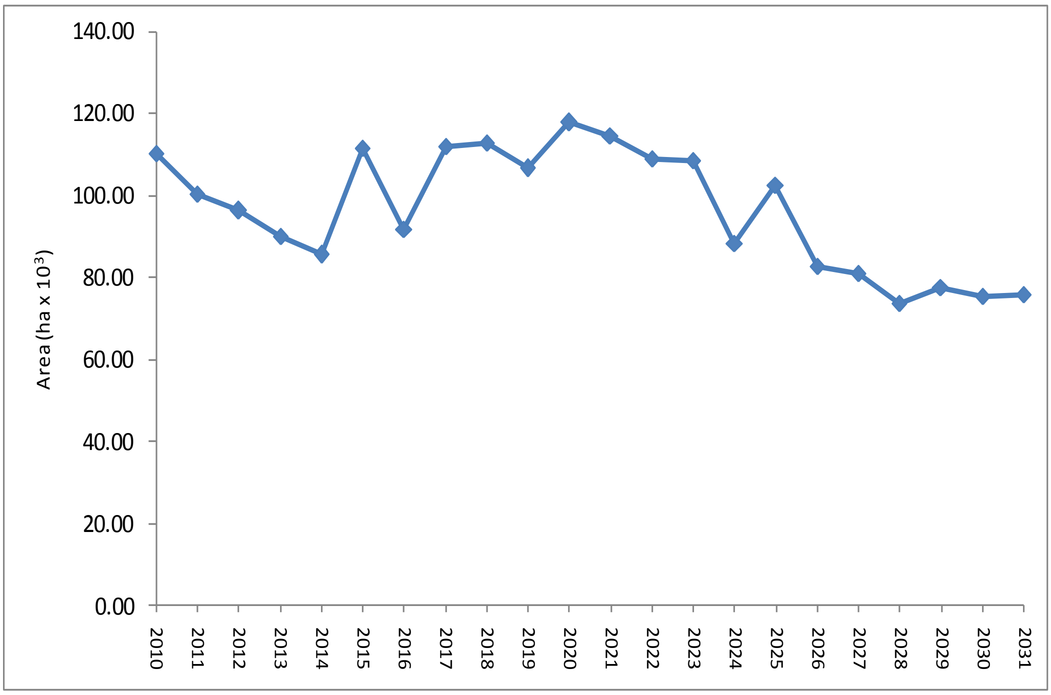

Figure 1.3.10.1

Total area of actual felling programmes for years 2010 – 2031

From the above figure, it can be concluded that the largest replanting area will accumulate in year 2020. The average number of oil palm trees that will be due for felling each year is about 96,521 ha.

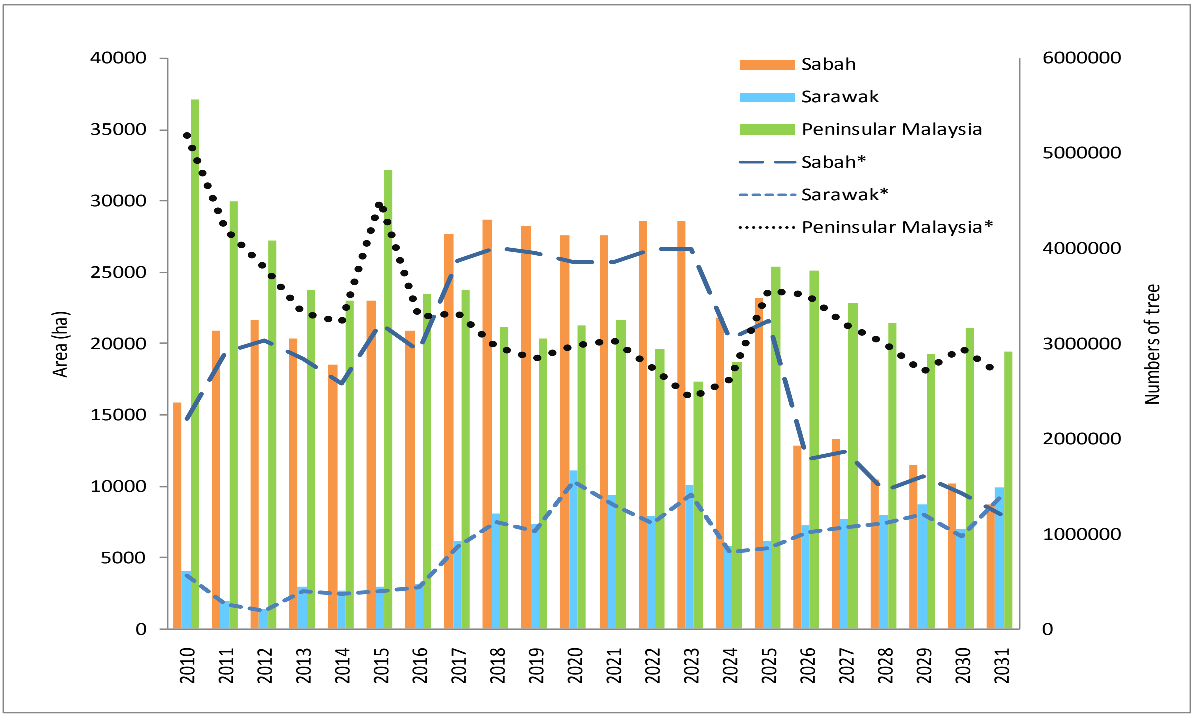

Figure 1.3.10.2

Actual area of felling programmes and number of WPT for years 2010 – 2031

Figure 1.3.10.2 shows the area of replanting programmes and number of trees available in each State for years 2010 - 2031.

Figure 1.3.10.3 shows the number of companies willing to sell their oil palm trunk after felling during the replanting programme. Sabah has the highest number of companies (54) that are willing to sell their trunks, with prices ranging from RM5.00 to RM50.00, followed by Johor (40) with prices ranging from RM3.50 to RM20.00. However price is dependent on the market and can be negotiable. In addition the price will be dependent on the demand for palm trunks.

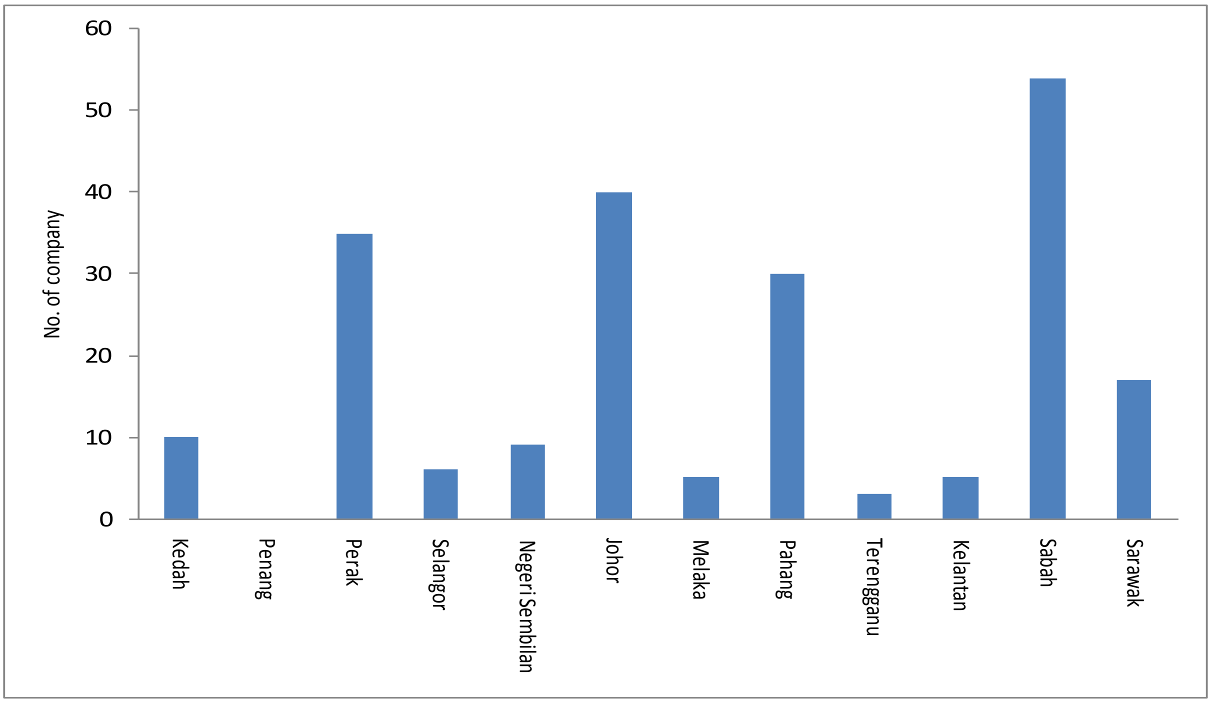

Figure 1.3.10.3

Number of oil palm plantation companies willing to sell their oil palm trunks

1.4 Conclusion

The WPT at felling consists of mostly lignocellulosic materials from its different parts such as the trunk, fronds and leaves. The major part of the WPT is the trunk which comprises about 70% of the total weight. WPT chemical composition is comprised of lignin, celluloses and some extractives. The total dried biomass of WPT per hectare is 98.99 tons. The macro nutrients available per hectare WPT were found to be 100.95 kg of N, 15.24 kg of P, 143.38 kg of K, 21.72 kg of Mg and 34.09 kg of Ca. The ash content was found to be about 2506 kg/ha. The major components of sugars present in the trunk are glucose and xylose. The calorific value of WPT is estimated to be 728,967 MJ/ha.

The total oil palm area planted in Malaysia is currently approximately 4.7 million hectares. The projected area of potential WPT availability within the next 20 years looks very promising, with a maximum availability of 200,803 ha in the year 2022. This will generate dried biomass material of about 15.2 million tons. The locality of potential WPT availability varies yearly. However, the largest area of WPT availability in 2022 will be in Sabah, with 132,579 ha. There will be an average area of 128,296 ha potential WPT in the next 20 years in Malaysia with a total estimated potential energy value of 93.5 PJ (based on the fact that 9,604 L of bioethanol can be derived from one ha of WPT). The average potential of bioethanol production from oil palm sap annually from WPT is estimated to be 1.23 billion litres. Of this amount, only 48.8% will be required to satisfy the E5 biofuel requirement for Malaysia.

Results obtained from the case study showed the actual amount and locality of potential WPT compared to the quantification results reported in this session. The case study results when compared to the National Key Economic Areas (NKEA) report on oil palm showed 73% accuracy.

Based on the above findings, the projected availability of WPT in Malaysia is considerable. WPT biomass represents approximately 18.6% of the total biomass generated annually in Malaysia. This percentage can be compared to approximately 4.24% of the total in China, 37% of the total in Korea and 72.6% of the total in Thailand. WPT biomass has been demonstrated to have various applications as product material for existing industries, in addition to showing potential for energy generation. However, this resource is currently not being used to capacity. Future efforts geared towards realizing the full potential of WPT biomass will be of considerable benefit to both the economy and the environment of the nation.

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Appendices

Table 1.A

Distribution of oil palm based on year planted (Refer to figure 1.3.1.1)

Year Planted	*Age of tree*	*P. Malaysia*	*Sabah*	*Sarawak*	*Total*
1975	36	568,561	59,139	14,091	641,791
1976	35	629,558	69,708	15,334	714,600
1977	34	691,706	73,303	16,805	781,814
1978	33	755,525	78,212	19,242	852,979
1979	32	830,536	86,683	21,644	938,863
1980	31	906,590	93,967	22,749	1,023,306
1981	30	983,148	100,611	24,104	1,107,863
1982	29	1,048,015	110,717	24,065	1,182,797
1983	28	1,099,694	128,248	25,098	1,253,040
1984	27	1,143,522	160,507	26,237	1,330,266
1985	26	1,292,399	161,500	28,500	1,482,399
1986	25	1,410,923	162,645	25,743	1,599,311
1987	24	1,460,502	182,612	29,761	1,672,875
1988	23	1,556,540	213,124	36,259	1,805,923
1989	22	1,644,309	252,954	49,296	1,946,559
1990	21	1,698,498	276,171	54,795	2,029,464
1991	20	1,744,615	289,054	60,359	2,094,028
1992	19	1,775,633	344,885	77,142	2,197,660
1993	18	1,831,776	387,122	87,027	2,305,925
1994	17	1,857,626	452,485	101,888	2,411,999
1995	16	1,903,171	518,133	118,783	2,540,087
1996	15	1,926,378	626,008	139,900	2,692,286
1997	14	1,959,377	758,587	175,125	2,893,089
1998	13	1,987,190	842,496	248,430	3,078,116
1999	12	2,051,595	941,322	320,476	3,313,393
2000	11	2,045,500	1,000,777	330,387	3,376,664
2001	10	2,096,856	1,027,328	374,828	3,499,012
2002	9	2,187,010	1,068,973	414,260	3,670,243
2003	8	2,202,166	1,135,100	464,774	3,802,040
2004	7	2,201,606	1,165,412	508,309	3,875,327
2005	6	2,298,608	1,209,368	543,398	4,051,374
2006	5	2,334,247	1,239,497	591,471	4,165,215
2007	4	2,362,057	1,278,244	664,612	4,304,913

Table 1.B

Oil palm area available based on ownership category (ha) (Refer to figure 1.3.1.2)

Year	*Total Malaysia*	*Private Estate*	*FELDA*	*FELCRA*	*RISDA*	*State Scheme*	*Smallholders*
2011	116,912	70,580	18,390	4,454	2,210	8,511	12,767
2012	73,564	44,411	11,572	2,803	1,390	5,355	8,033
2013	133,048	80,321	20,928	5,069	2,515	9,686	14,529
2014	140,636	84,902	22,122	5,358	2,658	10,238	15,357
2015	82,905	50,050	13,041	3,159	1,567	6,035	9,053
2016	64,564	38,977	10,156	2,460	1,220	4,700	7,050
2017	103,632	62,563	16,301	3,948	1,959	7,544	11,317
2018	108,265	65,360	17,030	4,125	2,046	7,882	11,823
2019	106,074	64,037	16,685	4,041	2,005	7,722	11,583
2020	128,088	77,327	20,148	4,880	2,421	9,325	13,987
2021	152,199	91,883	23,941	5,799	2,877	11,080	16,620
2022	200,803	121,225	31,586	7,651	3,795	14,618	21,928
2023	185,027	111,701	29,105	7,050	3,497	13,470	20,205
2024	235,277	142,037	37,009	8,964	4,447	17,128	25,692
2025	63,271	38,197	9,953	2,411	1,196	4,606	6,909
2026	122,348	73,861	19,245	4,661	2,312	8,907	13,360
2027	171,231	103,372	26,935	6,524	3,236	12,466	18,698
2028	131,797	79,566	20,732	5,021	2,491	9,595	14,392
2029	73,287	44,243	11,528	2,792	1,385	5,335	8,003
2030	176,047	106,280	27,692	6,707	3,327	12,816	19,224
2031	113,841	68,726	17,907	4,337	2,152	8,288	12,431
2032	139,698	84,336	21,974	5,322	2,640	10,170	15,255

**Based on 2007 data distribution*

Table 1.C

Number of trees available based on ownership category (Refer to figure 1.3.1.4)

Year	*Private Estate*	*FELDA*	*FELCRA*	*RISDA*	*State Scheme*	*Small holders*	*Total Malaysia*
2011	9,881,168	2,574,636	623,609	309,349	1,191,567	1,787,351	16,367,680
2012	6,217,482	1,620,026	392,390	194,650	749,764	1,124,646	10,298,960
2013	11,244,951	2,929,983	709,678	352,045	1,356,025	2,034,038	18,626,720
2014	11,886,273	3,097,086	750,152	372,123	1,433,362	2,150,043	19,689,040
2015	7,006,965	1,825,734	442,215	219,367	844,968	1,267,452	11,606,700
2016	5,456,820	1,421,828	344,384	170,836	658,036	987,054	9,038,960
2017	8,758,769	2,282,184	552,773	274,210	1,056,217	1,584,326	14,508,480
2018	9,150,341	2,384,212	577,486	286,469	1,103,437	1,655,155	15,157,100
2019	8,965,162	2,335,962	565,799	280,672	1,081,106	1,621,659	14,850,360
2020	10,825,742	2,820,754	683,221	338,921	1,305,473	1,958,209	17,932,320
2021	12,863,555	3,351,726	811,829	402,719	1,551,212	2,326,818	21,307,860
2022	16,971,468	4,422,084	1,071,083	531,325	2,046,584	3,069,876	28,112,420
2023	15,638,112	4,074,665	986,934	489,581	1,885,795	2,828,693	25,903,780
2024	19,885,141	5,181,270	1,254,968	622,543	2,397,943	3,596,915	32,938,780
2025	5,347,538	1,393,354	337,488	167,415	644,858	967,287	8,857,940
2026	10,340,608	2,694,348	652,604	323,733	1,246,971	1,870,456	17,128,720
2027	14,472,102	3,770,849	913,346	453,077	1,745,186	2,617,780	23,972,340
2028	11,139,219	2,902,434	703,005	348,735	1,343,275	2,014,913	18,451,580
2029	6,194,071	1,613,926	390,913	193,917	746,941	1,120,412	10,260,180
2030	14,879,140	3,876,907	939,035	465,820	1,794,271	2,691,407	24,646,580
2031	9,621,614	2,507,007	607,228	301,223	1,160,267	1,740,401	15,937,740
2032	11,806,996	3,076,429	745,149	369,641	1,423,802	2,135,703	19,557,720

Table 1.D

Total area of oil palm based on State (hectares) (Refer to figure 1.3.1.5)

Year planted	*Age*	*P. Malaysia*	*Sabah*	*Sarawak*	*Johor*	*Kedah*	*Kelantan*	*Melaka*	*N. Sembilan*	*Pahang*	*P. Pinang*	*Perak*	*Perlis*	*Selangor*	*Terengganu*
1975	36	568,561	59,139	14,091	161,471.3	18,194.0	23,879.6	11,939.8	40,936.4	154,648.6	3,411.4	84,715.6	62.6	31,270.9	38,662.1
1976	35	629,558	69,708	15,334	178,794.5	20,145.9	26,441.4	13,220.7	45,328.2	171,239.8	3,777.3	93,804.1	69.3	34,625.7	42,809.9
1977	34	691,706	73,303	16,805	196,444.5	22,134.6	29,051.7	14,525.8	49,802.8	188,144.0	4,150.2	103,064.2	76.1	38,043.8	47,036.0
1978	33	755,525	78,212	19,242	214,569.1	24,176.8	31,732.1	15,866.0	54,397.8	205,502.8	4,533.2	112,573.2	83.2	41,553.9	51,375.7
1979	32	830,536	86,683	21,644	235,872.2	26,577.2	34,882.5	17,441.3	59,798.6	225,905.8	4,983.2	123,749.9	91.4	45,679.5	56,476.4
1980	31	906,590	93,967	22,749	257,471.6	29,010.9	38,076.8	19,038.4	65,274.5	246,592.5	5,439.5	135,081.9	99.8	49,862.5	61,648.1
1981	30	983,148	100,611	24,104	279,214.0	31,460.7	41,292.2	20,646.1	70,786.7	267,416.3	5,898.9	146,489.1	108.2	54,073.1	66,854.1
1982	29	1,048,015	110,717	24,065	297,636.3	33,536.5	44,016.6	22,008.3	75,457.1	285,060.1	6,288.1	156,154.2	115.4	57,640.8	71,265.0
1983	28	1,099,694	128,248	25,098	312,313.1	35,190.2	46,187.1	23,093.6	79,178.0	299,116.8	6,598.2	163,854.4	121.0	60,483.2	74,779.2
1984	27	1,143,522	160,507	26,237	324,760.2	36,592.7	48,027.9	24,014.0	82,333.6	311,038.0	6,861.1	170,384.8	125.9	62,893.7	77,759.5
1985	26	1,292,399	161,500	28,500	367,041.3	41,356.8	54,280.8	27,140.4	93,052.7	351,532.5	7,754.4	192,567.5	142.3	71,081.9	87,883.1
1986	25	1,410,923	162,645	25,743	400,702.1	45,149.5	59,258.8	29,629.4	101,586.5	383,771.1	8,465.5	210,227.5	155.3	77,600.8	95,942.8
1987	24	1,460,502	182,612	29,761	414,782.6	46,736.1	61,341.1	30,670.5	105,156.1	397,256.5	8,763.0	217,614.8	160.8	80,327.6	99,314.1
1988	23	1,556,540	213,124	36,259	442,057.4	49,809.3	65,374.7	32,687.3	112,070.9	423,378.9	9,339.2	231,924.5	171.3	85,609.7	105,844.7
1989	22	1,644,309	252,954	49,296	466,983.8	52,617.9	69,061.0	34,530.5	118,390.2	447,252.0	9,865.9	245,002.0	181.0	90,437.0	111,813.0
1990	21	1,698,498	276,171	54,795	482,373.4	54,351.9	71,336.9	35,668.5	122,291.9	461,991.5	10,191.0	253,076.2	187.0	93,417.4	115,497.9
1991	20	1,744,615	289,054	60,359	495,470.7	55,827.7	73,273.8	36,636.9	125,612.3	474,535.3	10,467.7	259,947.6	192.0	95,953.8	118,633.8
1992	19	1,775,633	344,885	77,142	504,279.8	56,820.3	74,576.6	37,288.3	127,845.6	482,972.2	10,653.8	264,569.3	195.5	97,659.8	120,743.0
1993	18	1,831,776	387,122	87,027	520,224.4	58,616.8	76,934.6	38,467.3	131,887.9	498,243.1	10,990.7	272,934.6	201.6	100,747.7	124,560.8
1994	17	1,857,626	452,485	101,888	527,565.8	59,444.0	78,020.3	39,010.1	133,749.1	505,274.3	11,145.8	276,786.3	204.5	102,169.4	126,318.6
1995	16	1,903,171	518,133	118,783	540,500.6	60,901.5	79,933.2	39,966.6	137,028.3	517,662.5	11,419.0	283,572.5	209.5	104,674.4	129,415.6
1996	15	1,926,378	626,008	139,900	547,091.4	61,644.1	80,907.9	40,453.9	138,699.2	523,974.8	11,558.3	287,030.3	212.0	105,950.8	130,993.7
1997	14	1,959,377	758,587	175,125	556,463.1	62,700.1	82,293.8	41,146.9	141,075.1	532,950.5	11,756.3	291,947.2	215.7	107,765.7	133,237.6

Year planted	*Age*	*P. Malaysia*	*Sabah*	*Sarawak*	*Johor*	*Kedah*	*Kelantan*	*Melaka*	*N. Sembilan*	*Pahang*	*P. Pinang*	*Perak*	*Perlis*	*Selangor*	*Terengganu*
1998	13	1,987,190	842,496	248,430	564,362.0	63,590.1	83,462.0	41,731.0	143,077.7	540,515.7	11,923.1	296,091.3	218.7	109,295.5	135,128.9
1999	12	2,051,595	941,322	320,476	582,653.0	65,651.0	86,167.0	43,083.5	147,714.8	558,033.8	12,309.6	305,687.7	225.8	112,837.7	139,508.5
2000	11	2,045,500	1,000,777	330,387	580,922.0	65,456.0	85,911.0	42,955.5	147,276.0	556,376.0	12,273.0	304,779.5	225.2	112,502.5	139,094.0
2001	10	2,096,856	1,027,328	374,828	595,507.1	67,099.4	88,068.0	44,034.0	150,973.6	570,344.8	12,581.1	312,431.5	230.8	115,327.1	142,586.2
2002	9	2,187,010	1,068,973	414,260	621,110.8	69,984.3	91,854.4	45,927.2	157,464.7	594,866.7	13,122.1	325,864.5	240.7	120,285.6	148,716.7
2003	8	2,202,166	1,135,100	464,774	625,415.1	70,469.3	92,491.0	46,245.5	158,556.0	598,989.2	13,213.0	328,122.7	242.4	121,119.1	149,747.3
2004	7	2,201,606	1,165,412	508,309	625,256.1	70,451.4	92,467.5	46,233.7	158,515.6	598,836.8	13,209.6	328,039.3	242.3	121,088.3	149,709.2
2005	6	2,298,608	1,209,368	543,398	652,804.7	73,555.5	96,541.5	48,270.8	165,499.8	625,221.4	13,791.6	342,492.6	253.0	126,423.4	156,305.3
2006	5	2,334,247	1,239,497	591,471	662,926.1	74,695.9	98,038.4	49,019.2	168,065.8	634,915.2	14,005.5	347,802.8	256.9	128,383.6	158,728.8
2007	4	2,362,057	1,278,244	664,612	670,824.2	75,585.8	99,206.4	49,603.2	170,068.1	642,479.5	14,172.3	351,946.5	260.0	129,913.1	160,619.9

Table 1.E

Plantation area available for harvesting (25 years) (Refer to figure 1.3.2.1)

Year available	*Semenanjung*	*Sabah*	*Sarawak*	*Total*
2011	118,524	1,145	-2,757	116,912
2012	49,579	19,967	4,018	73,564
2013	96,038	30,512	6,498	133,048
2014	87,769	39,830	13,037	140,636
2015	54,189	23,217	5,499	82,905
2016	46,117	12,883	5,564	64,564
2017	31,018	55,831	16,783	103,632
2018	56,143	42,237	9,885	108,265
2019	25,850	65,363	14,861	106,074
2020	45,545	65,648	16,895	128,088
2021	23,207	107,875	21,117	152,199
2022	32,999	132,579	35,225	200,803
2023	27,813	83,909	73,305	185,027
2024	64,405	98,826	72,046	235,277
2025	-6,095	59,455	9,911	63,271
2026	51,356	26,551	44,441	122,348
2027	90,154	41,645	39,432	171,231
2028	15,156	66,127	50,514	131,797
2029	-560	30,312	43,535	73,287
2030	97,002	43,956	35,089	176,047
2031	35,639	30,129	48,073	113,841
2032	27,810	38,747	73,141	139,698

Notes:

1. Plantation area is estimated by subtracting the total area after 25 years with the total area of the subsequent year.
2. Majority of the oil palm plantations are not doing replantation even after 25 years. There will be older oil palms available if the replantation exceeds 25 years.

Table 1.F

Availability of oil palm trunks (dry matter tons) based on ownership category (Refer to figure 1.3.2.2)

Year	*Private Estate*	*FELDA*	*FELCRA*	*RISDA*	*State Scheme*	*Smallholders*	*Total Malaysia*
2011	5,328,773	1,388,464	336,303	166,828	642,595	963,893	8,826,856
2012	3,352,999	873,657	211,611	104,972	404,337	606,506	5,554,082
2013	6,064,241	1,580,098	382,719	189,853	731,285	1,096,928	10,045,124
2014	6,410,097	1,670,214	404,546	200,681	772,992	1,159,488	10,618,018
2015	3,778,756	984,592	238,480	118,301	455,679	683,519	6,259,328
2016	2,942,785	766,772	185,722	92,130	354,870	532,304	4,874,582
2017	4,723,479	1,230,749	298,103	147,878	569,603	854,404	7,824,216
2018	4,934,648	1,285,771	311,430	154,489	595,068	892,602	8,174,008
2019	4,834,784	1,259,751	305,127	151,362	583,025	874,538	8,008,587
2020	5,838,168	1,521,192	368,452	182,775	704,023	1,056,034	9,670,644
2021	6,937,131	1,807,538	437,808	217,180	836,547	1,254,820	11,491,025
2022	9,152,470	2,384,767	577,620	286,536	1,103,694	1,655,540	15,160,627
2023	8,433,410	2,197,408	532,239	264,024	1,016,982	1,525,474	13,969,539
2024	10,723,773	2,794,185	676,786	335,729	1,293,177	1,939,765	17,763,414
2025	2,883,851	751,416	182,002	90,285	347,763	521,644	4,776,961
2026	5,576,542	1,453,023	351,940	174,584	672,474	1,008,710	9,237,274
2027	7,804,598	2,033,565	492,555	244,338	941,154	1,411,731	12,927,941
2028	6,007,222	1,565,241	379,121	188,068	724,409	1,086,614	9,950,674
2029	3,340,374	870,367	210,814	104,577	402,815	604,222	5,533,169
2030	8,024,108	2,090,761	506,408	251,210	967,625	1,451,437	13,291,549
2031	5,188,799	1,351,993	327,469	162,445	625,716	938,574	8,594,996
2032	6,367,344	1,659,074	401,848	199,342	767,836	1,151,754	10,547,199

* 75.5 ton/ha (dry matter)

Table 1.G

Plantation area available for replanting (25 years and older) one year range based on State (hectares) (Refer to figure 1.3.2.3)

Year	*Sabah*	*Sarawak*	*Johor*	*Kedah*	*Kelantan*	*Melaka*	*N. Sembilan*	*Pahang*	*P. Pinang*	*Perak*	*Perlis*	*Selangor*	*Terengganu*	*Total Semenanjung*	*Total Malaysia*
2011	1145	-2757	33652	3768	5006	2464	8573	32187	668	17612	13	6489	8093	118524	116912
2012	19967	4018	14077	1576	2094	1031	3586	13464	279	7367	5	2714	3385	49579	73564
2013	30512	6498	27267	3053	4056	1997	6946	26081	541	14270	11	5258	6558	96038	133048
2014	39830	13037	24920	2790	3707	1825	6348	23835	494	13042	10	4805	5993	87769	140636
2015	23217	5499	15385	1723	2289	1127	3919	14716	305	8052	6	2967	3700	54189	82905
2016	12883	5564	13094	1466	1948	959	3336	12524	260	6853	5	2525	3149	46117	64564
2017	55831	16783	8807	986	1310	645	2243	8423	175	4609	3	1698	2118	31018	103632
2018	42237	9885	15940	1785	2371	1167	4061	15246	316	8342	6	3074	3834	56143	108265
2019	65363	14861	7339	822	1092	537	1870	7020	146	3841	3	1415	1765	25850	106074
2020	65648	16895	12931	1448	1924	947	3294	12368	257	6768	5	2493	3110	45545	128088
2021	107875	21117	6589	738	980	483	1679	6302	131	3448	3	1271	1585	23207	152199
2022	132579	35225	9369	1049	1394	686	2387	8961	186	4903	4	1807	2253	32999	200803
2023	83909	73305	7897	884	1175	578	2012	7553	157	4133	3	1523	1899	27813	185027
2024	98826	72046	18286	2048	2720	1339	4658	17490	363	9570	7	3526	4398	64405	235277
2025	59455	9911	-1731	-194	-257	-127	-441	-1655	-34	-906	-1	-334	-416	-6095	63271
2026	26551	44441	14581	1633	2169	1068	3714	13946	289	7631	6	2812	3507	51356	122348
2027	41645	39432	25597	2866	3808	1875	6521	24483	508	13396	10	4936	6156	90154	171231
2028	66127	50514	4303	482	640	315	1096	4116	85	2252	2	830	1035	15156	131797
2029	30312	43535	-159	-18	-24	-12	-41	-152	-3	-83	0	-31	-38	-560	73287
2030	43956	35089	27541	3084	4097	2017	7016	26342	546	14414	11	5311	6624	97002	176047
2031	30129	48073	10119	1133	1505	741	2578	9678	201	5296	4	1951	2434	35639	113841
2032	38747	73141	7896	884	1175	578	2011	7552	157	4132	3	1523	1899	27810	139698

Table 1.H

Number of trees available for harvesting (25 years and older) one year range based on State (Refer to figure 1.3.2.4)

Year	*Sabah*	*Sarawak*	*Johor*	*Kedah*	*Kelantan*	*Melaka*	*N. Sembilan*	*Pahang*	*P. Pinang*	*Perak*	*Perlis*	*Selangor*	*Terengganu*	*Total Semenanjung*	*Total Malaysia*
2011	160300	-385980	4711227	527547	700831	345017	1200166	4506176	93460	2465642	1826	908433	1133035	16593360	16367680
2012	2795380	562520	1970723	220675	293160	144322	502033	1884949	39095	1031387	764	380001	473952	6941060	10298960
2013	4271680	909720	3817428	427462	567872	279561	972474	3651278	75729	1997868	1480	736088	918079	13445320	18626720
2014	5576200	1825180	3488742	390657	518977	255491	888743	3336898	69209	1825849	1353	672710	839031	12287660	19689040
2015	3250380	769860	2153966	241194	320419	157741	548714	2060217	42730	1127288	835	415334	518022	7586460	11606700
2016	1803620	778960	1833111	205265	272689	134244	466977	1753327	36365	959367	711	353466	440857	6456380	9038960
2017	7816340	2349620	1232939	138060	183409	90292	314086	1179276	24459	645264	478	237739	296518	4342520	14508480
2018	5913180	1383900	2231636	249891	331973	163429	568500	2134506	44271	1167937	865	430311	536701	7860020	15157100
2019	9150820	2080540	1027515	115058	152851	75248	261755	982794	20384	537755	398	198129	247114	3619000	14850360
2020	9190720	2365300	1810375	202719	269307	132579	461185	1731580	35914	947468	702	349082	435389	6376300	17932320
2021	15102500	2956380	922458	103294	137223	67554	234992	882309	18299	482773	358	177871	221848	3248980	21307860
2022	18561060	4931500	1311682	146877	195123	96058	334146	1254592	26021	686475	509	252922	315455	4619860	28112420
2023	11747260	10262700	1105543	123795	164458	80962	281632	1057425	21931	578591	429	213174	265880	3893820	25903780
2024	13835640	10086440	2560044	286665	380826	187479	652160	2448620	50785	1339810	993	493635	615682	9016700	32938780
2025	8323700	1387540	-242271	-27129	-36040	-17742	-61718	-231726	-4806	-126794	-94	-46715	-58265	-853300	8857940
2026	3717140	6221740	2041357	228584	303668	149495	520027	1952509	40496	1068353	791	393621	490940	7189840	17128720
2027	5830300	5520480	3583544	401273	533080	262433	912893	3427574	71089	1875464	1389	690990	861831	12621560	23972340
2028	9257780	7071960	602438	67459	89617	44118	153469	576217	11951	315289	234	116164	144884	2121840	18451580
2029	4243680	6094900	-22260	-2493	-3311	-1630	-5671	-21291	-442	-11650	-9	-4292	-5353	-78400	10260180
2030	6153840	4912460	3855746	431753	573572	282368	982235	3687929	76489	2017922	1495	743477	927295	13580280	24646580
2031	4218060	6730220	1416620	158628	210733	103743	360878	1354963	28103	741394	549	273157	340692	4989460	15937740
2032	5424580	10239740	1105424	123781	164440	80953	281602	1057311	21929	578528	429	213151	265851	3893400	19557720

*based on 140 trees/hectare

Table 1.I

Available oil palm trunks (dry matter tons) (Refer to figure 1.3.2.5)

Year	*Sabah*	*Sarawak*	*Johor*	*Kedah*	*Kelantan*	*Melaka*	*N. Sembilan*	*Pahang*	*P. Pinang*	*Perak*	*Perlis*	*Selangor*	*Terengganu*	*Total Semenanjung*	*Total Malaysia*
2011	86448	-208154	2540698	284498	377948	186063	647232	2430116	50402	1329686	985	489905	611030	8948562	8826856
2012	1507509	303359	1062783	119007	158097	77831	270739	1016526	21083	556212	412	204929	255596	3743215	5554082
2013	2303656	490599	2058684	230524	306245	150763	524441	1969082	40840	1077422	798	396962	495107	7250869	10045124
2014	3007165	984294	1881429	210676	279877	137783	479286	1799542	37323	984654	729	362783	452478	6626560	10618018
2015	1752884	415175	1161603	130072	172797	85068	295914	1111046	23044	607930	450	223984	279362	4091270	6259328
2016	972667	420082	988571	110697	147057	72396	251834	945544	19611	517373	383	190619	237748	3481834	4874582
2017	4215241	1267117	664906	74454	98910	48693	169382	635967	13190	347982	258	128209	159908	2341859	7824216
2018	3188894	746318	1203489	134762	179028	88135	306584	1151109	23875	629852	467	232060	289435	4238797	8174008
2019	4934907	1122006	554124	62049	82430	40580	141161	530007	10993	290003	215	106848	133265	1951675	8008587
2020	4956424	1275573	976309	109324	145233	71498	248711	933816	19368	510956	379	188255	234799	3438648	9670644
2021	8144563	1594334	497469	55705	74002	36431	126728	475817	9869	260352	193	95923	119640	1752129	11491025
2022	10009715	2659488	707371	79209	105227	51803	180200	676584	14033	370206	274	136397	170121	2491425	15160627
2023	6335130	5534528	596203	66761	88690	43662	151880	570254	11827	312026	231	114962	143385	2099882	13969539
2024	7461363	5439473	1380595	154594	205374	101105	351701	1320506	27388	722541	535	266210	332029	4862578	17763414
2025	4488853	748281	-130653	-14630	-19436	-9568	-33283	-124967	-2592	-68378	-51	-25193	-31422	-460173	4776961
2026	2004601	3355296	1100875	123272	163764	80620	280443	1052960	21839	576148	427	212274	264757	3877378	9237274
2027	3144198	2977116	1932554	216401	287482	141527	492310	1848442	38338	1011411	749	372641	464773	6806627	12927941
2028	4992589	3813807	324886	36380	48329	23792	82763	310746	6445	170031	126	62646	78134	1144278	9950674
2029	2288556	3286893	-12004	-1344	-1786	-879	-3058	-11482	-238	-6282	-5	-2315	-2887	-42280	5533169
2030	3318678	2649220	2079349	232838	309319	152277	529705	1988847	41250	1088237	806	400946	500077	7323651	13291549
2031	2274740	3629512	763963	85546	113645	55947	194616	730712	15155	399823	296	147310	183731	2690745	8594996
2032	2925399	5522146	596139	66754	88680	43657	151864	570193	11826	311992	231	114949	143370	2099655	10547199

Note: Amount of trunks assumed to be 75.5 tons/ha (dry matter)

Table 1.J

Fronds available during replanting (tons of dry matter) (Refer to figure 1.3.3)

Year	*Sabah*	*Sarawak*	*Johor*	*Kedah*	*Kelantan*	*Melaka*	*N. Sembilan*	*Pahang*	*P. Pinang*	*Perak*	*Perlis*	*Selangor*	*Terengganu*	*Total Semenanjung*	*Total Malaysia*
2011	1145	-2757	33652	3768	5006	2464	8573	32187	668	17612	13	6489	8093	118524	116912
2012	19967	4018	14077	1576	2094	1031	3586	13464	279	7367	5	2714	3385	49579	73564
2013	30512	6498	27267	3053	4056	1997	6946	26081	541	14270	11	5258	6558	96038	133048
2014	39830	13037	24920	2790	3707	1825	6348	23835	494	13042	10	4805	5993	87769	140636
2015	23217	5499	15385	1723	2289	1127	3919	14716	305	8052	6	2967	3700	54189	82905
2016	12883	5564	13094	1466	1948	959	3336	12524	260	6853	5	2525	3149	46117	64564
2017	55831	16783	8807	986	1310	645	2243	8423	175	4609	3	1698	2118	31018	103632
2018	42237	9885	15940	1785	2371	1167	4061	15246	316	8342	6	3074	3834	56143	108265
2019	65363	14861	7339	822	1092	537	1870	7020	146	3841	3	1415	1765	25850	106074
2020	65648	16895	12931	1448	1924	947	3294	12368	257	6768	5	2493	3110	45545	128088
2021	107875	21117	6589	738	980	483	1679	6302	131	3448	3	1271	1585	23207	152199
2022	132579	35225	9369	1049	1394	686	2387	8961	186	4903	4	1807	2253	32999	200803
2023	83909	73305	7897	884	1175	578	2012	7553	157	4133	3	1523	1899	27813	185027
2024	98826	72046	18286	2048	2720	1339	4658	17490	363	9570	7	3526	4398	64405	235277
2025	59455	9911	-1731	-194	-257	-127	-441	-1655	-34	-906	-1	-334	-416	-6095	63271
2026	26551	44441	14581	1633	2169	1068	3714	13946	289	7631	6	2812	3507	51356	122348
2027	41645	39432	25597	2866	3808	1875	6521	24483	508	13396	10	4936	6156	90154	171231
2028	66127	50514	4303	482	640	315	1096	4116	85	2252	2	830	1035	15156	131797
2029	30312	43535	-159	-18	-24	-12	-41	-152	-3	-83	0	-31	-38	-560	73287
2030	43956	35089	27541	3084	4097	2017	7016	26342	546	14414	11	5311	6624	97002	176047
2031	30129	48073	10119	1133	1505	741	2578	9678	201	5296	4	1951	2434	35639	113841
2032	38747	73141	7896	884	1175	578	2011	7552	157	4132	3	1523	1899	27810	139698

Amount of frond replanting assumed to be 14.4 tons/ha (dry matter)

Table 1.K

Fronds (pruning) of oil palm available (tons) (Refer to figure 1.3.3)

Year	*Sabah*	*Sarawak*	*Johor*	*Kedah*	*Kelantan*	*Melaka*	*N. Sembilan*	*Pahang*	*P. Pinang*	*Perak*	*Perlis*	*Selangor*	*Terengganu*	*Total Semenanjung*	*Total Malaysia*
2011	11908	-28673	349977	39189	52062	25630	89155	334744	6943	183162	136	67484	84168	1232650	1215885
2012	207657	41787	146397	16393	21778	10721	37294	140025	2904	76617	57	28229	35208	515622	765066
2013	317325	67579	283580	31754	42185	20767	72241	271238	5626	148413	110	54681	68200	998795	1383699
2014	414232	135585	259164	29020	38553	18979	66021	247884	5141	135635	100	49973	62328	912798	1462614
2015	241457	57190	160009	17917	23803	11718	40762	153045	3174	83741	62	30853	38482	563566	862212
2016	133983	57866	136174	15248	20257	9972	34690	130247	2701	71267	53	26257	32749	479617	671466
2017	580642	174543	91590	10256	13625	6707	23332	87603	1817	47934	36	17661	22027	322587	1077773
2018	439265	102804	165779	18563	24661	12140	42231	158563	3289	86761	64	31966	39869	583887	1125956
2019	679775	154554	76330	8547	11355	5590	19445	73008	1514	39947	30	14718	18357	268840	1103170
2020	682739	175708	134485	15059	20006	9849	34259	128632	2668	70383	52	25932	32343	473668	1332115
2021	1121900	219617	68525	7673	10194	5018	17457	65543	1359	35863	27	13213	16480	241353	1582870
2022	1378822	366340	97439	10911	14495	7136	24822	93198	1933	50995	38	18789	23434	343190	2088351
2023	872654	762372	82126	9196	12217	6014	20921	78552	1629	42981	32	15836	19751	289255	1924281
2024	1027790	749278	190175	21295	28290	13927	48446	181897	3773	99529	74	36670	45736	669812	2446881
2025	618332	103074	-17997	-2015	-2677	-1318	-4585	-17214	-357	-9419	-7	-3470	-4328	-63388	658018
2026	276130	462186	151644	16981	22558	11105	38631	145044	3008	79363	59	29240	36470	534102	1272419
2027	433108	410093	266206	29809	39600	19495	67815	254620	5281	139320	103	51331	64022	937602	1780802
2028	687721	525346	44753	5011	6657	3277	11401	42805	888	23421	17	8629	10763	157622	1370689
2029	315245	452764	-1654	-185	-246	-121	-421	-1582	-33	-865	-1	-319	-398	-5824	762185
2030	457142	364926	286427	32073	42608	20976	72966	273960	5682	149903	111	55230	68885	1008821	1830889
2031	313342	499959	105235	11784	15654	7707	26808	100654	2088	55075	41	20292	25309	370646	1183946
2032	402969	760666	82117	9195	12216	6014	20919	78543	1629	42976	32	15834	19749	289224	1452859

Amount of frond pruning assumed to be 10.4 tons/ha (dry matter)

Table 1.L

Availability of EFB (tons) from year 2011 - 2032

Year	*Sabah*	*Sarawak*	*Johor*	*Kedah*	*Kelantan*	*Melaka*	*N. Sembilan*	*Pahang*	*P. Pinang*	*Perak*	*Perlis*	*Selangor*	*Terengganu*	*Total Semenanjung*	*Total Malaysia*
2011	1832	-4411	53843	6029	8010	3943	13716	51499	1068	28179	21	10382	12949	189638	187059
2012	31947	6429	22523	2522	3350	1649	5738	21542	447	11787	9	4343	5417	79326	117702
2013	48819	10397	43628	4885	6490	3195	11114	41729	865	22833	17	8412	10492	153661	212877
2014	63728	20859	39871	4465	5931	2920	10157	38136	791	20867	15	7688	9589	140430	225018
2015	37147	8798	24617	2756	3662	1803	6271	23545	488	12883	10	4747	5920	86702	132648
2016	20613	8902	20950	2346	3116	1534	5337	20038	416	10964	8	4040	5038	73787	103302
2017	89330	26853	14091	1578	2096	1032	3590	13477	280	7374	5	2717	3389	49629	165811
2018	67579	15816	25504	2856	3794	1868	6497	24394	506	13348	10	4918	6134	89829	173224
2019	104581	23778	11743	1315	1747	860	2991	11232	233	6146	5	2264	2824	41360	169718
2020	105037	27032	20690	2317	3078	1515	5271	19789	410	10828	8	3990	4976	72872	204941
2021	172600	33787	10542	1180	1568	772	2686	10084	209	5517	4	2033	2535	37131	243518
2022	212126	56360	14991	1679	2230	1098	3819	14338	297	7845	6	2891	3605	52798	321285
2023	134254	117288	12635	1415	1880	925	3219	12085	251	6612	5	2436	3039	44501	296043
2024	158122	115274	29258	3276	4352	2143	7453	27984	580	15312	11	5642	7036	103048	376443
2025	95128	15858	-2769	-310	-412	-203	-705	-2648	-55	-1449	-1	-534	-666	-9752	101234
2026	42482	71106	23330	2612	3470	1709	5943	22314	463	12210	9	4499	5611	82170	195757
2027	66632	63091	40955	4586	6092	2999	10433	39172	812	21434	16	7897	9849	144246	273970
2028	105803	80822	6885	771	1024	504	1754	6585	137	3603	3	1328	1656	24250	210875
2029	48499	69656	-254	-28	-38	-19	-65	-243	-5	-133	0	-49	-61	-896	117259
2030	70330	56142	44066	4934	6555	3227	11226	42148	874	23062	17	8497	10598	155203	281675
2031	48206	76917	16190	1813	2408	1186	4124	15485	321	8473	6	3122	3894	57022	182146
2032	61995	117026	12633	1415	1879	925	3218	12084	251	6612	5	2436	3038	44496	223517

Table 1.M

Area of replanting programmes for each State

Year	*Kedah*	*Penang*	*Perak*	*Selangor*	*Negeri Sembilan*	*Johor*	*Melaka*	*Pahang*	*Terengganu*	*Kelantan*	*Sabah*	*Sarawak*
2010	569	57	3931	1085	1392	9147	736	13424	2471	4224	15840	4042
2011	387	59	4936	1645	1437	8347	457	9201	1409	2068	20829	1886
2012	705	0	4400	1025	1809	6926	742	9095	1159	1314	21629	1387
2013	418	77	3700	1583	1769	5196	336	8420	1180	1040	20311	2893
2014	812	113	3022	689	1147	6279	223	8598	1141	936	18444	2670
2015	633	123	4579	1029	1051	6794	390	10378	5355	1798	22947	2887
2016	624	147	4022	428	226	5265	141	11942	56	594	20903	3142
2017	1142	51	2871	879	500	7442	455	8611	905	836	27653	6149
2018	995	50	3147	918	953	4959	457	7759	1471	470	28618	8079
2019	1029	30	5116	888	1510	5462	831	4336	758	337	28182	7354
2020	1080	93	1597	1252	962	3900	972	9384	1522	453	27583	11065
2021	1174	75	2565	722	819	5585	90	9639	275	688	27584	9310
2022	822	0	3479	778	694	4117	99	6449	2591	578	28550	7901
2023	743	0	3745	889	832	3854	248	5202	513	1294	28551	10048
2024	886	57	4700	678	2689	2948	97	4732	669	1209	21808	5771
2025	1755	78	6081	749	1236	5045	476	7064	1840	1028	23157	6107
2026	1607	97	7049	857	1366	5566	871	5467	1091	1081	12795	7265
2027	993	30	6886	755	1360	4688	723	5697	948	724	13316	7672
2028	1187	24	6365	533	2548	4389	134	4035	1024	1183	10462	7943
2029	234	0	2513	445	693	10017	88	2016	1780	1461	11462	8653
2030	221	70	1701	928	1421	5256	89	5503	2993	2848	10173	6916
2031	0	59	1839	216	195	3842	160	8447	3122	1509	8656	9863

Table 1.N

Number of trees for area of replanting programmes for each State

	Kedah	*Kedah*	*Penang*	*Perak*	*Selangor*	*Negeri Sembilan*	*Johor*	*Melaka*	*Pahang*	*Terengganu*	*Kelantan*	*Sabah*	*Sarawak*
2010	569	79717	7980	550400	151929	194841	1280541	103071	1879314	345934	591408	2217544	565898
2011	387	54207	8232	691061	230338	201149	1168604	64033	1288184	197319	289586	2915996	264088
2012	705	98713	0	615945	143511	253220	969597	103896	1273296	162222	183974	3028036	194174
2013	418	58558	10780	518041	221579	247632	727444	47040	1178782	165218	145540	2843558	404954
2014	812	113742	15844	423013	96468	160567	879102	31184	1203767	159722	131013	2582114	373869
2015	633	88676	17262	640994	144088	147173	951220	54593	1452915	749763	251663	3212640	404176
2016	624	87388	20576	563149	59860	31678	737131	19795	1671860	7868	83131	2926424	439842
2017	1142	159888	7154	401877	123022	70006	1041904	63716	1205541	126642	116988	3871385	860881
2018	995	139278	7000	440616	128541	133400	694263	63930	1086195	205994	65747	4006482	1131007
2019	1029	144099	4214	716190	124331	211387	764718	116280	607094	106103	47195	3945418	1029517
2020	1080	151242	12964	223644	175325	134720	546048	136018	1313768	213081	63465	3861638	1549034
2021	1174	164304	10472	359166	101112	114643	781942	12600	1349452	38458	96380	3861691	1303366
2022	822	115121	0	487007	108874	97117	576317	13924	902860	362792	80947	3997020	1106206
2023	743	104020	0	524285	124453	116445	539550	34679	728349	71842	181178	3997083	1406689
2024	886	124074	8036	658046	94972	376496	412700	13649	662434	93625	169190	3053095	807990
2025	1755	245633	10864	851306	104905	173001	706327	66613	988924	257636	143851	3241976	854953
2026	1607	224931	13538	986803	119931	191300	779185	122003	765359	152708	151381	1791259	1017092
2027	993	138996	4228	964067	105661	190367	656376	101154	797518	132668	101417	1864185	1074018
2028	1187	166132	3416	891120	74682	356685	614418	18803	564890	143403	165603	1464666	1111967
2029	234	32760	0	351774	62349	96991	1402412	12325	282225	249264	204541	1604673	1211420
2030	221	30884	9814	238122	129934	198887	735881	12417	770452	418989	398768	1424283	968283
2031	0	0	0	257425	0	27353	537827	22413	1182586	437079	211240	1211885	1380786

2. Chapter 2: Assessment of current waste oil palm tree management systems, practices and utilization at national and local levels

2.1 Introduction

2.1.1 Background

The mature oil palm tree is made up of roots, trunk and the foliage. The roots provide good anchorage and an effective absorbing system for water and inorganic nutrients. Like other palms, the trunk is made up of a mass of vascular bundles and tissues. The trunk is completely enclosed by the fronds which can start to fall off when the palm reaches more than 10 years and continue falling throughout the life span of the palm. The trunk can grow to a height of about 15 to 18 meters with an average growth rate of about 45 cm per year.

The older trees have smoother trunks apart from the scars left by the fronds which have withered and fallen off (figure 2.1.1.2). The vascular tissues found in the trunk provide both mechanical support and serve as a conduit for the transportation of nutrients to the other parts of the tree. Apart from that they support the leaves and function as a storage organ. The palm tree produces between forty to sixty fronds at any time with two to three new fronds coming out every month.

Figure 2.1.1.1
Differences in physical appearance and shape: young (left) and old palm trees (right)

A normal oil palm tree will start bearing fruit after 30 months of planting and will continue to do so for the next 20 to 30 years, ensuring a consistent supply of fruit for the extraction of oil.

Normally the trees are replanted when they reach the age of 25 years as the height of the palms makes it difficult to harvest the bunches. Moreover, there is a need to introduce better planting materials which produce better yield and resistance to disease, characteristics achieved through continuous breeding programmes by the industry players, which are not present in aging palms. Another contributing factor is that especially in coastal and old oil palm areas, trees have thinned down due to *Ganoderma* infestation over the years. Finally, current oil palm stands have a much lower yield compared to the much higher expected productivity of modern oil palm planting material. Present day planting material is able to generate up to 20 T/FFB/ha and produces 5 T/ha to 6 T/ha during the first year of maturity. In older estates, where replanting work sometimes enters the third cycle, pests and diseases tend to be endemic. On peat, there exists a special problem of termite infestation, which is up to 70% in some areas. In such areas and where the *Ganoderma* problem is serious, sanitation is the only policy to establish new and healthy oil palm planting (figure 2.1.1.2).


Figure 2.1.1.2
Oil palm trees infested with *Ganoderma*

The traditional method of establishing new oil palm plantations or replanting is the clean clearing technique. Forest or old palm stands are felled, stacked and burnt, releasing an extensive amount of smoke to the environment. Burning of biomass in the land clearing process is aimed at disposing of waste material so that it does not obstruct plantation management, and eliminating pests and diseases by destroying their breeding medium. In addition, burning of unwanted biomass and other waste material is apparently the cheapest and fastest method of waste disposal. This activity causes excessive release of CO_2 to the atmosphere and may contribute to climate change and global warming. Particles as a result of the burning definitely cause a haze problem. The Malaysian Department of the Environment (DOE) responded to this problem through the 1974 Air Quality Act already in place which outlawed open burning. A stricter regulation carrying a maximum fine of RM500K (USD 150K) was imposed on open burning offenders. With the zero burning policies implemented, the oil palm plantation companies in Malaysia were forced to find alternative ways of disposing of the felled trees. It was also reported that the zero-burning technique in oil palm cultivation was found to be financially and economically superior to the burn method (*Azmalisa, 2010*).

Good agricultural practices have also been developed by government authorities such as MPOB to support sustainable practices for palm oil production to be followed by estates and smallholders. Some of the practices include a zero-burning policy, good water management, maintaining riparian reserves, avoiding soil compaction, using correct fertilizers, maintaining soil fertility (using cover crops), good waste management systems like converting POME into compost, and converting trunks, pruned fronds and empty fruit bunches into value added products.

2.1.2 Scope and objectives

The scope of this report is to establish the baseline data on assessment of current waste oil palm trees management systems, practices and utilization at the national and local levels. The objectives of this report are to present current waste oil palm tree management systems and waste oil palm tree utilization. Waste oil palm tree management systems include previous and current methods of disposal, harvesting and clearing oil palm trees. An overview of the potential utilization of waste oil palm trees into value added products is also presented.

2.2 Waste oil palm tree management systems

2.2.1 Introduction

Conventional methods of land clearing for replanting oil palms involve the slash and burn method. This method involves the felling of old trees and shredding into smaller components left to dry, after which the biomass is burned off. Another method is by poisoning the old trees. The poisoning of the palms is carried out prior to felling. This pre-felling poisoning is primarily to prevent *Ganoderma* infestation and to reduce moisture content of the stem. The poison (a sodium arsenic solution) is applied through two holes drilled into the stem (2). For felling, heavy equipment is used. After uprooting, the stump and crown of the palm are cut and left to dry. At a later stage, the stems are cross-cut into logs of 1-1.5 meter length and stacked in windrows (figure 2.2.1.1). Burning is carried out in stages with the dried cross-cut stems being fired in the field after a few weeks into the felling process (figure 2.2.1.2).

Figure 2.2.1
Poisoned trees stacked in windrows

Burning of biomass is aimed at disposing of the waste material so that it does not obstruct plantation management. The other objective is the elimination of pests and diseases by destroying their breeding sites. In addition, burning of unwanted biomass and other waste material is apparently the cheapest method of waste disposal. Burnt biomass releases moisture, gases and suspended particles to the atmosphere. About 48% of all dry palm components consist of carbon. Functioning as a carbon sink, oil palms store about 40 T of carbon per hectare. When burnt, carbon dioxide (CO_2), carbon monoxide (CO) and suspended particles of unburned carbon are released to the atmosphere. Release of CO_2 to the atmosphere contributes to global warming. The particulate emissions cause haze problems and also contribute to black carbon-related global warming. Other contents of palm biomass are nitrogen, phosphorous, sulphur, potassium, magnesium and calcium in varied quantities. The non-metallic components are released to the atmosphere as gaseous products while the metallic components remain as ash (*Mohd Noor, 2003*).

2.2.2 Implementation of zero burning replanting techniques in Malaysia

Zero burning replanting techniques were first introduced commercially in 1985 by Golden Hope Plantations Berhad, (presently one of the merged entities under Sime Darby Berhad) (4). Proven to be a more environment-friendly technique, it was subsequently adopted as the industry standard in oil palm replanting. Apart from the environmental consideration, this technique has also been proven superior to the slash and burn technique. In April 1999, the ASEAN Environmental Ministers adopted a policy on zero burning and urged all member countries to implement the necessary laws and regulations to enforce this decision (see reference #5). Air pollution through open burning of agricultural and industrial waste has become a serious problem in recent years in the region. The zero burn technique allows replanting to be done without violating the Environmental Quality (Clean Air Regulations) Act of 1978.

Figure 2.2.2.1
Shredded oil palm trees left to decompose (left) and then burnt (right) in the fields

Figure 2.2.2.2
Under-planting method where young palms are planted under poisoned old palm trees

Presently, the most popular zero burning technique applied in Malaysia is chipping and windrowing (figure 2.2.2.1) and under-planting methods (figure 2.2.2.2). Through the chipped and windrowed method, the trunks are first felled, chipped into sizes of not more than 10 cm, and then transported to trenches drugged at the fourth palm row. If the trunks are shredded, they are normally stacked at the second palm row in the field. In the case of contour planting, the shredded palms are spread in the inter rows and left to decompose. In the "under-planting method," young palms are planted under old palms which are being gradually poisoned (figure 2.2.2.2).

- **Drawbacks of earlier zero burning methods**

  Malaysia has banned open burning of old oil palm biomass since 1985. To date, more than 80,000 hectares of oil palm have been replanted using this technique. This is a better option compared to the earlier slash and burn practices. Zero burning replanting is a practical and environmentally sound technique that has been adopted and implemented by the plantation industry.

The most widely adopted zero burn techniques of replanting oil palms in Malaysia currently are the “chip and windrow “and “under-planting” methods. The windrowed palm biomass and the poisoned palms will take over two years to decompose completely. This has resulted in very extensive breeding of *Oryctes rhinoceros* beetles, which have become the most serious pest in immature and young mature palms in Malaysia (figure 2.2.2.3). This beetle has traditionally been a pest of coconuts, and has now adapted to oil palms, where it causes serious damage (*Mohd Noor, 2003*). In Peninsular Malaysia, this pest has been known to cause extensive damage along the coastal districts of the west coast where there has been a long history of coconut cultivation. Traditionally, the beetle problem has been more serious where under planting is carried out by poisoning of the old stand, which is then left to rot amidst young replants.

Figure 2.2.2.3:
Oryctes rhinoceros **beetle**

The continuous palm-to-palm replanting on an estate could result in rapid build up of these beetles and serious damage to the palms resulting in loss of yield. Liau et al. (1991) reported that at 50% damage incidence, up to 40% of the FFB crop in the first year of harvesting could be lost. Chung et al. (1999) found that severe beetle damage (16.4 fronds out of 23.9 fronds) on a 21-month old planting resulted in 92% loss of the first 12 month crop and moderate damage (14.3 out of 29.2 fronds) caused 16% crop loss.

Apart from the beetle problem, palm biomass can also become the source of rats and *Ganoderma boninense* disease problems. The presence of large amounts of big chunks of palm biomass, equivalent to about 85 T/ha of dry matter, impede field access and hinder replanting and the subsequent field upkeep work. Nutrients released by the decomposing palm biomass intended for mulching and nutrient recycling were found to be too far beyond the root zone of the young replanted palms to be of any benefit (*Mohd Noor, 2003*).

- **Newer zero burning methods**

Newer zero burn methods of clearing old oil palms for replanting were subsequently introduced to overcome the drawbacks from the earlier methods. These methods involve entire palms being pulverized into fine pieces of less than 0.1g of dry weight each and spread widely over the entire field, and the root mass dug up at felling. More than 50% of the pulverized palm biomass decomposes within 24 weeks after pulverization and increases to 80% by the

56th week. These methods have good potential for reducing Ganoderma boninense disease, breeding of rats and rhinoceros beetles (figure 2.2.2.3).

These new clearing methods reduce the fallow period, facilitate replanting and the subsequent field upkeep work, and improve the utilization by the newly replanted palms of nutrients released by the decomposing palm biomass. These methods of clearing old oil palms for replanting are environmentally less polluting and also improve the sustainability of oil palm plantations. However, this method requires the use of heavy machinery and equipment. There are various types of machines being introduced for clearing old oil palms on site in Malaysia. All have the same basic objective to pulverise the entire palm into fine pieces and spread them thinly through the field. The types and performances of the systems being introduced for clearing oil palms on site are summarized in table 2.2.2 below. Detailed information is included in the Appendix.

Table 2.2.2

Performance of machinery for clearing WPT

System	*Clearing method*	*Productivity per day*	
		Palm	*Ha*
EnviroMulcher	a. EnviroMulcher pulverizing palms b. Excavator stacking fronds/digging up root mass/covering up holes	60 200	0.43 1.45
MountainGoat	a. Excavator felling palms/digging up root mass/filling up holes b. Mountain Goat pulverising palms felled by excavator	200 400	1.45 2.90
Beaver	a. Beaver felling/pulverizing palms/digging up root mass	60	0.43
Palm Eater System	a. Push-fell b. Pulverising whole tree	24	0.17
Willibald WSC 2000	a. Shredding a whole palm tree	160-240	1.14-1.71

All of the above machines have been introduced and demonstrated to the oil palm plantations and planters.

- **Limitations of newer zero burning methods**

The newer zero burn methods introduced so far require specialized machines to implement the clearing and disposal of the old palm trees. Machine acquisition and maintenance usually involves a high cost to the plantation. Only large plantations are able to afford these new no burn methods. The weather also plays a major role, since during wet periods the mobility of these machines is hindered. Consequently, clearing and felling cannot be carried out all year round, which often extends the period of replanting and causes delays. Mobility of these machines is also limited to flat landscapes, whereas oil palm plantations are usually terraced type planting and are also established on uneven and swampy peat areas. Heavy machinery can cause damage to plantation roads and compaction of soil can reduce its fertility to newly planted seedlings.

To date, the most practical technique, and that which is the most widely adopted by oil plantations to clear fields, is the push-fell and shred method. Using this method, a mobile excavator equipped with a sharp hydraulic cutter "pushes-fells" the palm tree, at which point a cutter sections the bulky trunks into smaller pieces (figure 2.2.2.4), shredding felled oil palm trunks into one foot-thick slice slabs of two feet- slanted diameter lengths each. This is by far the most popular method of oil palm tree disposal. The shredded pieces are then left to dry in the fields (figure 2.2.2.4).

Figure 2.2.2.4

Mobile excavator push felling old palm trees (left) and shredded WPT left in the fields (right)

Since the problems of pest and disease will still be present until the waste oil palm trees are cleared from the fields, an alternative method must be adopted for clearing the WPT. Serious attention should be given to exploring a multi-pronged solution to the problem of WPT removal, which could include utilising the lingocellulosic residues for wood-based industries and energy.

2.3 Waste oil palm tree utilization

2.3.1 Methods of harvesting WPT/oil palm trunks (OPT) for value-added products

When oil palm trunks or other parts of WPT are to be utilized for further value-added processing, non-destructive harvesting methods need to be applied, which include felling activities, followed by the appropriate collection and transport of the desired parts of the trees to relevant sites for further processing. The techniques described below are based on observations of oil palms in Malaysia, which include felling, bucking, skidding, bulldozer operations and transportation (figure 2.3.1).

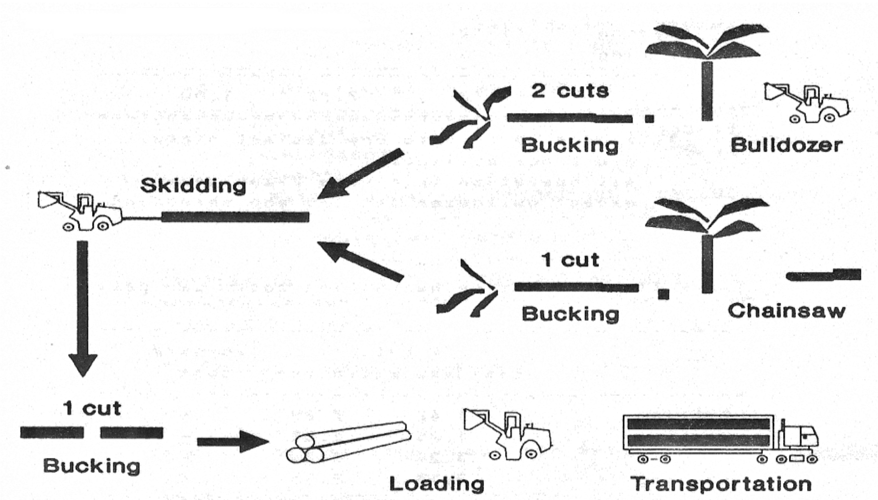

Figure 2.3.1
Oil palm trunk harvesting methods

The processes involved in harvesting WPT are described below:

- **Chain sawing**

  Felling using a chainsaw is done by a two-man team. Based on field observations, the average time taken to fell a palm is about eight minutes, or 45 palms per day (based on six effective working hours daily). Based on an average stocking of 102 palms per hectares, about 2.25 days would be required to clear fell one hectare. Felling time could be shortened if the felling operation is contracted out and paid on a piece-rate basis (see reference #2).

- **Bulldozing**

  Based on the experience gathered, an operator manning a bulldozer can clear fell one hectare per day. With this method, the whole palm is uprooted *(Killman, 1990).*

- **Bucking**

  Bucking is carried out at two different stages: during felling and at the landing site. When the bulldozer felling method is employed, the crown and stump are cut off using a chainsaw before the whole trunk is skidded to the landing area. At the landing area the trunk is bucked into suitable lengths before being transported to the saw mill. Based on field observations, it is estimated that four minutes are needed per cut. Thus, in the case of chainsaw felling eight minutes are required per palm (based on two cuts per palm). A two-man team would be able to buck about 45 palms per day at 2.25 days per hectare. In the case of bulldozer felling, the number of palms felled is about 30 per day (based on three cuts per palm) amounting to 3.4 days per hectare.

- **Skidding**

  The palm trunks are skidded to the landing area by a tractor or bulldozer equipped with a logging chain. At the landing area, the palms are stacked in parallel rows. About 1.5 hectares per day are required to transport one hectare of felled palm trees. The skidding distance can be up to 100 meters from the field to a suitable landing site on the roadside, where they are aligned parallel to each other for easy bucking and loading.

- **Loading and transporting**

  Loading is done most effectively with a grapple attached to the truck. The loading of one palm is observed to take about five minutes, or 12 palms per hour (in the case of a six ton truck, this is equivalent to 2.5 truck loads). Transportation of goods within the country is generally contracted out. Based on a radius distance of 50 miles to mill site, a green weight of 1.3 T/palm and a six-ton carrying capacity of the truck, the transportation cost per palm ranges from RM10 - RM15 (USD3.3 – 4.5) per trunk.

2.4 Utilization of WPT

Intensive research and development on oil palm biomass value-added products was carried out by local research institutions and universities in the late 1980s. However, to date, total utilization has yet to be realised for WPT. WPT biomass has the potential to be converted into an energy source in addition to other value-added products. Some products researched, which have capitalized on the unique properties of the oil palm tree biomass, have been successfully commercialised by the industry. However, most are still in the development stage, and slowly making their way from the laboratory to the pilot project phase.

2.41 WPT for value-added products

One promising utilization of oil palm biomass is as an alternative feedstock material to replace the dwindling supply of tropical wood available for wood-based industries. Success in developing this avenue could reduce the country’s dependency on the tropical forest. The oil palm frond and trunks have been successfully used to produce animal feed commercially (figure 2.4.1). The development of animal feed for ruminants and non-ruminants is due to its carbohydrate and fibre contents. Production sites are usually located near the oil palm plantations.

Figure 2.4.1
Animal feed from oil palm trunks (OPT)

Trials on ruminant feed production from oil palm trunks showed that it had higher digestibility energy when compared to rice straw. Roughage value was the highest with OPT silage followed by untreated OPT.

Apart from animal feed, oil palm tree biomass has potential applications for replacing wood fibres in the production of wood-based composite panel products such as particleboard, medium density fibreboards and cement bonded boards. Such products have demonstrated good potential in the laboratory for further commercial manufacturing. However, the economics of the process must be established in order to achieve a viable manufacturing plant. Application of oil palm biomass for pulp and paper has good potential returns if commercially implemented. The technologies to produce these products have been established and research work on this technology has been carried out by many institutions in Malaysia such as MPOB, FRIM and UPM. Research and development on plywood from oil palm trunks has been applied commercially, and shown great promise. A positive indication is that the mechanical strength properties of oil palm trunk plywood meet the strength requirements as stipulated in the Japanese Standard Method (JAS 233:2003). Other applications of oil palm biomass at various levels of commercialization trials will be discussed in detail in the following reports.

2.4.2 WPT for energy

WPT which consists of the trunk as the major component is high in moisture and requires drying. Consequently, its utilization as solid fuel in the form of charcoal and fuel pellets is not economical. This is due to the unbalanced energy input and output during manufacturing. However, conversion into liquid biofuels such as ethanol through chemical and bioprocesses has shown to be promising. It has been established that lignocellulosic ethanol can be derived from palm trunk material (see reference #1). In addition, the sap which contains 8-10% sugar can be squeezed out and directly fermented into ethanol. Pilot scale oil palm sap production equipment has been developed for this purpose (figure 2.4.2). Thus, availability of oil palm WPT will be the main component in the projections of bioethanol production in Malaysia. The potential production of bioethanol from felled oil palm tree is expected to be 2.7 billion litres per year (*Yamada, 2010 & Kosugi, 2010*). This process will be discussed further in the following report.

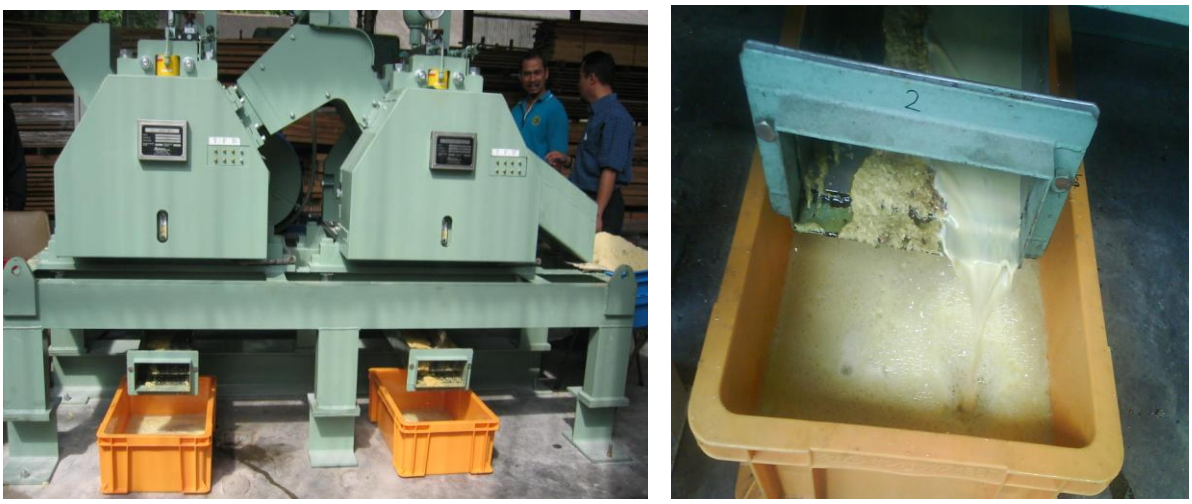

Figure 2.4.2
Oil palm trunk sap squeezing pilot scale equipment (left) and sap produced (right)

2.5 Conclusion

All zero burn methods introduced for clearing old oil palms for replanting discussed in this chapter have good potential for reducing rhinoceros beetle, rat and Ganoderma disease problems. In addition, they offer other benefits such as reducing the fallow period, facilitating replanting procedures and the subsequent field work. They also improve soil fertility from nutrients released by the decomposing palm biomass, an added advantage for the newly replanted palms. Although these facts have been announced by plantations, only the use of EFB generated from the mills for mulching the young palm trees has been quantified as a requirement for newly planted palms. Requirements governing the use of felled palm trees for mulching were only considered when felling was actually carried out (personal communications), since mulching with shredded WPT could only be undertaken once every 25 years.

Therefore, other utilizations of this material need to be explored. Research and development efforts are still actively being carried out with advancing technologies being developed locally and internationally. All these efforts are now evolving towards a more environmental friendly waste oil palm tree utilization. If this abundant biomass could be economically converted into value added products and energy, it could further spur economic activities, increase national income, and make a lasting contribution to the overall sustainable development of the nation.

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Appendix

Appendix 2: Machines used for WPT disposal

EnviroMulcher method

The EnviroMulcher, a Malaysian invention, is an improved version of the clearing method. The EnviroMulcher is basically an attachment mounted at the end of a track-type 120-horsepower excavator's boom, consisting of a cylindrical steel drum bolted with 111 tungsten carbide tip knives. The method is composed of the following operations:

- To pulverize a palm, the excavator first places the EnviroMulcher on the highest part of a palm trunk that can be reached by the excavator boom and then proceeds to cut it into two. The upper portion of the trunk and canopy is allowed to fall to the ground. The EnviroMulcher then pulverizes the standing portion of the trunk until the root bole. The excavator then moves towards the fallen trunk and continues to pulverize the remaining portion of the palm including the crown but excluding the fronds, which are left in situ. The pulverized palm biomass is spread evenly over the ground in the process.

- Another track-type 120-horsepower excavator fitted with a chipping bucket follows behind to stack the fronds into alternate inter-rows and also to dig up the root mass and spread them out beside the frond stacks. The excavator then covers up the resulting holes with soil.

Figure A.1
EnviroMulcher

MountainGoat Method

The Morbark 50/36 E-Z MountainGoat is used to cut soft wood and shrubs into fine chips in the USA. It is built on a Caterpillar 325L undercarriage and powered by a 750 horsepower Caterpillar 3412 engine. The method is composed of the following operations:

- Two track-type 120-horsepower excavators fitted a chipping bucket fell the palms and line them in neat rows for the MountainGoat. The trunk is split into two halves longitudinally if it is more than 90cm in diameter. The same excavators also dig up the root boles and the surrounding root mass and chip them into small pieces before spreading them in the field. They then cover up the resulting holes with soil.

- The MountainGoat follows the excavators to pulverise the entire palm including the fronds and spreads the pulverized biomass fairly evenly throughout the field.

Figure A.2
MountainGoat

Beaver Method

The Beaver is another Malaysian invention built on a D3 Caterpillar undercarriage and powered by a 300 horsepower Caterpillar 3306 engine. The method is composed of the following operations:

- To fell a palm, the Beaver pushes a cutting blade into the ground immediately below the root bole to severe as much of the root mass as possible on one side of the palm. The palm is then pushed down with the same cutting blade.

- The felled palm is then pushed forward and away from the root bole and its surrounding root mass dug up with the cutting blade.

- The Beaver then proceeds to pulverize the felled palm in situ by driving over the felled palm in a forward and backward direction. Usually two forward and one backward passes are required to pulverize a full palm. Pulverisation is achieved by a rotating drum fitted with 20 pieces of self-sharpening flails and mounted at the front of the Beaver. The pulverized biomass is discharged behind the Beaver in rows over the fallen palms. About 30% of the fronds are not pulverized but left in situ.

Figure A.3
Beaver

Palm Eater System

The Palm Eater System was fabricated by a local company, commissioned and tested in the field, and was recommended to be used on oil palm trees. It is equipped with a specially designed cutter system capable of withstanding severe conditions during operation. This system is able to shred a mature oil palm tree down to the stump within 20 minutes. The resulting loose fibrous mass is suitable for the manufacturing of value-added products such as cement board and compost. The cutting bits are reported to last up to 100 operating hours before they require sharpening. In addition, it is versatile enough to be mounted onto various pieces of heavy machinery to suit in situ applications. This innovation is a step in overcoming the shortage of locally developed technology for processing of oil palm residues.

Figure A.4
Palm Eater System

Willibald-Hammer Milling System

The Willibald system, introduced into Malaysia in 1990s, offers a wide variety of products from small scale to bigger and flexible type systems. The most well known equipment associated with processing of oil palm residue is called the WSC 2000 for trunk processing. The WSC 2000 is capable of shredding whole push-felled tree trunks into fibrous form. The processing capacity of this machine is 20 to 30 oil palm trunks per hour.

Figure A.5
Willibald WSC 2000

Willibald system characteristics:

1. It allows a complete return of organic matter to the soil. This helps to preserve, restore and improve soil fertility, chemical and physical properties of the soil.
2. The fallow period is reduced considerably because the new stand is planted simultaneously with felling or shredding operations.
3. Felling/clearing is no longer dependent on the vagaries of weather. In the past, wet weather often delayed burning and thus replanting. Such delays are now avoided.
4. In the absence of burning, the cost of land clearing is substantially cheaper.
5. It provides an environmentally sound approach as it does not cause air pollution. Zero burning is generally non-polluting, contributes positively towards minimizing global warming through reduction of (GHG) emissions, particularly CO_2, and complies with environmental legislation.

3. Chapter 3: Identification, assessment and selection of environmentally sound technologies (ESTs) for converting waste oil palm trees into material or energy

3.1 Introduction

3.1.1 Background

In Malaysia, biomass from waste oil palm trees (WPT) contributes to an average of 1.28 million tons annually, representing 18.6% of the total biomass generated in the country. This value is derived from the estimated hectares of old palm trees to be felled annually. Due to the size of the volumes generated, WPT biomass has the potential to be converted into value added products for various applications.

WPT, which has CHONS values close to empty fruit bunch (EFB) biomass, has the potential to be used as a resource for renewable energy generation similar to EFB. There are already a number of power plants in Malaysia using EFB as feedstock. New plants are being planned in the states of Sabah and Sarawak. Also, recent studies have shown that oil palm trunks (OPT) and oil palm fronds (OPF) contain a high sugar content that can be easily converted into ethanol, thus increasing the value of WPT as an energy resource material.

At present, WPT biomass is mainly used for soil mulching and as fertilizer for nutrient recycling, with a limited use in manufacturing plywood, panels and a few other value-added products. In short, WPT is currently under utilized, and its full potential in terms of benefits to the economy and the environment has yet to be realised.

Utilization of WPT benefits the environment due to several factors:

- Using WPT as an energy resource lessens the demand for fossil fuels.
- When WPT is used as an alternative lumber or wood based product, other valuable and scarce forest resources are conserved.
- Concerns over competing food resources related to feedstock security may provide the incentive to develop sustainable second generation biofuels from WPT sources.

In this report, the term WPT refers to the major parts of the tree after felling i.e. the entire tree including trunk, fronds, and crown but excluding fruit bunches.

3.1.2 Objectives

The main objectives of this report are to identify, assess and select environmentally sound technologies (ESTs) for utilizing WPT as a resource material for value added products and for renewable energy. Selection is based on greenhouse gas (GHG) emissions and economic evaluation of the manufactured products and process or technology utilized. The reduction of GHG emissions for each potential product is calculated and estimated from literature data *(Meil, 2009*) and data from surveys conducted for this study.

The main section of this report explains the existing products that can be derived from WPT biomass and their technology routes, followed by an assessment of each technology's potential economic value and impact on the environment, through measuring GHG emissions and carbon sequestration.

The report concludes by putting forward a number of recommendations to be adopted in order to realise the full potential of WPT as a resource, taking into account the current context in Malaysia.

3.2 Potential products and renewable energy/fuel from WPT

Malaysia is a major producer of the world's supply of palm oil with 47% of the total world output, and accounts for the highest percentage of the vegetable oil and fat trade (see reference #2). The industry also generates annually millions of tons of wastes and residues from both its upstream and downstream activities in the form of palm oil mill effluents (POME) and lignocellulosic materials such as EFB, mesocarp fibres, palm kernel shells (PKS) and WPT.

Researchers and other stakeholders from the industry have been motivated by a concern for the environment, and a need to optimize processes and maximise resources, to take another look at waste biomass. Materials initially regarded as waste by-products, such as fibres from EFB, are now being considered suitable for converting into value added products, including biofuels, bio chemicals and animal feed.

With regard to lignocellulosic waste materials, EFB has received a lot of attention due to the sustainability of supply and large quantities available. Predictability and sustainability of raw material supply are very important when planning for the development of any product. Financial institutions in Malaysia generally will not award loans to companies unable to provide evidence that the raw materials for their process have been secured for at least five years. At present, EFB is being used extensively to produce fibres, energy pellets, feed for power plants and other smaller scale products.

Mesocarp fibres and PKS find ready use as boiler feed in palm mills. PKS is also used to produce activated carbons for water filtration and other applications. All these materials (EFB, PKS and mesocarp fibres) are generated around the clock at palm oil mills.

In contrast, oil palm trees are only felled for replanting after 25 years. On the other hand, given the planting history and the total hectarage of oil palm plantations available, WPT could in fact become available on a continuous basis. The problem is that the localities where WPT is available are constantly changing. This scenario leads to a number of obstacles in the conversion of WPT into products, including first and foremost the logistics of transporting WPT to the processing points. Nevertheless, with proper strategy, planning and coordination, it is possible to overcome this obstacle. These issues will be discussed in more detail in the recommendation section.

This chapter reports on existing uses as well as other potential products that can be derived from WPT. Among those presented are technologies to convert WPT into products and energy which are already in use commercially, under pilot scale implementation or under laboratory testing (research and development). Existing and potential products from WPT are summarized in Table 3.2.1.

3.2.1 Products from WPT

There are only a small number of commercialized WPT based products at present as illustrated by table 3.2.1. This may be partly due to factors mentioned in the opening section of this chapter, such as logistical and supply security issues. EFB, which is much more readily available, tends to be the preferred raw material to be utilized for downstream products, and as an energy resource material.

Table 3.2.1

Status of existing and potential products from WPT

WPT part	*Product*	*Development status*
Oil palm trunks (OPT)	Plywood	Commercial
	Lumber	Commercial
	Flooring	Commercial
	Bioethanol	R&D
	Lumber	Commercial
	Fibre	Pilot scale
	Pulp and paper	R&D
	Oil palm sap	Pilot scale
	Panel products (MDF, particle boards, cement boards)	R&D
Oil palm sap	Sugar	R&D
	Chemical derivatives	R&D
	Bioethanol	R&D
	Bioplastic	R&D
Oil palm fronds (OPF)	Animal feed	Commercial
	Pulp and paper	R&D
	Panel products (MDF, particle boards)	R&D
	Cellulose	Pilot Scale
	Fibre	R&D
Oil palm leaves	Dietary supplement	R&D

Moreover, OPT has a very high moisture content (80%) compared to EFB (60%). Production of plywood and lumber from OPT would require large amounts of energy for the drying process. The presence of sugar in the trunks also causes the OPT logs to degrade faster than timber, for example, thus reducing OPT's attractiveness as an alternative timber replacement. Consequently, the production of sap from WPT for further conversion into sugars and other specialty chemicals looks more promising, and will be discussed in the following sections.

3.2.2 Commercialized products

Besides plywood, WPT based products that have been commercialized include lumber, flooring and animal feed pellets. Information on commercial products was obtained from a survey that has been conducted for this study. Table 3.2.2 lists the current commercialized products from WPT.

Table 3.2.2

Commercialized products from WPT

Co.	*Year established (Co.)*	*WPT parts utilized*	*WPT based products*	*Production capacity (m^3/yr)*	*WPT utilized (WPT/yr)*	*Capital cost (RM Million)*
A	1970	Trunk	OPT logs	25000	NA	NA
B	2000	Trunk	Plywood	15000	60000	25
C	2007	Trunk	Plywood	18000	72000	30
D	1969	Trunk	Plywood	15000	60000	25
E	Not stated	Veneer and Trunk	Plywood	6000	24000	10
F	2004	Veneer	Plywood	6000	24000	10
G	2006	Veneer	Timber/flooring	20000	30000	10
H	2006	Trunk	OPT lumber products	6000	30000	5
I	2007	Frond	Animal feed pellets	1200-2400	1200-2400	13

- **Plywood**

The bulk of WPT utilization at the moment is in the production of plywood (figure 3.2.2.1). Felled palm trees are cut into 30 feet logs and transported to plywood mills where they are unloaded and peeled into veneers. The WPT veneers are then dried, applied with glue, pressed and cut into size to produce plywood.

Figure 3.2.2.1
Veneer production for plywood manufacture from OPT

The plywood manufacturing process is presented in figure 3.2.2.2. At present, a number of plywood mills in Malaysia have begun using OPT for the manufacture of plywood, including seven plywood mills utilizing the outer parts of OPT for plywood manufacture. These mills utilize about 40% of the OPT, with the remaining 60% discarded as waste (figure 3.2.2.2) *(Mohamad, 2005).* Five of these plywood mills responded to the survey conducted for this study.

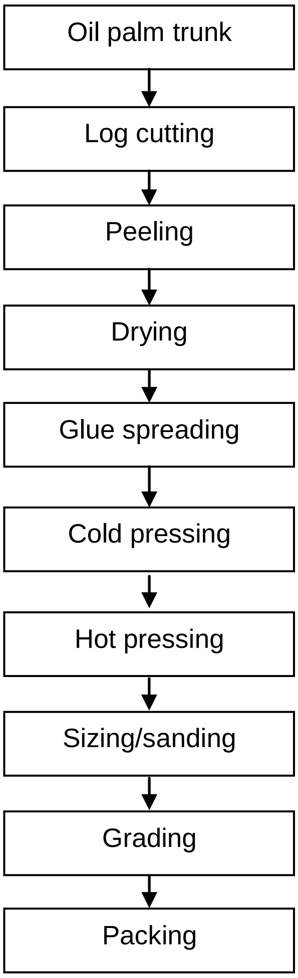

Figure 3.2.2.2
Manufacturing of oil palm plywood (see reference #25)

  

Figure 3.2.2.3

Wastes generated from OPT plywood mills: end-logs (left) veneer off-cuts (middle) and core-logs (right)

Selection of oil palm logs is based on the straightness of the trunk and uniformity of diameter between the bottom and the top end. In general, two logs of 19 foot length can be obtained from one trunk and transported to the factory *(Sarip, 1998).* OPT is processed to produce plywood following the stipulated standards. In this production process, as shown in figure 3.2.2.3, several problems identified by the manufacturers will still need to be resolved through further research and development. OPT consists of numerous vascular bundles embedded in the parenchyma ground tissue. The parenchyma behaves like a sponge and holds high moisture. This requires modifications to the drying process as it is quite different from the timber veneer drying process. The trunks also contain high silica which is abrasive to knife-edges, thus requiring frequent replacement and high maintenance of the knives.

- **OPT lumber products**

The shortfall of lumber which has been forecasted for the near future warrants seeking alternative lumber materials. OPT has been shown to be an alternative wood lumber material which can be worked much like wood with ordinary tools. Oil palm lumber has been successfully utilized in the past as lumber core in the production of blockboard *(Koh, 2009)*. It was first seasoned and trimmed to remove defective portions. The lumber in assorted sizes was then planed and end-trimmed before being passed through a gang strip saw to obtain strips of equal width and thickness. The strips were then composed in a composer into larger pieces and layered with hardwood face veneers. An advantage of using lumber core from OPT is its light weight. Figure 3.2.2.4 details the procedure of OPT lumber production.

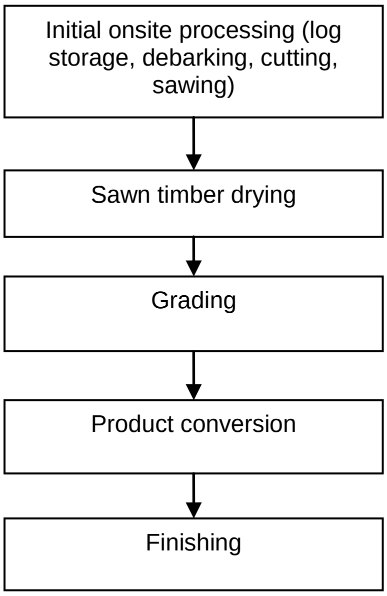

Figure 3.2.2.4
Process flow for lumber production

Acceptable quality furniture has been successfully made from oil palm lumber though only the bottom portion of the trunk appears suitable for furniture making. Several modifications to normal process and handling procedures were made to handle specific OPT processing and operating issues. It was first treated with a mixture of 5% PCP/5% boric acid, air dried then kiln dried to 10% final moisture content. After seasoning, the chosen lumber pieces were planed and shaped to the specified dimensions and sanded before the completed parts were sent for finishing and assembly. Lacquer was used as sealer and polyurethane for the final surface layer of transparent gloss. The latter process, besides enhancing the natural oil palm grain or stripes (tiger wood appearance), also protects the wood from scratches, insects and fungal attack. Only a small part of the stem’s bottom portion appears to have these stripes (figure 3.2.2.5).

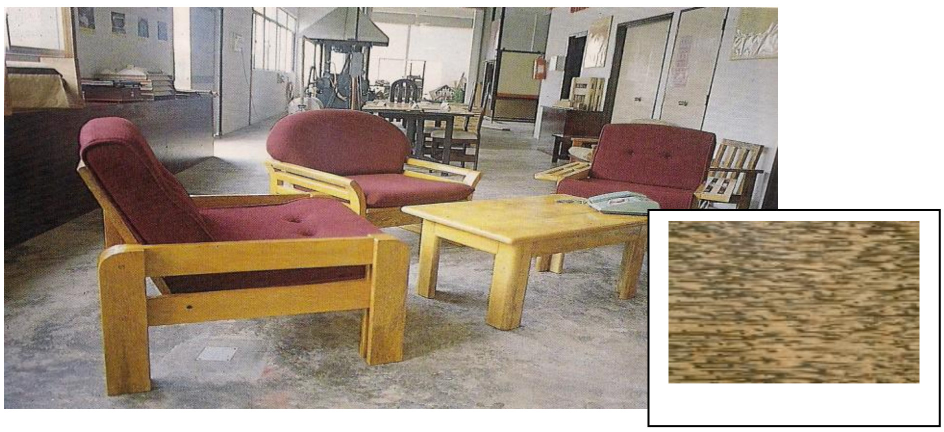

Figure 3.2.2.5
Furniture made from OPT lumber and tiger wood grain (insert)

At the present time, a number of products and furniture components are being commercialized, catering mostly to local markets.

- **Flooring**

Resin impregnated oil palm wood flooring is another green technology product that utilizes oil palm trunks as an alternative material for engineered and solid timber flooring. The reinforced palm wood flooring is produced by combining thermo-set resins at different points during loading and curing. The combination of thermo-set polymer with wood fibre reinforces the strength and durability of palm wood. Oil palm flooring has already passed tests for technical requirements of flooring application, such as UV coating performance tests, hardness and biological tests. Figure 3.2.2.6 shows the flow diagram for resin impregnated oil palm flooring production.

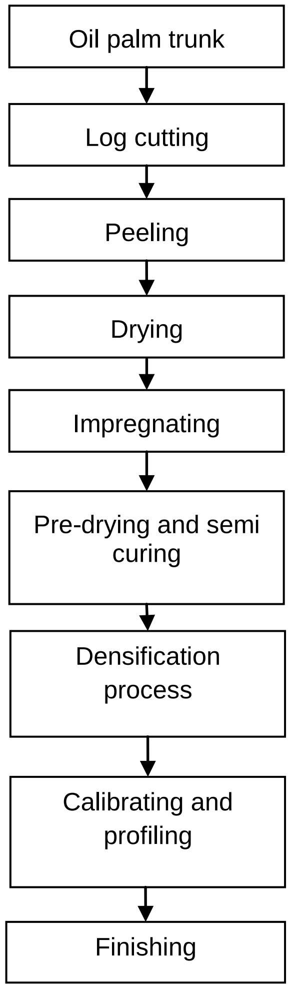

Figure 3.2.2.6
Manufacture of oil palm flooring

- **Animal feed**

MARDI first demonstrated an interest in processing oil palm biomass into animal feed in the mid-eighties. The oil palm biomass studied include both OPT and OPF. Today, however, there is only one manufacturer producing animal feed, specifically from OPF, which is FELDA in Bukit Sagu, Kuantan, a town within the State of Pahang.

The OPF generated from the daily pruning and occasional replanting activities is used as feedstock in the production process. To limit transportation and overall operating costs, the OPF utilized is acquired from plantation activities located within a 25 km radius of the mill. The animal feed plant, with a designed production capacity of up to 12,000 tons per annum, was built at a RM13 million investment cost, mostly funded by the government.

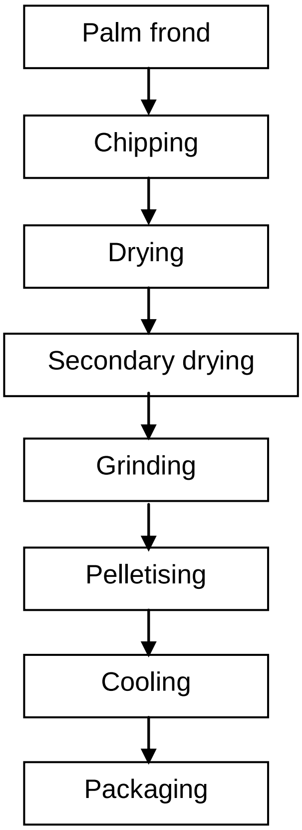

Figure 3.2.2.7
Process flow of animal feed pellet production

Currently, the plant is running at around 10–20 per cent capacity per month and only supplies customers upon specific requests, on an as needed basis. The products are sold for a price of between RM450–1050 per ton, depending on the mix either for cow or goat feed. Likewise, depending on the types of mix, production costs for feed manufacture run from between RM300-900 per ton of product. Figure 3.2.2.7 shows the process flow to produce animal feed pellets from OPF at a FELDA operated factory in Bukit Sagu. Figures 3.2.2.8 and 3.2.2.9 show the nature of OPF before and after product manufacture.

Figure 3.2.2.8

Newly arrived OPF for processing (left) and shredded OPF fibres (right) for animal feed pellet manufacture

Figure 3.2.2.9

Close up of animal feed pellets manufactured from OPF (left) and pellet packages ready for distribution (right)

3.2.3 Products at pilot scale

As of today, there are only two pilot scale activities with regard to the utilization of WPT biomass: production of cellulose from oil palm fronds (OPF), and production of oil palm sap for further conversion to value added products.

- **Oil palm sap**

  There is considerable interest in converting oil palm biomass into energy products, either in the form of solids, liquids or gases (in the form of H_2, HC gases, especially methane and CO). The gaseous products are not easily transportable or stored, and in most cases have to be utilized on site or immediately converted to liquid products. A more feasible proposition is to produce energy products or biomass-derived fuels in liquid or solid form.

Although solid fuels tend to have a higher CV per unit volume, they also have higher undesirable emissions such as CO and un-burnt materials that are

detrimental to the environment. Thus, energy products in the form of liquids probably provide the better solution, as they are characterized by cleaner and more efficient burning, easily transportable and allow better storage.

Waste oil palm trees (WPT) appear to have this potential. Research studies by FRIM and JIRCAS have confirmed that valuable reducing sugars are present in oil palm sap extracted from the trunk itself. The 80% moisture contained in OPT can be extracted out in the form of sap which is a golden yellow liquid similar to that of sugar cane. The sap extracted from the OPT core log contains 10-15% sugar with the main component being glucose (figure 3.2.3.1).This sugar can be further fermented with selected yeasts into ethanol, and then blended with petrol to be used as fuel. About 200 L of sap can be extracted from one palm tree using processing machines developed by Sojitz-JIRCAS-FRIM in a collaborative project. This processing system consists of a shredder and squeezer that are able to shred and squeeze out the sap from plywood mill OPT wastes in the form of oil palm core logs (figure 3.2.3.2). This system can also extract out the sap from OPT veneers. Another system has also been developed by FRIM recently, designed to extract the sap from shredded WPT available from the field immediately during felling. These continuous processes consist of a shredder and squeezer-cutter equipment (figure 3.2.3.3). Preliminary data has shown that about 350 L of sap can be extracted from this system, which compliments the Sojitz-JIRCAS-FRIM method in which the entire WPT can be utilized for sap extraction. Lists of available processing systems are shown in table 3.2.3. Figure 3.2.3.4 shows the flow chart of the sap extraction process and production into bioethanol.

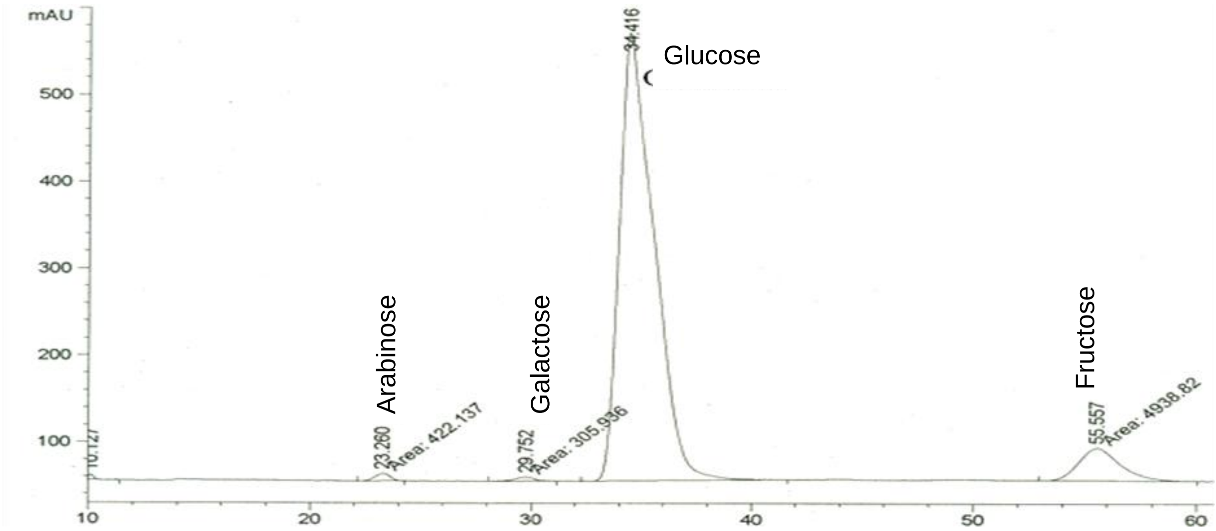

Figure 3.2.3.1

HPLC chromatogram of oil palm sap with glucose as the major component

Figure 3.2.3.2

Oil palm core-logs (left) used for sap extraction (right) on Sojitz-FRIM-JIRCAS processing system

Figure 3.2.3.3

Shredded WPT from fields (left) used for sap extraction on FRIM processing equipment (right)

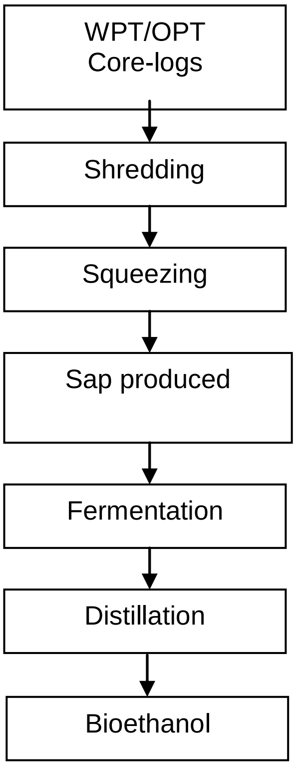

Figure 3.2.3.4

Process flow for sap extraction and bioethanol conversion from sap

Table 3.2.3.1

List of renewable energy/fuel from WPT systems developed at pilot scale stage and potential capacity

Institution name	*Year of establishment*	*Technology*	*Part of WPT*	*Product*	*System capacity*
Sojitz-JIRCAS-FRIM	2009	Sap extraction from OPT core-logs	OPT	Sap	200 L/ Trunk
FRIM	2011	Sap extraction from shredded WPT	WPT	Sap	350 L/ Trunk

- **Cellulose from OPF**

Cellulose has been widely used in food or non-food applications such as in paint and detergent manufacture. At the higher end, microcrystalline cellulose is used in pharmaceutical products as fillers. Cellulose can be shaped into sheets or films in order to make it available for various industries. It can also be transformed into high value chemicals, through the use of certain processes such as hydrolysis, fermentation, acid modification and hydrogenation.

Malaysia imports over RM300 million worth of cellulose every year (*Sarip, 1998*). This is the main reason motivating various stakeholders to exploit the potential of OPF as a readily available, sustainable and low cost material to produce cellulose. MARDI reported that there is an estimated 26.2 million tons of oil palm fronds available for utilization annually in Malaysia (*Wan Zahari, 2003*).

Oil palm trees are pruned of their OPF in regular cycles for the purpose of easy access to the oil palm fruit bunches during harvesting. The pruned OPF is usually used as mulch and placed on top of exposed soil in between the mature palm rows. Past practices include burning to dispose of the waste.

Table 3.2.3.2

Composition of oil palm fronds

Oil palm frond component	**(%)**
Lignin	15.2
Holocellulose	82.2
Ash	0.7

OPF cell walls are composed mainly of cellulose, hemicellulose and lignin (table 3.2.3.2). The total cellulose or holocellulose make up to more than 80% of the OPF fibre. Research in other parts of the world and in Malaysia has shown that the celluloses can be effectively recovered through the “steam explosion process” which essentially pre-treats the fibres for the more effective alkaline extraction and bleaching processes that follow. Figure 3.2.3.5 shows the process flow for cellulose production from OPF. Steam explosion takes place in a steam gun which requires high pressure to break down the lignin structure of the fronds and releases the cellulose.

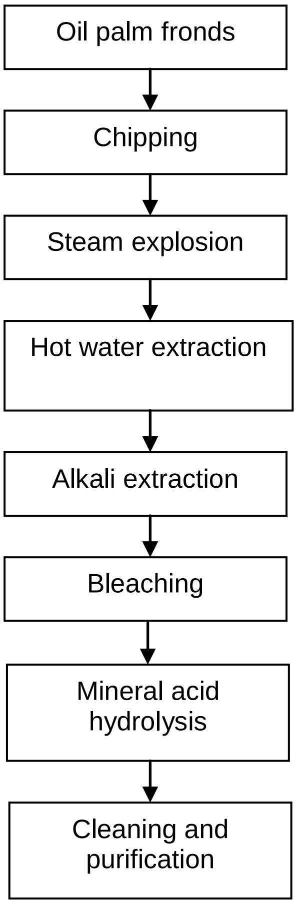

Figure 3.2.3.5
Process flow of micro cellulose production (Sarip, 1998)

Earlier studies on the steam explosion process in Malaysia were conducted by Universiti Sains Malaysia (USM) in collaboration with Sabutek Sdn Bhd and with the financial support of the Malaysian Technological Development Corporation (MTDC). In 2010, Universiti Malaysia Pahang (UMP) with LKPP Corporation as the collaborator managed to secure a RM1.2 million grant from the Ministry of Agriculture (MOA) to develop a pilot scale system for the purpose of pre-commercialization work. LKPP will provide the raw materials, site and supplementary funding for the project. Initial production is designed to be about 200 kg of cellulose per day.

3.2.4 Products at the research and development stage

On the research front, there are a number of organizations looking at product development from WPT such as the Malaysian Agriculture and Development Institute (MARDI), Malaysian Palm Oil Board (MPOB), Forest Research Institute of Malaysia (FRIM), USM and UMP.

As shown in table 3.2.4, although WPT-based plywood, lumber and animal feed have found some commercial applications, their limited success warrants further research in order to produce better quality products with greater versatility and better financial returns. Other non-energy products still in research and development which have yet to enter the commercialization stage are pulp and paper from WPT, particle board and dietary supplements.

Table 3.2.4

R&D on WPT - based products

Raw material	*Product*	*Research area*	*Institution*	*Source/reference*
OPT	Plywood	Mechanical, physical and thermal characterization	USM	[4]
		New hybrid plywood	USM	[5]
	Lumber	Treatment of oil palm lumber	MPOB	[6]
OPF	Pulp and paper	Optimization in pulp and paper process.	UMP	[7]
	Particle board	Characterization and manufacturing of particle board	USM, Japan & USA	[8]
	Insulation board	Production of insulation board using wet forming process	Mahedart U & Kasesart U, Thailand	[9]
	Animal feed	Production of animal feed using OPF	MARDI, UPM	[10]
	Animal feed	Effects of antioxidants on animal muscle	UPM	[11]
Oil palm leaves	Dietary supplement	Oil palm leaves (OPL) ethanolic extract to reduce blood glucose (diabetes mellitus)	UPM	[12]

- **Particle board**

The manufacturing process of particle board can be divided into stages as illustrated in figure 3.2.4. Products were developed to replace tropical veneer moulded parts. This product is environmentally friendly and can be produced at a competitive cost. End products include school and office desks and chairs, table tops and cabinets. Other applications include trays, electrical meter boards, transport pallets and chair parts for upholstery use.

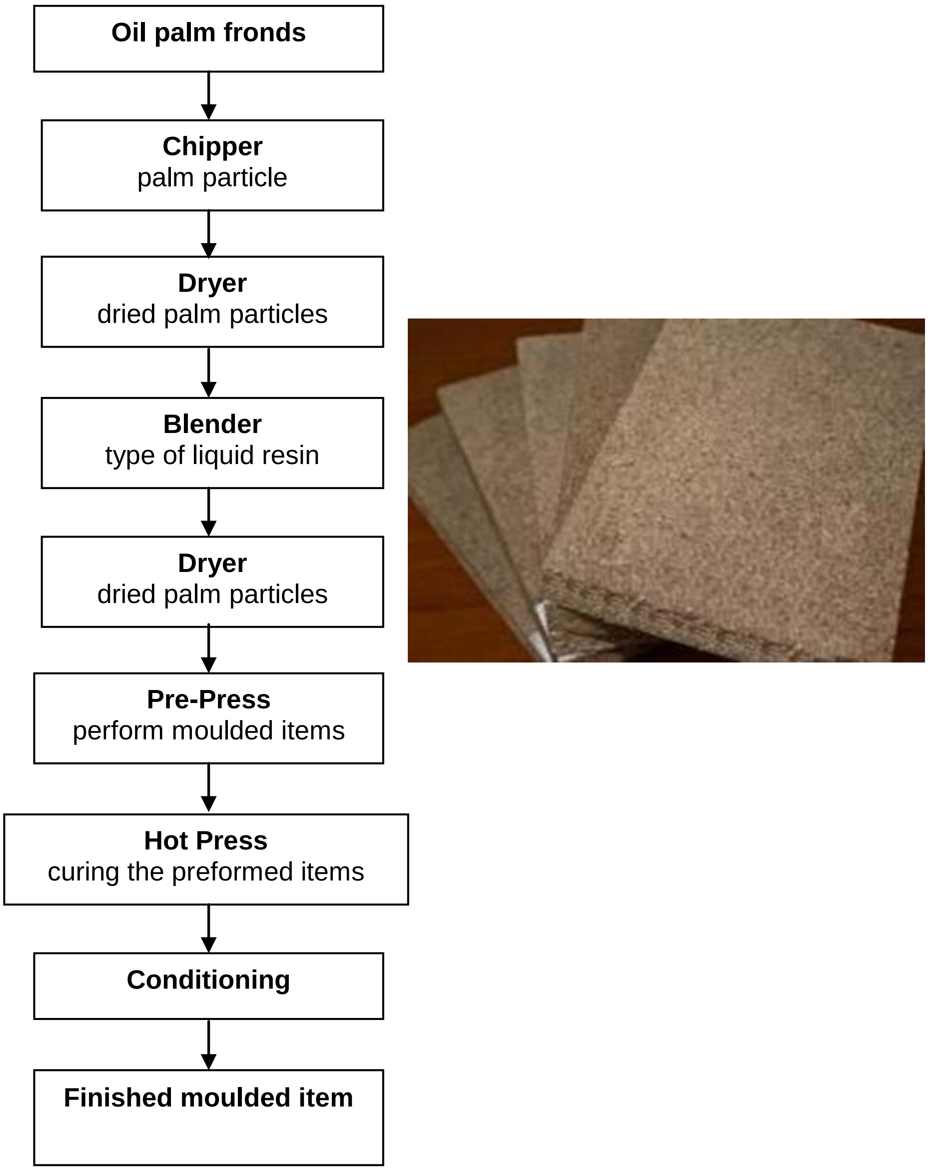

Figure 3.2.4.
Process flow for no-skin moulded particle board (*Asa Naim, 2005*)

- **Renewable energy/fuel**

As a result of the energy crisis of the mid-seventies, Malaysia realised the importance of diversifying its energy sources. In 2001, a fifth dimension i.e. renewable energy (RE) was included in the energy mix previously known as the "four fuel policy" (oil, gas, coal and hydro). The objectives of this fifth fuel policy are to: increase the RE contribution to the national power generation mix, facilitate the growth of the RE industry, ensure a reasonable RE generation cost, preserve the environment for future generations and create awareness on the role and importance of RE. This policy was in response to depleting fossil fuel resources which led to price volatility globally. The National Biofuels Policy, published by the Ministry of Energy in March 2006, and gazetted in 2011, outlines the strategy for attaining the following objectives:

- Supplementing the depleting supply of fossil fuels with renewable resources
- Mobilising local resources for biofuels
- Exploiting local technology to generate energy for the transportation and industrial sectors
- Paving the way for export of biofuels
- Benefiting from the spinoff effect of more stable prices for palm oil

Although there have been numerous discussions, the implementation of a truly integrated renewable energy policy in Malaysia is still lagging behind when compared to more developed countries, and even when compared with its close neighbours such as Thailand and Indonesia. Factors hindering the promotion of renewable energy usage include the continuous and heavy government subsidies on fuel prices, as well as the overlapping jurisdiction of various ministries and agencies. Nevertheless, subsidies are being reduced gradually to encourage more prudent and efficient usage, and incentives have been introduced to encourage the production of renewable energy.

Due to Malaysia's geographical location the percentages of renewable energy derived from wind, ocean waves and geothermal sources are not very significant. The two forms of renewable energy that have the biggest growth potential in Malaysia are solar and biomass-derived energy. The latter is supported by the presence of expansive plantations (especially oil palm) that provide large sustainable production of biomass materials that can be converted to an energy resource year round.

3.2.5 Commercialized energy/fuels from WPT

None available

3.2.6 Pilot scale study of energy/fuels from WPT

None available

3.2.7 Energy/fuels at research and development stage

Renewable energy derived from WPT like biofuel is biodegradable, non-toxic, and has significantly fewer emissions than petroleum-based fuel (petrol-diesel) when burned (*Sumathi, 2008*). Most of the biofuel renewable energy currently commercialized has been derived from empty fruit bunches (EFB), with OPT and OPF usage still at the R&D stage. Some of the R&D projects presently engaged in converting WPT into renewable energy and the institutions involved are highlighted in table 3.2.7.

Table 3.2.7
List of research and development projects on energy from WPT

Raw material	*Product*	*Research area*	*Institution*	*Source/reference*
Oil palm trunks	Bioethanol	Optimization of glucose production from oil palm trunk via enzymatic hydrolysis for conversion to bioethanol	UMP, FRIM	[13]
		Bioethanol recovery from old oil palm trunks	UMP, FRIM	[14]
		Raw material used process of steam explosion	Kasetsart University, Thailand	[15]
		Optimization of fermentation technique	UPM	[16]
		Production using sap squeezed technique	FFPRI, FRIM, USM,JIRCAS	[17]
		Production using fermentation technique	USM	[18]
		Glucose extraction via acid hydrolysis	USM	[19]
Oil palm fronds	Bioethanol	Optimization and pre-treatment of raw material	USM	[20]
		Optimization and pre-treatment of raw material through fermentation	USM	[21]
		Hot compressed water pre-treatment of OPF	USM	[22]
		Optimising ethanolic hot compressed water (EHCW) cooking on pre-treatment of OPF	USM	[23]
	Hydrogen	Different types of thermo-chemicals to produce hydrogen from oil palm biomass	UPM	[24]

3.2.8 Other possible products from WPT

- **Compost**

One potential product that could be produced from WPT is compost. Composting is a method by which organic matter is recycled. The product being transformed into compost material could serve as planting media, natural organic fertilizer and soil conditioner. This material is an important ingredient for organic produce such as vegetables and crops. There are various types of composting methods that include the use of either effective microbes or worms, or both methods incorporated together. Composting using worms as its composting media is termed as vermicomposting, with the resulting product known as vermicompost (figure 3.2.8.1).

Figure 3.2.8.1
Vermi compost from EFB produced by Waynetech^{TM} in Kota Marudu, Sabah

The volume of compost produced represents generally one-third of the starting material before composting. The process takes about 60-75 days to complete. For every ton of WPT, roughly 330 kg of compost is produced. The cost of one ton of compost ranges from USD2300-2500. A few commercial productions of compost using EFB as the raw material are now operating in Malaysia. One of the manufacturers operating in Sabah (Waynetech^{TM}) using EFB as the raw material has testified that WPT could be another potential raw material for the product. The EFB composting facility is set up near the palm oil mill where the raw material would be accessible. Adding a WPT composting component would make use of all parts of WPT, and could also integrate the waste/by-products of other production activities, thus resulting in a clean and zero waste production system.

- **Laminated veneer lumber (LVL)**

Another potential value added product from OPT is laminated veneer lumber (LVL). LVL consists of layers of wood veneers laminated together with the grain of each veneer aligned primarily along the length of the finished product (figure 3.2.8.2). The veneers used to manufacture LVL are about 3.2 mm (0.125 in) thick. The veneers are passed under a curtain or roll coater where phenol-formaldehyde (PF) resin is applied. Plants that manufacture LVL from hardwood species may use urea-formaldehyde (UF) resin rather than PF resin. Once resonated, the veneers are manually laid up into a long thick stack. The veneer stack is fed to a hot press where the veneers are pressed into a solid billet under heat and pressure. The LVL is manufactured to either a fixed length using a batch press, or to an indefinite length using a continuous press. Press temperatures range from about 120° to 230°C (250° to 450°F). Billets exiting the press may be up to 8.9 c (3.5 in) thick. Billets are produced in widths of up to 2.8 m (6 ft). The billets are typically ripped into numerous strips based on customer specifications. The LVL is produced in lengths of up to a maximum shipping length of 24 m (80 ft). Trademarks or grade stamps may be applied in ink to the LVL before it is shipped from the plant.

The cost production of producing OPT LVL is 30-35% cheaper compared to conventional hardwood, according to a business proposal submitted by Mitreworks Sdn Bhd for pilot plant production set up funding. At present, there is an acute shortage of tropical wood lumber worldwide whereas demand for lumber continues to increase due to rapid infrastructure and property development. The market price of LVL is USD350-550 per cubic meter for both LVL made from tropical hardwoods and palm based LVL (see Appendix 3A.3).

Figure 3.2.8.2
Product made from LVL from OPT

3.3 Assessment of environmentally sound technology (EST) for conversion of WPT into resources

3.3.1 Assessment of technology

The potential products that can be manufactured from WPT are considerable. Some of the technologies being researched by local researchers focus on adapting the raw material characteristics to available technologies. Of these technologies only a few have been taken up commercially (table 3.3.1). All the potential technology routes have been identified and discussed thoroughly. Some technologies are looked upon as very sound environmentally, with a potentially high profit margin. However, such technologies still might not be considered by investors, especially in Malaysia, if the cost of investment is too high. All in all cost usually plays a major role in the decision. Table 3.3.1 summarizes some of the important criteria being considered in the set-up of a plant manufacturing commercial products from WPT. Such criteria include cost of investment, capacity, man-power requirements, machinery requirements, product selling price and waste generated.

Table 3.3.1

Summary of important criteria to be considered in commercial production of various potential WPT products, including waste generated

Product	*Amount of raw material used monthly*	*Machinery involved*	*Mill capacity monthly*	*Man power*	*Production cost (RM)*	*Investment cost (RM)*	*Product selling price (RM)*	*Waste generated*
Plywood	6000 trunks	Chainsaw, lathe machine, dryer, scarf joint, glue spreader, cold press, hot press, trimming saw, sanding machine, knife grinder, conveyor, shovel, forklift & boiler	1000 m^3	90	350/cu^3	20 million	420/cu^3	End-logs, core logs, bark veneers, low quality & off-cut veneers
Lumber	2000 trunks	Band saw, boiler, dryer & treatment plant	500 m^3	30	800/cu^3	10 million	800-1200/cu^3	Bark & OPT core
Flooring	1000 veneers equivalent to 500 trunks	Impregnation plant, hot press, planer, moulder, saw profiler, sanding machine, coating line boiler & silo	2000 m^2	25	80/m^2	10 million		End-logs, core logs, bark veneers, low quality & off-cut veneers
Micro crystalline cellulose	140 tons equivalent to 140 WPT	Chipper, steam explosion, system, extractor system, centrifuge filtration, pressure vessels & discoloration vessels	28 tons	20	6000/ tons	20 million	12000/tons	Chemical waste, acid and soda effluent
Animal feed		Chipper, dryer, grinder, pelletizer, packager & cooler		10	300-900/ tons	13 million	450-1050/ tons	None
Bioethanol from sap	1344 tons equivalent to 1344 trunks	Shredder, squeezer, filtration systems, distillers & fermenters	90,000-100,000 Liters	10	1.5/L	20 million	RM5/L	Bark, end core-logs & squeezed fibres

* 1 ton is roughly equivalent to 1 WPT ++ 1USD= 3RM

3.3.2 Assessment on environmental Impact

The utilization of WPT for various products would reduce GHG, namely CO_2 emissions, through the sequestration of carbon in products such as plywood, lumber etc. Secondly, conversion into biofuels would reduce the demand on fossil fuels, thus indirectly reducing the amounts of new CO_2 being released into the environment.

- **Estimation of GHG (CO_2) emissions from decomposition of WPT**

The amounts of GHG emissions from decomposition of WPT were calculated based on IPCC guidelines (see reference #28). Assuming all the carbon was converted into CO_2, the amount of carbon contained in the various parts of WPT and the number of trees available annually (presented in Chapter 1's report) were used to calculate the total amount of CO_2 emissions during decomposition of WPT biomass after felling (table 3.3.2.1).

During decomposition the shredded oil palm trees were left to decompose in the fields and the biomass was biologically and chemically decomposed by agents such as microorganisms, termites, earthworms and beetles. The carbon contained in the WPT was then released into the atmosphere in the form of CO_2. A fraction of the carbon was also released as methane (CH_4) through these biological activities. Due to the uncertainty of the effect of clearing on termite populations and associated methane release, no guidelines for calculating this component were included in the IPCC methodology. Hence, the CO_2 released from WPT decomposition was estimated only based on direct function of WPT volume and carbon content.

Using the carbon content of WPT in Chapter 1's Report, the amount of CO_2 released (E_a) from the decomposition of one oil palm tree was calculated using Equation (3.1).

$$E_a = C_b * 3.67$$ **Equation (3.1)**

C_b is carbon content in the biomass in kg per oil palm tree part. The coefficient 3.67 is the conversion factor from C to CO_2 based on atomic weights of C and O of 12 g and 16 g, respectively. Only contributions from the trunk and fronds were considered, which constitute the major components of the WPT. In addition, the amount of CO_2 emitted from fossil fuel used during felling activity was also added into the calculation (Equation 3.2). Table 3.3.2.2 shows the calculated C_b and E_a obtained from these calculations. Detailed calculations are shown in Appendix C.

$$E_a\text{ (WPT)} = E_a\text{ (Trunk)} + E_a\text{ (Fronds)} + E_a\text{ (Fuel used during felling)}$$ **Equation (3.2)**

Table 3.3.2.1

Carbon contents and CO_2 emissions for major parts of WPT

WPT Part	C_b (kg of C)	E_a (kg of CO_2)
Trunk	122.53	449.69
Fronds	92.38	339.03
Total	214.91	788.72

- **Estimation of carbon sequestered from WPT conversion into value added products and renewable energy from 50% of WPT annual availability**

The estimation of CO_2 emission from the various types of products manufactured from WPT was also calculated using the general equation 3.3 below:

$$E_a \text{ (product)} = E_a \text{ (WPT component used)} + E_a \text{ (Fuel used during manufacturing)}$$

Equation (3.3)

Table 3.3.2.2 shows the net carbon balance per m^3 of products manufactured from wood *(Meil, 2009*). Assuming these values are comparable with WPT material which is also lignocellulosic in nature as wood, the amount of carbon sequestered for WPT conversion into these potential products was calculated. Calculations of the amounts of carbon that could be sequestered from the conversion of WPT into plywood and lumber were based on values derived for softwood plywood and lumber respectively.

Table 3.3.2.2

Net carbon balance per m^3 of manufactured products from wood (*Meil, 2009*)

No	*Type of products*	*Amount of carbon sequestered per m^3 of product manufactured (kg CO_2)*	**Amount of CO_2 emissions due to fossil fuel use per m^3 of product manufactured (kg CO_2)*	*Net carbon balance per m^3 (kg CO_2)*
1	Softwood lumber	764.55	90.45	674.1
2	Softwood plywood	586.95	76.08	510.87
3	Oriented strand board (OSB)	770.07	65.66	704.4
4	Particle board (PB)	999.85	88.09	911.75
5	Medium density fibre board (MDF)	1233.76	283.92	949.85

* Includes combustion and pre-combustion effects associated with thermal fossil fuel and electricity use in harvesting, transport and manufacturing

The total amount of CO_2 that can be sequestered was also calculated by taking 50% of the total potential WPT generated annually to be utilized in the production of the selected value-added products and renewable energy, at the commercial and pilot scale stage. Table 3.3.2.3 presents the percentage of CO_2 that can be reduced by converting the potential WPT into plywood and lumber from 2011-2032. Results show that converting WPT into lumber has higher potential, netting average values of 21.1% in reducing CO_2 emission as compared to 8.35% for plywood and flooring manufacture. The calculations were the same for these products due to the usage of the same raw material from WPT (Table 3.3.2.3). (See Appendix 3C.)

Due to unavailable information on GHG emissions from animal feed, micro-crystalline cellulose and bioethanol production, the total CO_2 emissions were calculated using equation (3.1), based on carbon content available in the trunk and fronds. However, this calculation does not include CO_2 generated from the fossil fuels and electricity used during product manufacturing. As for animal pellet and micro crystalline cellulose production, the amount of CO_2 emissions that can be reduced from animal pellet production annually can be estimated by assuming that 100% of fronds from one WPT are used to produce animal pellets. These calculations were also made based on taking 50% of the available WPT generated annually to be converted into animal feed and micro crystalline cellulose. Again, the calculations were the same for all these products due to the usage of the same raw material from WPT.

For bioethanol production from OPT sap, 35% of bioethanol can be produced from sap (based on 20% sap extraction efficiency). (See Appendix 3C.) This contributes to 7% of the total amount of CO_2 emissions that can be reduced from the decomposition of one trunk. Calculations were also done with the assumption that only 50% of the total potential WPT generated annually could be utilized to produce bioethanol. The potential reduction of CO_2 in converting WPT into micro-crystalline cellulose, bioethanol and animal pellets is presented in table 3.3.2.4. The table demonstrates that animal pellet and micro crystalline cellulose has a better potential for reducing CO_2 emissions (21.21%) than bioethanol (2.0%) from oil palm trunk sap.

Table 3.3.2.3

Potential reduction of CO_2 in converting WPT into plywood and lumber

Year	*Oil palm tree decomposition (mill tons CO_2/yr)*	*Amount of CO_2 sequestered in plywood and flooring (mill tons CO_2/yr)*	*Per cent CO_2 reduced by plywood and flooring manufacturing (%)*	*Amount of CO_2 sequestered in lumber (mill tons CO_2/yr)*	*Per cent CO_2 reduced by lumber manufacturing (%)*
2011	12.90	1.05	8.14	2.65	20.54
2012	8.13	0.66	8.12	1.67	20.54
2013	14.70	1.19	8.10	3.02	20.54
2014	15.60	1.26	8.08	3.19	20.45
2015	9.17	0.74	8.07	1.88	20.50
2016	7.14	0.58	8.12	1.46	20.45
2017	11.50	0.93	8.09	2.35	20.43
2018	12.00	0.97	8.08	2.46	20.50
2019	11.70	0.95	8.12	2.41	20.60
2020	14.20	1.15	8.10	2.91	20.49
2021	16.80	1.36	8.10	3.45	20.54
2022	22.20	1.8	8.11	4.55	20.50
2023	20.50	1.66	8.10	4.2	20.49
2024	26.00	2.11	8.12	5.34	20.54
2025	7.00	0.57	8.14	1.43	20.43
2026	13.50	1.1	8.15	2.77	20.52
2027	18.90	1.53	8.10	3.88	20.53
2028	14.60	1.18	8.08	2.99	20.48
2029	8.10	0.66	8.15	1.66	20.49
2030	19.50	1.58	8.10	3.99	20.46
2031	12.60	1.02	8.10	2.58	20.48
2032	15.40	1.25	8.12	3.17	20.58
Average	**14.19**	**1.15**	**8.11**	**2.91**	**20.50**

Table 3.3.2.4 **Potential reduction of CO_2 in converting WPT into bioethanol and animal feed**

Year	*Oil palm tree decomposition (mill tons CO_2/yr)*	*Amount of CO_2 sequestered in bioethanol from sap (mill tons CO2/yr)*	*Per cent CO_2 reduced by bioethanol production from sap*	*Amount of CO_2 sequestered in animal feed & microcrystalline cellulose production (mill tons CO_2/yr)*	*Per cent CO_2 can be reduced by animal feed & microcrystalline cellulose production (%)*
2011	12.90	0.25	1.94	2.76	21.40
2012	8.13	0.16	1.97	1.74	21.40
2013	14.70	0.29	1.97	3.14	21.36
2014	15.60	0.3	1.92	3.32	21.28
2015	9.17	0.18	1.96	1.96	21.37
2016	7.14	0.14	1.96	1.52	21.29
2017	11.50	0.22	1.91	2.45	21.30
2018	12.00	0.23	1.92	2.55	21.25
2019	11.70	0.23	1.97	2.50	21.37
2020	14.20	0.28	1.97	3.02	21.27
2021	16.80	0.33	1.96	3.59	21.37
2022	22.20	0.43	1.94	4.74	21.35
2023	20.50	0.4	1.95	4.37	21.32
2024	26.00	0.5	1.92	5.55	21.35
2025	7.00	0.14	2.00	1.49	21.29
2026	13.50	0.26	1.93	2.89	21.41
2027	18.90	0.37	1.96	4.04	21.38
2028	14.60	0.28	1.92	3.11	21.30
2029	8.10	0.16	1.98	1.73	21.36
2030	19.50	0.38	1.95	4.15	21.28
2031	12.60	0.24	1.90	2.69	21.35
2032	15.40	0.3	1.95	3.33	21.62
Average	**14.19**	**0.28**	**1.95**	**3.03**	**21.35**

- **Estimation of CO_2 emissions reduction based on the current WPT utilization for the conversion into value-added products in Malaysia**

  Table 3.3.2.5 shows the amount of CO_2 that is being reduced in the current product manufacturing activities using WPT as the raw material in Malaysia, based on a survey conducted on industries currently operating using WPT as feedstock. The highest percentage of CO_2 reduction was found from plywood manufacturing with reductions of 0.24%, followed by lumber and animal feed pellets with 0.08% and 0.03% respectively.

Table 3.3.2.5

Amount of CO_2 emissions reduced based on current commercial production of products from WPT

No	*Type of products*	*Current amount of CO_2 that can be sequestered in product manufactured (tons CO_2/yr)*	*Per cent CO_2 reduced (%)*
1	Plywood/flooring/laminated veneer lumber	30700	0.24
2	Lumber	9700	0.08
3	Animal feed pellet	3250	0.03

The above table illustrates that current activities are not contributing much to GHG reduction. Around 50% of the total potential WPT available will need to be utilized in order to make an average reduction of 20% (tables 3.3.2.3 & 3.3.2.4).

3.3.3 Assessment of environmentally sound technology (EST) for WPT conversion into material/resources

The technology involved for each product manufacture has been discussed previously in this section. All aspects must be considered in order to assess the EST for the conversion of WPT into products. However, the most important aspects were selected for the present assessment, which include the cost of investment, raw material replacement potential, technology feasibility, environmental concerns, level of WPT utilization and market needs. All of these criteria were given a rating of 1 to 5, with value 1 being the lowest and value 5 the highest. The EST section was based on the technology having the highest total rating. All values given are shown in table 3.3.3.1.

The "cost of investment" rating in table 3.3.3.1 encompasses other costs such as man power, cost of production, and market value of product e.g. selling price, etc. "Raw material replacement potential" takes into account the possibility of the WPT being replaced by other conventional types of material, that raw material's availability, and how critical it is to use WPT in place of the conventional material. "Technology feasibility" considers the number of methods and availability of equipment involved in the product manufacture. "Environmental impact" assesses and rationalizes GHG emission reduction potentials as calculated in section 3.3.2 above, in addition to the chemicals used and waste generated during product manufacture. The "level of WPT utilization" rating examines the percentage of utilization of WPT consumed for the product manufacture and also material balance. “Market need” weighs the current global scenario of demand and the importance of the product for human needs.

The “cost of investment” criteria showed the highest rating for lumber and flooring, which require a lower cost of investment (table 3.3.3.1). Higher costs were involved in bioethanol and plywood manufacture, which were thus given lower ratings. Bioethanol and animal feed were given the lowest raw material replacement rating, since the OPT sap and fronds could only be replaced by sugar cane juice/molasses for bioethanol production, and other high protein plant material for animal feed, neither of which are readily available in large quantities. For technology feasibility the highest ratings were given to plywood, lumber animal feed and flooring, since the technology has been commercialized and could be very easily adopted. On the other hand, bioethanol and microcrystalline cellulose production are still in pilot plant trials, and technology for large production, or from new raw materials such as oil palm biomass, has not yet been established.

For environmental impact criteria, high ratings were given to plywood, lumber (LVL) and flooring as calculated in Table 3.3.3.1. Lower ratings were given for bioethanol, animal feed and microcrystalline cellulose, due to the presence of chemicals contained in the waste waters generated, such as resins, acids and bases, which pollute the environment. Laminated veneer lumber uses a larger amount of resin adhesives that release formaldehyde into the environment. It must also be considered that although GHG reductions are high for the production of plywood, flooring and laminated veneer lumber, the life cycle for these products is quite short, i.e., only 2-3 years. Eventually the carbon sequestered will also be released to the atmosphere, which means the amount of carbon sequestered by the manufacture of these products is somewhat short-lived. Therefore the gap of ratings is the least among these products in terms of environmental concerns.

Plywood and flooring obtained the highest rating for levels of WPT utilization, due to the largest portion of WPT being utilized i.e. about 40% of the trunk, followed by lumber and bioethanol (about 20%). Animal feed and microcrystalline cellulose were given the lowest rating due to the utilization of the minor part of WPT i.e. the fronds. In terms of market need bioethanol has been rated highest given its high demand status globally, in light of global environmental efforts to address global warming and pollution by reducing fossil fuel consumption. Although plywood is also in demand by the world market, its utilization is a way of utilizing its abundant availability, and is merely a replacement for wood veneers. Other products such as microcrystalline cellulose had lower ratings, due to a less important demand globally, meaning that the current market would not be affected if palm wastes were not used for its manufacture.

As per the data captured in table 3.3.3.1, products with the highest ratings were lumber and flooring. These categories were followed by plywood and bioethanol. The next category was animal feed, with the lowest ratings being given to microcrystalline cellulose production. Thus, lumber and flooring would be the most environmentally sound technologies to be pursued for conversion of WPT into a resource.

Table 3.3.3.1

Rating of potential EST for WPT conversion into material/resources

Product	Cost of investment	Raw material replacement potential	Technology feasibility	Environmental impact	Level of WPT utilization	Market need	Total rating
Bioethanol	3 (RM25)	2	3	3	3	5	19
Plywood	3 (RM25)	3	4	4	4	3	21
Lumber (LVL)	5 (RM10)	3	4	4	3	3	22
Animal Feed	4 (RM13)	2	4	3	2	3	18
Flooring	5 (RM10)	3	4	4	4	2	22
Microcrystalline cellulose	4 (RM20)	3	3	3	2	2	17

5 4 3 2 1

Good Poor

The environmental soundness and material utilization of these categories could be further increased if integration of the activities were employed during the conversion of WPT into products. This would involve the maximum utilization of WPT as a raw material and reduced waste generation. Sharing of WPT pre-processing equipment would, for example, reduce the cost of investment. Multiple products produced would be rewarded with higher profit margins. Therefore, various factors should be considered before choosing the correct plan to develop an environmentally sound technology for WPT conversion into a resource.

- **Recommendation of EST: Scenario 1**

Complementing plywood manufacturing with bioethanol production would be one judicial choice for integration. This system would have the advantage of high raw material (WPT) utilization, as almost the entire OPT material could be utilized, resulting in minimal to zero waste manufacturing (figure 3.3.3.1).

Based on the current consumption and capacity of the existing plywood mill, the input is 6,000 tons/month of OPT that is equivalent to 6000 trunks/month. As discussed earlier, in plywood manufacturing only 40% from OPT generates usable veneers for plywood. This is equivalent to 2,400 tons/month, while the remaining 60% is discarded as waste material that consists of end logs and core-logs (50%), low quality and veneer off-cuts (10%) (figure 3.3.3.1). This amounts to 600 tons/month and 3,000 tons/month of core logs and veneer off-cuts respectively. The waste veneers can be sun dried and fully utilized as fuel for the boiler, while the OPT core and end logs can be used for bioethanol production.

About 20% of the sap can be extracted from OPT cores for bioethanol production. From sap extraction only 35% can be converted into ethanol while the remaining 65% is the by-product consisting of sap-squeezed fibres. This means that for 600 tons/day of sap, 210 tons/day of bioethanol will be produced. The remaining 80% residue from OPT cores can be converted to other potential products such as compost, animal feed and boiler fuel.

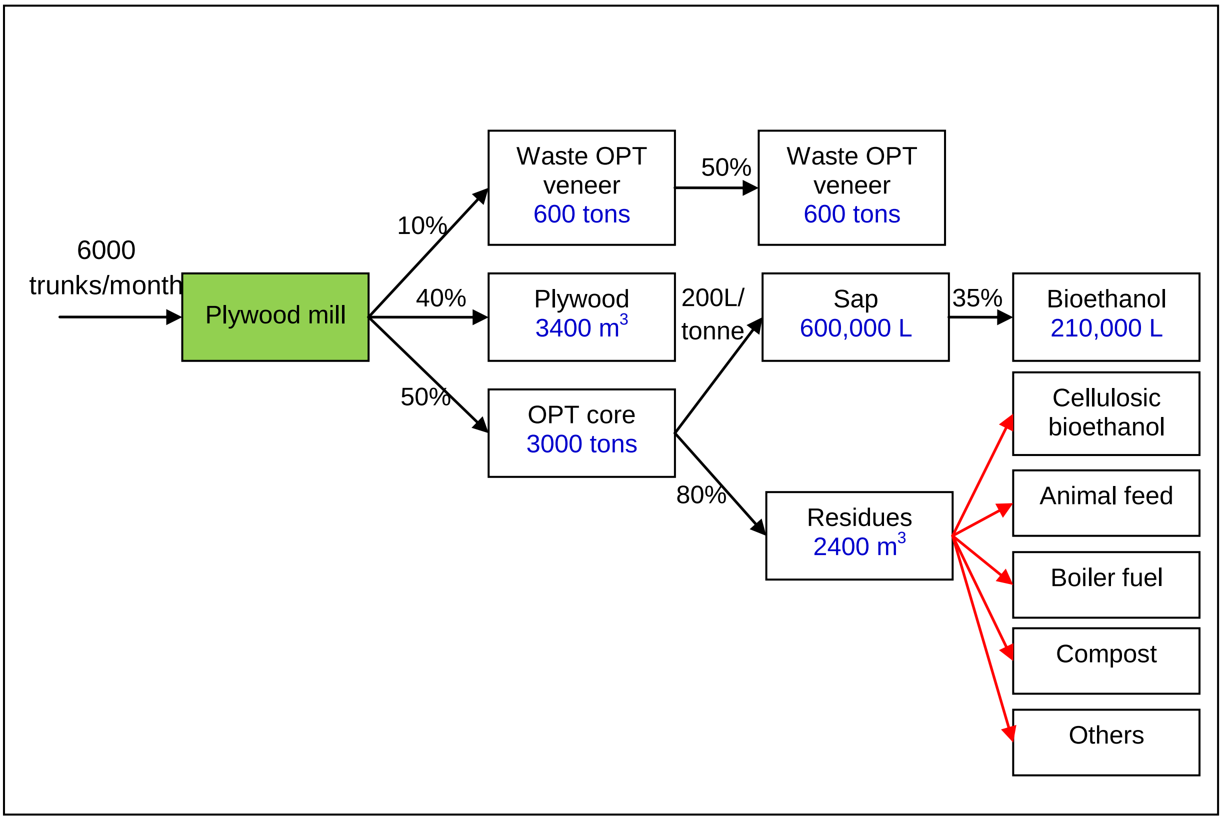

Figure 3.3.3.1

Integrated system for efficient WPT utilization based on current capacity of plywood mill

From the proposed integrated plant, an estimated 198,000 m^3/yr (792 metric tons/yr) of plywood panels can be produced, while simultaneously contributing 13.86×10^6 l/yr (69.3 metric tons/yr) of bioethanol production (under the assumption that the plant is operated 24 hours on 330 working days). Details of the mass balance calculations for an overall integrated plant are shown in tables 3.3.3.2 to 3.3.3.6

Table 3.3.3.2

Mass balance for plywood mill

Materials	*Input (tons/day)*	*Conversion (%)*	*Output(tons/day)*
OPT	6,000	-	-
Plywood	-	40	2400
Waste OPT veneer	-	10	600
OPT core	-	50	3000
Total	6,000	-	6,000

Table 3.3.3.3

Waste OPT veneer conversion

Materials	*Input (tons/day)*	*Conversion (%)*	*Output(tons/day)*
Waste OPT veneer	600	-	-
Boiler fuel	-	100	600

Table 3.3.3.4

OPT core conversion

Materials	*Input (tons/day)*	*Conversion (%)*	*Output(tons/day)*
OPT Core	3,000	-	-
Sap		20	600
Residues		80	2,400
Total	3,000		3,000

Table 3.3.3.5

Sap extraction

Materials	*Input (tons/day)*	*Conversion (%)*	*Output(tons/day)*
Sap	600	-	-
Bioethanol		35	210
By-product		65	390
Total	600		600

Table 3.3.3.6

Overall mass balance

Materials	*Input (tons/day)*	*Output(tons/day)*
OPT	6,000	-
Plywood	-	2,400
Biofuel	-	600
Bioethanol	-	210
By-product	-	390
Residues	-	2400
Total	6,000	6,000

- **Recommendation: Scenario 2 – centralized facilities**

  Another option of palm oil biomass product manufacturing is to locate manufacturing facilities near the resource supply or to centralize the biomass collection in order to make the raw material available to interested industries. The industries using the biomass could then be established near this centralised area. Malaysia has proposed to develop the first centralised or integrated plant for WPT biomass utilization in Lahad Datu, through the Sabah State Government Agency, i.e. Palm Oil Industrial Corridor Sdn. Bhd. (POIC). This company, owned by the State Government of Sabah, is under the supervision of the Ministry of Industrial Development of Malaysia. POIC has been set up to spearhead palm oil downstream processing such as biomass and biofuel in order to add value to its 1.4 million hectares of oil palm plantations, to create jobs and to provide business opportunities. The town Lahad Datu that is located near the port is also situated near Sabah's palm oil belt. This town has been equipped with adequate infrastructure such as ports/jetties, roads, electricity, telecommunications and waste treatment facilities.

  Operating companies that have been set up are Global Biodiesel Sdn. Bhd, and SPC Biodiesel Sdn. Bhd. POIC is responsible for coordinating and managing Sabah's oil palm industry. They also have the authority to make policies involving oil palms. In order to facilitate logistics, it is recommended that product manufacture utilizing oil palm biomass be centralized around Lahad Datu, and that a well-planned, integrated biomass manufacturing facility is established. This area could serve as a centralised hub for the entire oil palm biomass utilization industry. Interested parties could thus invest in the oil palm biomass-based manufacturing of their choice, and the resulting by-products could be utilized by other parties at the same locality. For West Malaysia, one POIC is also planned for the central State of Pahang, with development products from biomass transiting through this hub.

3.4 Conclusion and recommendations

Being lignocellulosic in nature and thus similar to wood, WPT biomass presents the possibility of being utilized in similar value added products. However, differing characteristics from wood, such as high moisture content and a fibrous nature, make it difficult for established wood based industries in Malaysia to exploit WPT's potential. Although various options for its utilization have emerged from R&D, very few products manufactured from WPT are currently being commercialized. In general, products from WPT that have potential to be developed but are still in the R&D stage include: panel products, sugar, chemical derivatives, bioethanol, pulp and paper and dietary supplements. Products being developed by industries at the pilot scale stage and prepared for commercial production include: plywood, lumber, flooring, micro-crystalline cellulose and animal feed pellets.

Products developed from WPT are able to sequester carbon dioxide directly and indirectly for a better environment. Calculating GHG emissions from one OPT using equations derived from the UNFCCC document (with some modifications), researchers found that the average amount of CO_2 emitted from the decomposition of WPT annually, available in years 2011-2032, would be equivalent to 14.19 million tons of CO_2.

The amounts of CO_2 that could be sequestered from the manufacture of potential products were also calculated. Assuming that 50% of the annual availability of WPT in Malaysia from years 2011-2032 would be converted, it was estimated that GHG emissions would be reduced by 8.11% through plywood and flooring manufacture, 20.50% through lumber manufacture, 1.95% through bioethanol production from sap, and 21.35% through animal feed and microcrystalline cellulose production. Thus, the most environmentally sound products to produce would be micro-crystalline cellulose and lumber. Nevertheless, the amounts of GHG being shown sequestered according to these calculations are not permanent, since the life cycle of these products is very short.

In order to choose the EST most suitable for conversion into products, other criteria and factors must be assessed apart from GHG reduction potential. The product to be manufactured must be versatile, highly in demand with good future market potential, and must demonstrate potential to have both a direct and indirect impact at the global level when manufactured and used. The production of this product could be a part of or integrated into an existing WPT utilization system, thereby ensuring raw material supply security (availability versus accessibility), simplifying logistics and addressing complexity of technology routes.

The strategy which best responds to the considerations mentioned above would be the production of sap for bioethanol production. Future demand for biofuels is very high, as global energy requirements increase yearly. Increased biofuel supply and utilization would have indirect and direct impacts at the global level, resulting in reduced demand and usage of fossil fuels, cleaner air from biofuels combustion, and an overall reduction in global warming. The production of bioethanol from oil palm sap could be integrated into existing wood based industries systems in Malaysia, since the wastes generated from plywood mills or lumber production could be channelled to the bioethanol plant as raw material supply. This integrated system could contribute towards greening the environment in several significant ways, including: reduction in waste generation from wood-based industries, and reduction in the deforestation that has such an important impact on global warming, where WPT is used as an alternative to timber.

In terms of logistics and infrastructure requirements, it would be advisable to locate the bioethanol plant near a palm oil mill/plywood mill/lumber mill or all of the above, located in a cluster in order to share the energy source and the pre-processing equipment. Another alternative would be to locate the plant within a centralised, planned industrial zone such as the POIC in Sabah, where all raw material supply, logistics and infrastructure requirements are available and well organized.

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Appendices

3A: Technologies in commercial use

3A.1: Resin impregnated oil palm flooring

Crop	Oil palm tree
Residue	OPT
Process	Impregnation, pre-dry and semi curing, densification, calibrating and profiling
Equipment	Shredder
Main products	Flooring
By-Products	OPT core

Process description

Impregnation process

The resin impregnation process is carried out by using a vacuum pressure system. A conventional modified thermosetting resin and wax emulsion are used in this process. The optimum pressure, time and chemical formulation of this solution are vital as they will determine the dimension stability after the curing process. Therefore, it is important to ensure that uniformity of resin distribution throughout the cross section of the oil palm wood is attained.

Pre-dry and semi curing process

This is an important process to reduce the moisture content to a certain level in order to reach gel transition for the resin before further process. This is a critical stage for achieving dimensional stability of the reinforced palm flooring produced. It is also an important process for achieving lower rejection rates and maximum productivity in oil palm flooring production

Densification process

There are two phases in this process which are densification and bonding, and water vaporization. The objective of this process is to achieve the hardness, moisture content and density required for flooring application.

Calibrating and profiling process

The operations involved in this process are blanking, ripping, sanding and T&G profiling. Most of the processes are tailored towards reinforced oil palm flooring characteristics and properties. This is mainly due to different physical and mechanical properties of a product produced from a *monocot* species. Special selected machinery and tools are needed for producing resin impregnated flooring such as sand material for sandpaper.

Finishing process

The objective of this process is to meet acceptable standards of UV surface performance coating that are required for the flooring market. In order to achieve a considerably better surface coating, norms have been established. The best surface coating result can be obtained by a correct formulation of coating materials and a slightly altered process through small modifications to the roller, levelling zone and various other machines.

Product description

The resin impregnated palm-wood flooring is produced by combining thermo-set resins at different loading and curing points. The combination of a thermo-set polymer with wood fibres is designed to reinforce the strength and durability of palm wood, offering both a new processing method and a new utilization opportunity for the wood-based industry.

Product specifications

Size	Thickness 12.5 mm x width 135/130 mm x length 445/595/1200 mm
Structure	Top wane layer - 2.0 mm of solid palm timber supported by 5 to 7 layers of marine plywood
Edge configuration	Perfect tongue and groove (Micro bevelled edge)
Finishing	10 layers of UV acrylic lacquer (300 g / m^2)
Hardness	4.4 (brinel hardness test)
Packing	24 pcs. per box

Product features

Abrasion resistant	10 layers of UV-cured lacquer coating to ensure optimal abrasion/ scratch resistance and hardness
Stain resistant	Tested for coffee, vinegar, ammonia, acetone, etc.
Eco friendly	Palm wood is environmentally friendly as it is from farmed plantations, not from forests.
15 year life	Warranty against manufacturing defects such as coating surface ware through CE certified products
Pre-finished	Already sanded and sealed, ready to use immediately after laying. Natural grain texture without having knots and other natural wood defects. Good mechanical and working properties such as cutting and moulding. Termite and insect resistant.

Plant capacity: 20,000 m^3/yr

Waste utilized: 3,000 trunks/yr

Potential buyers

PROGRESS
Sos. Bersului 45, 410605 – Oradea, Romania
Tel: +40 259406290/435784
Fax: +40 259 406291
Website: www.proges.ro

SEQUIOIA FLOORING
2800 Etienne Lenoir, Laval, Quebec, H7R 0A3, Canada
Tel: 866.839.2888 Ext.13
Fax: 866.922.9990
Website: www.sequoiafloorings.com

ATLAS-PE "OBJECTIVE"
Roman Karmen Street 21. 65058, Odessa, Ukraine
Tel: (38-0482) 357-091,357-092, 357-093, 357-094
Email: atlas@paco.net

BAHAG AG
Gutenbergstr. 21, 68167 Mannheim, Germany
Tel: +49 (621) 3905-7396
Fax: +49 (621) 3905-7396
Website: www.bauhaus.info

U. MONSTADT
Holter Weg 11, D-44388 Dortmund (Germany)
Tel: +49 (0)231 691940,
Fax: +49 (0)231 691930
Website: www. IN-PARKETT.de

JAMES ZIMMERMAN
Architectural Flooring Concepts, LC,
6939 San Mateo Blvd, Dallas, Texas 75223
Tel: 214.660.3484

INTERNATIONAL WOOD LLC.
2300 N.Sugar Sweet Ave., Weslaco, Texas 78596
Tel: 956-969-8666 Ext. 132

Market demand/potential market

There are no competitors of this product in the flooring market. However, the buyers may benchmark the product with coconut flooring, which has been in the flooring market for quite some time. The target is to get one sole distributor agent in the U.S., China, Europe and Japan to promote the product in the respective countries. The product should be able to penetrate the Canadian and the U.S. flooring markets.

In 2006, the total export of mouldings by Peninsular Malaysia amounted to 532.82 million. Flooring is one of the items included in this moulding category. The major importing countries were the U.S. (18.86%), Japan (17.09%), the Netherlands (16.50%) and Australia (15.48%).

Current selling price: RM85.05/m^2

The pricing of resin impregnated palm wood flooring is acceptable in the flooring market if compared to that of other species. The ability to competitively price this product is mainly due to the cheap and abundant supply of palm wood material.

Environmental aspect

Many overseas buyers are now looking for certified timber. The interest in purchasing plantation timber is also increasing. As palm wood is from farm plantations and not the forest, reinforced oil palm wood is considered to be a healthy and sustainable resource.

Operations and maintenance requirements

The major challenge of UV surface coating of resin impregnated palm flooring is to obtain a flat surface of resin. This is mainly due to the non-uniform density and hardness between parenchymatous tissue and vascular bundles.

Investment and operating costs

Investment Cost: RM10 million

Operating Cost: RM355,000.00

Social aspects

- *Job potential*

  Increased employment as well as enhancement of the social well-being of the local communities near the project site. A total of 42 job vacancies will be created.

- *Social acceptability*
  - Benefit to the applicant company
  - Benefit to the collaborating partners
  - Benefit to the nation
  - Creation of wealth from waste with potential downstream economics activities
  - Revival of sluggish tropical wood plywood industry and related downstream industries

Company using the technology

POLYPALM WOOD PRODUCTS SDN BHD
Level of Use: Commercial
Name of Project: Commercialisation of resin impregnated oil palm flooring
Location: Malaysia

Technology/equipment suppliers

KAOYANG & SONS TRADING SDN BHD
No. 4969, Bagan Ajam, 13000, Penang, Malaysia
Tel: +604-333 3569
Fax: +604-3311598

RIGMA MACHINERY CO LTD
No. 14, Lane 592, Shen Jou Rd., Shen Kang Hsiang,
Taichung Hsien, Taiwan R.O.C.
Tel: +886-4-25287787
Fax:+886-4-25287819
Email: rigma@ms47.hinet.net

MICHAEL WEINIG ASIA PTD LTD
18 Woodlands East Industrial Estate Singapore 738392
Tel: +65 6758 5178
Email: info@weinigasia.com

Appendix 3A.2: Plywood

Crop	Oil palm tree
Residue	OPT
Process	Peeling, drying, pressing, assembly
Equipment	Rotary lathe, spindleless lathe, veneer clipper, glue, spreader, hot press
Main products	Plywood

Process Description

Plywood processing of OPT is divided into three categories: green veneer production, dry veneer production and panel production.

Green veneer production

Green section	Activities
A. Pre-peeling and peeling	OPT – Pre determining the peripheral/outer zone and inner zone prior to pre-peeling for the 'round up' and peeling process. Three methods of peeling apply for OPT logs: Process I: • Rotary lathe – doing 'round up' only (removing barks to obtain uniform diameter), followed by : • Spindleless lathe – peeling logs down to the smallest diameter (normally down to four inches, depending on the peeler) Process II: • Rotary lathe – round up and peeling logs down to about nine inches, followed by: • Spindleless lathe – peeling logs down to the smallest diameter (normally down to four inches) Process III: • One straight process (spindleless lathe): rounding up and immediately peeling logs down to the smallest diameter (normally down to about four inches) This type of lathe requires a bigger opening to adapt to a larger diameter of OPT. These lathes are modified (by increasing sturdiness of structure and parts) to enable both the 'round up' and peeling process. Peelers must be able to remove the bark residues effectively during the peeling process.

B. Preparing the logs for four foot lathes or nine foot lathes	All conventional plywood manufacturers should be able to peel OPT into an acceptable veneer quality. A slight modification to the peeler lathe is essential to accommodate and adapt to OPT logs. A rotary lathe is normally used for 'round up' purposes. The peeling process can always be continued if the setup is equipped with a conveyor and clipper. The peeling process, however, will be limited in terms of diameter size, depending on the diameter of the spindle chuck. It is normally possible to peel down to about nine inches in diameter (chuck diameter). The peeling process continues with spindleless peeler. Attempts to further process using these chucks will end up with spin-out incidents unless the spindle chuck is modified (see below).
C. Machinery – setup and modification	Modification on the spindle chuck pattern/design is required to obtain firm holding properties during the 'rounding up' process. This is due to the fact that the centre part of OPT is physically softer than conventional materials. Consequently, incidents of log spin off may occur without such a modification. This is also the main reason why further peeling is only done by a spindleless lathe. Most of the peeling process is carried out using a spindleless lathe, which offers the advantage of being able to peel logs down to three inches in diameter with acceptable uniform thickness. The spindleless lathe however, does require a slight modification especially to the opening. The conventional spindleless lathe opening is about eight inches. Manufacturers can use any brand of lathe either local or imported (especially from China). These lathes should be rugged, able to peel OPT uniformly and require little maintenance. Since OPT possesses very high moisture content, the lathe should be able to endure greater wear and tear. Most of the spindleless lathes used should first be modified to accommodate a bigger opening (more than thirteen inches) to adapt to the larger diameter of round up logs.
D. Veneer thickness	The OPT veneer's thickness varies based on the final plywood configuration and thickness. The thickness is normally set for 4.0 mm, 4.5 mm and 5.0 mm. These sets vary in order to compensate for loss in volume/thickness after drying and pressing, which is mainly caused by extreme anatomical variations within the OPT.
E. Peeling process	Note: The inner zone of OPT which is less dense and 'softer', requires a much thicker set for veneer thickness. The peeling process using a rotary lathe is carried out according to usual practices. However, in the case of spindleless lathes or peeling the inner portion of OPT, controlling the pressure is deemed crucial, as it goes further into the billet. For practical and technical reasons, veneer produced from the inner portion will have a greater thickness than the outer portion. This is to compensate for the higher shrinkage and compression loss of the veneer.

F. Conveyor	Unlike wood veneer, OP veneer is a bit softer and easily breakable, particularly in the inner zone. The veneer needs to be handled with care. A conveyor that attaches to the peeler is a prerequisite. This conveyor should have sufficient length and speed before clipping, in order to optimize production time.
G. Clipper	Clipper – clip veneer to desire size OP veneer should be clipped to size once peeled, by attaching a clipper to the conveyor. The end veneer is then cut to size (three or four feet, or other, as required).
H. Veneer sorting	Sorting of OP veneer - for drying purposes • Sort veneer according to outer zone and inner zone, as each veneer has different drying characteristics • Sorting is applied for Processes I and III (refer to section A above: pre-peeling and peeling

Dry veneer production

Drying section	**Activities**
A. OP veneer characteristics	OP veneer Possesses high moisture content range between 300-500% Significant variation within trunk (outer and inner zone; height portion/part). Grouping veneers of inner, outer zone and portions of the trunk will help to speed up drying process and minimize drying defects. It is recommended that these groups be dried by batches.
B. Dryer and requirements	Two types of dryers – roller & net dryer Both dryers can be used to dry green OP veneer down to about eight per cent moisture content. However, the roller dryer is preferable, as it has shown slightly better performance in terms of veneer quality. Recommended general requirements for drying: Since OP veneers possess extremely high moisture content, greater energy (BTU) is required to remove this moisture content. Following are the recommended general requirements for drying OP veneers: • Consistent high steam (pressure and temperature) supply • Large capacity boiler system – 25 tons and above (depending on the number of dryers and their capacity) • Bigger capacity and longer haul dryer with more sections (20 sections and above) • Efficient and effective dryer system – capable of ensuring temperature consistency and low heat losses.

C. Pre-drying and drying	Pre-drying is carried out due to extremely high moisture content of OPT veneer and under capacity of conventional dryers. The aim is to reduce moisture content of OP veneer as much as possible prior to using a conventional dryer. The normal practice is by "sun-drying" and/or by mechanical pressure. The latter practice utilizes an unused cold press, whereby a pile of green veneer will be pressed (or squeezed) at a consistent pressure for a certain period. Both practices have been shown to result in a significant reduction of moisture content (down by more than 70 %). Both conventional net and roller dryers can be used for drying green OP veneer. However, again due to higher moisture content, both dryers have shown a lower capacity in terms of output production. Normal drying time for OP veneer is between 40 to 50 minutes. In some case the drying process has to be carried out twice. Note: Handling OP veneer requires special attention and trained operators.

Gluing process

Gluing section	Activities
Gluing	Glues and gluing procedures are the same as for tropical timber veneer. In general, R&D has demonstrated that OP veneer has no bonding problem when subjected to common industrial adhesives as a binder. Major glue suppliers have experience in handling, supplying and advising correct glue formulation for any type of veneer, including OP veneer. Common glues used for OP veneer are phenol-formaldehyde, urea-formaldehyde and melamine urea-formaldehyde. Experience with gluing during R&D has shown that bonding properties of glue have never failed, except in cases of improper handling by operators. In most cases the failure occurred because of poor materials (woody part). The same applies to OP veneer. The gluing process of OP veneer is carried out similar to normal tropical timbers except for a few aspects which warrant specific attention. OP veneer absorbs a higher quantity of glue (estimated to be about 25 to 30% higher) than tropical veneer. Therefore, it is advisable to improve the efficiency of glue spreading, and carry out the procedure in a "one-time roll" over the entire surface of the veneer. This can be achieved through a better glue spreader system, which would have the following characteristics: • Suitable doctor roll groove patterns • More roller spreaders (presently in states of two) • Bigger diameter of roller spreader to be able to carry out the "one time roll" • A higher ratio of industrial flour is expected to be used to fill more surface area of OP veneer (higher variation on "peaks and valleys" due to parenchyma properties).

Assembly section - panel production.

Assembly section	Activities
Panel assembly	Generally, the assembly line for plywood manufacturing using OPT veneer is identical to that of tropical species. It consists of gluing, lay-up, pre-press (cold press) and pressing (hot press). The principle of hot pressing is to cure the glue as fast as possible without any defects. However, close control of the assembly time is still important and required in order to prevent defective glue joints. These defects probably result from pre-curing (or hardening) of the glue before adequate pressure is applied and/or excessive squeeze-out of the thin glue if pressure is applied too quickly. In hot-pressing, hydraulically operated presses are employed, with platen temperatures ranging from 120-130^{o} C and applied pressure ranging from 6 to 15 kg/cm^{3}.
Pre-press and pressing	Pressing time may range from five minutes up to 10 or 15 minutes. This depends upon the thickness of the plywood assemblies, the type and rate of cure of the glue, and the percentage of cure required. Manufacturing of plywood from OP veneer may undergo a single process and/or a double process method. In the single process, hot-pressing is carried out one time. The manufacturers are required to control the pressure and/or to have a 'stopper' to hold excessive pressure over the OP plywood. In the double process, the same method is applied except that the face and back veneer are not included during the first hot-pressing. A calibrating sander is used for the cure OP plywood and then a second hot-pressing is carried out for the face and back veneers.

Market demand

The output of palm plywood has mainly been confined to product specifications of 8 x 4 ft 5-ply 12 mm waterproof formwork plywood for the construction sector. The perception of palm plywood in the domestic market is that since the product is produced utilizing wastes from plantations, it is inferior in quality compared with hardwood plywood. As this perception is not necessarily false, palm plywood is currently sold at a lower price in order to be able to compete in the marketplace.

Investment and operating cost

For a plant with a production capacity of 15,000 m^3 per year, the investment cost is estimated at RM25 million.

List of companies using the technologies

GERBANG MASHYUR PAPAN LAPIS SDN BHD
Bukit Kepong, Johor.

OPT PANEL SDN BHD
Kulim, Kedah

NIPPON PALM CORPORATION SDN BHD
Kulai, Johore

PLUS INTERVEST SDN BHD
Batu Kikir, Negeri Sembilan

CENTRAL KEDAH PLYWOOD FACTORY SDN BHD
Sungai Petani, Kedah.

List of suppliers

KUNSHAN YONGMAO MACHINERY MAKE CO LTD
ZhenNan Road, Yushan Town, Kunshan City 215347
(Press dryers and other plywood machines)

KUNSHANG DACHANG MACHINERY, MANUFACTURE CO LTD
168# Dongfang Road, Zhoushi Kunshan 215337
(Press dryers and other plywood machines)

WUXI CITY HAOXING MACHINERY CO LTD
Yandai Dongbeitang Town Xishan District,
Wuxi City, Jiangsu Province
(Press dryers and other plywood machines)

JIANGSU JINGJIANGSHI YANGZI MUYE YOUXIAN GONGSI
Tang Shi Bridge, Chen Nan Siang
Jin Jiang Shi, Jiangsu Province

JIANGSU NATURE TIMBER CO LTD
Huishan Economic Dev. Area
Chang'an, Wuxi, Jiangsu Province
(Press dryers and other plywood machines)

CHANGZHOU ENERGY ENGINEERING CO LTD
7 East Puqian Road, Changzhou Js 213004
(Thermo-oil and heat exchange equipment)

CHANGSU XIANG YING WOOD-BASED
Platemachine Manufacturing Co Ltd
88 Su-Chang Highway, Changsu, Jiangsu Province
(Conventional dryers and other plywood machines)

Challenges

- *OPT as raw material input*

  The supply is abundant and sustainable but the mechanics of supply has not yet been established on a wider scale. Stability in supply needs to be a priority issue. It is important that relevant agencies work together to network with palm plantation owners and corporations, big and small, to achieve this end.

- *Processing of OPT*

  Factories in Malaysia have been designed and built to process hardwood logs, not OPT. OPT can be processed and palm plywood produced, but the level of operational efficiency leaves much room for improvement. Technical re-alignment in manufacturing operations, and new modified plants and equipment specifically for the purposes of processing OPT must be considered sooner rather than later.

- *Product development for palm plywood*

  There have been few resources channelled into product development by the plywood factories. Moreover, local market perception is that the product is of inferior quality, since it has been produced using by-product wastes from the palm plantation sector.

Appendix 3A.3: Laminated veneer lumber (LVL)

Company	Mitrework Sdn. Bhd
Crop	Oil palm tree
Residue	OPT
Process	Peeling, drying, pressing, assembly
Equipment	Rotary lathe, spindleless lathe, veneer clipper, glue, spreader, hot press
Main products	Lumber

Process description

Laminated veneer lumber (LVL) consists of layers of wood veneer laminated together with the grain of each veneer aligned primarily along the length of the finished product. The veneers used to manufacture LVL are about 3.2 mm (0.125 in) thick and are made from rotary-peeled hardwood (e.g., yellow poplar) or softwood species.

The start of the LVL manufacturing process depends on how the plant obtains veneers. Plants either peel and dry veneers on site, purchase green veneers and dry them on site, or purchase pre-dried veneers. If the plant peels and dries veneers on site, the first steps in the process are log debarking, cutting, steaming, and veneer cutting. If the plant purchases green veneers, the LVL manufacturing process begins with veneer drying. If the plant purchases pre-dried veneer, grading is the first step in the LVL manufacturing process. The veneer dryers used at LVL plants are the same types of veneer dryers in use at plywood plants.

Veneer dryers used at LVL plants are used to dry either predominantly hardwood or predominantly softwood species at a typical drying temperature of around 180°C (350°F). The veneer dryer may be a longitudinal dryer, which circulates air parallel to the veneer, or a jet dryer. Jet dryers direct hot, high velocity air at the surface of the veneers through jet tubes. Veneer dryers may be either direct-fired or indirect-heated. In direct-fired dryers, the combustion gases are blended with recirculated exhaust from the dryer to reduce the combustion gas temperature. Air is warmed over steam coils and circulated over the veneer in indirect-heated veneer dryers.

Once the veneers are dried, they are graded ultrasonically for stiffness and strength. The lower grade veneers are used for the LVL core and the higher grade veneers are used in the LVL face. Once graded, the veneers are passed under a curtain or roll coater where phenol-formaldehyde (PF) resin is applied. Plants that manufacture LVL from hardwood species may use urea-formaldehyde (UF) resin rather than PF resin. Once resinated, the veneers are manually laid up into a long thick stack. The veneer stack is fed to a hot press where the veneers are pressed into a solid billet under heat and pressure. The LVL is manufactured to either a fixed length using a batch press, or to an indefinite length using a continuous press. The LVL presses are heated by electricity, microwaves, hot oil, steam, or radio-frequency (RF) waves.

Press temperatures range from about 120° to 230°C (250° to 450°F). Batch presses may have one or more openings. Shorter lengths of LVL can be produced using multi-opening platen presses similar to the hot presses used in plywood manufacturing. However, most plants employ continuous pressing systems.

Billets exiting the press may be up to 8.9 cm (3.5 in) thick. Billets are produced in widths of up to 2.8 m (6 ft). The billets are typically ripped into numerous strips based on customer specifications. The LVL is produced in lengths up to the maximum shipping length of 24 m (80 ft). Trademarks or grade stamps may be applied in ink to the LVL before it is shipped from the plant.

Potential market demand

At present, there is an acute shortage of tropical wood lumber worldwide whereas demand for lumber continues to increase due to rapid infrastructure and property development. In table 3A.3.1 below, the Food and Agriculture Organization (FAO) forecasted the wood-based panel trade balance for six major importers for the year 2010. The data clearly shows demand, market size and market growth for lumber products.

Table 3A.3.1

Forecast wood-based panel (WBP) trade balance for six major importers - 2010 (FAO)

Country	*Product*	*Production (10^3 m^3)*	*Imports (10^3 m^3)*	*Exports (10^3 m^3)*	*Consumption (10^3 m^3)*	*Exports (%)*
Indonesia	OSB & Lumber	600	42	540	102	90
Malaysia		750	0	448	302	59.73
Thailand		750	0	680	70	90.67
Philippines		20	20	20	20	50.00
New Zealand	Lumber	150	0	90	60	60.00
Australia	OSB & Lumber	100	20	80	20	80.00

Current selling price: RM807.50 per m^3

The cost of production is 30-35% cheaper compared to conventional hardwood.

Table 3A.3.2

Price competitiveness of lumber manufactured from OPT versus lumber manufactured from tropical hardwood

LVL	*Tropical hardwood based LVL*	*Oil palm based LVL*
Market price m^3	USD350 - USD550 (subject to grade quality)	USD350 - USD550 (subject to grade quality)
Source of raw material	Depleting and non-sustainable	13.6 million OPT readily available
Objective of usage	Mostly structural applications	Extensive applications for non-structural usage, with potential for structural applications as well

Investment and operating costs (pilot plant)

Table 3A.3.3

Pilot plant project costs

No.	Expenses	Costs (RM)
1.	Pilot plant and equipment	753,1200
2.	Market testing of commercial ready prototype	1,010,385
3.	Consultancy fees	2,150,000
4.	Technical advisory and R&D	1,000,000
5.	Expenditure of services	5,460,102
Total		7,151,686

Return of investment before and after financing is about three years at a 60% production capacity.

List of buyers

All the companies have been identified as distributors, wood importers and exporters.

Local distributors

WINGLEY TRADING SDN BHD
No. 1A Jln 1/32A, Batu 6 ½ , Jalan Kepong, 52000 Kuala Lumpur
No. Tel: 03-62570688
No. Fax: 03-62512761

SYARIKAT YUENG FATT MARKETING SDN BHD
Lot 37681 No, 20 Jalan 3/37A, Kawasan Perusahaan , Taman Bukit Maluri
52100 Kepong, Kuala Lumpur
No. Tel: 03-61577123
No. Fax: 03-61581852

NATURE SUPPLY TRADING SDN BHD
No. 2 , Jln Haji Salleh, Sentul, 51100 Kuala Lumpur
No. Tel: 03-40424303
No. Fax: 03-3682209

LIM HOCK THYE TRADING
Pendamaran, 42000, Port Klang
No. Tel: 03-31675776
No. Fax: 03-31682209

Overseas distributors

1. Quanzhou Hifeng Import & Export Trade China
2. Jiangsu Nature Machinery Co Ltd China
3. Tradelink Wood Product Ltd UK
4. Patriot Timber Products Ltd UK
5. Korean Intercontinental Trading Co Korea

Social aspects: job potential

Employment requirements for the proposed pilot plant project can be categorised under four sections: lumber main plant, OP veneer mobile plant unit, R&D section and marketing division.

- *Lumber main plant running in 3 shifts*
  During the pre-commercialisation period, the plant will require 50 workers for one shift period. After the 2^{nd} year, it will require 120 to 150 workers a day, comprising 20% management and clerical staff and 80% machine operators and general labourers.

- *OP veneer mobile unit*
  About 15 to 20 persons per mobile unit will be needed at the replanting site. Development of the mobile unit system would create more work and employment opportunities for local entrepreneurs.

- *R&D section*
  About five researchers and engineers will be needed to carry out modifications to the critical machinery that will have to be developed to accommodate the unique properties of OPT.

- *Marketing division*
  A marketing team of about five persons will be needed to collect data and gather market information as well as to promote the lumber products.

List of suppliers

JIANGSU NATURE MACHINERY CO LTD
Shanghai, China.
(All Machinery)

CSO & SONS ENGINEERING SDN BHD
Kawasan Perindustrian Pengkalan Perak, Malaysia.
No. Tel: 05-32334402
No. Fax: 05-3222375

Yongshing Forestry Machinery Factory
Changan Town,Wuxi City, Jiangsu Province, China

Pros

LVL meets all the required specifications for conventional hardwood plywood. The cost of production is approximately 30-35% cheaper than conventional hardwood. This substitute to tropical wood has the potential to provide a stable source of supply for future timber-related industries. The expanding oil palm replanting activities will ensure an abundant supply of OPT in the future.

Cons

The main components of an ordinary machinery line to produce tropical plywood will require modifications in order to accommodate LVL. There is no way to predict whether or not the modified machinery will perform as required, and there is no manufacturer at present that has produced machinery expressly to manufacture palm lumber.

Appendix 3B: Technologies under pilot scale

Appendix 3B.1: Cellulose

Crop	Oil palm tree
Residue	Oil palm frond
Process	Steaming explosion, filtration, extraction, bleaching
Equipment	Steam explosion vessel, centrifugal filter, storage tank
Main products	Cellulose

Process description

The fibres obtained after steaming are subjected to hot water extraction, to isolate the hemicellulose hydrolysates.

Once the hot water extraction process is completed, the hemicellulose present in hot water is filtered out from the fibres using a centrifugal filter. In the centrifugal filter, the hemicellulose's rich liquid and fibres are separated. The hemicellulose's rich liquid is sent to an intermediate tank for further processing. Meanwhile the hemicellulose fibres are recycled to a jacketed pressure vessel for lignin removal through an alkali extraction process.

After the completion of separation, the centrifugal filter is washed before the alkali extracted fibre (AEF) is sent to the same centrifugal filter. At the end of this stage, the AEF is separated from the lignin solution and sent back to the jacketed pressure vessel for a decolouration process. Meanwhile the lignin is sent to another intermediate tank for further processing.

In the bleaching stage, the residual of AEF is decolourized. Prior to the input of bleached fibre, the centrifugal filter is washed after the separation of AEF and lignin solution. Then, decoloured fibre is delivered back to the jacketed pressure vessel for cellulose production.

General schematic diagram

Figure 3B.1 shows the general process flow diagram of cellulose production.

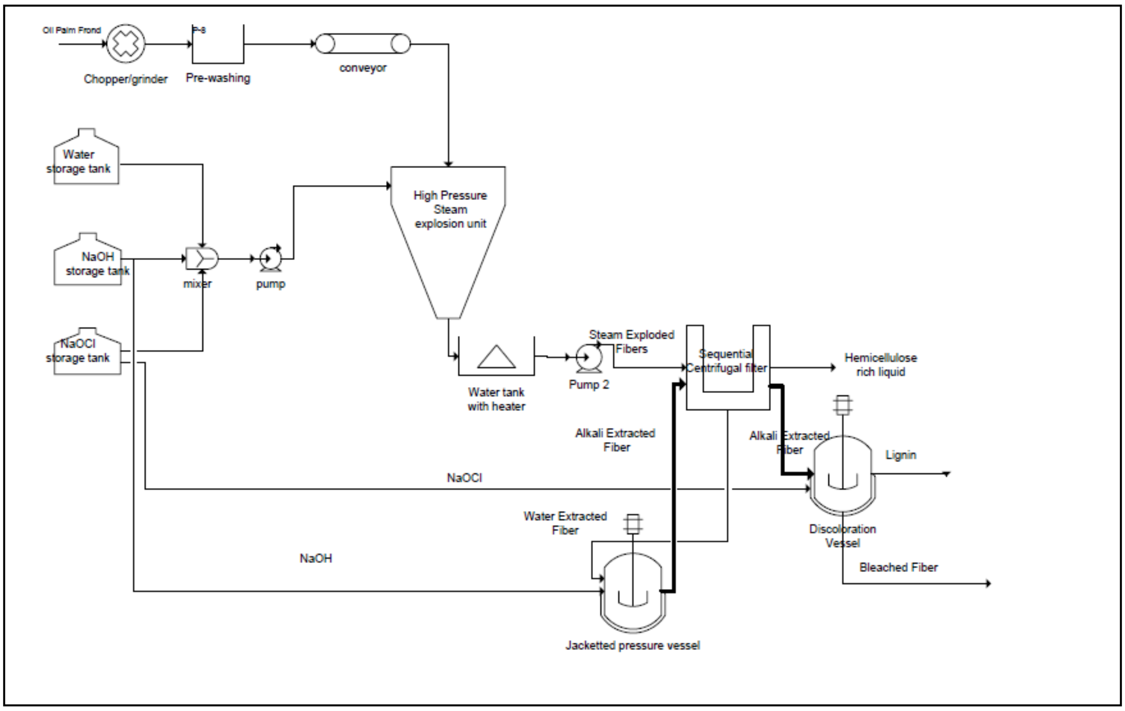


Figure 3B.1

Process flow diagram of cellulose production (*Sarip, 1998*)

List of Suppliers/Vendors

R.D. TECHNOLOGY SDN BHD
No.3 Jln TPP 5/9, Taman Perindustrian Puchong
Seksyen 5, 47100 Puchong, Selangor, Malaysia.
(Storage tank)

HEXAGON TOWER SDN BHD
No. 17 & 19 Perindustrian Industri Bercham 6
Off Jalan Bercham, 31100 Ipoh, Perak, Malaysia
(Centrifugal Filter and Mixer)

IKATAN ENGINEERING SDN BHD
Lot 51, IGB International Industrial Park
Jalan Kuala Kangsar, 31200 Ipoh, Perak, Malaysia.
(Jacketed Pressure Vessel)

Appendix 3B.2: Oil palm sap extraction

Shredder System

Crop	Oil palm tree
Residue	OPT
Process	Sap extraction
Equipment	Shredder
Main products	Sap
By-Products	OPT fibre

Basic description of the process

The process involves the shredding of OPT core logs (8 in dia., 4 ft long) using the shredding machine obtained from the plywood mill.

Shredder specifications:

Power requirement : 415 V x 50 Hz, 13.6 kW
Size : 3980 mm (width) x 1030 mm (depth) x 2230 mm (height)
Capacity : >100 kg/h

General schematic

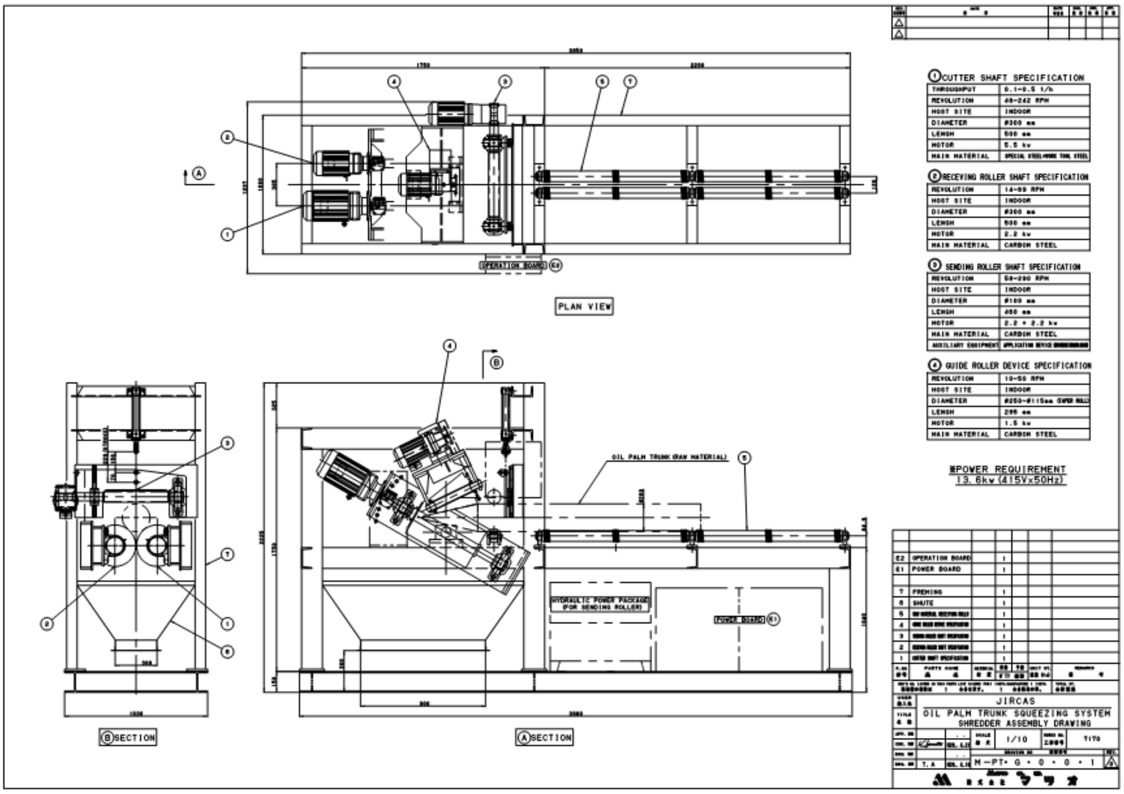


Figure 3B.2.1
General schematic for shredder (Japan)

Key for Figure 3B.2.1:

(1) Cutter
(2) Roller
(3) Roller
(4) Guide roller
(5) Feeding roller
(6) Chute
(7) Rack

(E1, 2): Controller

1. *Sap extraction - Japan*

(Japan/JIRCAS/ Sojitz, Pilot Demonstration)

Crop	Oil palm tree
Residue	OPT
Process	Sap extraction
Equipment	Squeezer
Main products	Sap
By-Products	OPT fibre

Basic description of the process

The shredded particles collected from the shredder are then fed into the squeezing machine extracting the sap out. The sap is then collected for further use.

Squeezer specifications

Type:	3-roll hydraulic press
Roll size:	240 mm i.d. x 340 mm width
Maximum speed:	6.6 rpm
Capacity	> 100 kg/h
Power requirement	415 V x 50 Hz, 15 kW
Size	2450 mm (width) x 2020 mm (depth) x 1800 mm (height)

General schematic

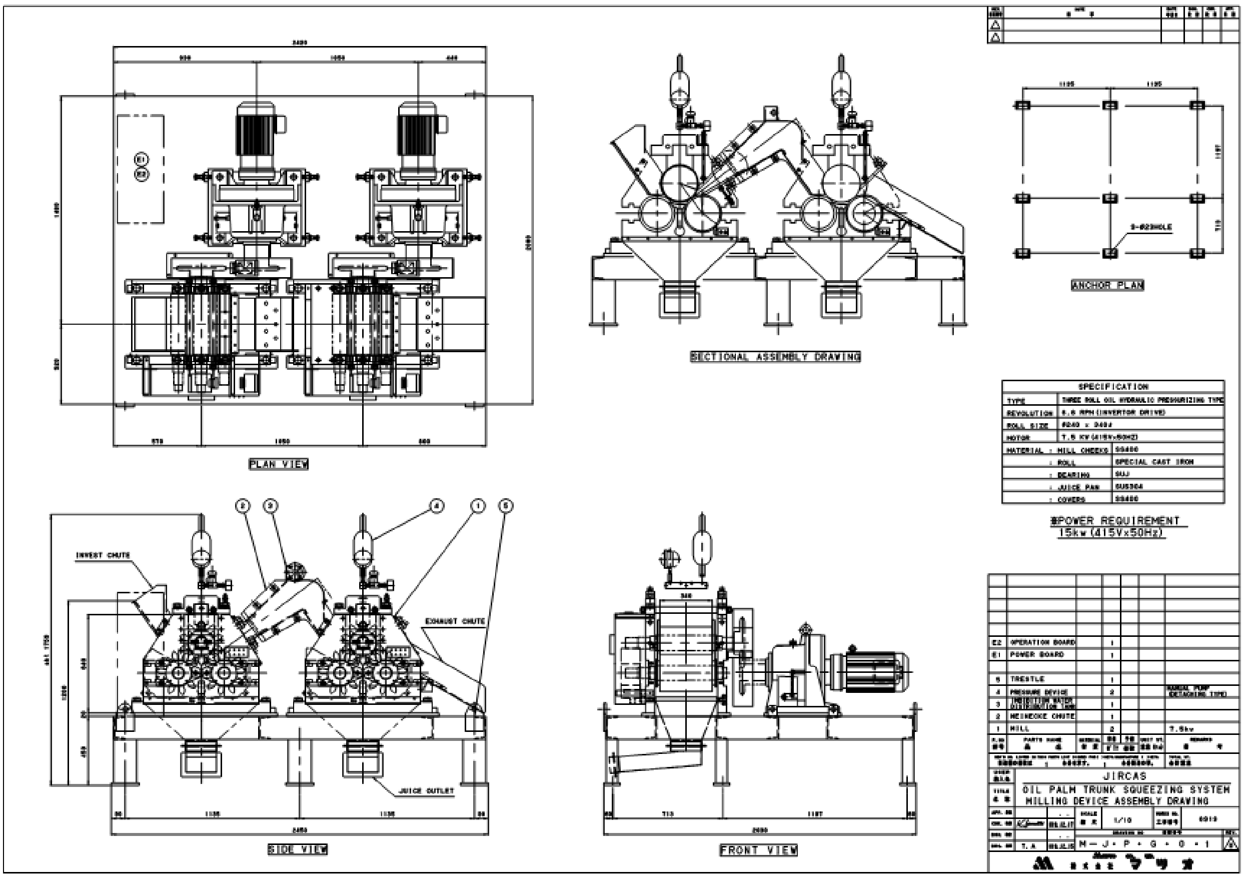


Figure 3B.2.2

General schematic for squeezer (Japan)

Key for Figure 3B.2.2:

(8) Squeezing mill: 2 sets
(9) Chute
(10) Shower tank
(11) Press
(12) Rack
(13) (E1, 2) Controller

Suppliers

Japan supplier:

Sojitz Machinery Corporation (SOMAC)

9F/10F, NBF Nihombashi Muromachi Center Bldg.,
2-15 Nihombashi Muromachi 3-chome, Chuo-ku, Tokyo 103-0022, Japan
TEL: +81(3)5204-5600

2. Sap extraction - Malaysia

(FRIM, Malaysia, Pilot Demonstration)

Crop	Oil palm tree
Residue	OPT
Process	Sap extraction
Equipment	Squeezer
Main products	Sap
By-Products	OPT fibre

Basic description of the process

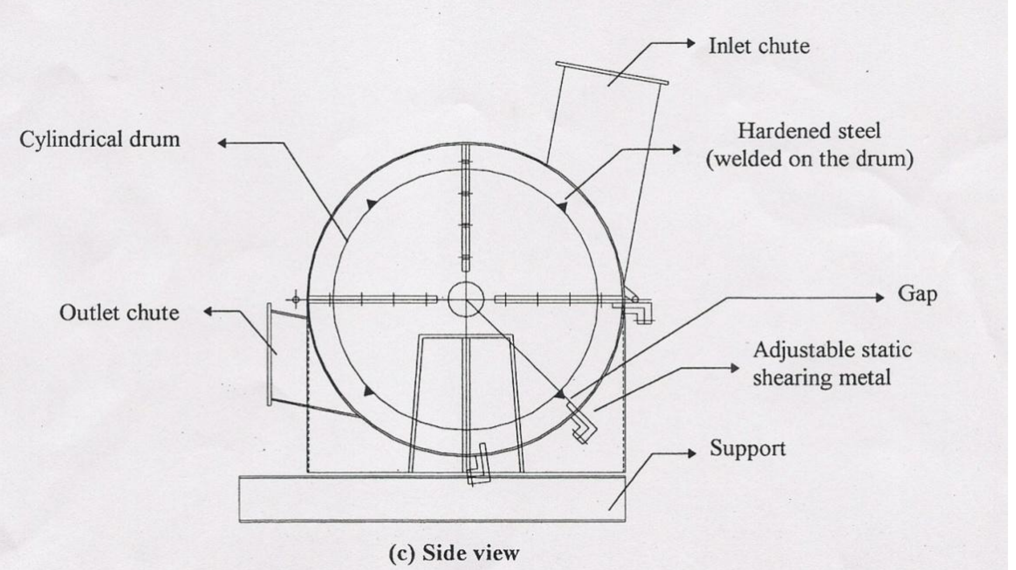
This process makes use of the shredded WPT available in the plantation after the normal felling procedure of WPT. The shredded slabs shredded by the excavator are fed into the shredder transforming the OPT into fibres.

Squeezer specifications

FRIM Shredder & Squeezer System

Technical features

- **Shredder**

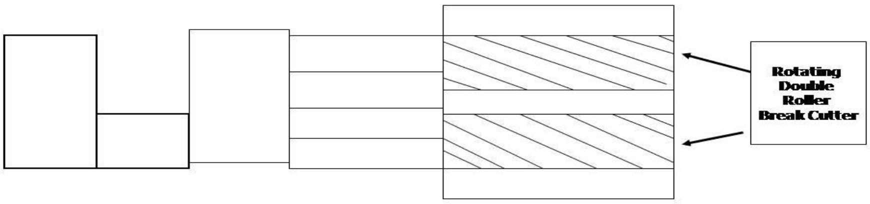


(c) Side view

Inlet chute is wide and able to receive slabs of oil palm trunks with dimensions 6 in (L) x 8 in (W) x 2 in thick.

The single cylindrical rotating drum equipped with adjustable static shearing metals is mounted on a hardened steel that is able to shred and tear the OPT slabs into a semi fibrous state as shown above with the EFB samples.

- **Sap extractor (top view)**



1. The part that functions as the break-shred-squeeze is the double roller cutter screw press extruder with an adjustable gap in between, that is able to pull in the shredded OPT fibres from the shredder to further break-cut and squeeze the sap.

2. The squeezed sap falls downward from the double roller into the receptacle to flow into the funnel siever, and then into the drum container for collection.

3. The solid residue is driven horizontally by the screw press extruder out of the system into a fibre receptacle for collection.

Shredded OPT fibres **inlet**

Sap **outlet**

Supplier

Szetech Engineering SDN BHD
Jln Sungai Rasa,
41300 Klang,
Selangor Tel: 03-5510 6817
Fax: 03-5510 7052

Summary of pros and cons

FRIM, Malaysia	**Japan**
Shredder	**Shredder**
1) Able to utilize OPT slabs directly from felling and shredding activities in the oil palm fields. OPT slabs fed directly in any direction into shredder 2) Entire OPT can be utilized 3) Debarking of logs is not required. 4) Converts OPT slabs into semi fibrous forms in a shredder machine via tearing and twisting mechanism (i.e. without using cutting mechanism) therefore more suitable for tough OPT fibre 5) Less maintenance required since blades/cutting devices are not used in the shredder	1) Uses OPT In log form and fed into shredder longitudinally 2) Able to use OPT logs of 6-8 inches in diameter only 3) Debarking and reduction in size of OPT logs is required using a peeling machine prior to shredding. Veneers can be used in the squeezer as well. 4) Shredding equipment uses cutting mechanisms such as a penil sharpening device. 5) Requires more frequent maintenance of cutting devices due to wear and tear on blades 6) Capacity: >100 kg/h
Sap extractor	**Squeezer**
1) Able to extract up to 60 L of sap from 100 kg of OPT (60% extraction efficiency) 2) Uses break, shred and squeeze mechanism for shortening the semi fibrous OPT and simultaneously squeezing the sap out in one step milling process 3) Requires only one single mechanism sap extraction 4) Faster time for sap extraction 5) Capacity: 6 tons/hr 6) Speed: 1500 RPM	1) Able to extract 200 L of sap from 1000 kg of OPT (20% extraction efficiency) 2) Uses 3-roll hydraulic press to squeeze out the OPT sap 3) Requires double mechanism for sap extraction similar to sugar cane juice extraction machine 4) Longer time required to squeeze out sap 5) Capacity: >100 kg/hr 6) Speed: 6.6 RPM
Sap filter system	**No filter system**
Detachable filtration system of plastic/wire mesh	
Sap collector system	
Detachable liquid detector container	

Appendix 3C: Potential reduction of CO_2 in converting WPT into plywood, lumber, bioethanol and animal feed

Year	Total area (ha)	*No of trees @ 50% hectares	Ea from WPT decomposition (mill tons CO_2/yr)	Ea Plywood (mill tons CO_2/yr)	CO_2 reduced by plywood production (%)	Ea for lumber (mill tons CO_2/yr)	CO_2 reduced by lumber production (%)	Ea for bioethanol production from OPT sap (mill tons CO_2/yr	CO_2 reduced by bioethanol production from sap (%)	Ea for animal feed production (mill tons CO_2/yr)	CO_2 reduced from animal feed pellet production (%)
2011	**116912**	**8183840**	12.90	1.05	8.14	2.65	20.54	0.25	1.94	2.76	21.40
2012	**73564**	**5149480**	8.13	0.66	8.12	1.67	20.54	0.16	1.97	1.74	21.40
2013	**133048**	**9313360**	14.70	1.19	8.10	3.02	20.54	0.29	1.97	3.14	21.36
2014	**140636**	**9844520**	15.60	1.26	8.08	3.19	20.45	0.3	1.92	3.32	21.28
2015	**82905**	**5803350**	9.17	0.74	8.07	1.88	20.50	0.18	1.96	1.96	21.37
2016	**64564**	**4519480**	7.14	0.58	8.12	1.46	20.45	0.14	1.96	1.52	21.29
2017	**103632**	**7254240**	11.50	0.93	8.09	2.35	20.43	0.22	1.91	2.45	21.30
2018	**108265**	**7578550**	12.00	0.97	8.08	2.46	20.50	0.23	1.92	2.55	21.25
2019	**106074**	**7425180**	11.70	0.95	8.12	2.41	20.60	0.23	1.97	2.50	21.37
2020	**128088**	**8966160**	14.20	1.15	8.10	2.91	20.49	0.28	1.97	3.02	21.27
2021	**152199**	**10653930**	16.80	1.36	8.10	3.45	20.54	0.33	1.96	3.59	21.37
2022	**200803**	**14056210**	22.20	1.8	8.11	4.55	20.50	0.43	1.94	4.74	21.35
2023	**185027**	**12951890**	20.50	1.66	8.10	4.2	20.49	0.4	1.95	4.37	21.32
2024	**235277**	**16469390**	26.00	2.11	8.12	5.34	20.54	0.5	1.92	5.55	21.35
2025	**63271**	**4428970**	7.00	0.57	8.14	1.43	20.43	0.14	2.00	1.49	21.29
2026	**122348**	**8564360**	13.50	1.1	8.15	2.77	20.52	0.26	1.93	2.89	21.41
2027	**171231**	**11986170**	18.90	1.53	8.10	3.88	20.53	0.37	1.96	4.04	21.38
2028	**131797**	**9225790**	14.60	1.18	8.08	2.99	20.48	0.28	1.92	3.11	21.30
2029	**73287**	**5130090**	8.10	0.66	8.15	1.66	20.49	0.16	1.98	1.73	21.36
2030	**176047**	**12323290**	19.50	1.58	8.10	3.99	20.46	0.38	1.95	4.15	21.28
2031	**113841**	**7968870**	12.60	1.02	8.10	2.58	20.48	0.24	1.90	2.69	21.35
2032	**139698**	**9778860**	15.40	1.25	8.12	3.17	20.58	0.3	1.95	3.33	21.62
Average			**14.19**	**1.15**	**8.11**	**2.91**	**20.50**	**0.28**	**1.95**	**3.03**	**21.35**

**Assuming only 50% of the total potential WPT generated every year can be utilized to produce each of the potential value-added products and renewable energy*

Appendix 3D: Calculations of amount of CO_2 released from one WPT

Decomposition E_a (WPT)

E_a (WPT) = E_a (trunk) + E_a (fronds)

a) E_a (trunk)

Total weight of trunk per WPT = $293.36 \frac{kg}{tree}$

Weight percent = 40.64%

Calculation of C_b (trunk)

$$40.64 = \frac{x}{293.36}$$

$$C_b = x = 119.2 \frac{kg\ C}{trunk}$$

$$E_a\ (trunk) = C_b \times 3.67$$

$$= 119.26 \frac{kg\ C}{trunk} \times 3.67$$

$$= 437.54 \frac{kg\ CO_2}{trunk}$$

b) E_a (fronds)

Total weight of fronds = $169.21 \frac{kg}{frond}$

Weight percent = 52.58%

Calculation of C_b (fronds)

$$52.58 = \frac{x}{169.21}$$

$$C_b = x = 88.74 \frac{kg\ C}{frond}$$

$$E_a = C_b \times 3.67$$

$$= 88.47 \frac{kg\ C}{frond} \times 3.67$$

$$= 324.67 \frac{kg\ CO_2}{frond}$$

Therefore E_a from one WPT decomposition is

$$E_a\ (WPT) = 437.54 \frac{kg\ CO_2}{trunk} + 324.67 \frac{kg\ CO_2}{frond} = 762.2 \frac{kg\ CO_2}{tree}$$

E_a for tree consumption of year 2011:

$$E_a = 762.2\ \frac{kg\ CO_2}{tree} \times 140\ \frac{tree}{ha} \times 116{,}912\ \frac{ha}{yr}$$

$$= 12.5 \times 10^9\ \frac{kg\ CO_2}{yr}\ @\ 12.5\ \text{million tons}\ \frac{kg\ CO_2}{yr}$$

Fuel from felling activity

Diesel usage = $100\ \frac{l}{day}$

No. of trees = $80\ \frac{tree}{day}$

E_a for diesel = $10.66\ \frac{kg\ CO_2}{gal}$

E_a fuel = $100\ \frac{l}{day} \div 4.4\ \frac{l}{gal} \div 80\ \frac{tree}{day} = 3.03\ \frac{kg\ CO_2}{tree}$

E_a for tree consumption of year 2011:

$$E_a = 3.03\ \frac{kg\ CO_2}{tree} \times 140\ \frac{tree}{ha} \times 116{,}912\ \frac{ha}{yr}$$

$$= 49.6 \times 10^6\ \frac{kg\ CO_2}{yr}$$

Total E_a of WPT decomposition:

$$E_a = E_a\ (Tree) + E_a\ (Fuel)$$

$$= 12.5 \times 10^9\ \frac{kg\ CO_2}{yr} + 49.6 \times 10^6\ \frac{kg\ CO_2}{yr}$$

$$= 1.25 \times 10^{10}\ \frac{kg\ CO_2}{yr}$$

Potential reduction of CO_2 by converting WPT into plywood and lumber

Volume of plywood produced from 1 trunk = $0.25\ m^3$

Emission of CO_2 from plywood based wood = $510.87\ \frac{kg\ CO_2}{m^3}$

Emission of CO_2 from plywood based WPT = $510.87\ \frac{kg\ CO_2}{m^3} \times 0.25\ m^3$

= $1.28 \times 10^{2}\ \frac{kg\ CO_2}{tree}$

Emission of CO_2 that can be trapped from 50% of number of available trees in 2011

$$= 0.5 \times 140\ \frac{tree}{ha} \times 116{,}912\ \frac{ha}{yr} \times 1.28 \times 10^2\ \frac{kg\ CO_2}{tree}$$

$$= 1.05 \times 10^9\ \frac{kg\ CO_2}{yr}$$

Potential reduction of CO_2 by converting WPT into bioethanol and animal feed pellets

Emission of CO_2 release per trunk = $437.54\ \frac{kg\ CO_2}{trunk}$

200 L sap can be extracted from trunk (20% of the trunk) -- 200 L of sap can produce 70 L of ethanol (35% of the sap)

Amount of CO_2 that can be trapped by ethanol from sap

$$= 0.2 \times 437.54\ \frac{kg\ CO_2}{trunk} \times 0.35$$

$$= 30.63\ \frac{kg\ CO_2}{tree}$$

Emission of CO_2 can be trapped from 50 % of available WPT in year 2011

$$= 30.63\ \frac{kg\ CO_2}{tree} \times 0.5 \times 140\ \frac{tree}{ha} \times 116{,}912\ \frac{ha}{yr}$$

$$= 2.51 \times 10^8\ \frac{kg\ CO_2}{yr}$$

Appendix 3E: Calculations of GHG emission reductions through biofuel production (bioethanol production from sap and feed pellets) via fossil fuel replacement

Table 3E.1

Calculation of equivalent carbon dioxide emissions for bioethanol production from sap

Assume:

- 1 kg petrol releases 2.331 kg CO_2
- 200 L sap from one WPT
- 35% of sap converted to ETOH
- Efficiency of ETOH to petrol = 70%

Year	*# WPT @ 50% felling*	*Amt. of sap (mill L/yr)*	*Amt. of ETOH produced (mill L/yr)*	*CO_2 Equiv. fossil fuel replacement (mill tons/yr)*
2011	8183840	1636.768	572.8688	0.935
2012	5149480	1029.896	360.4636	0.588
2013	9313360	1862.672	651.9352	1.064
2014	9844520	1968.904	689.1164	1.124
2015	5803350	1160.67	406.2345	0.663
2016	4519480	903.896	316.3636	0.516
2017	7254240	1450.848	507.7968	0.829
2018	7578550	1515.71	530.4985	0.866
2019	7425180	1485.036	519.7626	0.848
2020	8966160	1793.232	627.6312	1.024
2021	10653930	2130.786	745.7751	1.217
2022	14056210	2811.242	983.9347	1.605
2023	12951890	2590.378	906.6323	1.479
2024	16469390	3293.878	1152.8573	1.881
2025	4428970	885.794	310.0279	0.506
2026	8564360	1712.872	599.5052	0.978
2027	11986170	2397.234	839.0319	1.369
2028	9225790	1845.158	645.8053	1.054
2029	5130090	1026.018	359.1063	0.586
2030	12323290	2464.658	862.6303	1.408
2031	7968870	1593.774	557.8209	0.910
2032	9778860	1955.772	684.5202	1.117
Average	**8980726.364**	**1796.145**	**628.651**	**1.026**

Table 3E.2

Calculation of equivalent carbon dioxide emissions for OPT pellets

Assume:

- 1 kg coal releases 2.93 kg CO_2
- 30% dried wt. of OPT left after sap squeezing
- Efficiency of OPT pellets to coal = 19 MJ/38.5 MJ= 49.4%

Year	*# WPT @ 50% felling (mill trees)*	*Amt. pellets (mill tons/yr)*	*CO_2 emission equiv. to coal (million tons/yr)*
2011	8183840	3273.536	4.738
2012	5149480	2059.792	2.981
2013	9313360	3725.344	5.392
2014	9844520	3937.808	5.700
2015	5803350	2321.34	3.360
2016	4519480	1807.792	2.617
2017	7254240	2901.696	4.200
2018	7578550	3031.42	4.388
2019	7425180	2970.072	4.299
2020	8966160	3586.464	5.191
2021	10653930	4261.572	6.168
2022	14056210	5622.484	8.138
2023	12951890	5180.756	7.499
2024	16469390	6587.756	9.535
2025	4428970	1771.588	2.564
2026	8564360	3425.744	4.958
2027	11986170	4794.468	6.940
2028	9225790	3690.316	5.341
2029	5130090	2052.036	2.970
2030	12323290	4929.316	7.135
2031	7968870	3187.548	4.614
2032	9778860	3911.544	5.662
Average	**8980726.364**	**3592.291**	**5.200**

Table 3E.3

Total percentage of CO_2 reduction from biofuel production from OPT

Year	*Oil palm tree decomposition (mill tons CO_2/yr)*	*CO_2 reduction by ETOH (mill tons CO_2/yr)*	*CO_2 reduction by fuel pellets (mill tons CO_2/yr)*	*Total % reduction*
2011	12.9	0.935	4.738	43.98
2012	8.13	0.588	2.981	27.67
2013	14.7	1.064	5.392	50.05
2014	15.6	1.124	5.700	52.90
2015	9.17	0.663	3.360	31.18
2016	7.14	0.516	2.617	24.29
2017	11.5	0.829	4.200	38.98
2018	12	0.866	4.388	40.72
2019	11.7	0.848	4.299	39.90
2020	14.2	1.024	5.191	48.18
2021	16.8	1.217	6.168	57.25
2022	22.2	1.605	8.138	75.53
2023	20.5	1.479	7.499	69.60
2024	26	1.881	9.535	88.50
2025	7	0.506	2.564	23.80
2026	13.5	0.978	4.958	46.02
2027	18.9	1.369	6.940	64.41
2028	14.6	1.054	5.341	49.58
2029	8.1	0.586	2.970	27.57
2030	19.5	1.408	7.135	66.22
2031	12.6	0.910	4.614	42.82
2032	15.4	1.117	5.662	52.55
Average	**14.19**	**1.026**	**5.200**	**48.26**

4. Chapter 4: Report of UNEP workshop on converting waste oil palm trees into a resource
Legend Hotel, Kuala Lumpur, 12 July 2011

4.1 Introduction

The Forest Research Institute Malaysia (FRIM), in collaboration with Universiti Malaysia Pahang (UMP) and Universiti Sains Malaysia (USM), organized a workshop on 12 July 2011 to share the findings of the UNEP-supported project on *“Converting Waste Oil Palm Trees into a Resource”.*

The workshop, which was held at the Legend in Kuala Lumpur and themed *“Environmentally Sound Technologies (ESTs) for the Utilization of Waste Oil Palm Trees”,* was also conducted to obtain feedback from stakeholders on the results of the project activities jointly being conducted by researchers from FRIM, UMP and USM.

The overall objective of the project is to assist the Malaysia Government in the identification and implementation of environmentally sound technologies (ESTs) for converting waste agricultural biomass, specifically waste oil palm trees, into energy or material resources.

The project, kick-started in January 2011, is expected to conclude in August of the same year. The project seeks to:

- Build local capacity to identify and implement environmentally sound technologies (ESTs) for waste oil palm tree recycling
- Assess their potential for generating renewable energy, thereby reducing greenhouse gas (GHG) emissions
- Assess the feasibility of appropriate ESTs with respect to local socio-economic and environmental characteristics
- Demonstrate the benefits of selected ESTs through pilot projects.

The workshop, sponsored by the United Nations Environment Programme (UNEP) and officiated by FRIM Forest Products Division Director, Dr. Mohd Nor Yusoff, was attended by 30 invited participants. The participants included plantation companies, wood based industries, machinery manufacturers, research institutions, universities and relevant federal and state government agencies. The list of participants is given in Appendix 4A.

The welcoming and opening remarks were delivered by Dr. Mohd Nor Yusoff, Director of Forest Products Division of FRIM. He highlighted that research institutions such as FRIM and local universities were playing a crucial role in exploring the possible conversion of waste bio-based materials into products. However, it will require the active support and involvement of the industries to realise the full commercial impact of the studies. The speech was followed by a group photo session before beginning the main workshop activities.

The specific objective of this workshop was to raise awareness and to share the latest information among local stakeholders on the potential of utilising waste oil palm trees (WPT) for energy and non-energy products. The status of technologies available for resource exploitation was also presented.

The workshop also aimed to acquire feedback from the stakeholders to identify the gaps of the existing work and to confirm the report's findings. Issues, concerns and possible hurdles with respect to converting WPT into a resource were highlighted and discussed in order to seek a better strategy for utilization.

The relationship between the need to convert WPT into an economic resource and a sustainable and environmentally balanced approach was highlighted.

Based on the participants' feedback, the main concerns stakeholders reported were as follows:

- Impact on soil condition and rehabilitation upon removal of waste oil palm trees from the fields
- Logistics and material supply required for industries to adapt the ESTs for waste oil palm tree recycling on a commercial scale.

There were four presentations by key project members on the overall project background, objectives and approach as well as specific reports on the three main activities conducted, described in further detail below. The detailed program itinerary is provided in Appendix 4B while the program flyer is featured in Appendix 4C**.** The transcript of the panel discussion/Q&A session is provided in Appendix 4D.

4.2 Plenary sessions

4.2.1 Session I: Project briefing

Dr. Wan Asma Ibrahim, FRIM's Head of the bioenergy program, who is also project leader, kicked off the session by presenting the project background, objectives, and activities. She also presented the field trials conducted near a plantation in Kuantan to acquire first hand data on GHG emissions from felled oil palm trunks (OPTs). It was reported that work was still in progress and at the stage of data gathering.

- **Report 1**

  Report 1 on *Characterisation and Quantification of WPT and Future Projections for the Project Area* was presented by Prof. Dr. Othman Sulaiman of USM. He presented the data obtained from available sources such as the MPOB planted area in Malaysia. This data was analyzed and processed to identify the potential acreage available for felling across Peninsular Malaysia, Sabah and Sarawak, based on the oil palm tree estimated productive life of 25 years. An estimation of potential values of WPT available from chemical and energy perspectives based on published literature was also presented.

On questions raised with regard to the validity and current/age of the data presented, Dr. Othman highlighted that the data was acquired from published sources and also recent surveys conducted by team members from FRIM. Upon inspection, it was shown that findings concur with the data from MPOB and NKEA reports. With regard to the question raised on the nature of OPT, and whether it is considered as wood or non-wood, Dr. Othman explained that, through established convention, OPT is considered a non-wood material even though there is literature which states otherwise.

- **Report 2**

Mr. Puad Elham from FRIM presented Report 2 on *Assessment of Current WPT Management Systems, Practices and Utilization at National and Local Levels.* Current practices in the disposal of WPT in Malaysia were discussed.

In an effort to preserve the environment, Malaysia no longer practices slash and burn techniques when clearing lands for planting and replanting of oil palm trees. This has been mandated by law through the Environmental Quality Act (Clean Air Regulations) of 1978. At present, the felled OPTs are mostly shredded or cut for quick decomposition, serving as mulch, or for soil rehabilitation. From the planter's point of view, this process is necessary to provide the nutrients for the new plant to ensure strong and healthy growth. The question that remained to be elucidated was how much of the OPT was needed for this purpose?

In Report 1, it was established that there was a sizeable amount of potential nutrients per tree, while it is generally understood that young plant uptake rate is small. The rest of the nutrients would therefore be lost through leaching after heavy rainfall. Mr Elham's presentation also highlighted the various mechanized systems and processes available. However, these systems are mostly suitable for flat terrain operations whereas, in Malaysia, the trees are planted on hilly slopes and in other geographical configurations which make the systems impractical. Consequently, the planters were not interested in applying these types of systems.

- **Report 3**

Report 3 *on Identification, Assessment and Selection of Environmentally Sound Technologies (ESTs) for converting WPT into Energy and Non-Energy Products* was presented by Assoc. Prof. Zulkafli Hassan from UMP.

He presented the various stages of WPT utilization in Malaysia and the technologies that are currently being used and developed. In addition to assessment and identification of EST, potential for GHG emissions reduction by WPT utilization was presented through: literature on GHG emissions from various products manufactured, estimation of GHG emissions from decomposition of WPT, and estimation of GHG reductions from current utilization.

Given the current state of WPT utilization, the presenter proposed that planters become directly involved in utilization activities, in order to overcome or at least minimise logistical issues and transportation costs. Being in control of the WPT raw material source, and in most instances the mills, the planters would be in a good position to develop an integrated utilization plan to convert the WPT into downstream products.

A second alternative would be to work together with downstream companies, for example plywood companies utilising WPT, towards a win-win situation. The planters could help maintain supply to ensure production sustainability and encourage downstream companies to look at more value added, zero waste activities for WPT utilization. Based on the assessment of potential carbon capture, it was reported that converting WPT into alternative wood/lumber based products would provide the best return in terms of GHG reduction but probably not in terms of economic and demand perspectives.

4.2.2 Session II: Panel discussion

This session was moderated by Assoc. Prof. Zulkafli Hassan from UMP. The detailed script for this session is presented in Appendix 4D.

The chairman started off the discussion by highlighting the objectives and the expectations of the workshop in general. He also recommended that participants, in particular the industry and the planters, share their experiences on the management and utilization of waste oil palm trees, going beyond, if possible, what had been brought up by the presenters. Among the issues that he proposed were:

- Availability versus accessibility
- Logistical hurdles
- Preferred technology routes

The discussion session was very lively, reflecting the genuine interest of the community on the subject matter. Typically, from the industry perspective, interest was shown in obtaining very specific details on the proposals and technologies available, in order to enable speedy implementation or utilization without investing time and resources towards product development. The Government agencies on the other hand, tended to be more cautious with the data presented and the resources sought by the project team. The project team responded that all data acquired was from reliable sources and government annual publications. The Government agencies also commended the work done by the team, highlighting their need for this kind of feedback to assist them in formulating strategies and policies for the nation’s biomass use.

The planters meanwhile tended to be more conservative in their biomass utilization due to a concern for their main activity, oil production from a healthy plantation. Concern was expressed about soil nutrients when conventional mulching methods were disrupted, resulting in an increase in fertiliser requirements. Utilising biomass will only be adapted when management is confident that this additional activity will not affect their main source of income, which is crude palm oil production.

The debate on the relative merits of biomass utilization for value added products versus agronomical needs has already become an issue within plantation management. As a result, some of the plantations such as FELDA and Sime Darby have taken the initiative to utilise their oil palm biomass for various purposes such as EFB and POME for power generation.

The Chairman ended the session and thanked all participants for their presence, questions and inputs throughout the workshop. He added that their comments would be registered and added into the final report for completeness. The workshop ended at 1.00 pm and all participants were invited to have lunch before departing.

4.3 Conclusion

The workshop on "*Converting Waste Oil Palm Trees into a Resource"* was successfully conducted and well attended by the relevant stakeholders. The plenary and Q&A sessions were very lively with questions and feedback, reflecting the interest of the community with regard to the subject at hand. The main issues of contention by industry concerned supply security and regularity. The logistics and material supply required for industries to adapt ESTs for waste oil palm tree recycling on a commercial scale were also discussed. It appears that at the moment, the planters are more concerned with the impact of removal of waste oil palm trees from the fields upon soil condition and rehabilitation.

Appendices

Appendix 4A: List of participants

No.	Name of Participant	Agency/Company
1	Dr. Mohamed Nor Mohd Yusoff	Director, Forest Products Division (FRIM)
2	Dr. Hamdan Husain	Head, Wood Quality and Non-Wood Products Development (FRIM)
3	Dr. Gan Kee Seng	Head, Green Technology Programme (FRIM)
4	Dr. Rahim Sudin	Head, Biocomposites and Wood Protection Programme (FRIM)
5	Wan Hasamudin Wan Hassan	Ministry of Plantation Industries and Commodity (KPPK)
6	Wan Rafidah Awang Isa	Ministry of Plantation Industries and Commodity (KPPK)
7	Nasrin Abu Bakar	Malaysian Palm Oil Board (MPOB)
8	Seri Suriani	Sime Darby Research Sdn. Bhd.
9	Mohammed Faisal Mohammed Yunus	Sime Darby Research Sdn. Bhd.
10	Mok Chee Kheong	Malaysian Panel-Products Manufacturers Association (MPMA)
11	S.K. Pang	Malaysian Wood Industries Association (MWIA)
12	Juzaili Hasbul Wafi bin Mohamed	FELCRA Berhad
13	Lau Mei Oye	Malaysian Timber Industry Board (MTIB)
14	Dr. Ramli Mohd Noor	Malaysia Agriculture Research Development Inst. (MARDI)
15	Zaizul Azizi Zaman	FELDA Engineering Services Sdn Bhd
16	Shannon Kan Yean Khinn	Advanced Agroecological Research Sdn Bhd (AAR)
17	Chew Kian Sang	Szetech Engineering Sdn Bhd
18	Masrizal Ramly	LKKP Corporation Sdn Bhd
19	Penelope Abu Husin	Palm Oil industrial Corridoor (POIC) Sabah
20	Dr. Jamarei Othman	Universiti Putra Malaysia (UPM)

21	Dr. Khalik b. Mohd Sabil	Universiti Teknologi Petronas (UTP)
22	Yew Foong Kheong	Malaysian Palm Oil Council (MPOC)
23	Dr. Wan Asma Ibrahim	Head of Project (FRIM)
24	Assoc. Prof. Zulkafli Hassan	Project Member/Presenter (UMP)
25	Prof. Dr. Othman Sulaiman	Project Member/Presenter (USM)
26	Dr. Wan Rasidah A. Kadir	Project Member (FRIM)
27	Puad Elham	Project Member/Presenter (FRIM)
28	Shaharuddin Hashim	Workshop Committee (FRIM)
29	Habibah Mohamad	Workshop Committee (FRIM)
30	Rafidah Jalil	Project Member (FRIM)
31	Nurul Fahiza Ahmad Zalidi	Project Secretariat (FRIM)
32	Zainatul Bahiyah Handani	Project Member (UMP)
33	Khairatun Najwa Mohd Amin	Project Member (UMP)

Appendix 4B: Program itinerary

Time	Agenda
08.30 am	Registration
08.45 am	Arrival of Dr. Mohd Nor Mohd Yusoff Director of Forest Products Division
09.00 am	**Welcoming & Opening Remarks** **By Dr. Mohd Nor Mohd Yusoff** **Director of Forest Products Division**
09.25 am	Tea Break
09.45 am	**Briefing on Project Objectives** **Dr. Wan Asma Ibrahim (FRIM)**
10.00 am	**Session I** **Chairperson: Dr. Wan Asma Ibrahim (FRIM)**
	Report 1 *Characterization and Quantification of Waste Oil Palm Trees with Future Projections for Project Area* **Presenter: Prof. Dr. Othman Sulaiman (USM)**
10.30 am	**Report 2**
	Assessment of Current Waste Oil Palm Tree Management Systems, Practices and Utilization at National and Local Levels **Presenter: Mr. Puad Elham (FRIM)**
11.30 am	**Report 3** *Identification, Assessment and Selection of ESTs for Converting Waste Oil Palm Trees into Energy* **Presenter: Assoc. Prof. Zulkafli Hassan (UMP)**
12.00 pm	**Session II: Panel Discussion/Q&A** **Moderator: Assoc. Prof. Zulkafli Hassan (UMP)**
	Theme: *Environmentally Sound Technologies (ESTs) for Utilization of Waste Oil Palm Trees*
13.00 pm	Lunch/End of Programme

Appendix 4C: Workshop flyer

APPRECIATION

The Organisers wish to thank all companies and individuals for their support and cooperation in making this workshop a success

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(Ministry of Natural Resources and Environment)

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UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP) WORKSHOP ON CONVERTING WASTE PALM TREES INTO A RESOURCE

Environmental Sound Technologies (EST) for Utilisation of Waste Palm Tree

12 JULY 2011
THE LEGEND HOTEL, KUALA LUMPUR

Jointly Organised by:

Universiti Malaysia Pahang
USM

Supported by:

UNEP

Appendix 4D: Discussion/Q&A Session

Moderator/Chairman: Assoc. Prof. Zulkafli Hassan (UMP)

The Chairman started off the discussion by highlighting the objectives and the expectations of the workshop in general. He also recommended that participants, in particular the industry and the planters, share their experiences on the management and utilization of waste oil palm trees, going beyond, if possible, what had been brought up by the presenters.

The transcript of the session is as follows:

1. **Ms. S. K. Pang** from **Malaysian Wood Industries Association (MWIA)** stated that the report indicated that there is a large amount oil palm biomass available as raw material that could be utilized by the industry. However, most of the raw material cannot be readily assessed. Most of the major plantation companies are quite reluctant to bring biomass materials beyond their plantation borders. These companies prefer to shred the oil palm trunk and leave it as mulch in the field. She also highlighted the logistical issues of transporting oil palm biomass in general to the processing points. The cost of transportation of WPT, or any other oil palm biomass material, is high. She proposed that the project team consider finding a way to promote the utilization of WPT.

2. In response, **Assoc. Prof. Zulkafli Hassan (UMP)** indicated that the problem of raw material should be approached through consultation with plantation owners, and that the industries should take the initiative or explore further with plantation companies (such as FELDA and FELCRA) to come up with a win-win agreement. If this was not possible, he recommended that the plantation companies take the lead in converting oil palm biomass, specifically WPT, into a resource, thus adding value to the existing activities of WPT utilization. In many cases, they not only have the raw materials, but also the required infrastructure, such as the mills, enabling such processes to be integrated within other activities devoted to manufacturing products from biomass.

3. **Dr. Rahim Sudin (FRIM)** added that a researcher can only highlight the potential utilization of oil palm biomass. The industries need to seize the opportunity and deal with the problem accordingly. He illustrated his point by naming Szetech Engineering Sdn Bhd as one of the companies that manages to do this. He added that the industry should not merely wait for the information and technology to be implemented, but should take the initiative to provide feedback and guidance concerning potential problems which would need to be resolved. More importantly, they should directly support research work through financial, material and logistical support.

4. **Mrs. Penelope Abu Husin (POIC, Sabah)** reiterated the logistics issue and the high cost of transport for WPT, which could be even higher than the cost of the raw material itself. The price of oil palm trunk, similar to empty fruit bunches (EFB), fluctuates and is not governed by a controlled price mechanism. As such the price of WPT becomes uncertain. This uncertainty leads to problems in securing bank loans to develop WPT-based product manufacture. Typically the bank would require a five year guarantee of raw material supply to ensure project sustainability. Loans with banks present a problem because long-term contracts cannot be established.

5. **Mr. Zaizul Azizi (FELDA)** pointed out that there was a lack of understanding on the importance of mulching in oil palm replantation. Most of the oil palm trunk available in FELDA during replantation is shredded and left as mulch. Mulching provides fertiliser in the form of NPK, thus reducing the cost of organic/inorganic fertiliser as well as contributing to economic feasibility. FELDA uses 600,000 million tons/year of EFB for power plants. EFB is fully utilized by FELDA, and not for sale to third parties. FELDA receives many proposals to convert WPT to various products such as ethanol, sugar, animal feed, etc. Currently FELDA is working on mapping its potential biomass resources.

6. **Ms. Seri Suriani (Sime Darby)** stated that the major problem in WPT biomass utilization was its logistical aspect, and that WPT was found in scattered areas. In the case of Sime Darby, most of the WPT is used for mulching as ground cover and eventually becomes fertiliser. The panel responded that not all WPT should be used for mulch, and that a certain percentage of WPT could easily be used for other value added purposes. The panel suggested using mobile machinery rather than utilising WPT in a centralized area.

7. **Mr. Mok Chee Keong (MPMA)** asked for a clarification as to whether oil palm is considered wood or non-wood. The panel responded that based on the tree, oil palm would belong to the non-wood category. However, in terms of chemical constituents, both have the same type of cells (cellulose, hemicellulose and lignin).

8. **Mr. Wan Hassamuddin Wan Hassan (MPOB)** mentioned that WPT in oil palm trunks contained N, P, and K, and that the quantities could be estimated by analysing the breakdown of WPT. Mulching was adapted as a practice because of the policy of zero burning which had been put into place in Malaysia. He suggested that the team refer to Prof. Khalid's (MPOB) degradation study for different parts of oil palm. It was suggested that companies study their policies towards biomass management.

9. **Ms. S. K. Pang (MWIA)** remarked that the content of the workshop was too fundamental, and should have provided more concrete data and figures which could be beneficially used by the company. It would have been useful had the workshop provided more detailed reasons why companies should convert WPT into product. It was also suggested that the workshop offer some sort of a master plan, policy or guidance for the industry moving forward.

10. **Dr. Wan Asma Ibrahim (FRIM)** responded that UNEP's concern was environmental issues. Converting WPT into product prevents carbon from being released into the environment and reduces GHG emissions. The main focus of the workshop was to establish data and information impacting on environmental issues.

11. **Mdm. Wan Rafidah Awang Isa (KPPK)** recommended that the committee refer to MPOB or the Ministry to obtain valid and updated information on oil palm. She also recommended that the Committee give recommendations/suggestions to the Government on promoting full utilization of oil palm (including a decision on policy and foreign workers). The panel mentioned that data had been obtained from reliable sources such as MPOB and the Statistical Department, MPOB and FRIM's publications. Additional data was generated from these sources to create secondary or derived data.

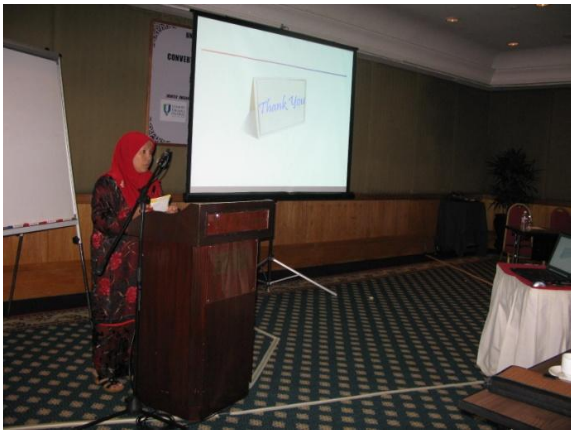
12. **Dr. Khalik Mohd Sabil** (UTP) mentioned that if there happened to be a data discrepancy between the Committee's work and other reports, it should be investigated. He suggested creating a website or database for oil palm information so that everyone could have a centralized point of access for the information. He also suggested that calculations of CO_2 being released should include energy/fuel that had been used throughout the process of WPT's product manufacture. He concluded by stating that the industry needed to explore how to overcome the logistics problem.

Appendix 4E: Photos on workshop activities

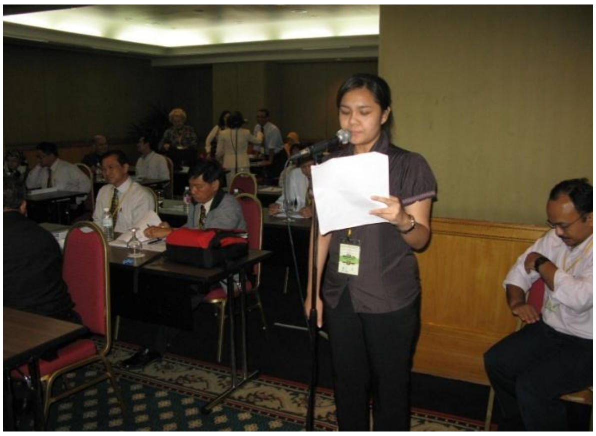
Welcoming and opening remarks by Dr. Mohd Nor Mohd Yusoff, Director of Forest Products Division of FRIM and token presentation by Project Leader, Dr. Wan Asma Ibrahim


Registration of participants


Project members interacting with participants



Plenary session presentations: Dr. Wan Asma Ibrahim (top left), Prof. Othman Sulaiman (top right), Mr. Puad Elham (bottom left), Assoc. Prof. Zulkafli Hassan (bottom right)

Panel discussion and Q/A session chaired by Assoc. Prof. Zulkafli Hassan

Q&A session

Group photo of workshop participants

Group photo of project members

Standing from left: Ms. Nurul Fahiza Ahmad Zalidi, Ms. Habibah Mohamad, Ms. Rafidah Jalil, Ms. Zainatul Bahiyah Handani, Ms. Khairatun Najwa Mohd Amin and Mr. Shaharuddin Hashim

Sitting from right: Mr. Paud Elham, Assoc. Prof. Zulkafli Hassan, Dr. Wan Asma Ibrahim, Prof. Dr. Othman Sulaiman and Dr. Wan Rasidah A. Kadir

Post workshop session with project members and workshop committee

5. Chapter 5: Report of techno-economic feasibility study of using waste oil palm trees for generating renewable energy

5.1 Introduction

The Government of Malaysia is making a concerted effort to review and develop related policy and programmes to support the expansion of alternative energy and feedstock sources for sustainable development of power generation in the country. Various energy-related policies have been developed with primary objectives involving supply, utilization and protection of the environment. Among the programmes and policies that are related to the development of renewable energy (RE) in the country is the “Fifth Fuel Policy” that was introduced in 2001. Its aim was to encourage the utilization of renewable resources i.e. biomass, solar, mini hydro, etc. as additional sources of electricity generation besides oil, gas, hydro and coal. This policy was implemented through the SREP (Small Renewable Energy Power) programme, and encouraged small RE power producers to generate electricity and sell the energy to national utility companies. A target of 5% or 500 MW of electricity generated from renewable energy projects was to be achieved, and then revised to 350 MW. Export capacity for power plants under this programme is limited to 10 MW.

Another programme is the Biomass Power Generation and Cogeneration Project (BioGen), a project jointly funded by the Government of Malaysia, the United Nations Development Programme (UNDP), and the Global Environment Facility (GEF). The objectives of the programme are to reduce the growth rate of greenhouse gas emissions (GHG) from fossil fuel combustion while at the same time promoting the use of unused waste residues from the palm oil industry. The Third Industrial Master Plan for years 2006 – 2020 has adopted a zero waste strategy on the utilization of biomass and biodiesel. This plan aims to promote palm oil for energy generation, in order to increase the palm biomass contribution to total energy production in Malaysia.

Finally, the National Biofuel Policy, introduced on 21 March 2006, promotes the use of environmentally friendly, sustainable and viable sources of energy to reduce the dependency on depleting supplies of fossil fuel. It also aims at enhancing the prosperity and well-being of all stakeholders in the agriculture and commodity-based industries through stable and remunerative prices. This policy will focus on six main areas, including the use of biofuel for industry and development of home grown biofuel technologies. The National Renewable Energy Policy was introduced in 2009 with the objectives listed below:

- To increase RE contribution to the national power generation mix
- To facilitate the growth of the RE industry
- To ensure reasonable RE generation costs
- To conserve the environment for future generations
- To raise awareness on the role and importance of RE

As a signatory to the UN Convention on Climate Change and the Kyoto Protocol, Malaysia has committed to take steps to reduce GHG emissions. The clean development mechanism (CDM) is a mechanism to promote GHG reduction activities. The programme offers incentives to CDM project developers involving the trading of emission reductions that result from a specific project (called CERs once such reductions are certified) to countries that can use these CERs to meet their targets. In return for the CERs, there is a transfer of money to the project that actually reduces greenhouse gases.

Although many RE policies have been introduced, the Government faces challenges in the implementation of these policies, including the following:

- **Security of fuel supply is questionable.**

- **In the past, mill locations were located too far from the plantation load center.**

- **The RE producer does not always benefit from traditional market mechanisms. For example, when there is only one buyer, such as a powerful utility, the potential RE project proponent is at a disadvantage in terms of bargaining power. Moreover, there are also various constraints which limit the performance of the RE market, such as economic, financial and technological factors.**

- **Market failure is compounded by the absence of a proper regulatory framework which prevents proper oversight and inhibits legal action.**

- **There is a lack of proper institutional measures to meet informational and technological needs.**

Nevertheless, the Government recently formed the Sustainable Energy Development Authority of Malaysia (SEDA Malaysia), a statutory body under the Sustainable Energy Development Authority Act of 2011 [Act 726]. The key role of SEDA is to administer and manage the implementation of the feed-in tariff mechanism which is mandated under the Renewable Energy Act of 2011 [Act 725]. This demonstrates the Government's commitment towards ensuring the success of these policies, and reflects the marketability of the local renewable energy industry.

As identified in Chapter three, the most environmentally sound technologies for converting waste oil palm trees (WPT) into an energy resource involve the conversion of WPT into either bioethanol from oil palm trunk sap, or fuel pellets manufactured from sap squeezed residues. According to projections, when 50% (about 8.7 million OPT) of available WPT was converted into bioethanol and fuel pellets, these activities resulted in carbon offsets of 39.87%.

The objective of this report is to determine the techno-economic feasibility of setting up a manufacturing plant producing both products. This report shows the financial feasibility and cash flow analysis of setting up a bioethanol and fuel pellet plant, with a capacity of producing 100 tons of bioethanol and 700 tons of fuel pellets per day.

5.2 Technical feasibility

5.2.1 Scope

1. The scope of the study is based on the production of bioethanol from oil palm trunk sap (OPT sap) and fuel pellet production from the sap squeezed residues (SSR) remaining.

2. The OPT sap and SSR will be delivered to the plant by contractors processing the felled palm trees on site.

3. The plant will aim to produce 100 tons of bioethanol per day. This will require OPT sap derived from 2500 WPT trunks (@200 L/trunk). The OPT felling area required per day would be 18 ha to feed the plant. A total of 700 tons of fuel pellets per day could then be derived from the SSR.

- **Proposed capacity**
  Both raw materials (the OPT sap and the SSR) will be delivered to the processing plant by contractors. The plant will buy the OPT sap and SSR at a price resulting in a manageable financial break-even point. Therefore, a range of prices will be identified for both raw materials in this report.

- **Location**
  The bioethanol and pellet production plant should ideally be located within proximity to an oil palm plantation area possessing the required amenities and infrastructure. Taking into consideration the requirement of 2500 oil palm trees per day, the plant should be situated in an area with accessibility to a 150,000 ha plantation expanse. This would be best in the South eastern region of Peninsular Malaysia, where the density of oil palm trees to be felled is purported to be the highest for the next 20 years (FRIM-JIRCAS project report, 2009). (See figure 5.2.1.1.)

Figure 5.2.1.1

Map of Peninsular & East Malaysia

For Sabah, it would be ideally located at Palm Oil Industrial Corridor (POIC) in Lahad Datu, where the infrastructure has been designed for palm based industries, including a port located nearby for export/shipping purposes.

Figure 5.2.1.2
Map of POIC, Lahad Datu Sabah

- **Production capacity**

There are basically two types of products to be manufactured, namely bioethanol and fuel pellets. For bioethanol production of 100 tons per day, 500 tons per day of OPT sap is required. For fuel pellet production of 700 tons per day, about 1800 tons of SSR is required.

The current selling prices of products manufactured are as follows:

Bioethanol	=	RM2772/ton (USD924/ton)
Fuel Pellets	=	RM320/ton (USD106.7/ton)

- **Raw materials**

Raw materials or feedstock required for the plant are OPT sap for bioethanol and SSR for fuel pellet manufacture. Availability and price of raw materials are the main aspects to be considered in order to sustain production. The ideal plant location would be the one nearest to raw material supply, in order to reduce transportation costs. Thus, a location within close proximity to a large plantation area is essential.

5.2.2 Process

- **Bioethanol production process**

OPT sap contains 10-15% sugar with the main component being glucose. The sugar can be fermented using yeast and transformed into bioethanol, which can then be used as fuel. After fermentation, the broth is distilled in distillers, followed by purification via dehydration. Purified bioethanol is first sampled for quality control purposes, and then packaged for storage before forwarding to the buyer. A flow chart illustrating the process is shown in figure 5.2.2.1.

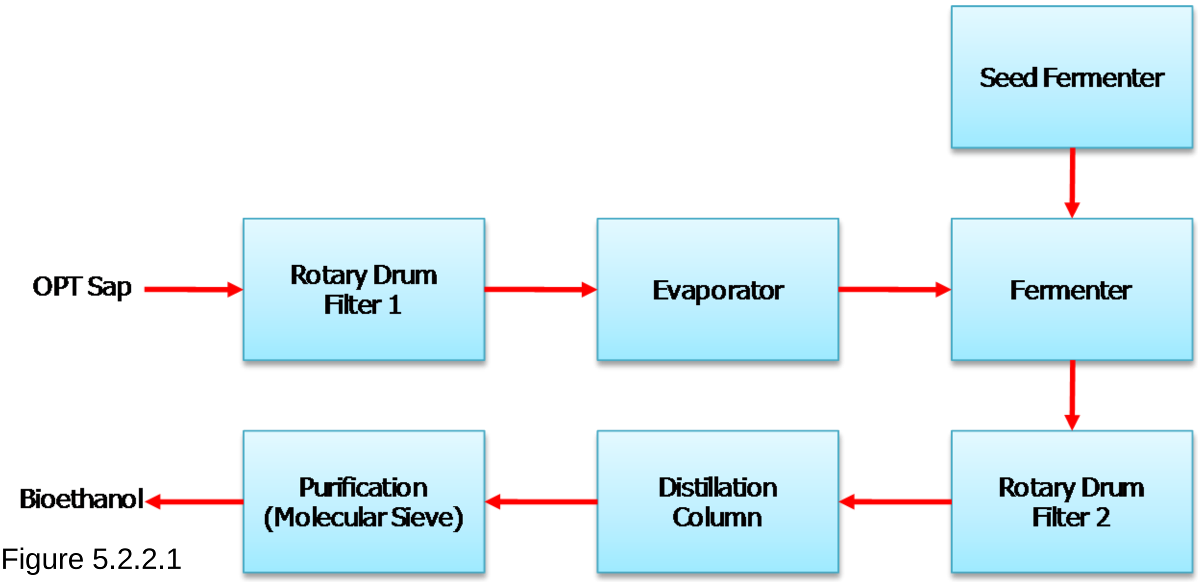


Figure 5.2.2.1
Bioethanol production process

Rotary drum filter 1 removes the suspended particles in the sap, followed by sterilization and concentration of the OPT sap in the evaporator. After sterilization, the OPT sap fermentation process is initiated in the fermenter, while the seed fermenter feeds in *Saccharomyces Cerevisiae* to the process. After fermentation, the product is filtered using rotary drum filter 2 to remove biomass yeast. The liquid next undergoes a dehydration process in the distillation column, followed by a purification process using the molecular sieve.

Each step of the process is described below:

Filtration

The OPT sap delivered to the plant is first filtered using rotary drum filter 1, as it contains impurities in the form of particles from the woody materials. The function of rotary drum filter 2 is to separate the yeast from the liquid product after the fermentation process. The product's liquid must be filtered before the dehydration process since the biomass yeast will affect the efficiency of the dehydration process.

Sterilization and concentration

The sterilization and concentration processes are carried out simultaneously in the evaporator. The OPT sap must be sterilized before the fermentation process, due to the existence of microorganisms naturally present in OPT sap. Sterilization ensures that only one specific strain of the microorganism is responsible for converting the sugar present in the sap into ethanol during the fermentation process. The goal is to maintain a steady production rate while preventing contamination. In addition to sterilization, a triple effect evaporator is used to concentrate the sap, in order to increase the efficiency of the fermentation process. The water vapour removed from the evaporator is recycled as steam, thereby reducing utility costs.

Fermentation

The biochemical process in the plant is the conversion of sugar to bioethanol using yeast. The major constituent of OPT sap is glucose. No additional nutrient is required in the fermentation process due to the rich nutrient content in the sap. Since the fermentation process is anaerobic, nitrogen purging is required to remove the oxygen contained in the medium.

Bioethanol recovery

After the fermentation and filtration process, the liquid substance undergoes dehydration in the distillation column. Bioethanol with a purity of 92.5% is produced in the first step using the distillation technique, and is further purified to 99.5% using a molecular sieve such as zeolite. Zeolite is known to be a good molecular sieve due to its high efficiency during the purification process.

- **Fuel pellet production process**

The pelletizing process is comprised of drying the SSR followed by screening to remove the impurities, followed by pelletizing and packaging, as shown in figure 5.2.2.2.

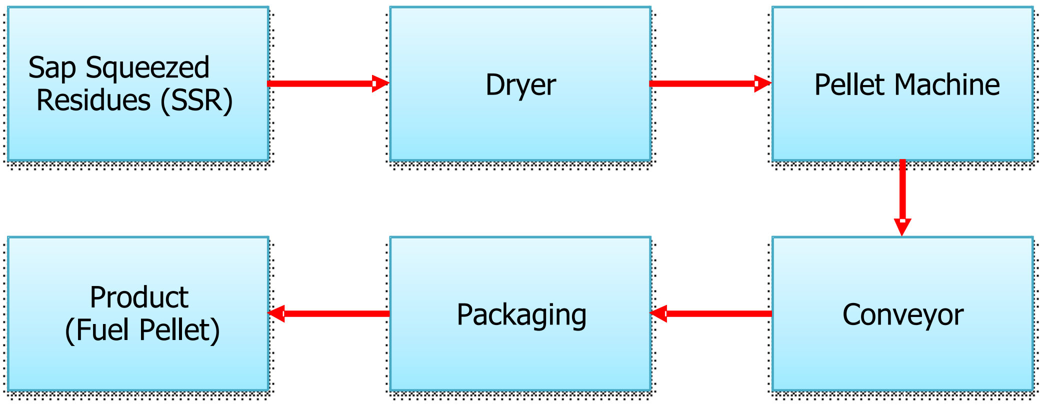


Figure 5.2.2.2
Fuel pellet production process

SSR received at the plant are fed into the dryer at 70^0 C, until moisture content of less than 12% is achieved. This is followed by a screening process to remove impurities, fixing the mesh size to 2 mm or below. The residue is then fed into the press where it is squeezed through a die having holes of the pellet size required. The pelletizing press is of a ring matrix type. The pellets are normally 6-10 mm in diameter with a length below 25 mm. Next, the extruded pellets are cut off at a specified length by means of a die. The machines can produce an output of up to 40 tons of fuel pellets per hour.

5.2.3 Land requirements

The land area required for the main plant and infrastructure is 25 hectares, including open space area. The plant layout consists of the process units involved, located at the main plant, and the auxiliary building. The auxiliary building and services required on the site in addition to the main process units include:

- Administration office
- Raw material and product storage
- Control room
- Mechanical and electrical workshop
- Research and development laboratory
- Central utilities
- Waste treatment plant.
- Canteen & parking space
- Land for future expansion

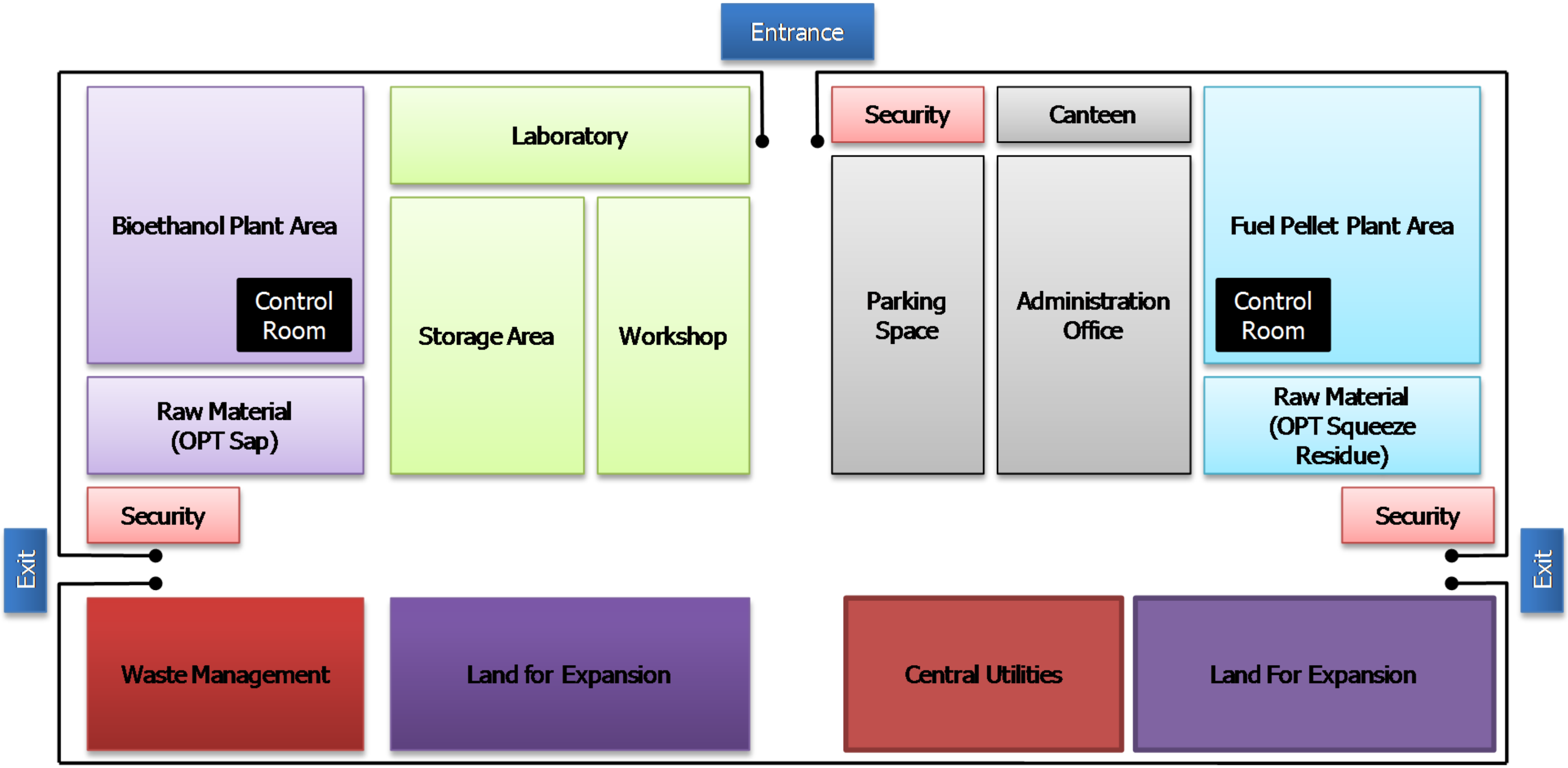


Figure 5.2.3
Plant layout

5.2.4 Equipment & machinery

Table 5.2.4.1

List of equipment & machinery for bioethanol production

No.	*Equipment/machinery*	*No. of units*	*Manufacturer*	*Capacity per unit*
1	Raw material storage tank	6	Local	250 m^3
2	Rotary drum filter 1	1	Local	30 m^3
3	Receiver tank	1	Local	30 m^3
4	Fermenter	6	Imported	800 m^3
5	Distillation unit	2	Imported	800 m^3
6	Molecular sieve	2	Imported	50 m^3
7	Evaporator	1	Local	800 m^3
8	Product storage tank	2	Local	500 tons

Table 5.2.4.2

List of equipment & machinery for pellet production

No.	*Equipment/machinery*	*No. of units*	*Manufacturer*	*Capacity per unit*
1	Pelletizing system	2	Imported	40 tons/hour
2	Dryer	4	Local	20 tons/hour
3	Silo	2	Local	20 tons

Table 5.2.4.3

List of analysis equipment

No.	*Equipment/machinery*	*No. of units*	*Function*
1	HPLC	1	Sugar analysis of OPT sap
2	GC	1	Bioethanol content
3	Bomb calorimeter	1	Calorific value of pellet
4	Furnace	1	Fixed carbon of pellet
5	Densimeter	1	Moisture content analysis

Table 5.2.4.4

List of possible suppliers

No.	*Name of supplier*	*Country*	*Types of equipment*
1	Sartorius AG	Germany	Bioreactor/fermenter
2	Anyang GEMCO Energy Machinery Co. Ltd.	China	Pelletizing system
3	Szetech Engineering	Malaysia	Dryer, screener, conveyor
4	Wenzhou Longqiang Light Industry Machinery	China	Distillation column
5	Nan gong Duan Xing Gas Machinery Co. Ltd.	China	Molecular sieves

5.2.5 Utilities

Power sub-station & electricity requirements

For both productions, the power sub-station set up should have a capacity of 2.5 MW per hour to supply electricity for the entire plant.

The power consumption is based on the total electricity used.

Water

Water is supplied by the utilities department, with the consumption amount based on the total water used. Basically, water is needed in the seed fermenter, cooling system and distillation unit.

Chemicals

The types of chemicals/materials required include: yeast for fermentation, sodium hydroxide for water treatment, ethanol for cleaning, and sugar standard for sugar content characterization.

Waste management

There are various waste products generated during the production of bioethanol and fuel pellets. For example, as described above, the filtration process which removes particles/fibre residues from OPT sap is carried out before feeding it into the evaporator and after fermentation is completed. The residues are generated as plant waste.

Another type of solid waste produced during the fermentation process is the residual yeast. Normally the yeast could be recycled, and sold to animal feed producers, thereby increasing the income of the plant. However, recycling could affect the yield of the process, due to the possibility of cells either dying before recycling, or becoming inhibited by the toxicity of the bioethanol from the final process. At present, given production rate imperatives, recycling of yeast cells in the pilot plant is not yet being considered, though future possibilities should be explored.

In addition to the examples above, each stage of the production process generates a specific type of waste, and requires a specific waste management solution. The most important issue in pollution prevention during process design is minimizing waste product generation. It is essential that systems be designed for maximum recovery, minimum energy usage, minimum effluent streams containing waste, and minimum leaks during storage and transfer operations.

5.2.6 Staff & labour requirements

Table 5.2.6.1
List of management team

No.	*Designation*	*Number of staff*
1	General manager	1
2	Manager	2
3	Assistant manager	2
4	Account clerk	1
5	Clerk	2
6	Office employee	1
	Total number of staff	9

Table 5.2.6.2
List of operation team

No.	*Designation*	*Number of staff*
1	Plant manager	2
2	Supervisor	4
3	Quality control	4
4	Operator	10

5.2.7 Environmental & safety aspects

- **Safety hazards**

Potential safety hazards in the plant include fires, explosions and accidental chemical releases. Occupational safety and health primarily covers the management of personal safety, and refers to the prevention of unintentional releases of chemicals, processes that can have serious effects on the plant and the environment.

In a bioethanol plant, potential safety hazards have been identified beginning from the storage of the raw material, all the way up until the storage of the product. OPT sap is used as a raw material while bioethanol is produced after the fermentation process. Table 5.2.7 below shows the chemicals/materials used in the production of bioethanol, the possible safety hazards and their potential effects on human safety.

Table 5.2.7

Chemicals used in the bioethanol production process

Item	Chemical/ material	Remarks
Feed	Oxygen	Health effects • Contact with combustible materials may cause fire. • Contact with rapidly expanding gases and liquid can cause frostbite. • Contact may result in eye irritation, skin irritation, and irritation to the respiratory system. • Contact with cryogenic liquid can cause frostbite and cryogenic burns. Fire and explosion • Nonflammable • Extremely flammable in presence of reducing materials, combustible materials and organic materials Stability and reactivity • Stable • Extremely reactive or incompatible with oxidizing materials, reducing materials and combustible materials
	Nitrogen	Health effects • Contact with rapidly expanding gas may cause burns or frostbites to eyes and skin through ingestion. • Substance acts as a simple asphyxia through inhalation. Fire and explosion • Nonflammable • Decomposition products may include nitrogen oxides. Stability and reactivity • Stable
	Sodium hydroxide	Health effect • Substance is hazardous in case of skin contact, eye contact, ingestion and inhalation. • The amount of tissue damage depends on length of contact. Fire and explosion • Nonflammable • Slightly explosive in presence of heat Corrosivity • Large spill: corrosive solid • Class 8 corrosive material Stability and reactivity • Stable, highly reactive with metals • Reactive with oxidizing agents, acids, alkalis and moisture Toxicity • Mutagenic for mammalian cells • May affect genetic material • Extremely hazardous in case of inhalation (lung corrosive)

Product	Bioethanol	Health effect • Causes severe eye irritation, moderate skin irritation • May cause gastrointestinal irritation through ingestion, and central nervous system effects through inhalation of high concentrations Fire and explosion • Containers can build up pressure if exposed to heat or fire, and could even explode if trapped in a fire.
		Stability and reactivity • Stable under normal temperatures and pressures • Avoid incompatible materials, ignition sources, excessive heat and oxidizers. • Incompatible with strong oxidizing agents, alkalis, metals and ammonia Toxicity • Not classified as human carcinogen
By-Product	Carbon dioxide	Health effect • No adverse effect anticipated with eye, skin or ingestion • Inhaling large concentrations causes rapid circulatory insufficiency leading to coma and death. Fire and explosion • Nonflammable Corrosivity • Moist carbon dioxide is corrosive by its formation of carbonic acid. Stability and reactivity • Stable • Upon contact with incompatible materials such as certain reactive metals, hybrids and moist cesium monoxide, it may ignite. • It decomposes to carbon monoxide and oxygen when heated at high temperatures. Carbonic acid formed in presence of moisture. Toxicity • It may cause oxygen deficiency during pregnancy which causes developmental abnormalities.
Purification	Zeolite	Health effect • Slightly hazardous in case of skin contact (irritant), eye contact (irritant), ingestion and inhalation Fire and explosion • Nonflammable Corrosivity • Non-corrosive in presence of glass Stability and reactivity • Stable • Unstable in contact with compatible materials Toxicity • Carcinogenic effects • Slightly hazardous in case of skin contact (irritant), ingestion and inhalation

- **Safety protective equipment & environment**

  Following is a list of required safety protective equipment:

  - Fire extinguisher
  - Fire blanket
  - Personnel protective equipment
  - Safety valve for sap storage tanks
  - Air ventilation for air quality monitoring and dust (vacuum air suction)
  - Fire hydrants

5.3 Economic viability

5.3.1 Introduction

This section provides a detailed economic viability study for the production of bioethanol from OPT sap and fuel pellet production from SSR. The economic viability study includes fixed investment, operating costs, profit and loss statement, projections, net present value (NPV), internal rate of return (IRR), benefit cost ratio (BCR), payback period, break-even point, gross profit margin and sensitivity analysis. The analysis was carried out in Malaysian Ringgit (RM). 1 RM is equivalent to 0.33 USD.

There are two major costs involved in calculating economic viability: fixed investment and operating costs. Figure 5.3.1 shows that operating costs are the major contributor to the total cost with RM1,473 million (69%), while fixed investment costs total only RM79 million (4%). An average profit margin of 27% within 15 years will be achieved for production of bioethanol and fuel pellets together.

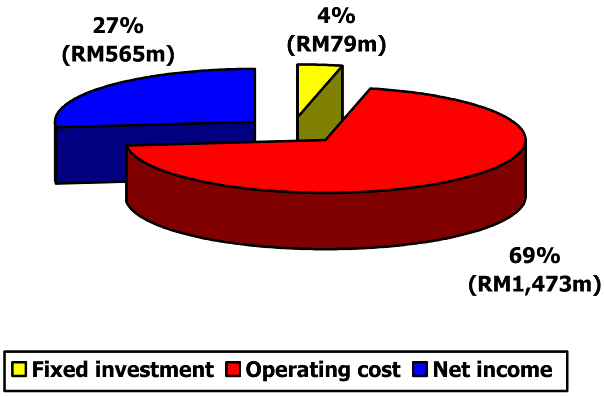


Figure 5.3.1
Distribution of major costs

5.3.2 Fixed investment

The fixed investment remains constant regardless of total production, with the assumption that expenditures are to be made in the first year. This fixed investment includes land, buildings, machinery and equipment, as well as other fixed investment costs (figure 5.3.2).

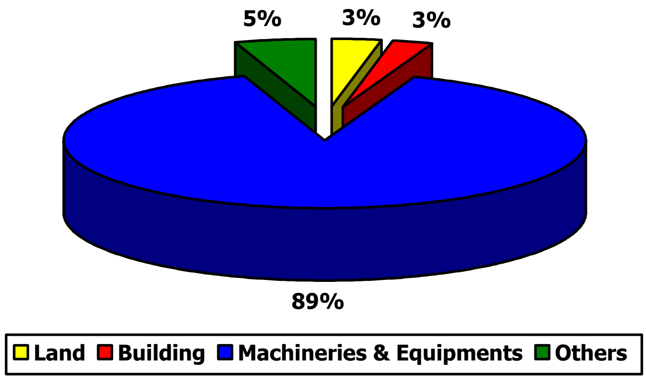


Figure 5.3.2
Distribution of fixed investment

The largest fixed investment is machinery and equipment, which are 89% (RM70.9 million) of the total fixed investment, followed by 5% (RM3.9 million) for other fixed investment costs. Total costs for land and buildings are RM2.5 million (5%) and RM2 million (5%), respectively. Details of the fixed investment costs are shown in table 5.3.2.

Table 5.3.2
Fixed investment costs

No	*Items*	*Unit*	*Price (RM)/unit*	*Cost (RM)*	*%*
1	Land	25 hectares	100,000	2,500,000	3.2
2	Building - plant, store, office, etc.	1	2,000,000	2,000,000	2.5
3	Machinery & equipment			70,900,000	89.4
	Bioethanol				
3.1	Raw material storage tank	6	600,000	3,600,000	4.5
3.2	Rotary drum filter 1	1	100,000	100,000	0.1
3.3	Receiver tank	1	600,000	600,000	0.8
3.4	Fermenter	6	7,000,000	42,000,000	53.0
3.5	Distillation	2	2,000,000	4,000,000	5.0
3.6	Molecular sieve	2	2,000,000	4,000,000	5.0
3.7	Evaporator	1	400,000	400,000	0.5
3.8	Product storage tank	2	800,000	1,600,000	2.0
3.9	Water treatment plant	1	2,000,000	2,000,000	2.5
	Sub-total			**58,300,000**	**73.5**

	Fuel pellets				
3.10	Pellet machine set	2	4,000,000	8,000,000	10.1
3.11	Dryer	4	1,000,000	4,000,000	5.0
3.12	Silo	2	100,000	200,000	0.3
3.13	Packaging	4	100,000	400,000	0.5
	Sub-total			**12,600,000**	**15.9**
4	Other fixed costs				
4.1	Motor vehicles	2	500,000	1,000,000	1.3
4.2	Workstation and equipment	1	200,000	200,000	0.3
4.3	Power sub station	1	1,200,000	1,200,000	1.5
4.4	Analysis equipment	1	1,500,000	1,500,000	1.9
	Sub-total			**3,900,000**	**4.9**
	Total fixed investment			**79,300,000**	**100.0**

5.3.3 Operating costs

Operating costs consist of raw materials, utilities, spares and consumables, labour and other costs. Raw materials are the largest cost element with 90% (RM1310 million) of the operating costs (figure 5.3.3). Of that figure, raw material cost for bioethanol and fuel pellets are 43% (RM634 million) and 46% (RM676 million), respectively.

The bioethanol plant would require the delivery of OPT sap amounting to 500 tons per day at a price of USD100 per ton. In addition, the amount of SSR for fuel pellet manufacture would amount to 1800 tons per day at a price of USD33.3 per ton. Raw material cost per ton of bioethanol is RM1501 and RM229 per ton for fuel pellets. The detail of the operating costs is shown in table 5.3.3.

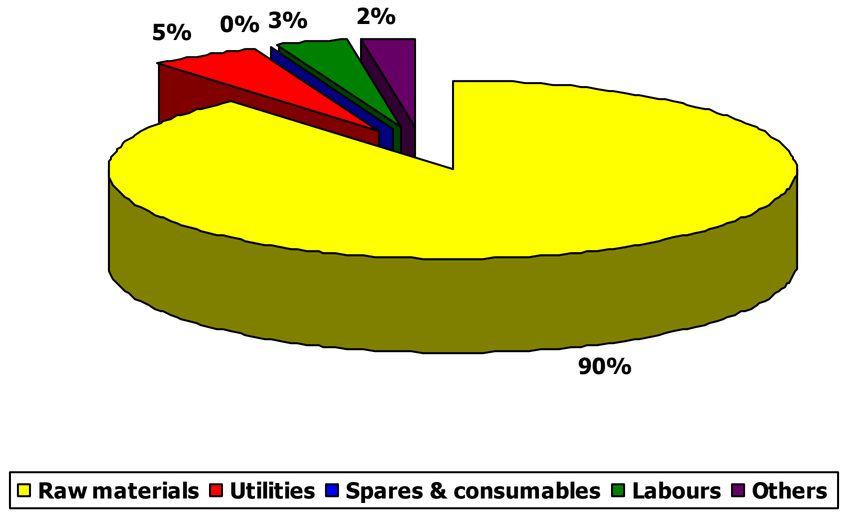


Figure 5.3.3
Distribution of operating costs

Table 5.3.3

Operating costs

No	*Items*	*Number of Units*	*RM/ Month/ Unit*	*Cost (RM)*	*%*
1	**Raw materials**				
1.1	Sap	13,750 tons	300	633,600,000	43.0
1.2	Chemicals for bioethanol		2,000	307,200	0.0
1.3	Sap residues	44,000 tons	100	675,840,000	45.9
	Total raw material costs			**1,309,747,200**	**88.9**
2	**Utility costs**				
2.1	Electricity			75,000,000	5.1
2.2	Water		4,000	624,000	0.0
	Total utility costs			**75,624,000**	**5.1**
3	**Spares and consumables**				
3.1	Administration costs (management, book keeping, office expenditure)		1,000	180,000	0.0
4	**Labour costs**				
4.1	*Management team*				
4.1.1	General manager	1 person	25,000	4,500,000	0.3
4.1.2	Manager	4 persons	10,000	7,200,000	0.5
4.1.3	Assistant manager	8 persons	7,000	10,080,000	0.7
4.1.4	Executive	8 persons	5,000	7,200,000	0.5
4.1.5	Clerk	2 persons	1,800	648,000	0.0
4.1.6	Office boy	1 person	1,500	270,000	0.0
	Sub-total	24 persons		29,898,000	2.0
4.2	*Operation team*				
4.2.1	Plant manager	2 persons	15,000	5,400,000	0.4
4.2.2	Supervisor	4 persons	3,500	2,520,000	0.2
4.2.3	Quality control	4 persons	3,800	2,736,000	0.2
4.2.4	Engineer	2 persons	8,000	2,880,000	0.2
4.2.5	Executive	6 persons	5,000	5,400,000	0.4
4.2.6	Operator	10 persons	1,500	2,700,000	0.2
	Sub-total	28 persons		21,636,000	1.5
	Total labour costs			**51,534,000**	**3.5**
5	**Other costs**				
5.1	Transportation cost	40 trips	200	33,792,000	2.3
5.2	Maintenance cost		10,000	1,536,000	0.1
5.3	Other miscellaneous costs		500	90,000	0.0
	Total other costs			**35,418,000**	**2.4**
	Total operating costs			**1,472,503,200**	**100.0**

5.3.4 Profit and loss statement

For the economic viability analysis, it is assumed that production of bioethanol and fuel pellets will not be running to full capacity for the first four years. Assumptions are as follows: no production in year 1, running at 40% capacity in year 2, 60% capacity in year 3, and 80% capacity in year 4. In the following years, production of bioethanol and fuel pellets will be at full capacity. The total production of bioethanol from OPT sap within 15 years will amount to 422,400 tons with total sales of RM1171 million. Total production of fuel pellets from SSR within the same period will be 2,956,800 tons, generating RM946 million of the total sales. The total revenue for both productions is projected at RM2117 million (table 5.3.4). Total fixed investment and operating costs are RM79 million and RM1473 million, respectively. The cumulative total cost for 15 years is RM1552 million. As a result, the production of bioethanol and fuel pellets will generate a profit with net income of RM565 million. Appendix 6.3.3 shows details of the profit and loss statement.

Table 5.3.4

Summary of profit and loss statement

Sales of bioethanol	1,170,892,800
Sales of pellets	946,176,000
Total income	2,117,068,800
Total fixed investment	79,300,000
Total operating costs	1,472,503,200
Total cost	**1,551,803,200**

5.3.5 Profitability and projection

The profit and loss statement shows that the production of bioethanol and fuel pellets will generate a total of RM565 million within 15 years. However, the production for both products projects a loss of RM88 million for the first year. Beginning from the second year onwards, the production will generate a positive gross profit even though the cumulative gross profit will be only be positive beginning from year 5, with RM47 million. Production in year 10 is projected to create a total of RM52 million in gross profit and a cumulative gross profit of RM306 million (table 5.3.5).

Table 5.3.5

Profitability and projection

Items	*Total (RM)*	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 10*	*Year 15*
Sales of bioethanol	1,170,892,800	0	36,590,400	54,885,600	73,180,800	91,476,000	91,476,000	91,476,000
Sales of pellets	946,176,000	0	29,568,000	44,352,000	59,136,000	73,920,000	73,920,000	73,920,000
Total income	2,117,068,800	0	66,158,400	99,237,600	132,316,800	165,396,000	165,396,000	165,396,000
Total cost	1,551,803,200	87,763,200	50,506,400	71,532,800	92,559,200	113,585,600	113,585,600	113,585,600
Gross profit	565,265,600	-87,763,200	15,652,000	27,704,800	39,757,600	51,810,400	51,810,400	51,810,400
Cumulative gross profit		-87,763,200	-72,111,200	-44,406,400	-4,648,800	47,161,600	306,213,600	565,265,600

5.3.6 Investment decisions

There are four major aspects to be considered when making investment decisions: net present value (NPV), internal rate of return (IRR), benefit cost ratio (BCR) and payback period.

NPV is the difference between the total income accruing, compared to the cost accumulated at present. It measures the excess or short fall of cash flow in present value terms. The NPV for production of bioethanol and fuel pellets is RM210,962,837. This means that the production of bioethanol and fuel pellets would add a value of RM210,962,837 to the firm, and that therefore, the investment would be viable. The formula can be written as follows:

$$NPV = \Sigma (B_t – C_t)/(1 + i)^t$$

Whereas:

B = Benefits/revenue	C = Costs
i = interest	t = Time frame

IRR is the rate of return on an investment. The IRR of a project is the discount rate that will give it a net present value of zero. It is used to evaluate the desirability of investments or projects, and is an indicator of the efficiency, quality, or yield of an investment. This is in contrast to the NPV, which is an indicator of the value of an investment. The IRR for production of bioethanol and fuel pellets is 39%, which is greater than the established minimum acceptable rate of return or cost of capital (12% hurdle rate). Therefore, an investment in producing these products simultaneously is considered acceptable. The formula to calculate IRR is as follows:

$$IRR= \Sigma\{(B_t – C_t)/(1 + i)^t\} 0$$

BCR reflects the ratio of how much profit (if any) will result from an investment. It is calculated by taking the net present value of expected future cash flows from the investment and dividing by the investment's original value. The BCR for production of bioethanol and fuel pellets is 1.28, indicating that the investment will be profitable because the BCR value is more than 1. BCR is also referred to as a profitability index. The formula to calculate BCR can be written as follows:

$$BCR =\Sigma \{B_t / (1 + i)^t\}/\Sigma\{C_t /(1 + i)^t\}$$

The payback period is the time taken to recover the initial investment. Based on the cumulative gross profit, a RM88 million initial investment that will make an average gross profit of RM38 million a year has a payback period of 4 years. Investments with a shorter payback period are preferred to those with a long period. Most companies using payback period as criteria will have a maximum acceptable payback period for investment decisions.

Based on these four criteria, financing the development of a bioethanol and fuel pellet production plant is considered to be a viable investment decision.

5.3.7 Break-even point

A break-even point is typically calculated so that businesses can determine if it would be profitable to sell a proposed product. Break-even analysis can also be used to analyze the potential profitability of expenditure in a sales-based business (Horngren, C. *et al.*, 1996). By conducting the analysis, we know the numbers of production for bioethanol and fuel pellets required to make a profit. The break-even point for a product is the point where total revenue received equals the total costs associated with the sale of the product ($T_R = T_C$).

The break-even point for the bioethanol and fuel pellet plant is calculated as follows:

Bioethanol

Break-even point	=	fixed cost / contribution per unit
Contribution (p.u)	=	selling price (p.u.) - variable cost (p.u)
Break-even point	=	118,156,000 / (2,772 – 1,541)

= **95,984 tons**

Fuel pellets

Break-even point	=	fixed cost / contribution per unit
Contribution (p.u)	=	selling price (p.u.) - variable cost (p.u)
Break-even point	=	80,514,000 / (320 – 234)

= **936,210 tons**

To achieve break-even point, the plant needs to produce a minimum of 95,984 tons of bioethanol and 936,210 tons of fuel pellets. Figures 5.3.7.1 and 5.3.7.2 illustrate the break-even analysis for both products, respectively. Refer to Appendices 5.1 and 5.2 for a detailed analysis showing the breakdown of profit by ton of production.

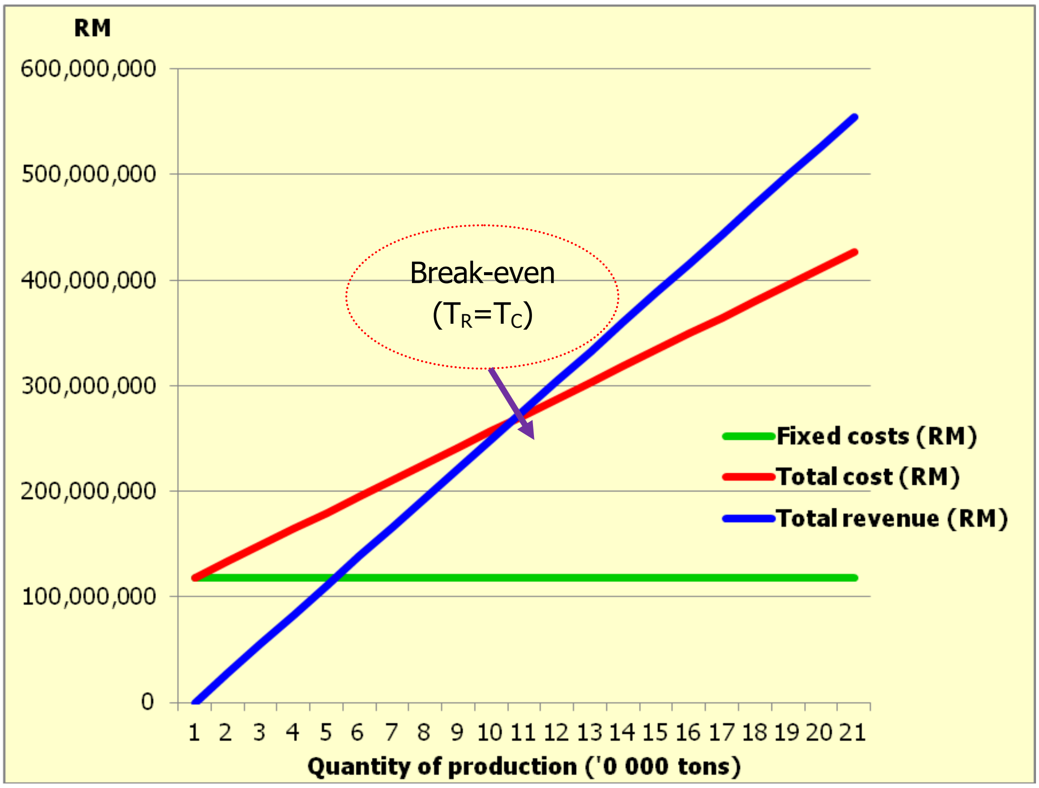


Figure 5.3.7.1

Break-even analysis for bioethanol

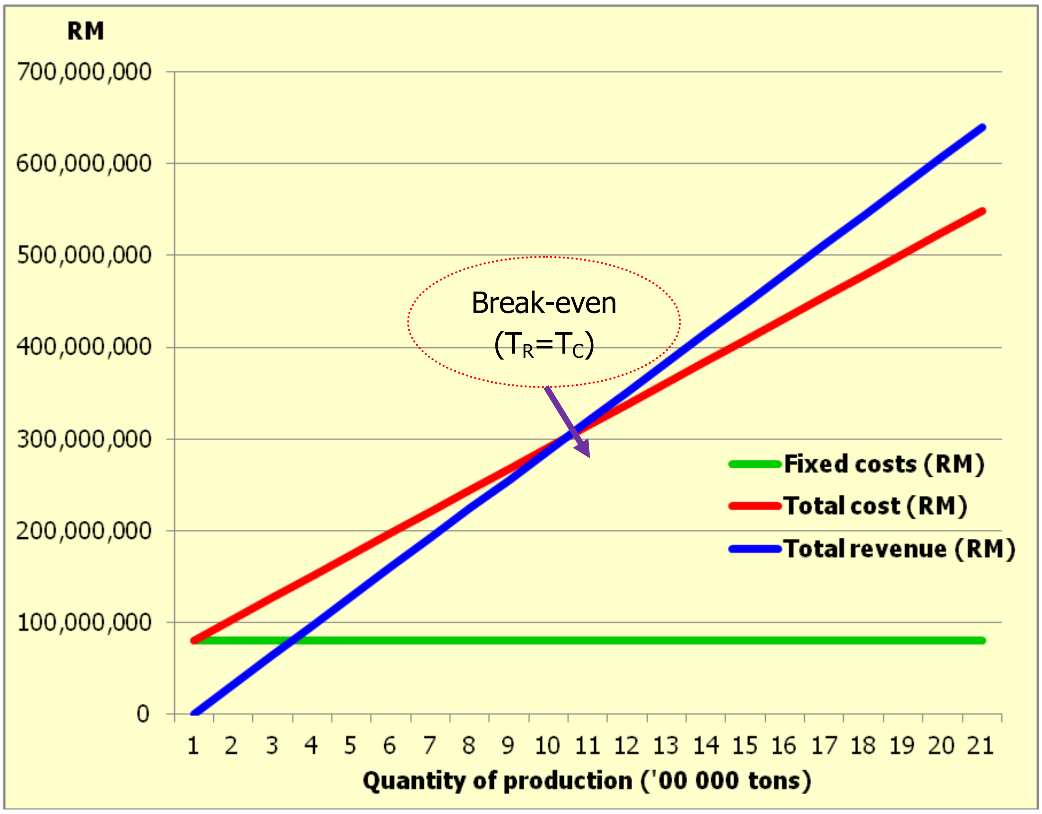


Figure 5.3.7.2

Break-even analysis for fuel pellets

5.3.8 Gross profit margin

Gross profit margin helps a company to manage the business effectively. Calculating and monitoring the gross profit margin percentage contributes to planning and controlling expenses, and provides indicators in terms of selling price. The purpose of gross profit margin is to determine the value of incremental sales, and to guide pricing and promotion decisions". In this study, the gross profit margin indicates the profitability ratio from the production of bioethanol and fuel pellets. The higher the gross profit margin, the better the company is considered to be controlling costs. The greater the profit ratio, the more efficiently the company is considered to be managing resources and turning raw materials into income.

The gross profit margin of the plant for the first year of development is zero, as there is no production during this period (Figure 5.3.8). The percentage of gross profit margin increases beginning in year 2 with 23.7%, followed by year 3 with 27.9%, and 30.0% in year 4. Beginning with year 5 onwards, the gross profit margin is sustained at 31.3%. This shows that performance is projected to gradually improve, with a positive average gross profit margin of 26.7% annually. The formula to calculate gross profit margin is as follows:

Gross profit margin = (Gross profit/income) * 100

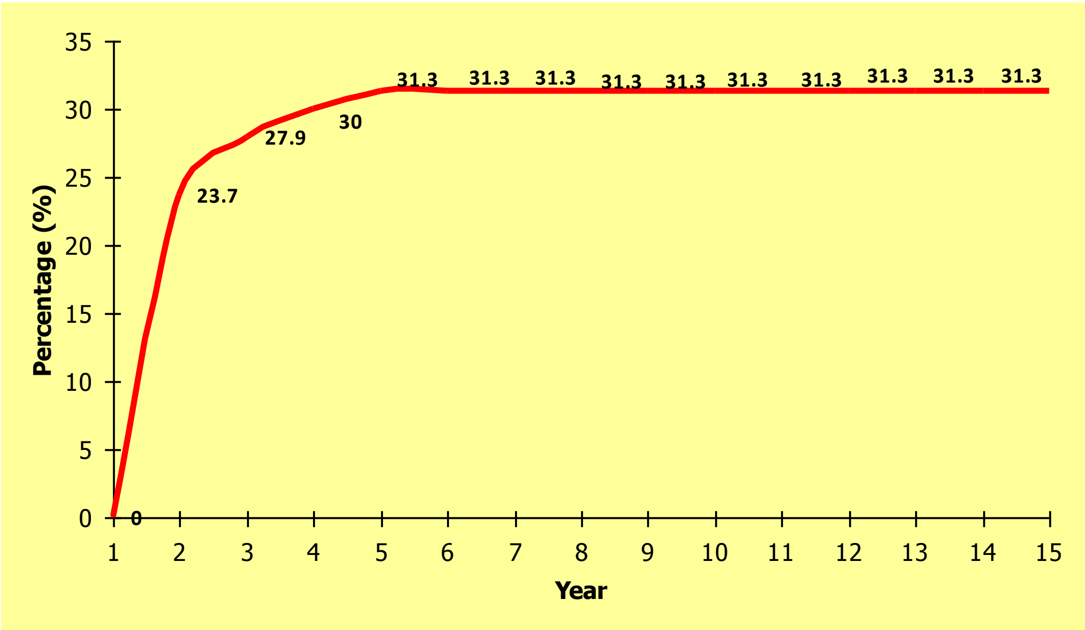


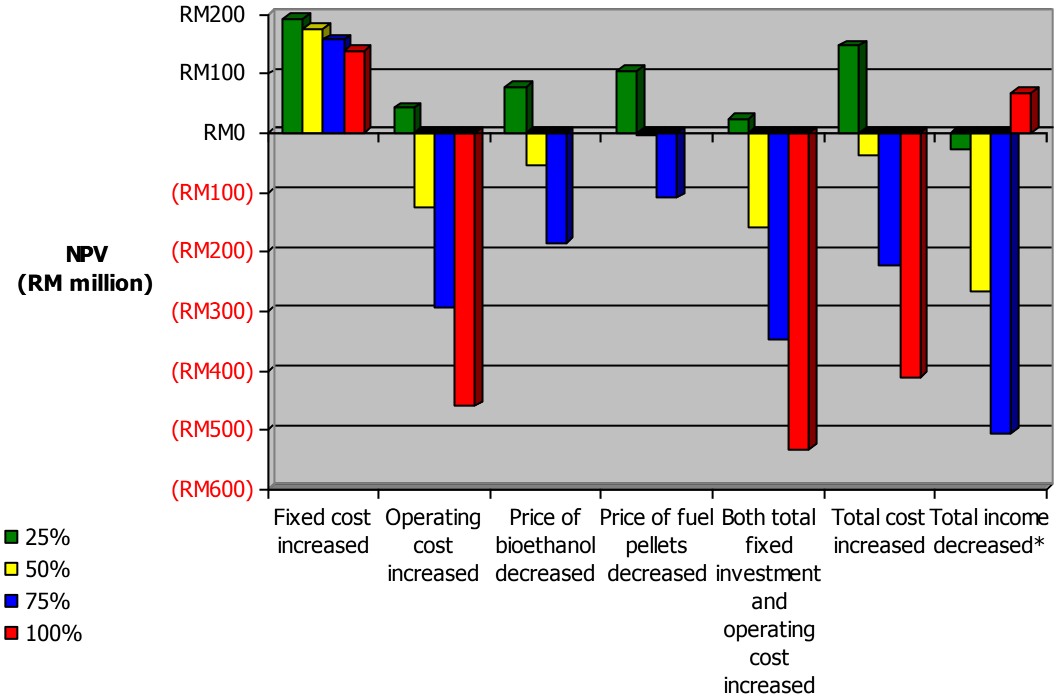
Figure 5.3.8

Gross profit margin for bioethanol and fuel pellet plant

5.3.9 Sensitivity analysis

Sensitivity analysis is a technique for systematically changing variables in a model to determine the effects of such changes. In any budgeting process there are always variables that are uncertain. Future tax rates, interest rates, inflation rates, headcount, operating expenses and other variables may not be known with great precision. Sensitivity analysis answers the question: If these variables deviate from expectations, what will the effect be on the business, model, system, (or whatever is being analyzed)?" It can be useful to support decision making or the development of recommendations/strategies for decision makers.

For this reason, 26 scenarios, including increase/decrease of costs and prices at different percentages were used to stimulate the effect to NPV, IRR, BCR and payback period (Figures 5.3.9.1 to 5.3.9.3). Results show that if there is an increase in fixed costs of even 100%, values for NPV, IRR and BCR will still be positive, and the project still feasible on an investment decision basis. However, results demonstrate that with an increase of 25% in operating costs, NPV is reduced from RM211 million to RM43 million, IRR is reduced from 39% to 17% and BCR is reduced from 1.28 to 1.05. Moreover, the payback period will be six years instead of four years. NPV values become negative if operating costs are increased by 50%. These scenarios demonstrate the importance for the company of controlling their operating costs, especially with regard to raw materials, in order to sustain their investment and profitability. The sensitivity analysis also indicates that selling price for bioethanol and fuel pellets cannot be reduced by more than 25% from the current price. Details of the sensitivity analysis are as in Appendix 5.3.



*Note: *red bar refers to 15%*

Figure 5.3.9.1

Net present value (NPV) at different scenarios

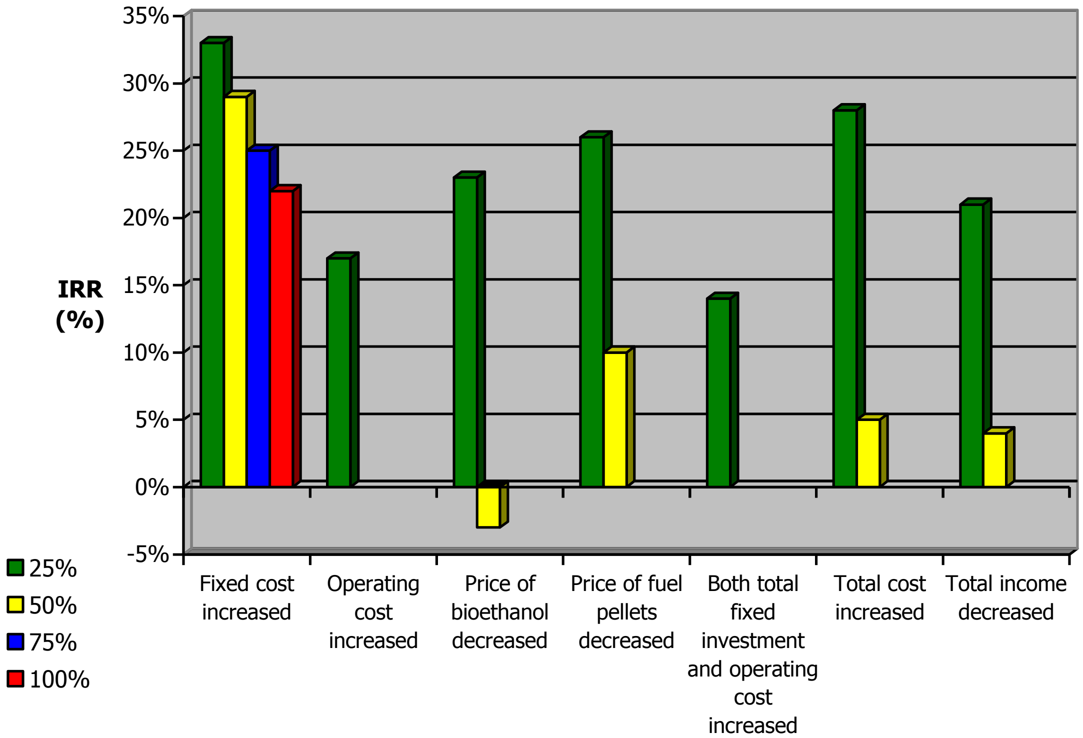
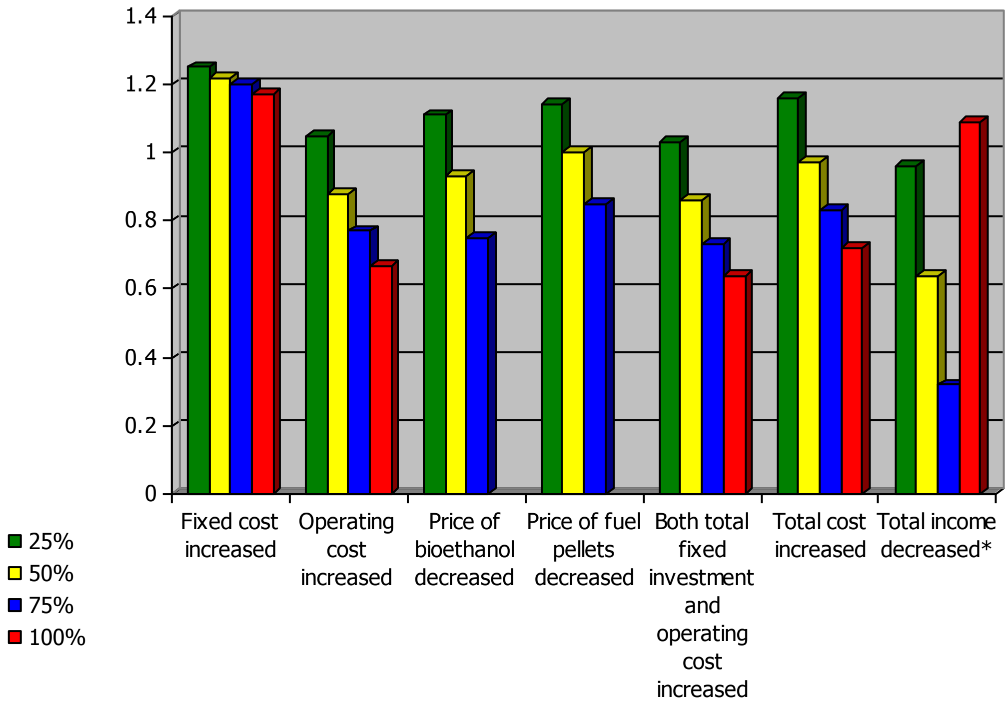


Figure 5.3.9.2

Internal rate of return (IRR) at different scenarios



*Note: *red bar refers to 15%*

Figure 5.3.9.3

Benefit cost ratio (BCR) at different scenarios

5.4 Conclusion

The cash flow analysis of the projected bioethanol and fuel pellet plant has demonstrated that the operation of the plant would be financially feasible. The calculations of the financial analysis resulted in a net present value (NPV) of RM210,958,098 (USD70,319,366), a 39% internal rate of return (IRR), a cost benefit ratio (BCR) of 1.28 and a payback period of four years.

The break even analysis showed that the plant would need to sell 109,221 tons of bioethanol and 854,879 tons of fuel pellets, generating revenues of RM302,759,592 (USD100,919,864) for bioethanol and RM273,561,141 (USD91,187,047) for fuel pellets. These figures would result in a gross profit of RM56,525,799 (USD18, 841,933), with a gross profit margin of 26.7%.

5.4.1 Recommendations

This bioethanol plant could further reduce its energy expenses by considering options such as:

- Channelling a fraction of the fuel pellets produced to satisfy its own energy requirements.

- OPT acquisition from the plantation immediately after felling, and pre-processing the raw material on site. Undertaking this option, however, would require a larger land area for the plant. Moreover, it could result in the compaction of soil and impact the fertility of the land. Any potential disruption to the development of young palm trees would not be looked upon favourably by plantation owners. Finally, the pre-processing facilities would become problematic once the plant location is no longer within the required economic radius (accessibility to 150,000 ha area) of OPT felling sites.

- Delivering raw materials to the plant that have already been pre-processed (shredded, squeezing OPT for sap and fibres) by contractors at the plantation, would have the advantage of requiring less land area for the production plant. On the other hand, a large number of lorries would be required to deliver the raw materials daily, which could be a disadvantage. In addition, the price of the raw material would fluctuate once the felling activities are no longer within the economic radius of the plant.

- The scenario of locating the plant in Peninsular Malaysia is consider to be quite difficult to implement, given the necessity of building in an area where the required infrastructure has already been developed. Therefore, it would be more suitable to construct the plant in a recently developed locality such as the POIC, in Sabah.

Appendices

Appendix 5.1 : Break-even report for bioethanol

Quantity of production (tons)	*Fixed costs (RM)*	*Variable costs (RM)*	*Total cost (RM)*	*Total revenue (RM)*	*Profit (RM)*
0	118,156,000	0	118,156,000	0	-118,156,000
10,000	118,156,000	15,410,000	133,566,000	27,720,000	-105,846,000
20,000	118,156,000	30,820,000	148,976,000	55,440,000	-93,536,000
30,000	118,156,000	46,230,000	164,386,000	83,160,000	-81,226,000
40,000	118,156,000	61,640,000	179,796,000	110,880,000	-68,916,000
50,000	118,156,000	77,050,000	195,206,000	138,600,000	-56,606,000
60,000	118,156,000	92,460,000	210,616,000	166,320,000	-44,296,000
70,000	118,156,000	107,870,000	226,026,000	194,040,000	-31,986,000
80,000	118,156,000	123,280,000	241,436,000	221,760,000	-19,676,000
90,000	118,156,000	138,690,000	256,846,000	249,480,000	-7,366,000
95,984	118,156,000	147,911,344	266,067,344	266,067,648	304
100,000	118,156,000	154,100,000	272,256,000	277,200,000	4,944,000
110,000	118,156,000	169,510,000	287,666,000	304,920,000	17,254,000
120,000	118,156,000	184,920,000	303,076,000	332,640,000	29,564,000
130,000	118,156,000	200,330,000	318,486,000	360,360,000	41,874,000
140,000	118,156,000	215,740,000	333,896,000	388,080,000	54,184,000
150,000	118,156,000	231,150,000	349,306,000	415,800,000	66,494,000
160,000	118,156,000	246,560,000	364,716,000	443,520,000	78,804,000
170,000	118,156,000	261,970,000	380,126,000	471,240,000	91,114,000
180,000	118,156,000	277,380,000	395,536,000	498,960,000	103,424,000
190,000	118,156,000	292,790,000	410,946,000	526,680,000	115,734,000
200,000	118,156,000	308,200,000	426,356,000	554,400,000	128,044,000

Appendix 5.2: Break-even report for fuel pellets

Quantity of production (tons)	*Fixed costs (RM)*	*Variable costs (RM)*	*Total cost (RM)*	*Total revenue (RM)*	*Profit (RM)*
0	80,514,000	0	80,514,000	0	-80,514,000
100,000	80,514,000	23,400,000	103,914,000	32,000,000	-71,914,000
200,000	80,514,000	46,800,000	127,314,000	64,000,000	-63,314,000
300,000	80,514,000	70,200,000	150,714,000	96,000,000	-54,714,000
400,000	80,514,000	93,600,000	174,114,000	128,000,000	-46,114,000
500,000	80,514,000	117,000,000	197,514,000	160,000,000	-37,514,000
600,000	80,514,000	140,400,000	220,914,000	192,000,000	-28,914,000
700,000	80,514,000	163,800,000	244,314,000	224,000,000	-20,314,000
800,000	80,514,000	187,200,000	267,714,000	256,000,000	-11,714,000
900,000	80,514,000	210,600,000	291,114,000	288,000,000	-3,114,000
936,210	80,514,000	219,073,140	299,587,140	299,587,200	60
1,000,000	80,514,000	234,000,000	314,514,000	320,000,000	5,486,000
1,100,000	80,514,000	257,400,000	337,914,000	352,000,000	14,086,000
1,200,000	80,514,000	280,800,000	361,314,000	384,000,000	22,686,000
1,300,000	80,514,000	304,200,000	384,714,000	416,000,000	31,286,000
1,400,000	80,514,000	327,600,000	408,114,000	448,000,000	39,886,000
1,500,000	80,514,000	351,000,000	431,514,000	480,000,000	48,486,000
1,600,000	80,514,000	374,400,000	454,914,000	512,000,000	57,086,000
1,700,000	80,514,000	397,800,000	478,314,000	544,000,000	65,686,000
1,800,000	80,514,000	421,200,000	501,714,000	576,000,000	74,286,000
1,900,000	80,514,000	444,600,000	525,114,000	608,000,000	82,886,000
2,000,000	80,514,000	468,000,000	548,514,000	640,000,000	91,486,000

Appendix 5.3: Sensitivity analysis for different scenarios

Scenario		*Net present value (NPV)*	*Internal rate of return (IRR)*	*Benefit cost ratio (BCR)*	*Pay-back period*
Baseline		RM210,962,837	39%	1.28	4 years
Scenario 1: Fixed cost increased by …	25%	RM192,940,110	33%	1.25	4 years
	50%	RM174,917,382	29%	1.22	4 years
	75%	RM156,894,655	25%	1.20	5 years
	100%	RM138,871,928	22%	1.17	5 years
Scenario 2: Operating cost increased by…	25%	RM43,390,959	17%	1.05	6 years
	50%	(RM124,180,918)	uc	0.88	uc
	75%	(RM291,752,796)	uc	0.77	uc
	100%	(RM459,324,674)	uc	0.67	uc
Scenario 3: Price of bioethanol decreased by….	25%	RM79,146,099	23%	1.11	5 years
	50%	(RM52,670,639)	-3%	0.93	uc
	75%	(RM184,487,377)	uc	0.75	uc
Scenario 4: Price of pellets decreased by….	25%	RM104,444,261	26%	1.14	5 years
	50%	(RM2,074,315)	10%	1.00	8 years
	75%	(RM108,592,892)	uc	0.85	uc
Scenario 5: Both total fixed investment and operating costs increased by …	25%	RM25,368,232	14%	1.03	7 years
	50%	(RM160,226,373)	uc	0.86	uc
	75%	(RM345,820,978)	uc	0.73	uc
	100%	(RM531,415,583)	uc	0.64	uc
Scenario 6: Total costs increased by …	25%	RM147,103,748	28%	1.16	4 years
	50%	(RM38,490,857)	5%	0.97	11 years
	75%	(RM224,085,462)	uc	0.83	uc
	100%	(RM409,680,067)	uc	0.72	uc
Scenario 7: Total revenue decreased by …	15%	RM67,961,648	21%	1.09	5 years
	25%	(RM27,372,477)	4%	0.96	11 years
	50%	(RM265,707,791)	uc	0.64	uc
	75%	(RM504,043,106)	uc	0.32	uc

- *Note: uc refers to uncountable within 15 years*
- *In RED means the project cannot be accepted*

6. Chapter 6: Business proposal for converting waste oil palm trees into renewable energy

6.1 Summary

The proposed project is to set up two pilot plants to produce bioethanol and pellets from one source of feedstock which is the oil palm trunk (OPT). A bioethanol pilot plant with a capacity of 100 tons per day is proposed to supplement the automotive fuel, while a fuel pellet production plant with a capacity of 700 tons per day is proposed to supplement the alternative fuel (especially for the boiler).

For bioethanol production, the technology will be based on fermentation processes using oil palm trunk sap (OPT sap). Commercial yeast known as *Saccharomyces cerevisiae* will be used in the fermentation process to convert the sugar in OPT sap into bioethanol. While the sap squeezed residues (SSR) are used for fuel pellet production, the residues will be dried to meet specific moisture content requirements before being pelletized. As pellet manufacturing is currently in demand, production of fuel pellets from SSR is a good opportunity to boost the economy of the nation. Furthermore, it offers contractors the opportunity to generate extra income while minimizing air pollution caused by burning residues.

This proposed project will be jointly carried out by FRIM-UMP with POIC and SIME Darby. POIC will provide the infrastructure and SIME DARBY will provide the raw material directly to the pilot plant.

6.2 Market outlook

6.2.1 Market demand

Today, the demand for green products is extremely high. Market demand for “green” products has been increasing over the years due to global warming and climate change issues. Bioethanol and fuel pellets are types of renewable energy sources that clearly support the “green” movement and are among the most demanded fuels today. Companies who support the use of green technology and recyclable materials to generate renewable energy sources make an important contribution to boosting the economy and preserving the environment.

The production of bioethanol serves as an alternative to traditional sources of automotive fuel, such as gasoline and diesel, both of which are subject to escalating prices on a global scale. At the same time, bioethanol production contributes to the reduction of greenhouse gases which are responsible for climate change. Currently, the United States, Brazil and Japan have fuel ethanol programmes. Many other countries have initiated biofuel initiatives and developed bioenergy policies, including China, India, Colombia, Thailand and South Africa.

Global production, consumption and trade of bioethanol have increased significantly in recent years. Brazil and the United States are the largest producers and consumers of bioethanol, with Brazil the primary source for the production, trade and consumption of sugar-based bioethanol. The largest bioethanol production facility in the world is based in China. Continued expansion in bioethanol demand, coupled with an increasing number of initiatives to diversify feedstock sources, are expected to result in fluctuating food and feed prices, volatile commodity markets, and increased demand for energy-related agricultural products.

Consequently, fuel pellet production is one of the most profitable industries today. The demand for fuel pellets is exceptionally high overseas as the usage of this product covers both domestic and industrial sectors. Existing overall supply cannot meet the ever-increasing demand however, as the raw materials currently used to produce the product (such as wood and other agriculture wastes) are in inadequate supply and decreasing in availability over time. As a result, the price of biomass itself is steadily increasing.

6.2.2 Market size

The utilization of fuel and diesel in a wide array of industries, such as the automobile, construction, agriculture, logistics, fisheries, etc., gives an indication of the enormous potential for any alternative to normal sources for petrol/fuel. The demand for petrol/fuel products is in excess of billions of ringgit per annum.

6.2.3 Market survey

In 2003, about 95% of the bioethanol feedstock came from agricultural crops. Bioethanol production from agricultural products is expected to continue increasing in future. In terms of future perspectives, fuel ethanol programs will be established in the European Union as well as in India, Thailand, China, Australia and Japan. The increase in production and consumption of bioethanol as a renewable fuel these past few years has created an opportunity to expand the use of bioethanol in conventional vehicles. Bioethanol can be blended with gasoline as a renewable transport fuel component. The market for bioethanol is rapidly growing, as nations around the world craft legislation to address climate change, reduce dependency on fossil fuels for road transport, and increase security of energy supply.

Fuel pellets have been widely used as a fuel source over these past few decades by many countries. In China for instance, rural people use this product as fuel for cooking, while in western countries, it is used as a catalyst to light coal fires during the winter season. The usage of fuel pellets as fuel in Malaysia, however, is quite limited compared with other nations, and usually restricted to use by industrial sectors to heat the boiler.

6.2.4 Target market

The target markets will be both the domestic and international sectors. For the domestic market, the project will focus more on industrial sectors, whereas the focus for the international market will be countries for which the consumption and demand for bioethanol and fuel pellets is high, such as Europe, the Middle East, Australia, Korea, India and Japan.

6.2.5 S.W.O.T analysis

Strengths

Enough/adequate raw materials	As Malaysian climate is generally suitable for oil palm plantations, the problem of insufficient raw materials is not a major concern under normal circumstances.
Support for the green technology movement	Since residue burning activities are decreased, air pollution is reduced, thus contributing to the mitigation of climate change and global warming. In addition, less pollution means a more healthy environment, and better health for the workers.
Provision of additional income	Locally sourcing the raw materials provides additional income for the community.
Less threat from new entries	Entry into the market by new companies is generally difficult, due to the capital intensive nature of the business and the patented technology.

Weaknesses

Less opportunity in domestic market	In Malaysia, the uses of bioethanol and fuel pellets are limited to small scale and industrial sectors only, thus restricting the expansion into new markets.
High competition In the international market	As a newcomer to the bioethanol and fuel pellet manufacturing industries, Malaysia has less experience and more limited networks compared with other competitors (especially international rivals).

Opportunities

Enough/adequate raw materials	Due to the high demand and inadequate supply available in the international market, prices for bioethanol and fuel pellets are becoming exceptionally high. With adequate access to the needed raw materials, Malaysia has the opportunity to produce and to export these products to countries in need, and to undercut competitors by selling at a lower price.
Expansion of the business to other product lines	Apart from bioethanol and fuel pellets, Malaysia can produce products such as animal feed, bio-fertilizer and fuel for outdoor usage activities such as barbecuing, camping (bonfires), etc.

Threats

Rivals expanding their product lines	It is possible that manufacturers currently producing different products with the same raw materials, and with the same easy access, could decide to shift to bioethanol and fuel pellet production.
Problems with suppliers	The supplier may refuse to sell raw materials at the proposed selling price (and demand a higher price) due to a shortage in raw material.

6.2.6 Growth potential and future plan

With the demand for green products and renewable energy sources continually increasing, the potential market growth for this industry is reasonably promising. At the moment, if the business succeeds, future plans are to set up more processing plants and add more machinery to the fixed assets list, in order to increase efficiency and productivity.

6.3 Financial analysis

6.3.1 Profitability & projection

For the economic viability analysis, it is assumed that production of bioethanol and fuel pellets will not be operating at full capacity for the first four years. Assumptions are: no production in year 1, 40% capacity in year 2, 60% capacity in year 3 and 80% capacity in year 4. Only in the following years will the production of bioethanol and fuel pellets be running at full capacity. The total production of bioethanol from OPT sap within 15 years will amount to 422,400 tons with total sales of RM1,171 million. Total production of fuel pellets from SSR within the same period is 2,956,800 tons, generating RM946 million in total sales. The total revenue for both productions is RM2,117 million (table 6.3.1.1). Total fixed investment and operating cost are RM79 million and RM1,473 million, respectively. The cumulative total cost for 15 years is RM1,552 million. Therefore, the production of bioethanol and fuel pellets will generate a profit with net income of RM565 million.

Table 6.3.1.1

Summary of profit and loss statement

Items	*Total (RM)*
Sales of bioethanol	1,170,892,800
Sales of pellets	946,176,000
Total income	2,117,068,800
Total fixed investment	79,300,000
Total operating cost	1,472,503,200
Total cost	1,551,803,200
Gross profit	**565,265,600**

The profit and loss statement shows that the production of bioethanol and fuel pellets is projected to generate a total of RM565 million within 15 years. However, the production for both products will net a loss for the first year of RM88 million. Beginning from the second year onwards, the production will generate positive gross profit even though the cumulative gross profit will be only be positive beginning with year five, with RM47 million. Production in year ten will create a total of RM52 million in gross profits and a cumulative gross profit of RM306 million (table 6.3.1.2).

Table 6.3.1.2

Profitability and projection

Items	Total (RM)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10	Year 15
Sales of bioethanol	1,170,892,800	0	36,590,400	54,885,600	73,180,800	91,476,000	91,476,000	91,476,000
Sales of pellets	946,176,000	0	29,568,000	44,352,000	59,136,000	73,920,000	73,920,000	73,920,000
Total income	2,117,068,800	0	66,158,400	99,237,600	132,316,800	165,396,000	165,396,000	165,396,000
Total cost	1,551,803,200	87,763,200	50,506,400	71,532,800	92,559,200	113,585,600	113,585,600	113,585,600
Gross profit	565,265,600	-87,763,200	15,652,000	27,704,800	39,757,600	51,810,400	51,810,400	51,810,400
Cumulative gross profit		-87,763,200	-72,111,200	-44,406,400	-4,648,800	47,161,600	306,213,600	565,265,600

6.3.2 Source of funding

There are several financing/products/credit terms that are offered by local and international banks operating in Malaysia such as sole proprietor, partnership and professional financing, BizLoan and BizFexi, and commercial property financing. The list of banks is as follows:

6.3.3 Cash Flow for 15 years

The cash flow for production of bioethanol and fuel pellets shows in table 6.3.3

Table 6.3.3

Cash flow for production of bioethanol and fuel pellets

No	*Items*	*Total (RM)*	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*	*Year 9*	*Year 10*	*Year 11*	*Year 12*	*Year 13*	*Year 14*	*Year 15*
1	Production of bioethanol from OPT sap	**422,400**	0	13,200	19,800	26,400	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000
	Cumulative production		0	13,200	33,000	59,400	92,400	125,400	158,400	191,400	224,400	257,400	290,400	323,400	356,400	389,400	422,400
	Sales of bioethanol	**1,170,892,800**	0	36,590,400	54,885,600	73,180,800	91,476,000	91,476,000	91,476,000	91,476,000	91,476,000	91,476,000	91,476,000	91,476,000	91,476,000	91,476,000	91,476,000
2	Production of pellets from sap squeezed residues	**2,956,800**	0	92,400	138,600	184,800	231,000	231,000	231,000	231,000	231,000	231,000	231,000	231,000	231,000	231,000	231,000
	Cumulative production		0	92,400	231,000	415,800	646,800	877,800	1,108,800	1,339,800	1,570,800	1,801,800	2,032,800	2,263,800	2,494,800	2,725,800	2,956,800
	Sales of pellets	**946,176,000**	0	29,568,000	44,352,000	59,136,000	73,920,000	73,920,000	73,920,000	73,920,000	73,920,000	73,920,000	73,920,000	73,920,000	73,920,000	73,920,000	73,920,000
A	**Total income**	**2,117,068,800**	**0**	**66,158,400**	**99,237,600**	**132,316,800**	**165,396,000**	**165,396,000**	**165,396,000**	**165,396,000**	**165,396,000**	**165,396,000**	**165,396,000**	**165,396,000**	**165,396,000**	**165,396,000**	**165,396,000**
	FIXED INVESTMENT																
1	Land	**2,500,000**	**2,500,000**														
2	Building - plant, store, office, etc.	**2,000,000**	**2,000,000**														
3	Machinery & equipment	**70,900,000**	**70,900,000**														
	Bioethanol																
3.1	Raw material storage tank (1tank=250 m^3/run)	**3,600,000**	**3,600,000**														
3.2	Rotary drum filter 1	**100,000**	**100,000**														
3.3	Receiver tank	**600,000**	**600,000**														
3.4	Fermenter	**42,000,000**	**42,000,000**														
3.5	Distillation	**4,000,000**	**4,000,000**														
3.6	Molecular sieve	**4,000,000**	**4,000,000**														
3.7	Condenser	**400,000**	**400,000**														

No	***Items***	***Total (RM)***	***Year 1***	***Year 2***	***Year 3***	***Year 4***	***Year 5***	***Year 6***	***Year 7***	***Year 8***	***Year 9***	***Year 10***	***Year 11***	***Year 12***	***Year 13***	***Year 14***	***Year 15***
3.8	Product storage tank (500 ton tank)	**1,600,000**	**1,600,000**														
3.9	Water treatment plant	**2,000,000**	**2,000,000**														
	Sub-total	**58,300,000**	**58,300,000**														
	Fuel pellets																
3.10	Pellet machine set	**8,000,000**	**8,000,000**														
3.11	Dryer (20 tons/hour)	**4,000,000**	**4,000,000**														
3.12	Silo	**200,000**	**200,000**														
3.13	Packaging (6 minutes/ton)	**400,000**	**400,000**														
	Sub-total	**12,600,000**	**12,600,000**														
4	Other fixed cost																
4.1	Motor vehicles	**1,000,000**	**1,000,000**														
4.2	Workstation and equipment	**200,000**	**200,000**														
4.3	Power sub station (2.5 megawatt hour)	**1,200,000**	**1,200,000**														
4.4	Analysis equipment	**1,500,000**	**1,500,000**														
	Sub-total	**3,900,000**	**3,900,000**														
B	**Total Fixed Investment**	**79,300,000**	**79,300,000**														

No	Items	Total (RM)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
	OPERATING COSTS																
1	Raw materials																
1.1	Sap (RM300/ton delivered)	**633,600,000**	0	19,800,000	29,700,000	39,600,000	49,500,000	49,500,000	49,500,000	49,500,000	49,500,000	49,500,000	49,500,000	49,500,000	49,500,000	49,500,000	49,500,000
1.2	Chemicals for bioethanol	**307,200**	0	9,600	14,400	19,200	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
1.3	Sap residues (RM100/ton)	**675,840,000**	0	21,120,000	31,680,000	42,240,000	52,800,000	52,800,000	52,800,000	52,800,000	52,800,000	52,800,000	52,800,000	52,800,000	52,800,000	52,800,000	52,800,000
	Raw materials cost for bioethanol	**633,907,200**	0	19,809,600	29,714,400	39,619,200	49,524,000	49,524,000	49,524,000	49,524,000	49,524,000	49,524,000	49,524,000	49,524,000	49,524,000	49,524,000	49,524,000
	Raw materials cost for fuel pellets	**675,840,000**	0	21,120,000	31,680,000	42,240,000	52,800,000	52,800,000	52,800,000	52,800,000	52,800,000	52,800,000	52,800,000	52,800,000	52,800,000	52,800,000	52,800,000
	Total raw materials costs	**1,309,747,200**	0	40,929,600	61,394,400	81,859,200	102,324,000	102,324,000	102,324,000	102,324,000	102,324,000	102,324,000	102,324,000	102,324,000	102,324,000	102,324,000	102,324,000
	Raw materials cost per ton of bioethanol	**1,501**	0	1,501	1,501	1,501	1,501	1,501	1,501	1,501	1,501	1,501	1,501	1,501	1,501	1,501	1,501
	Raw materials cost per ton of fuel pellets	**229**	0	229	229	229	229	229	229	229	229	229	229	229	229	229	229
2	Utility costs (unit rate and total cost)																
2.1	Electricity	**75,000,000**	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
2.2	Water	**624,000**	9,600	19,200	28,800	38,400	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000
	Total utility costs	**75,624,000**	5,009,600	5,019,200	5,028,800	5,038,400	5,048,000	5,048,000	5,048,000	5,048,000	5,048,000	5,048,000	5,048,000	5,048,000	5,048,000	5,048,000	5,048,000
3	Spares and consumables																
3.1	Administration costs (management, book keeping, office expenditures)	**180,000**	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000

No	Items	Total (RM)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
4	Labour costs																
4.1	***Management team***																
4.1.1	General manager	**4,500,000**	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000
4.1.2	Manager	**7,200,000**	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000
4.1.3	Assistant manager	**10,080,000**	672,000	672,000	672,000	672,000	672,000	672,000	672,000	672,000	672,000	672,000	672,000	672,000	672,000	672,000	672,000
4.1.4	Executive	**7,200,000**	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000	480,000
4.1.5	Clerk	**648,000**	43,200	43,200	43,200	43,200	43,200	43,200	43,200	43,200	43,200	43,200	43,200	43,200	43,200	43,200	43,200
4.1.6	Office employee	**270,000**	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
	Sub-total	**29,898,000**	1,993,200	1,993,200	1,993,200	1,993,200	1,993,200	1,993,200	1,993,200	1,993,200	1,993,200	1,993,200	1,993,200	1,993,200	1,993,200	1,993,200	1,993,200
4.2	***Operation team***																
4.2.1	Plant manager	**5,400,000**	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000
4.2.2	Supervisor	**2,520,000**	168,000	168,000	168,000	168,000	168,000	168,000	168,000	168,000	168,000	168,000	168,000	168,000	168,000	168,000	168,000
4.2.3	Quality control	**2,736,000**	182,400	182,400	182,400	182,400	182,400	182,400	182,400	182,400	182,400	182,400	182,400	182,400	182,400	182,400	182,400
4.2.4	Engineer	**2,880,000**	192,000	192,000	192,000	192,000	192,000	192,000	192,000	192,000	192,000	192,000	192,000	192,000	192,000	192,000	192,000
4.2.5	Executive	**5,400,000**	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000
4.2.6	Operator	**2,700,000**	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000
	Sub-total	**21,636,000**	1,442,400	1,442,400	1,442,400	1,442,400	1,442,400	1,442,400	1,442,400	1,442,400	1,442,400	1,442,400	1,442,400	1,442,400	1,442,400	1,442,400	1,442,400
	Total labour costs	**51,534,000**	3,435,600	**3,435,600**	**3,435,600**	**3,435,600**	**3,435,600**	**3,435,600**	**3,435,600**	**3,435,600**	**3,435,600**	**3,435,600**	**3,435,600**	**3,435,600**	**3,435,600**	**3,435,600**	**3,435,600**
5	Other costs																
5.1	Transportation cost	**33,792,000**	0	1,056,000	1,584,000	2,112,000	2,640,000	2,640,000	2,640,000	2,640,000	2,640,000	2,640,000	2,640,000	2,640,000	2,640,000	2,640,000	2,640,000
5.2	Maintenance cost	**1,536,000**	0	48,000	72,000	96,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000
5.3	Other miscellaneous costs	**90,000**	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
	Total other costs	**35,418,000**	6,000	1,110,000	1,662,000	2,214,000	2,766,000	2,766,000	2,766,000	2,766,000	2,766,000	2,766,000	2,766,000	2,766,000	2,766,000	2,766,000	2,766,000

Summary of Table 6.3.3 – Cash flow for production of bioethanol and fuel pellets

No	Items	Total (RM)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
A	Total income	2,117,068,800	0	66,158,400	99,237,600	132,316,800	165,396,000	165,396,000	165,396,000	165,396,000	165,396,000	165,396,000	165,396,000	165,396,000	165,396,000	165,396,000	165,396,000
B	Total fixed investment	79,300,000	79,300,0000														
C	Total operating costs	1,472,503,200	8,463,200	50,506,400	71,532,800	92,559,200	113,585,600	113,585,600	113,585,600	113,585,600	113,585,600	113,585,600	113,585,600	113,585,600	113,585,600	113,585,600	113,585,600
D	Total cost (B + C)	1,551,803,200	87,763,200	50,506,400	71,532,800	92,559,200	113,585,600	113,585,600	113,585,600	113,585,600	113,585,600	113,585,600	113,585,600	113,585,600	113,585,600	113,585,600	113,585,600
E	Gross profit (before tax) (A – D)	565,265,600	-87,763,200	15,652,000	27,704,800	39,757,600	51,810,400	51,810,400	51,810,400	51,810,400	51,810,400	51,810,400	51,810,400	51,810,400	51,810,400	51,810,400	51,810,400
	Cumulative gross profit		-87,763,200	-72,111,200	-44,406,400	-4,648,800	47,161,600	98,972,000	150,782,400	202,592,800	254,403,200	306,213,600	358,024,000	409,834,400	461,644,800	513,455,200	565,265,600

6.3.4 Return on investment

The return on investment (ROI) percentage shows how profitable a company's investments are in generating revenue. It's a useful number for comparing competing companies in the same industry.

For year 1, ROI for the bioethanol and fuel pelles plant is negative 110.7% as there is no production during that first year period. For Year 2, a 40% production capacity will generate total income of RM66 million and ROI at 20%. In years 3 and 4, ROI will be increased to 35% and 50%, respectively. After the payback period (starting year 5), ROI will achieve 65% annually (Figure 6.3.4). The formula to calculate ROI is as follows:

Return on investment = (Gross income/ total investment)*100

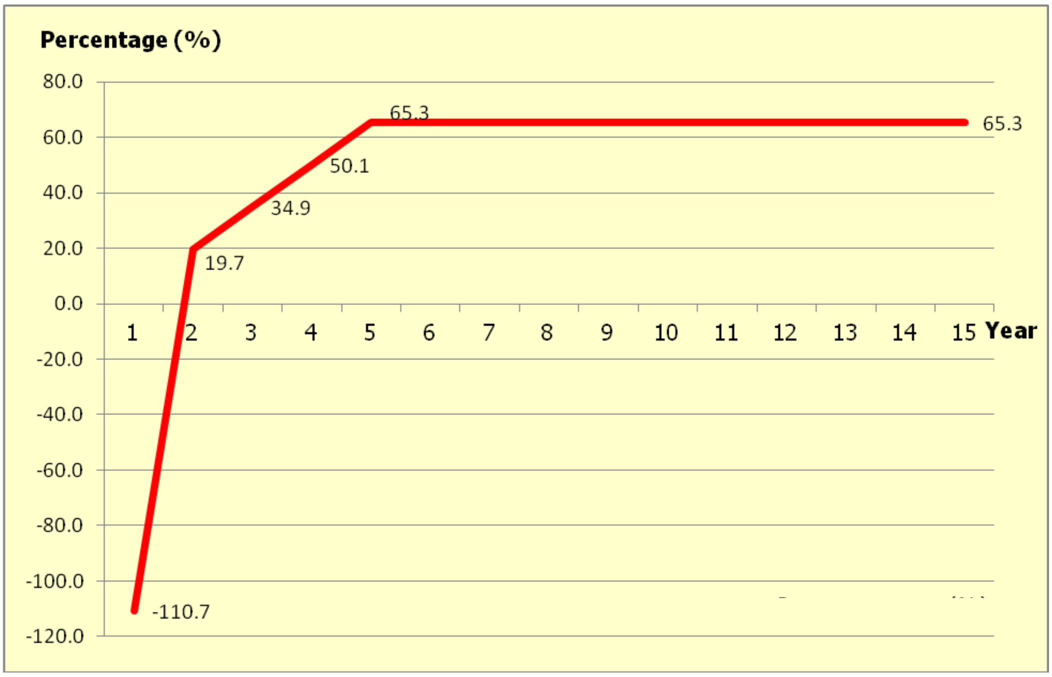


Figure 6.3.4

Return on investment (ROI) for bioethanol and fuel pellet plant

6.4 Conclusion

The business proposal for converting WPT into renewable energy looks promising given the demand for green products globally. The ideal potential business partners would be plantation owners who own the raw material source (WPT), and organizations such as the POIC which can provide the infrastructure needed for the production line.

The financial analysis detailed in the previous chapters demonstrates that combining the production of bioethanol with fuel pellets in a single production facility is a sound business investment, and can result in substantial benefits, both in terms of boosting the economy and preserving the environment of Malaysia for generations to come.

About the UNEP Division of Technology, Industry and Economics

Set up in 1975, three years after UNEP was created, the Division of Technology, Industry and Economics (DTIE) provides solutions to policy-makers and helps change the business environment by offering platforms for dialogue and co-operation, innovative policy options, pilot projects and creative market mechanisms.

DTIE plays a leading role in three of the six UNEP strategic priorities: climate change, harmful substances and hazardous waste, resource efficiency.

DTIE is also actively contributing to the Green Economy Initiative launched by UNEP in 2008. This aims to shift national and world economies on to a new path, in which jobs and output growth are driven by increased investment in green sectors, and by a switch of consumers' preferences towards environmentally friendly goods and services.

Moreover, DTIE is responsible for fulfilling UNEP's mandate as an implementing agency for the Montreal Protocol Multilateral Fund and plays an executing role for a number of UNEP projects financed by the Global Environment Facility.

The Office of the Director, located in Paris, coordinates activities through:

> The International Environmental Technology Centre - IETC (Osaka), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.

> Sustainable Consumption and Production (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.

> Chemicals (Geneva), which catalyses global actions to bring about the management of chemicals and the improvement of chemical safety worldwide.

> Energy (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.

> OzonAction (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.

> Economics and Trade (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies. This branch is also charged with producing green economy reports.

DTIE works with many partners (other UN agencies and programmes, international organizations, governments, non-governmental organizations, business, industry, the media and the public) to raise awareness, improve the transfer of knowledge and information, foster technological cooperation and implement international conventions and agreements.

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This six chapter publication is designed to share the latest information on the potential of converting waste oil palm trees (WPT) into a resource, either as raw material for various industrial applications or for utilization in energy generation.

The document provides a baseline study on the quantity, characteristics and current uses of WPT, identifies the most environmentally sound technologies, and presents a business proposal for converting WPT into renewable energy. Applying the principles outlined in the study can result in substantial benefits, both in terms of boosting the economy and preserving the environment of Malaysia for generations to come.

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